CHAPTER 14

KRISHNA AND GODAVARI BASINS

14.1. THE KRISHNA BASIN

The Krishna is the second largest eastward draining interstate river in Peninsular India. It rises in the Mahadev range of the Western Ghats at an altitude of 1,337 m near Mahabaleshwar in Maharashtra State, about 64 km from the Arabian Sea. It flows for a distance of 305 km in Maharashtra, 483 km in Karnataka and 612 km in Andhra Pradesh before finally out falling into the Bay of Bengal. Thus the length of the river is about 1,400 km and it flows across the whole width of the peninsula, from west to east, through Maharashtra, Karnataka and Andhra Pradesh states. The basin lies between latitudes 13°07′ N and 19°20′ N and longitudes 73°22′ E and 81°10′ E. On the north, the basin is bounded by the range 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 extends over an area of 258,948 km^2, which is nearly 8% of the total geographical area of the country. An index map of the Krishna basin is given in Figure 1.

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. The western border of Krishna basin is formed by an unbroken line of ranges of the Western Ghats. Most other parts of this basin are comprised of rolling and undulating terrain. The state-wise distribution of drainage area is given in Table 1.

The Tungabhadra, Narayanpur, Srisailam, Nagarjunasagar and Prakasam barrage, are the existing major projects in the basin. Jurala and Almatti are the ongoing major projects while Pulichintala is the proposed major project.

Water balance studies carried by NWDA (by sub-dividing the whole basin into 12 sub-basins) have shown that the basin will be water deficit to the tune of 3,235 Mm^3 in the ultimate development scenario.

14.1.1. Tributaries of Krishna River

Thirteen major tributaries join the Krishna River along its course, out of which six are right bank tributaries and seven are left bank tributaries. All the major tributaries draining the base of the triangle fall into the Krishna River in the upper two-thirds of its length. Among the major tributaries, the Ghatprabha, the Malprabha and

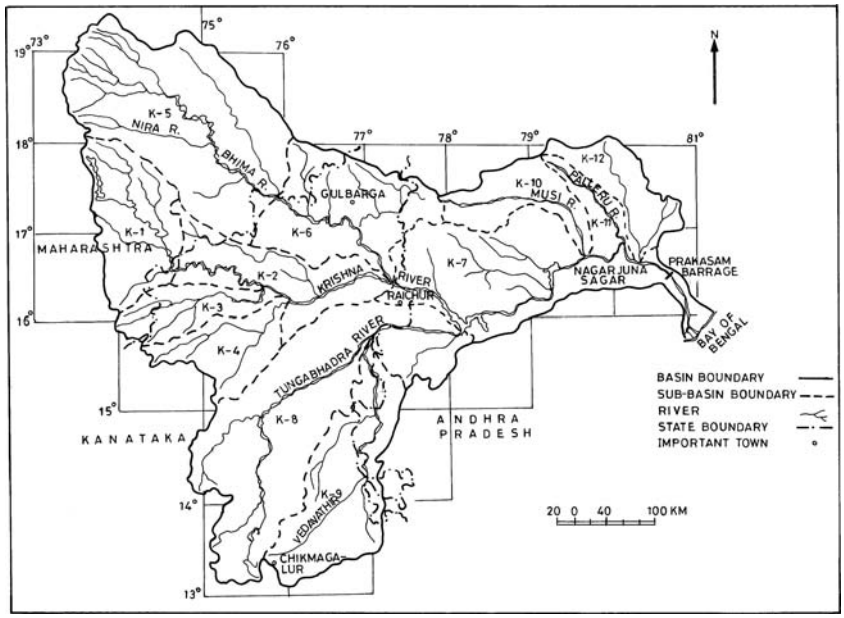

Figure 1. Index map of Krishna Basin

the Tungabhadra are the principal right bank tributaries which together account for 35.45% of the total catchment area, whereas the Bhima and the Musi are the principal left bank tributaries which together account for 35.62% of the total catchment area. The catchment area, length and elevation of source of the tributaries are given in Table 2. Flow Diagram of Krishna basin is given in Figure 2.

In the following, a detailed description of the principal tributaries is given.

The Tungabhadra river

Tungabhadra River is formed from the union of the two rivers, namely, Tunga and Bhadra, which together rise in Varahagiri in the Western Ghats of Karnataka State at an altitude of about 1,196 m. The two rivers confluence at a village called Kudali

Table 1. Statewise area of Krishna Basin

State	Length (km)	Drainage area (sq. km)	Percentage of total area
Maharashtra	305	69, 425	26.8
Karnataka	483	113, 271	43.7
Andhra Pradesh	612	76, 252	29.5
Total	1, 400	258, 948	100.0

Table 2. Details of major tributaries of Krishna River

SN	Name of tributary	Bank	Elevation of source (m)	Length (km)	Catchment area (sq. km)
1.	Koyna	Right	4, 719	118	4, 890
2.	Panchganga	Right	1, 020	74	2, 575
3.	Dudhganga	Right	870	103	2, 350
4.	Ghataprabha	Right	884	283	8, 829
5.	Malaprabha	Right	793	304	11, 549
6.	Bhima	Left	945	861	70, 614
7.	Tungabhadra	Right	610	531	71, 417
8.	Dindl	Left	718	178	3, 490
9.	Peddavagu	Left	707	109	2, 343
10.	Halia	Left	708	112	3, 780
11.	Musi	Left	661	265	11, 212
12.	Paleru	Left	515	152	3, 263
13.	Munneru	Left	238	195	10, 409

near Shimoga. The united Tungabhadra River flows for about 531 km in a generally northeasterly direction, through Mysore and Andhra Pradesh and joins the Krishna at an elevation of about 264 m beyond Karnool. The length of the river is 786 km. The important tributaries of the Tungabhadra River are the Varada, the Hagari, the Vedavati, and the Kumudvati. The total drainage area of the Tungabhadra is 71,417 km^2. The mean annual rainfall in the Tungabhadra basin is 884 mm (NIH, 1992).

The catchment area of Tungabhadra sub-basin can be demarcated into three zones depending on the vegetative growth viz., (i) The Western Ghat belt from Agumbe to Honnali with thick forest and heavy rainfall, (ii) thin vegetative cover from Honnali up to Harihar with moderate rainfall, and (iii) very thin vegetative growth with bare topped hills beyond Harihar and up to Mallapuram with scanty rainfall. The land use in the catchment consists of forest (14.5%), cultivation (59%), pastures (9%), wasteland (12%); the rest (5.5%) is fallow land (KERS 1985).

Drainage density of the catchment is 0.44 km/km^3 and the average slope is 6%. On the basis of topography, vegetation and the type of soil the value of runoff coefficient is 0.21 The river derives major portion of its flow in its initial course of 206 km, draining from the Western Ghats.

The annual river flow varies from 8,412 Mm^3 to 17,148 Mm^3, the average being 11,427 Mm^3. Although the volume of rainfall is quite high, the rate of soil erosion is low because of good forest cover. In addition, the soils are mainly lateritic, which are not easily susceptible to erosion when there is vegetation cover.

The storage projects existing in the area are: (1) Bhadra Reservoir across Bhadra near Lakkavalli, (2) Tunga anicut across Tunga near Gajanur, (3) Hagari-Bommanhalli reservoir across the river Hagari, (4) Bhadra anicut near Bhadravathi, (5) Dharma reservoir across the river Varada, and (6) Anjanapura reservoir across

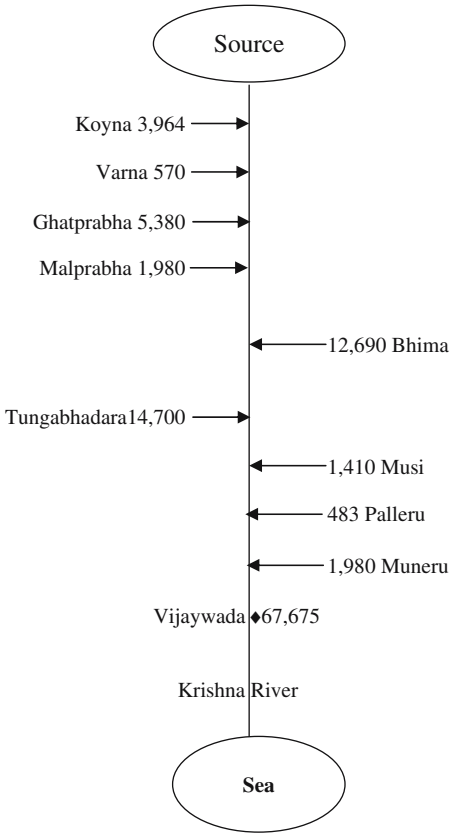

Figure 2. Flow Diagram of Krishna basin

Kumudvathi. In addition, the catchment area is intercepted with a large number of minor tanks. Counting the major and medium reservoirs in the catchment, the intercepted catchment is approximately 6,740 km^2 and the independent catchment is approximately 21,440 km^2.

The Malprabha river

Malprabha is a right bank tributary of Krishna River. The Malprabha catchment lies between North latitudes 15°00′ and 16°12′ and east longitudes 74°14′ and 76°05′. The Malprabha River originates from the Chorla Ghats, a section of the Western Ghats, at an elevation of about 792 m about 35 m south-west of Belgaum District of Karnataka. The river flows east and north-west and joins Krishna at Kapila Sangam in the Bijapur District at an elevation of about 488 m. Malprabha traverses a length of 306 km before meeting the Krishna River. The Bennihala and the Hirehalla are the principal tributaries of the river Malprabha. The total

catchment area of the Malprabha including its tributaries is 11,549 km^2, which lies wholly in the State of Karnataka.

To harness the waters of the Malprabha River a dam has been constructed at Niviluteerth, Belgaum District to impound 1,377 Mm^3 water. The reservoir catchment covers an area of 3,300 km^2.

Physiography: The Malprabha catchment is approximately triangular in shape. The terrain is flat to gently undulating except for a few hillocks and valleys. The northern boundary is the common ridge between the Malprabha and the Ghatprabha rivers and the eastern boundary is the common bridge between the Malprabha, the Krishna and the Tungabhadra rivers. The southern and western boundaries are the common ridge between the Malprabha and the west flowing rivers. The important rock formations in the sub-basin are: (i) sedimentary rock formation (Kaladgi group) comprising limestone, shale and quartzites, (ii) Schistose rock formations (Dharwad super group) comprising granite, gneiss and crystalline rocks. The important soil types found in the basin are black soils, red soils, laterite and lateritic soils, alluvium, mixed soil, red and black soil and saline and alkaline soils.

Climate: Three main seasons prevailing in the catchment are: the summer from March to April, the monsoon from May to November, and the winter from December to February.

Rainfall is mainly received by the south-west monsoon. The rainfall in the non-monsoon period is insignificant. The average annual rainfall of the catchment for the periods from 1901–02 to 1930–31, 1931–32 to 1948–49 and 1949–50 to 1984–85 were 718 mm, 775 mm and 815 mm respectively. Except the monsoon months, the climate of the catchment is generally dry. The mean relative humidity is high during the south-west monsoon season and comparatively low during the non-monsoon period. In summer, the weather is dry and the humidity is low.

During the monsoon season, winds flow from the south-west or west. In the non-monsoon season, winds from north-east and south-east are common. During the south-west monsoon, sky is heavily clouded. During the remaining part of the year, clear or lightly clouded sky prevails.

The Bhima river

The Bhima River is a major left bank tributary of the Krishna River, which also rises in the Western Ghats and flows south-eastwards through Maharashtra and Mysore. It falls into the Krishna River at about 26 km north of Raichur at an altitude of 343 m. The total length of the river before joining Krishna River is 861 km. The main tributaries of the Bhima are the Mula, the Mutha, the Nira, the Ghod, the Man and the Sina. The total catchment area of the Bhima sub-basin is 76,614 km^2.

Twenty medium and major reservoir projects have been constructed on the Bhima River and its tributaries in Maharashtra. Most of the headwater reservoirs are ungated. The dams in Bhima system are operated to meet various conservation requirements and for controlling the flood in the Bhima valley. The Bhima project, also known as Ujjani dam, is the biggest dam in the system that has been constructed

on the Bhima River in the Krishna basin in Solapur district, Maharashtra state. The main purposes of this dam are irrigation and flood control. Pandarpur is an important religious place which is to be protected against floods. The 15 major projects are:

1. Pimpalgaon joge
2. Yedgaon
3. Manikdoha
4. Wadaj
5. Dimbhe
6. Chaskaman
7. Pawana
8. Varasgaon
9. Panshet
10. Khadakwasla
11. Bhatghar
12. Bhama Askhed
13. Veer
14. Ghod
15. Ujjani

Following five lakes are operated by the Tata group and are known as Tata lakes:
1. Andhra 2. Mulshi 3. Shirota 4. Lonawala 5. Valvan

The current practice of operating the dams in this system is based on thumb rule as scientific analysis of the operation procedure for the reservoirs has not been carried out. This implies sub-optimal management of reservoirs in the basin. Water scarcity and flood situations occur quite frequently. Figure 3 shows the line diagram of the Bhima system.

The Solapur district critically depends on the Ujjani reservoir for drinking and irrigation water supply, with almost 80% of its water coming from the reservoir. Ujjani irrigates some 350 Mm^2 of land in Solapur through various lift irrigation schemes and another 1,500 Mm^2 benefit through water discharged into the Bhima

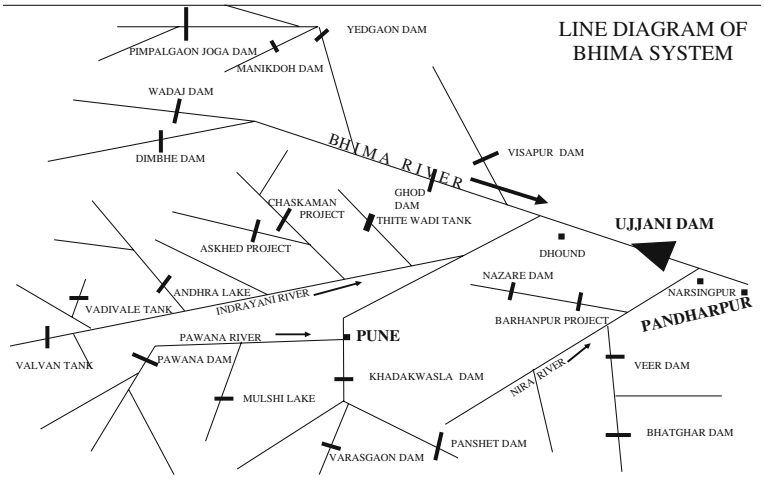

Figure 3. Line diagram of Bhima system

River. The Ujjani catchment is spread over 14,856 km^2. However, in some recent dry years, the ready-to-use water stock in Ujjani, with a capacity of 1,517 Mm^3 was nearly over.

The Ghatprabha river

Rising from the Western Ghats at an altitude of 884 m, the Ghatprabha River is one of the southern tributaries of the Krishna River. The catchment area of Ghatprabha lies between latitude 15°45′ and 16°25′ N and longitude 74°00′ and 75°55′ E. The Ghatprabha River flows eastwards for a distance of 283 km before joining Krishna at Kudalisangam, 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 Karnataka. In Karnataka, it flows through Belgaum and Bijapur Districts and joins the Krishna about 16 km from Almatti. The catchment area of Ghatprabha including its tributaries is 8,829 km^2.

Tributaries of Ghatprabha River: The principal tributaries of Ghatprabha River are the Tampraparni, and Hiranyakeshi and the Markandeya. The Tamraparni, rising in Maharashtra flows through the Sindudurg district. It forms the boundary between Maharashtra and Karnataka for 6 km and after a run of 19 km in Karnataka, joins Ghatprabha on the left bank. The Markandeys, rising in Maharashtra flows for 8 km and after a run of 66 km in Karnataka, joins the Ghatprabha on the right bank.

A dam has been constructed at Hidkal in Hukkeri taluk to impound 2,202 Mm^3 water running two canals on either bank and coupled with weirs and lift irrigation schemes on the foreshores.

Physiography and Geology: The sub-basin is approximately triangular in shape. Its northern boundary is the common ridge between the Krishna and the Ghatprabha rivers; the southern boundary is the common bridge between the Ghatprabha and the Malprabha rivers. Except for isolated hillocks and valleys, most of the catchment area is flat to gently undulating.

The geological formations found within the sub-basin are (i) Deccan trap of tertiary age, (ii) Sedimentary formations known as ‘Kaladagi group’ comprising limestone, shale and quartzities, (iii) Schists, Gneiss and other crystallizing rocks, and (iv) Laterite rocks. The soils generated from the formations are mostly permeable. As the surface is covered with moorum, runoff is moderate in the catchment.

Hydrogeological studies carried out in the sub-basin reveal that ground water occurs in all the geological formations, viz., the Dharwar Schists, Peninsular Gneisses, quartzites and alluvial deposits. The occurrence and movement of ground-water in these rocks is controlled by the nature and extent of weathering and the presence of joints and fractures in them. The sub-soil water table generally does not exceed 9 m below ground water level under normal conditions. The ground water development in the sub-basin is from open wells and dug-cum-borewells.

Climate: The climate of the catchment is marked by a hot summer and a mild winter. In the western parts of catchment, the summer season is mild but it is severe in the other parts. On certain days during summers, the day temperature rises up to

41 °C. The monsoon sets early in June and withdraws by the end of October. With the onset of monsoon in early June, there is an appreciable drop in the day temperature. The winter season lasts from November to December. Generally December is the coldest month with the mean daily maximum and minimum temperature being 29.3 °C and 13.9 °C respectively. April is generally the hottest month with mean daily maximum and minimum temperatures of 35.7 °C and 19.5 °C. Expectedly, the relative humidity is high during the south-west monsoon and low during the non-monsoon period. In summer the weather is dry and humidity is low.

Wind velocities are generally low with some increase during the late summer and in the monsoon season. From April to Sept., wind blows mainly from the south-west and west. In October, it is from the directions between north and east but on some days from south-west or west. During November and December, wind is mostly north-easterly or easterly. South-westerly and westerly appear in January and from February onwards the easterlies decrease in frequency and by April the afternoon wind blows predominantly from the west and south-west.

During the south-west monsoon, the sky is heavily clouded. Cloud cover decreases in the post-monsoon period. From December to February, the sky is generally clear with occasional light clouds. Cloud cover increases from April onwards. The sunshine percentage in the catchment varies from 21 to 96.

The Musi river

The Musi River is a major left bank tributary of Krishna, having its origin in the hills of Anathagiri near Vikarabad, Rangareddy District, A.P. It flows through Hyderabad city and runs mostly west to east until the Aleru River joins it. Flowing southwards, it meets the Krishna River near Wazirabad at an elevation of about 61 m. When it confluences with Krishna river, Musi River has already flown for 267 km.

The river has a rocky and very steep fall. It brings very heavy and sudden floods during the monsoon. During the year 1908, Musi swelled up in high floods and submerged a major portion of Hyderabad city and many villages on its banks, and caused severer damages to the property and life. Immediately after this disaster, the problem of controlling flood received the attention of Government of Hyderabad. Consequently two major reservoirs Himayatsagar and Osmansagar were constructed on the two branches of river Musi called Easa and Musa (Musi). The storages of these two reservoirs are exclusively being utilized for water supply to the twin cities of Hyderabad and Secunderabad. In recent years also, the city of Hyderabad has seen flooding and unplanned urban growth is one of the reasons for this.

14.1.2. Climate of Krishna Basin

The climate of the Krishna basin is dominated by the southwest monsoon, which provides most of the precipitation for the basin. High flow in the river occurs during the months of August–November and the lean flow season is from April to

May (at Vijayawada). Climatic types range from per-humid through dry sub-humid in the west through semi-arid in the central and eastern parts of the basin. The south-central part of the basin is truly arid.

On an average, annual rainfall in the Krishna basin is 784 mm. The southwest monsoon sets in by middle of June and withdraws by the middle of October. About 90 percent of the annual rainfall is received during the monsoon months; more than 70% occurs during July, August and September.

Except the monsoon months, the climate of the catchment remains dry. From the climatological observations, it is seen that the mean daily maximum temperature in the basin varies from 27.7 °C to 40.4 °C and the mean daily minimum temperature varies from 20.6° to 27.2 °C.

The relative humidity in the basin ranges from 17 to 92 percent. Mean relative humidity is high during the monsoon period and comparatively low during the post monsoon period. In summer, the weather is dry and the humidity is low.

Winds in the basin are generally light with some increase in force during the later half of summers. The catchment is influenced by south-west winds during the monsoon season. In the post monsoon season, they blow from north-west to north. In the winter season the winds blow from the north-west and south-west directions. In the Krishna basin, wind speed varies from 4.0 to 21.7 km/hr.

Sky is generally heavily clouded during the monsoon season. Cloudiness decreases sharply in the post monsoon months. During rest of the year, sky is clear or lightly clouded. The cloud cover in the basin varies from 0.8 oktas to 8.00 oktas.

14.1.3. Geology of Krishna Basin

The geology of the Krishna basin is dominated in the northwest by the Deccan Traps, in the central part by unclassified crystallines, and in the east by the Cuddapah Group. The Dharwars (southwest central) and the Vindhian (east central) form a significant part of the outcrops within the unclassified crystallines. Krishna delta is predominantly formed by Pleistocene to recent material. Figure 4 shows the valley of Krishna River in Eastern Ghats.

14.1.4. The Deltaic Plain

The Krishna delta is situated between latitudes 15°42′ to 16°30′ N and longitudes of 80°30′ to 81°15′ E with its head at Vijayawada. After cutting the Eastern Ghats, the river forms a deltaic plain which is nearly 95 km wide and covers an area of about 4,736 km^2. The main river splits in four distributaries which debauch into the Bay of Bengal. The first channel begins near Avanigodda and the three main distributaries are the Golumuttapaya, the Nadimieru and the Main channels. A weir at the head controls the flow within the deltaic plain. Vast amounts of sediment material has been added at the mouths of the distributaries during the past 50 years leading to the formation of river mouth bars and barrier islands with associated

Figure 4. Valley of Krishna River in Eastern Ghats

back island lagoons. As the delta progressed, these lagoons were filled in with finer grained sediments. From Vijayawada to the Bay, the average slope is 20 cm/km. The Krishna delta has large tracts of mangrove swamps along the coast with maximum concentration surrounding the three main distributaries.

Tidal flats occupy a considerable area of the lower deltaic plain especially between the Golumuttapaya and Avanigodda distributaries (Div Island). In fact, the tidal flats may be the product of a degraded inter-distributary bay between two (now abandoned) former channels.

14.1.5. Surface Water Potential of Krishna Basin

Average annual surface water potential of this basin has been assessed at 78.1 km^3. Out of this, 58.0 km^3 is utilizable water. Culturable area in the basin is about 0.203 Mm^2, which is 10.4% of the total culturable area of India. The hydropower potential of the basin has been assessed as 2,997 MW at 60% load factor.

At present, the utilization of surface water in the basin is 50.0 km^3. Past few decades have seen significant increase in storage capacity in the basin. From just about 3.2 km^3 in the pre-plan period, the total storage capacity of the completed projects has increased to 34.5 km^3. In addition, the projects under construction would add storage quantity of over 4.9 km^3 on completion. Figure 5 shows the gross flows of Krishna River at Vijayawada. This figure does not show any major trend in the data. The annual average observed runoff at some CWC sites in Krishna basin is given in Table 3.

14.1.6. Water Quality Aspects

Based on the systematic sampling of river water at many locations in the basin, its suitability for various purposes is determined by CPCB and the results are listed in

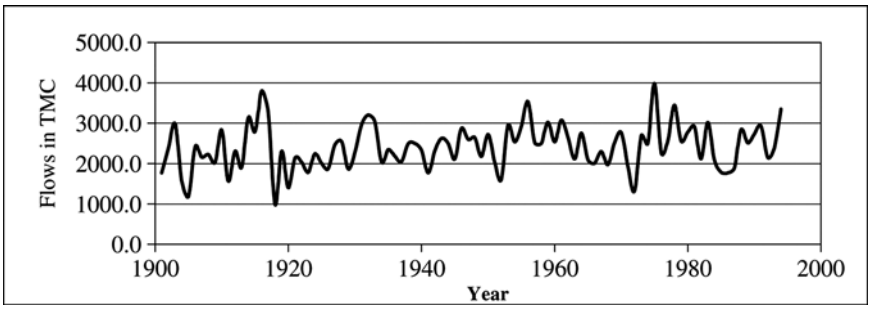

Figure 5. Gross flow of Krishna River at Vijayawada

Table 4. In general, the quality is not as per the desired class and BOD remains the most critical parameter. At some places, DO and total coliform are also causing problem.

14.1.7. Major Existing Water Resources Projects in Krishna Basin

A number of dams and barrages have been constructed and are under construction in the Krishna basin to utilize water resources. Nagarjunasagar and Srisailam are

Table 3. Annual average observed runoff at some CWC sites in Krishna basin

Name of the site	Name of the stream	Catchment area (km^2)	Annual average runoff (BCM)
Arjunwad	Krishna	12, 660	46.6
Kurundwad	Krishna	15, 190	65.2
Galagali	Krishna	22, 560	99.0
Huvenhedgi	Krishna	55, 150	100.1
Krishna Agraharam	Krishna	132, 920	203.2
Pondugala	Krishna	221, 220	184.0
Wadenapalli	Krishna	235, 544	130.2
Vijayawada	Krishna	251, 360	102.1
Dhond	Bhima	11, 660	32.5
Narsingpur	Bhima	22, 856	31.5
Takali	Bhima	33, 916	32.6
Yadgir	Bhima	69, 863	57.0
Wadakbal	Sina	12, 092	56.8
Hariahalli	Tungabhadra	14, 582	97.5
Ollenur	Tungabhadra	33, 018	80.4
Mantralayam	Tungabhadra	60, 630	84.6
Bawapuram	Tungabhadra	67, 180	61.5
T. Ramapuram	Hagari	23, 500	5.7
Damercherla	Musi	11, 501	8.9
Bhupasamundram	Vadavathi	15, 026	4.6

Table 4. Desired and existing water quality status of Krishna River (1997–2001)

Location	Desired class	Observed class & critical parameters				
		1997	1998	1999	2000	2001
Krishna at Mahabaleshwar Dhom Dam Near Koina Dam, Maharashtra	C	D BOD	D BOD	D BOD	D BOD	D BOD
Krishna at Krishna Bridge, Karad, Maharashtra	C	D BOD, Totcoli	D BOD	D BOD	D BOD	D BOD
Krishna at Kurundwad in Kolhapur, Maharashtra	B	D BOD	D BOD	D BOD	D BOD	D BOD, Totcoli
Krishna at Sangli, Maharashtra	C	D BOD	D BOD	D BOD	D BOD	D BOD
Krishna at U/S of Ugarkhurd Barrage, Karnataka	C	NA	C	C	C	C
Krishna at D/S of Narayanpura Dam, Karnataka	C	NA	C	NA	NA	C
Krishna at Tintini Bridge, Karnataka	C	C	C	C	C	C
Krishna at Rajapur Weir, Maharashtra	B	D DO, BOD	D BOD	D BOD	D BOD	D BOD
Krishna at D/S Of Devasagar Bdg., Karnataka	C	C	NA	C	C	C
Krishna after Confl. with Tungabhadra, Sangameshwaram A.P.	C	D BOD	NA	NA	D BOD	NA
Krishna at Vijaywada, A.P.	C	C	C	C	NA	NA

* NA - Not Available.
Source: Central Pollution Control Board.

two large terminal reservoirs on Krishna. These two have enough storage to regulate the inflows received in Andhra Pradesh for irrigation and hydropower. The left and right bank canal systems of Nagarjunasagar extend up to Godavari and Pennar delta and are notable examples of intra-basin water transfer. Telugu Ganga canal taking off from the Srisailam reservoir and carrying water up to Tamil Nadu for Chennai water supply is another praiseworthy example of inter-basin transfer with cooperation amongst the states.

A brief description of the important projects in Krishna basin is given here.

Upper Krishna project stage – 1

The first stage of the project comprises of two components:

- A dam across the Krishna River near Almatti village in Bagewadi taluk of Bijapur district to storing water up to RL 512.20 m for providing irrigation to an area of 160 Mm^2.
- Another dam across the Krishna River, at Narayanapur (downstream of Almatti Dam) near Bachihal and Siddapur village in Muddebihal taluk of Bijapur district. A Left Bank Canal from the dam will provide irrigation under to 4,250 Mm^2 area and the water utilization will be 3,368 Mm^3. The salient features of the Narayanpur dam are given in Table 5.

Narayanpur or Upper Krishna Stage I dam is located downstream of Almatti dam after confluence of the Malaprabha and Krishna rivers. A major part of Upper Krishna command is covered under the Narayanpur canals for which, the main supplementing storage would be at Almatti. Narayanpur dam is a composite dam, located at north latitude of 16°10′00″ and an east longitude of 76°21′00″ near village Siddapur in Muddebihal Taluka of Bijapur district. Narayanpur dam is 10,637.52 m long and 29.72 m high. The catchment area of the reservoir is 47,850 km^2. The Project provides water for irrigation to the drought prone areas of Bijapur, Bagalkote, Gulbarga, Raichur and Koppal Districts. This project has been taken up in two stages. A view of Narayanpur dam can be seen in Figure 6.

Upper Krishna project stage – 2

The second stage of the project envisages raising FRL of Almatti Dam to 524.26 m to utilize further quantum of 1,907 MCM for providing irrigation to an additional area

Table 5. Salient features of Narayanpur dam

Particulars	Details
75 % dependable yield	22,914.40 Mm^3
Gross Storage capacity	1,072.08 Mm^3
Live Storage capacity (above MDDL)	863.04 Mm^3
Dead Storage capacity (below sill)	203.03 Mm^3
Utilization of water	3,369.70 Mm^3
MWL of dam	492.25 m
FRL of dam	492.25 m
MDDL of dam	481.58 m
Sill level of dam	462.90 m
Location of spillway	Central
Length of spillway	459.00 m
Discharge from spillways	37,922 cumec
Type and number of crest gates	Radial, 30
Size of crest gates	15 × 12 m
Submergence area	132.06 Mm^2
Villages affected	41
Population affected	48,125
Irrigable area	4,087.47 Mm^2

Figure 6. A view of Narayanpur dam

of 1,972 Mm^2. However, the state of Maharashtra claims that in case the reservoir water level rises beyond 519.6 m, there will be submergence in Maharashtra which a violation of the stipulation that the reservoir should not cause any submergence in its territory.

Almatti dam of Upper Krishna project is located on the Krishna River about 10 km downstream of the confluence of its tributary Ghatprabha. The Almatti dam is located at a north latitude of 16°19′48″ N and east longitude of 75°53′15″ E near village Almatti in Bagewadi Taluka of Bijapur district. This is a 49.29 m high composite dam of length 1,565 m. The catchment area of the dam is $35,925\,km^2$. Irrigation and hydropower generation are planned at Almatti dam apart from ensuring releases for the Narayanpur dam which is downstream to it. The salient features of the dam are given in Table 6. A view of Almatti dam can be seen in Figure 7.

The power house at Almatti has 5 units of 55 MW each and one unit of 15 MW, totaling 290 MW. The MDDL varies from 505.97 to 511.16 m and the tail race level is 489.0 m. For the 55 MW units, the rated head is 26.6 m and for the 15 MW unit, it is 24.0 m.

Srisailam dam

The Srisailam project, renamed as ‘Neelam Sanjiva Reddy Sagar’ in the honour of the former president of India, was originally planned as hydroelectric project by the Govt. of Andhra Pradesh. Subsequently, the domestic water supplies to Chennai and irrigation benefits to upland areas have been included. This is a part of the scheme for integrated development of the water resources of river Krishna in the state of Andhra Pradesh. The dam is located near the famous shrine ‘Srisailam’ known as “South Benaras” after the confluence of Tungabhadra and Bhima rivers

Table 6. Salient features of Almatti dam

Particulars	Details
75 % dependable yield	21,057.54 Mm^3
Gross Storage capacity	3,485 Mm^3
Live Storage capacity (above MDDL)	2,986 Mm^3
Dead Storage capacity (below sill)	353.11 Mm^3
Top of dam	528.756 m
FRL of dam	519.6 m
MDDL of dam	506.87 m
Location of spillway	Central
Length of spillway	486.50 m
Flood lift of spillway	15.24 m
Discharge from spillway	31,000 cumec
Number of crest gates of spillway (radial)	26
Size of crest gates of spillway	15 × 15.24 m
Sill level of river sluice	495.30 m
Submergence area	242.30 Mm^2
Villages affected	136
Population affected	180,000
Length of Almatti left bank canal	103 km
Irrigation from Almatti left bank canal	162.00 Mm^2

with the Krishna. Srisailam village is about 200 km south of Hyderabad and the Srisailam dam is situated at about 869 km downstream of the origin of Krishna River where the catchment area is 211,700 km^2. A view of Srisailam dam can be seen in Figure 8.

Figure 7. A view of Almatti dam

Figure 8. A view of the Srisailam dam and reservoir

The project involves the construction of a masonry dam of straight gravity type with an overall length of 512 m and a maximum height of about 144 m from the deepest foundation level. The reservoir formed behind the dam has a storage capacity of 8,720 Mm^3. The spillway portion is 266.4 m long having 12 bays of 18.3 m clear span each and controlled by 18.3 m × 16.7 m radial gates. It has a discharging capacity of 37,380 m^3/s. The non-overflow of the dam is on either side of spillway portion. At FRL of 269.75 m, the storage capacity is 8,723 Mm^3. The dead storage level of the dam is 260.3 m and live storage is 7,080 Mm^3. The catchment area at the dam is 203,600 km^2.

Two powerhouses are located near the dam. At the right bank powerhouse, 7 units of 110 MW each have been installed while the left bank powerhouse has 6 units of 150 MW each. The powerhouses were submerged in a flood in 1998 which caused extensive damage to them. When the Srisailam reservoir touches FRL, the backwater extends up to the Kurnool town. Fishing is also carried out in the reservoir and some recreation facilities are being setup. From the Srisailam reservoir, planned annual irrigation is 3,100 Mm^2, utilizing about 2,209 Mm^3 of water. A noteworthy feature of this dam is that nearly 5.9 km^3 of water is stored against the gates. Thus, a large quantity of water is not stored against a passive wall but against a 'live' and moving device. Recall that Ukai dam (Chapter 12) is another large dam where enormous volume of water is held behind gates.

In summer months, the river flows dwindle down to less than 30 m^3/s. The maximum flood observed in Krishna River at the dam site is of the order of 18,500 m^3/s during monsoon period (June-October). During the construction, a problem of deciding river diversion arrangements arose. The maximum river discharge data for fifteen consecutive years were studied to select the optimum discharge which would give the largest working period. Finally, diversion arrangements were designed for about 850 m^3/s capacity which ensured about 195 working days during the period from Nov–June.

The diversion arrangements finally adopted comprised of: A 9.14 m diameter circular tunnel of 567 m^3/s capacity through the left abutment; a diversion channel

of 15.24 m bed width to carry the balance of 283 m^3/s; and two semi-permanent concrete upstream and downstream cofferdams to divert the river flows for isolation of the construction area.

Papanasi temple: When the Srisailam project was planned, the Papanasi and Sangameswara temples happened to fall in its submergence area. To save these ancient monuments, these were cut and moved block-by-block. At Alampur in Mehbubnagar District, the temples were reconstructed exactly the same way as they were at the original site. Shifting of Papanasi temple is a fine example of how water resources development can be carried out while protecting the cultural heritage of the country. Recall that the famous Abu Simbel temple in Egypt was also shifted in the same manner when the Aswan Dam was constructed on Nile River in Egypt.

Pulichintala project

The Pulichintala project was originally investigated as an irrigation project. But due to construction of Nagarjunasagar dam, this project was not taken up as the entire ayacut that was originally to be irrigated under Pulichintala project was covered by Nagarjunasagar project. The present proposal is to construct a dam to stabilize irrigation in the existing ayacut in the Krishna delta for the paddy. Hydropower generation by utilizing the irrigation releases for the delta is also planned by using installed capacity of 60 MW.

At the proposed site, the catchment area is 240,733 km^2. The FRL of the reservoir will be at 53.34 m and MDDL at 42.67 m. Pulichintala reservoir will have gross storage capacity of 1,296 Mm^3 and a live storage of 1,026 Mm^3.

Nagarjunasagar project (NSP)

The Nagarjunasagar project is the largest and highest masonry dam (125 m) in the world. It is situated downstream of Srisailam reservoir on the main Krishna river in Andhra Pradesh. It is a multipurpose project with irrigation, hydropower and flood control components.

The Nagarjunasagar dam is Located near Nandikonda village, Pedavoora Mandal, Nalgonda district, latitude is 16°34′24″ N and longitude 79°18′47″ E. It is one of the dams whose height is more than 100 m; it is 124.663 m above the deepest foundation level. The catchment area at the dam at 215,193 km^2; the annual rainfall in the catchment is 889 mm, the maximum observed flood is 30,050 cumec, and the design flood (return period 1,000 year) is 58,340 cumec. For the reservoir, the FRL, DSL, and MDDL of the reservoir are at 179.83 m, 121.92 m, and 156.36 m, respectively. For this reservoir, the maximum storage is 11,555 Mm^3 and the live storage is 6,940 Mm^3. Spillway at the masonry dam is 470.916 m long and has its crest at 166.421 m. It is equipped with 26 gates of size 13.71 m × 13.14 m. When the Nagarjunasagar reservoir is full, its backwater extends up to the Srisailam dam and covers an area of 285 sq. km. A view of Nagarjunasagar dam can be seen in Figure 9.

Figure 9. A view of Nagarjunasagar dam

Nagarjunasagar project complex has substantial capacity for hydropower generation. It has one conventional and seven reversible units, each with 110 MW capacity. The right bank canal power house has 3 units of 30 MW each and left canal power house has 2 units of 20 MW each.

On an average, the Nagarjunasagar project will annually provide irrigation to a command of 12,480 Mm^2 ha by utilizing 7,465 Mm^3 water. The work on the project was completed in 1974. The project comprises a dam with two canals taking off on either side. The Nagarjunasagar Right Main (Jawahar) Canal is 203 km long and envisages creating irrigation potential in an area of 4,750 Mm^2 in Guntur and Prakasam districts. The Nagarjunasagar Left Main (Lal Bahadur) Canal is 179 m long and envisages creating irrigation potential in an area of 4,200 Mm^2 in Nalgonda, Khammam and Krishna districts. Each of these canals can carry maximum discharge of 311.5 cumec. The irrigation potential created by June 1999 was 8,100 Mm^2.

Ghatprabha dam

The Ghatprabha project comprises three stages. The first stage consists of a 71 km long left bank canal from the Dupdhal weir constructed across Ghataprabha River in 1897 near Dupdhal for providing irrigation to an extent of 425 Mm^2. The second stage comprises of extension of left bank canal from km 72 to its full length of 109 km and a dam across Ghatprabha River near Hidkal, up to a partial height of RL 650.14 m. The Ghatprabha dam is located near Hidkal town in Hukkeri taluk of Belgaum district at latitude 16°9′0″ N and longitude 74°38′0″ E. At the dam site, the catchment area is 1,412 km^2 and the water yield is 1,970.38 Mm^3.

Ghatprabha dam has a live storage capacity of 1,387 Mm^3 to provide irrigation to a total area of 1,396 Mm^2, inclusive of the area under stage I. The third stage

involves raising the FRL of Hidkal dam to its final level of RL 662.94 m (RL 2,175.00 feet) thereby creating gross storage of 1,448 MCM and constructing a 202 km long Right Bank Canal and 86 km long Chickkodi Branch Canal to irrigate 1,913.86 Mm^2. Thus, the total command area under the project comes to 3,310 Mm^2. Figure 10 shows a view of the dam. The salient features of the reservoir are given in Table 7

Tungabhadra project

Tungabhadra is the largest tributary of the Krishna River which contributes an annual discharge of 14,700 Mm^3 at its confluence with the main river. The Tungabhadra dam is located at Mallapuram, 5 km away from Hospet in the Bellary district. The latitude and longitude of the dam are 15°15′0″ N and 76°21′0″ E, respectively. With full reservoir level of 497.74 m above MSL, the reservoir extends over 378.14 Mm^2. The catchment up to the dam site is 28,168 km^2. The annual rainfall in the upper catchment of the river is 104 cm. Minor rivers that feed the Tungabhadra River are dammed at many places, creating small to medium sized reservoirs, such as Vanivilas Sagar and Anjanapur, and several large tanks, such as Shantisagar and Madag. The river carries large amount of silt and therefore, silt deposition in the reservoir is high. This has reduced the capacity of the reservoir by 13.5% in its first decade of existence. The salient features of the reservoir are given in Table 8. A view of Tungabhadra dam can be seen in Figure 11.

The climate at the reservoir site is mainly dry (humidity 80.7% to 93.7%); the average monthly maximum and minimum air temperatures ranging from 31.0 to 39.5 °C and 13.8 °C to 22.3 °C, respectively. The water remains warm (23.1 to 29.5 °C) throughout the year.

Figure 10. A view of Ghatprabha dam (Hidkal dam)

Table 7. Salient features of the Ghatprabha (Hidkal) dam

Particulars	Details
Gross Storage capacity	1,448.69 MCM
Live Storage capacity (above MDDL)	1,387 MCM
Dead Storage capacity (below sill)	60.31 MCM
Height of Dam	60 m
Type of Dam	Composite
FRL of dam	662.94 m
MDDL of dam	633.83 m
Length of spillway	149.35 m
Discharge from spillway	4,613 cumec
Crest gates of spillway (radial)	10
Size of crest gates of spillway	12.19×7.62 m
Submergence area	63.38 Mm^2
Villages affected	22
Population affected	15,660
Power Generation	32 MW
Irrigable area	3, 310.00 Mm^2
Length of Left bank canal	109 km
Capacity of Left bank canal	80.7 cumec
Area of Left bank canal	1, 618.80 Mm^2
Length of Right bank canal	202 km
Capacity of Right bank canal	66.56 cumec
Area of Right bank canal	1, 691.29 Mm^2
Withdrawals by canals	2,110.45 MCM
Reservoir losses	92.60 MCM
Gross utilization	2,203.05 MCM

Vanivilas sagar project

Vanivilas Sagar dam is situated on the Vedavati River in Chitradurga district, about 104 km northeast of the Babudan Hills (the source of the Vedavati River). Created in 1901, it is one of the oldest reservoirs in the State. Total Catchment area at the dam site is 5,374.00 km^2 and the independent catchment area is 1,554 km^2. Mean annual precipitation for the catchment is 600.00 mm and mean annual run-off at dam site is 294.49 Mm^3. Maximum flood discharge at the dam site has been estimated to be 1,000 cumec. The salient features of the reservoir have been given in Table 9. At full reservoir level of 652.28 m, the impoundment has a water spread area of 87.63 km^2. The latitude and longitude of the dam are 13°16′0″ N and 75°16′20″ E, respectively. In the headwaters area, the river receives high rainfall to the tune of 375 cm per annum. However, the precipitation in the local catchment is just 60 cm per year, as the reservoir is situated in the semi-arid plains.

The reservoir water is uniformly warm throughout the year (22.3 to 26.3 °C) and no thermal stratification develops. The pH of the water usually lies in the range 8.4–8.5.

Table 8. Salient features of the Tungabhadra project

Particulars	Details
Yield	11,978.026 Mm^3
Gross Storage capacity	3,737.82 Mm^3
Live Storage capacity	3,308.54 Mm^3
Dead Storage capacity (below sill)	65.128 Mm^3
Height of Dam	35.36 m
Length of Dam	2,449 m
Type of Dam	Composite
FRL of dam	497.74 m
MDDL of dam	477.01 m
Type of Spillway	Central
Length of spillway	701 m
Peak Discharge from spillway	18,408 cumec
Crest gates of spillway (radial)	33
Size of crest gates of spillway	18.29 m × 6.10 m
Power Generation	99 MW
Irrigable area	3,627.95 Mm^2
Length of Left bank canal	227 km
Capacity of Left bank canal	198 cumec
Irrigable Area of Left bank canal	2,439 Mm^2
Length of Right bank canal	251 km
Capacity of Right bank canal	71 cumec
Irrigable Area of Right bank canal	375.04 Mm^2
Withdrawals by canals	3,383.86 Mm^3
Reservoir losses	353.96 Mm^3
Gross utilization	3,737.82 Mm^3

Figure 11. A view of Tungabhadra dam

Table 9. Salient features of Vanivilas Sagar project

Particulars	Details
Full reservoir level	652.28 m
Storage capacity at FRL	850.30 Mm^3
Water spread area FRL	87.63 Mm^2
Dead storage level	630.950 m
Dead storage capacity	47.80 Mm^3
Live storage capacity	802.50 Mm^3
Length of dam	405.4 m
Villages affected	32
Length of High Level Canal	9.60 km
Design discharge of High Level Canal	8.825 cumec
Irrigable area of High Level Canal	4.47 Mm^3
Length of Left Bank Canal	48.00 km
Design discharge of Left Bank Canal	8.85 cumec
Irrigable area of Left Bank Canal	60.59 Mm^3
Length of Right Bank Canal	46.40 km
Design discharge of Right Bank Canal	8.85 cumec
Irrigable area of Right Bank Canal	56.29 Mm^3

Bennihora project

Bennihora project is a major river valley projects across Bhima River, a tributary of Krishna River. The dam is located in Chithapur Taluk, Gulbarga District. Its latitude is 17°27′00″ N and longitude 77°01′00″ E. The catchment area of the reservoir is 2,204.09 km^2. The salient features of the dam are given in Table 10.

Bhadha reservoir project

This is a major multipurpose river valley project across the Tungabhadra River. The dam is located near Lakkavalli village in Tarikere Taluk, of Chickamagalur District, and its latitude is 13°42′00″ N and longitude 75°38′20″ E. The catchment area of the reservoir is 1,968 km^2. The salient features of the dam are given in Table 11.

Bhima irrigation project

The Bhima project is a major river valley projects across Bhima River, a tributary of Krishna River near, near Ujjani Village in Solapur District. The dam is located at latitude 18°4′26″ N and longitude 75°07′15″ E. The gross catchment area of the reservoir is 14,856 km^2 and the free catchment area is 9,766 sq. km. salient features of the dam are given in Table 12.

Hipparagi barrage

The Hipparagi Barrage project is located near village Hipparagi, in Jamakhandi Taluka of Bijapur district. The latitude and longitude of the barrage are

Table 10. Salient features of Bennihora Project

Particulars	Details
Utilization	162.82 MCM
Catchment Area	2,204 sq. km
Gross Storage Capacity	149.97 MCM
Live Storage Capacity	140.68 MCM
Dead Storage Capacity	9.29 MCM
Type of Dam	Composite
Length of Dam	2,270 m
Tank Bund Level	441.71 m
Full Reservoir Level	438.89 m
Spillway Discharge	8,800.80 cumec
Spillway Gates	7 Nos. (15 m × 11.5 m)
Submergence Area	24.73 Mm^2
Villages Affected	9
Population Affected	9,338
Length of Left Bank Canal	66 km
Length of Right Bank Canal	82 km
Gross Command Area	248.59 Mm^2
Net Command Area	202.34 Mm^2

Table 11. Salient features of Bhadha Reservoir Project

Particulars	Details
75% dependable yield	2,396.45 Mm^3
Gross Storage Capacity	2,024.65 Mm^3
Dead storage Capacity	240.69 Mm^3
Live storage Capacity	1,783.96 Mm^3
Total Submergence area	112.51 Mm^2
Forest area	7.17 Mm^2
Cultivable area	32.75 Mm^2
Villages affected	28
Allocation of Water as per Krishna Water Disputes Tribunal Award	1,747.15 Mm^3
Gross command area	1,628.18 Mm^2
Cultivable command area	1,215.00 Mm^2
Irrigable area	1,055.70 Mm^2
Type of Dam	Composite
Length of Dam	1,708 m
Height of Dam above river bed level	59.13 m
MWL	657.75 m
Full Reservoir level	657.75 m
Minimum draw down level	636.40 m
Dead storage level	631.50 m
Type and length of Spillway	Ogee, 82.30 m
Discharging capacity of Spillway	3,020 cumec
Type of Crest Gates	Vertical
Size of Crest Gates	7.62 m × 18.28 m
Installed capacity for hydropower	160 MW

Table 12. Salient features of Bhima Project

Particulars	Details
Gross Storage Capacity	3,114 Mm^3
Dead Storage Capacity	1,700 Mm^3
Live Storage Capacity	1,414 Mm^3
Total submerged area	29,000 ha
Villages submerged	82
Annual Utilization	2,410 Mm^3
Length of Dam	2,467 m
MWL of Dam	497.58 m
FRL of Dam	496.83 m
Type and length of Spillway	Ogee, 608 m
Discharging capacity of Spillway at FRL	15,717 cumec
Number and Size of Crest gates	41,12 m × 6.5 m
Length of Left bank canal	126 km
Irrigable area of Left bank canal	68,840 ha
Length of Right Bank Canal	112 km
Irrigable area of Right Bank Canal	44,100 ha

16°33′00″ N75°10′00″ E, respectively. The catchment area at the barrage is 22,699 km^2. The salient features of the project are given in Table 13.

Malprabha project

This project is located on the Malprabha tributary of Krishna River, near village Navilutheertha, in Saundatti Taluka of Belgaum district. The latitude and longitude of the barrage are 15°49′00″ N and 75°6′0″ E, respectively. The catchment area of the reservoir is 2,564 km^2. Salient features of the dam are given in Table 14. A view of Malprabha dam can be seen in Figure 12.

Upper tunga project

This project is located near Shimoga Taluka of Shimoga district, 100 m downstream of existing Anicut. Salient features of the dam are given in Table 15.

Koyna dam

Koyna is multipurpose masonry gravity dam on Koyna River, located at a distance of 20 km from Chiplun, in Ratangiri District, Maharashtra. The catchment area at the dam is 891.78 km^2. The height of the dam is 85.35 m. The reservoir has a live storage capacity of 2,662 MCM at FRL which is at 650.85 m and the MDDL is at 609.50 m. The mean annual inflow at Koyna dam is 4,745 MCM. Four power houses have been constructed under this scheme. Koyna I & II power houses have 4 units of 65 MW and 4 units of 75 MW each with a total installed capacity of 560 MW. Koyna III power house has 4 unit of 80 MW each and Koyna IV power house has 4 units of 250 MW each.

Table 13. Salient features of Hipparagi Barrage

Particulars	Details
75 % dependable Yield	17,393.91 Mm^3
Gross Storage Capacity	169.90 Mm^3
Live Storage Capacity	138.75 Mm^3
Dead Storage Capacity	31.156 Mm^3
Withdrawals by canals	308.65 Mm^3
Reservoir losses	25.76 Mm^3
Water supply	28.31 Mm^3
Total Utilization	362.74 Mm^3
Type of Dam	Composite
Length of Dam	5,463.00 m
Height of Dam	26.00 m
MWL of Dam	531.40 m
FRL of Dam	531.40 m
MDDL of Dam	517.47 m
Length of Spillway	368.78 m
Discharge capacity of Spillway	19,810 cumec
Crest gates of Spillway	23 of size 8.22 m × 13.72 m
Submersion Area	29.98 Mm^2
Villages affected	28
Population affected	49,364
Irrigable area	596.90 Mm^2
Foreshore lift canal	
a) Ainapur	
i) lift	33.14 m
ii) length in km	76
iii) command area	267.41 Mm^2
b) Haliyal	
i) lift	37.63
ii) length in km	94
iii) command area	329.49 Mm^2

Markendaya project

The Markendaya project is located on Ghatprabha tributary of Krishna River, near village Shirur in Hukkeri Taluka of Belgaum district. The latitude and longitude of the barrage are 16°02′00″ N and 74°38′33″ E, respectively. The catchment area at the project side is 432 km^2. The salient features of the dam are given in Table 16.

Singatalur lift irrigation

The Singatalur Lift Irrigation project is located on Tungabhadra River near village Hammige, in Mundaragi Taluka of Gadag district. The latitude and longitude of the barrage are 15°02′00″ N and 75°50′0″ E respectively. The catchment area at the project is 19,850 km^2. The salient features of the dam are given in Table 17.

Table 14. Salient features of Malprabha Project

Particulars	Details
Yield	1,205.44 Mm^3
Gross Storage Capacity	1,068.39 Mm^3
Live Storage Capacity	866.25 Mm^3
Dead Storage Capacity	95.99 Mm^3
Irrigable Area	2,181.91 Mm^2
Submerged Area	135.78 Mm^2
Village affected	43
Population affected	41,000
Type of Dam	Masonry
Height of Dam	56 m
Length of Dam	69 m
MWL of Dam	633.83 m
FRL of Dam	633.83 m
MDDL of Dam	623.93 m
Location of Spillway	Central
Length of Spillway	85.34 m
Discharging capacity of Spillway	5,236 cumec
Type of Gates of Spillway	radial
Gates of Spillway	4 of size 15.24 m × 12.19 m
Length of Right Bank Canal	138.00 km
Capacity of Right Bank Canal	58.10 cumec
Command Area of Right Bank Canal	1,399.21 Mm^2
Length of Left Bank Canal	168.00 km
Capacity of Left Bank Canal	38.91 cumec
Command Area of Left Bank Canal	531.34 Mm^2

Krishna irrigation project

The Krishna Irrigation Project covers Satara and Sangli Districts in Southern Maharashtra. The project consists of two storage dams across the Krishna River (Dhom) and its tributary Venna River (Kanher) for irrigation in downstream semi-arid and arid zones as well as industrial water supply to Wai and Karad towns.

The Krishna Irrigation Project (K.I.P.) was cleared for implementation in the year 1966. The proposed water utilization of the Krishna Irrigation Project with three storage reservoirs was 1,051.54 Mm^3. However, in view of the reduced quantum of water from the Krishna basin allotted to Maharashtra State as a result of Krishna tribunal award (year 1974–75), it was decided to reduce the utilization of Krishna irrigation project to 849.62 Mm^3.

The Krishna irrigation project's catchment area of the storages and command area lies in between latitude 17°0′ N and 18°0′ N; and longitude 73°45′ E to 74°45′ E. This command area can be classified in the three groups: (1) Having normal annual rainfall 700 to 800 mm; (2) Having normal annual rainfall 400 to 500 mm (semi arid zone), and (3) Having normal annual rainfall below 400 mm (arid zone). Kanher and Dhom command area falls under the 1st category. Arphal command area up to 40 km falls under the 1st category, from 40 km to 100 km comes under the 2nd

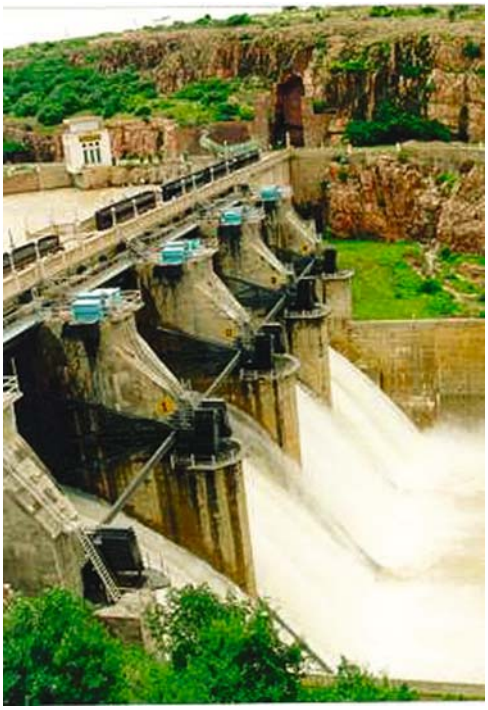

Figure 12. A view of Malprabha dam

category, and beyond 175 km of the Arphal left bank canal, the area is under the 3rd category.

Annual rainfall in the command area varies from 700 to 800 mm; it is less than 400 mm in the tail reach. Nearly 75% of annual rain falls during the months of June to September. Average annual runoff at Dhom reservoir site is 423.30 Mm^3. Catchment area at Dhom dam site is 217.56 km^2. Average annual runoff at Kanher reservoir (Venna River) site is 483.60 MCM and the catchment area at this dam is 204.69 km^2.

Part of the command area of this project is under semi-arid and arid zone. Demand for irrigation water in arid zone from Krishna irrigation project has increased due to increase in irrigation area. Reservation of water from Krishna irrigation project storages for the industrial area (Wai and Karad towns) has also increased. But the reduced water allocation for Krishna irrigation project necessitated the revision of water planning for the project whole. The 75% dependable yield from the two storages viz. Dhom and Kanher is approximately 822.15 MCM. The quantum of water available is not adequate to cater to all demands of extending irrigation facilities (Dhom command, Kanher command, Arphal command) and reserving water for industrial area (Wai and Karad). Hence it is necessary to use the available water optimally.

Table 15. Salient features of Upper Tunga project

Particulars	Details
Type of dam	Composite
Length of dam	770 m
FRL of dam	588.24 m
Top level of dam	592.20 m
Canal off take	584.45 m
Length of canal on left bank	339.50 m
Type of Spillway	Ogee with roller bucket
Length of Spillway	311 m
Crest level of Spillway	583.50 m
Type of Crest gates	Radial
Number of Crest gates	22
Size of Crest gates	11.75 m × 4.74 m
Length of non-over flow section	335.00
Sill level of river sluice	573.00
Number of gates of river sluice	3
Size of gates of river sluice	2.5 m × 4.0 m
Length of embankment	192 m
Top width of embankment	7.5 m
Top level of embankment	593.2 m
Number of Gates in Left side irrigation sluice	5
Size of Gates in Left side irrigation sluice	2.5 m × 1.829 m
Sill level of Left side irrigation sluice	582.168 m
Number of Gates in Right side irrigation sluice	2
Size of Gates in Right side irrigation sluice	2.5 m × 1.219 m
Sill level of Right side irrigation sluice	582.778 m
Irrigable area	947.00 Mm^2
Water utilization	349.35 Mm^3

Accordingly, the project planning was changed by deleting storage scheme at Borkhal; reducing the water losses in conveyance by lining the canals; deleting some of the command area under the Arphal left bank canal; diluting the crop pattern and extending the irrigation facilities to the more command area; and reserving the water for industrial area at Wai and Karad. Jowar, groundnut and pulses are major Kharif crops, and the major Rabi crop is Jowar (local) or hybrid variety; and well irrigation for perennial crop is only practiced in the Dhom and Kanher command area.

Osmansagar reservoir

The Osmansagar reservoir is situated near Gandipet village in Rangareddy district, AP, at latitude and longitude 17°22′30″ and 78°22′0″ respectively. It was constructed across Musi River in the year 1920 with live capacity of 156.81 MCM and gross storage capacity of 180.54 MCM. The designed maximum flood discharge is 2,971 cumec. Though the main purpose of the reservoir at the time of construction was to absorb flood water but it is now serving as a water supply source to the twin

Table 16. Salient features of Markendaya Project

Particulars	Details
Average yield	124.31 Mm^3
Gross Storage Capacity	104.66 Mm^3
Dead Storage Capacity	14.47 Mm^3
Live Storage Capacity	70.20 Mm^3
Total submerged area	8.98 Mm^2
Villages submerged	9
Population affected	2,258
Gross Utilization	113.27 Mm^3
Irrigable area	191.05 Mm^2
Type of Dam	Gravity dam in concrete
Length of Dam	1,356 m
Height of Dam	39.10 m
MWL of Dam	704.00 m
FRL of Dam	704.00 m
MDDL of Dam	690.55 m
Dead Storage Level of Dam	688.85 m
Type of Spillway	High ogee
Length of Spillway	112.50 m
Discharging capacity of Spillway	3,728.00 cumec
Type and number of Crest gates	Radial, 7 gates
Size of Crest gates	8.00 m × 12.7 m
Length of Left bank canal	12 km
Irrigable area of Left bank canal	8.90 Mm^2
Length of Right Bank Canal	80 km
Irrigable area of Right Bank Canal	182.15 Mm^2

Table 17. Salient features of Singatalur Lift Irrigation Project

Particulars	Details
75 % dependable yield	7,204.94 Mm^3
Type of weir	Ungated concrete barrage
Length of weir	402.00 m
Height of weir	3.00 m
Irrigable area	194.25 Mm^2
MWL of Dam	508.75 m
FRL of Dam	507.00 m
Minimum water level of Dam	501.00 m
Type of Spillway	Low ogee
Discharging capacity of Spillway	14,724.62 cumec
Type of Crest gates	Vertical lift type
Number of gates	27
Size of gates	12.0 m × 3.0 m

cities of Hyderabad and Secunderabad. The catchment area up to Osmansagar is 738.15 sq. km comprising 637.14 sq. km free and rest of 101.01 sq. km intercepted. The salient features of the reservoir are given in Table 18.

According to the sedimentation study made by Vishwantaham and Eashwaraiah (2004) through remote sensing, the current live storage capacity of Osmansagar reservoir is 100.19 MCM and the loss of live capacity works out to 56.63 MCM over a period of 82 years. The average annual loss of live capacity is approximately at the rate of 0.7 MCM/year.

Prakasam barrage

This barrage is the terminal structure on the Krishna River to meet the delta requirements in the Krishna basin. It has been named after a former chief minister of the Andhra Pradesh. The barrage is located near Vijayawada in Andhra Pradesh. At the barrage, the catchment area is 257,078 km^2 and the pond level is 17.4 m. Prakasam barrage provides irrigation to a command of 4,450 Mm^2 utilizing 5,132 Mm^3 of water.

Other existing projects

In addition to the above, there are several existing water resources projects in the basin. Salient features of existing water resources projects with a live storage capacity of 10 Mm^3 and above have been presented in Table 19.

14.1.8. Major Ongoing Water Resources Projects in Krishna Basin

Telugu ganga project (TGP)

Telugu Ganga Project (TGP) is a prestigious on-going project in this basin. Telugu Ganga Project is an interstate project formulated to utilize flood water of Krishna and Pennar rivers to irrigate 2,327.025 Mm^2 in drought prone areas of Kurnool, Cuddapah and Chittoor districts of Rayalaseema and uplands of Nellore districts in A.P., besides conveying 15 TMC (424.80 MCM) of Krishna water of Chennai City. The scheme consists of 408 km long canal from Srisailam dam up to the Andhra Pradesh and Tamil Nadu border. The project commenced in 1983 and the target date of project completion was 2005. The project also envisages power generation at three locations: Velugodu (9 MW), Chennamukkapalli (15 MW), and Kandaleru (99 MW).

Table 18. Salient features of Osmansagar Reservoir

Full reservoir level	545.59 m
Maximum water level for absorbing flood	550.16 m
Water spread area	27.22 sq. km
Capacity at FRL	180.54 MCM
Capacity at MWL	328.45 MCM
Live storage capacity at FRL	156.82 MCM
Flood storage	147.92 MCM
Free catchments area	637 sq. km

Table 19. Salient features of selected existing projects in Krishna basin

Name of the Project	State	Year of completion	Gross storage capacity (million cubic meter)	Live storage capacity (million cubic meter)	Designed annual irrigation (million Sq. Meter)	Installed capacity (MW)
Bhariravuni Tippa	Andhra Pradesh	1961	74.24	65.29	68.00	–
Dindi Project	Andhra Pradesh	1943	5, 901.00	58.14	127.50	–
Gajuladinne	Andhra Pradesh	1979	48.14	42.47	129.50	–
Himayat Sagar	Andhra Pradesh	1926	216.60	104.80	–	–
Jutpally	Andhra Pradesh	1965	94.12	85.48	9.80	–
Koilsagar Project	Andhra Pradesh	1955	69.83	64.46	43.00	–
Kotepallyvagu	Andhra Pradesh	1969	44.52	36.85	3.30	–
Lakhnapur	Andhra Pradesh	1968	92.85	85.48	10.40	–
Lanka Sagar	Andhra Pradesh	1968	18.81	17.26	12.30	–
Musi Dam	Andhra Pradesh	1961	136.94	130.26	167.30	–
Pakhal	Andhra Pradesh	1919	–	82.50	38.40	–
Paliar	Andhra Pradesh	1928	72.45	66.50	79.70	–
Pendlipakla	Andhra Pradesh	1938	15.32	14.53	13.70	–
Sarala Sagar Project	Andhra Pradesh	1959	15.05	13.91	16.80	–
Siddapur	Andhra Pradesh	1919	24.74	18.56	2.50	–
Wyra Project	Andhra Pradesh	1930	70.13	59.39	70.40	775
Ambligola	Karnataka	–	12.39	11.70	29.50	–
Bhadra	Karnataka	1963	2, 023.00	1, 635.00	1, 060.00	58
Chamdrampalli	Karnataka	1971	34.20	31.40	52.20	–
Dharma	Karnataka	1964	23.00	21.10	27.90	–
Gayatri Reservoir	Karnataka	1963	27.53	18.10	9.50	–
Jamradhalla	Karnataka	1968	37.00	28.00	15.40	–
Ramanahalli	Karnataka	1960	12.86	11.68	19.40	–
Ashti	Maharashtra	1976	–	22.99	47.70	–
Bhatghar	Maharashtra	1892	672.67	665.59	–	18
Budhiyal	Maharashtra	1966	–	19.02	42.50	–
Chandhani	Maharashtra	1966	20.70	15.20	20.20	–
Ekruk	Maharashtra	1891	–	61.17	26.10	–
Ghod	Maharashtra	1957	216.31	170.74	246.00	–
Hirani	Maharashtra	1966	12.57	11.17	16.60	–
Hingani	Maharashtra	1978	45.51	31.97	–	–
Kanhar	Maharashtra	1988	286.00	271.68	91.80	–
Khadakwasla	Maharashtra	1979	85.92	62.59	620.00	–
Khairi	Maharashtra	–	15.11	13.74	28.00	–
Khasapur	Maharashtra	1956	19.81	15.84	21.40	–
Kolkewadi Dam	Maharashtra	1975	36.22	11.22	–	40
Kurnur	Maharashtra	1970	35.24	32.26	36.40	–
Lonawala	Maharashtra	1916	–	11.52	13.10	72
Mangi	Maharashtra	1966	32.69	31.70	31.20	–
Manikdoh	Maharashtra	1986	308.06	288.07	–	–
Mehekari	Maharashtra	1966	16.13	12.98	40.50	–
Mhaswad	Maharashtra	1988	47.91	46.21	40.50	–
Morna	Maharashtra	1985	21.18	15.16	51.70	–

(*Continued*)

Table 19. (*Continued*)

Name of the Project	State	Year of completion	Gross storage capacity (million cubic meter)	Live storage capacity (million cubic meter)	Designed annual irrigation (million Sq. Meter)	Installed capacity (MW)
Mulshi	Maharashtra	1929	–	522.00	81.60	150
Nazare	Maharashtra	1974	16.17	10.50	32.00	–
Panshet	Maharashtra	1971	303.96	256.00	–	–
Pathari	Maharashtra	1905	11.87	11.61	63.00	–
Pawana	Maharashtra	1975	305.00	274.00	–	10
Radhanagari	Maharashtra	1954	236.79	219.00	265.60	–
Shefal	Maharashtra	1901	17.55	16.93	–	–
Shirwata	Maharashtra	1920	185.98	130.41	–	–
Sina	Maharashtra	1990	67.95	52.30	73.60	–
Thokarwadi	Maharashtra	1922	363.70	360.91	29.00	–
Tisangi	Maharashtra	1966	26.16	24.46	40.90	–
Tulashi	Maharashtra	1978	98.29	91.92	57.10	–
Vir	Maharashtra	1961	278.53	265.78	161.10	–
Visapur	Maharashtra	1936	33.22	25.72	53.20	–
Wadaj	Maharashtra	1981	36.00	33.20	–	–
Walwan	Maharashtra	1916	72.50	54.37	–	–
Yadegaon	Maharashtra	1978	93.42	79.37	–	–

The project benefits include irrigation for $1,112.925\,Mm^2$ in Kurnool and Cuddapah districts with Krishna flood waters amounting to $820.99\,Mm^3$ and irrigation for $1,214.10\,Mm^2$ in Nellore and Chittoor districts with Pennar flood waters: $849.30\,Mm^3$. For the Chennai city, water requirement from Krishna basin will be $424.65\,Mm^3$. Out of this, the share of Andhra Pradesh, Karnataka, and Maharashtra each will be $141.55\,Mm^3$. The components include four balancing reservoirs: Velugodu Balancing Reservoir, S.P.V. Balancing Reservoir, Somasila Reservoir, and Kandaleru Reservoir.

Other under construction projects

In addition to the above, there are several under construction water resources projects in the basin. Salient features of under construction water resources projects with a live storage capacity of $10\,Mm^3$ and above have been presented in Table 20.

14.1.9. Krishna Water Dispute Tribunal

In 1969, the government of India constituted the Krishna Water Dispute Tribunal to adjudicate upon the water dispute regarding the Krishna River. The KWDT gave its award in 1973 and it was published in 1976. Details about the award are given in Chapter 21.

Table 20. Salient features of selected Under construction projects in Krishna basin

Name of the project	State	Gross storage capacity (MCM)	Live storage capacity (MCM)	Designed annual irrigation (million sq. m)	Installed capacity (MW)
Gajuladinne	Andhra Pradesh	127.43	121.20	128.00	–
Varadarajaswamy Gudi	Andhra Pradesh	11.02	10.20	34.80	–
Amarja	Karnataka	44.01	40.07	89.00	–
Bennithora Project	Karnataka	155.06	145.78	200.00	–
Hagaribommanhalli	Karnataka	57.00	50.00	29.80	–
Hirehalla	Karnataka	47.23	41.56	80.20	–
Lower Mullamari	Karnataka	49.13	39.90	97.10	–
Maskinalla	Karnataka	13.11	10.70	28.30	–
Narihalla	Karnataka	22.92	20.86	14.10	–
Rangayyanadurga	Karnataka	14.20	13.10	–	–
Upper Mullamari	Karnataka	21.23	17.55	32.80	–
Bori	Maharashtra	37.46	30.72	104.50	–
Chaskaman	Maharashtra	238.17	210.99	390.00	–
Chikotra	Maharashtra	42.80	39.99	46.90	–
Dimbhe	Maharashtra	382.22	353.91	–	–
Dudhganga	Maharashtra	701.78	663.83	650.00	15
Jaggamhatti	Maharashtra	27.79	26.29	31.40	–
Jawalgaon	Maharashtra	34.75	25.19	53.40	–
Kadvi	Maharashtra	71.24	70.56	92.20	215
Kasari	Maharashtra	78.56	77.96	94.60	215
Kasarsai	Maharashtra	13.75	12.62	–	–
Kumbhi	Maharashtra	76.88	76.49	88.90	27
Patgaon	Maharashtra	76.26	75.79	83.60	–
Pauna	Maharashtra	–	244.00	–	5
Sankh	Maharashtra	19.93	14.87	–	–
Urmodi	Maharashtra	82.94	76.73	90.40	–
Veer Baji Pasalkar	Maharashtra	374.00	275.00	–	11
Varna	Maharashtra	963.97	799.73	1, 140.00	27
Wadivala	Maharashtra	32.48	22.00	36.30	–
Yerlawadi	Maharashtra	32.82	19.61	–	–

14.2. THE GODAVARI BASIN

Godavari is the largest river in Peninsular India and third largest in India. Godavari is held in reverence as "Vridha Ganga" or "Dakshin Ganga". Holy places are located on the banks of the river at Nasik and Bhadrachalam. Godavari rises in the Sahyadris near Triambakeswar, about 80 km from the shore of Arabian Sea, at an elevation of 1,067 m in the Nasik district of Maharashtra. Kumbh Mela which attracts millions of devotees is organized at Nasik after every 12 years. After flowing for about 1,465 km in a general south-easterly direction through Maharashtra and Andhra Pradesh, Godavari falls into the Bay of Bengal north of Rajahmundry. The basin

lies between latitudes 16°16′0″ N and 23°43′ N longitudes 73°26′ E and 83°07′ E. The basin extends over an area of 312, 813 km^2, which is nearly 10% of the total geographical area of the country. It is bounded on the north by the Satmala Hills, the Ajanta Range and the Mahadeo Hills, on the east and south by the Eastern Ghats and on the west by the Western Ghats. The state-wise distribution of the catchment area is shown in Table 21. Important tributaries of the Godavari are the Pravara, the Purna, the Manjra, the Maner, the Penganga, the Wardha, the Pranhita, the Indravati and the Sabari. The Jayakwadi project, Sriram Sagar project and Cotton barrage (Dowleswaram) are the important projects existing in the basin. The proposed major projects are Bhopalpatnam, Inchampalli and Polavaram. An index map of Godavari basin is given in Figure 13.

About 64 km from its source, Godavari receives the waters from Dharna, on its right bank and a short distance lower down the Kadwa joins it from the left. The combined waters of the Pravara and 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 from the Purna and Dudhna rivers and after a further 138 km at the border of Maharashtra and Andhra Pradesh, the waters of the Manjira River join it from the south. At this point, Godavari flows at an elevation of about 329 m.

The Pranhita River, conveying the combined waters of Penganga, Wardha and Wainganga, which drain Nagpur and southern slopes of the Satpura ranges, falls into the Godavari about 306 km below its confluence with the Manjira. Forty-eight km lower, the waters of the Indravathi 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.

Further below Rajahmundry, the river branches off into two main streams – the Gautami Godavari on the east and Vasishta Godavari on the west. Further down, a branch Vainateyam splits from the Vasishta Godavari at Gannavaram 22 km from the coastline. All these streams run down to sea through arid alluvial delta formed over the ages by the mass of silt that has been deposited. The basin is roughly triangular in shape and the river itself runs practically along the base of the triangular.

Table 21. Distribution of catchment area in Godavari basin

S. N.	State	Drainage area (sq. km)	% of the total basin area
1.	Maharashtra	152, 199	48.6
2.	Andhra Pradesh	73, 201	23.4
3.	Madhya Pradesh	31, 821	10.0
4.	Chhattisgarh	33, 434	10.9
5.	Orissa	17, 752	5.7
6.	Karnataka	4, 406	1.4
	Total	312, 813	100.0

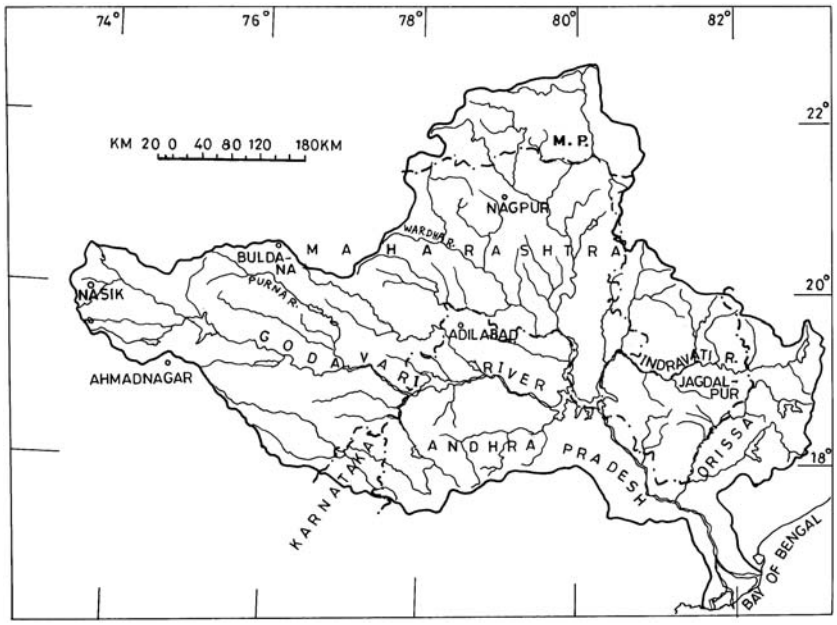

Figure 13. Index map of Godavari basin

14.2.1. Topography

The Godavari basin is bounded on the north by the Satmala hills, on the south by the Ajanta range and the Mahadeo hills, on the east by the Eastern Ghats and on the west by the Western Ghats. 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.

The upper reaches of the Godavari drainage basin are occupied by the Deccan Traps containing minerals, hypersthene, augite, diopside, enstatite, magnetite, epidote, biotite, zircon, rutile, apatite and chlorite. The middle part of the basin is principally Archean granites and Dharwars composed of phyllites, quartzites, amphiboles and granites. The downstream part of the middle basin is occupied mainly by the Cuddapah and Vindhyan metasediments and rocks of the Gondwana group. The Cuddapahs and Vindhyan are quartzites, sandstones, shales, limestones and conglomerates. The Gondwanas are principally detritals with some thick coal seams. The Eastern Ghats dominate the lower part of the drainage basin and are formed mainly from the Khondalites which include quartz- feldspar- garnet- sillimanite gneisses, quartzite, calc-granulites and charnockites. In the coastal region the tertiary Rajahmundry sandstones crop out.

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 m with its general slope eastwards. Great undulating plains, divided from each other by flat topped ranges of hills, are the chief characteristics of this plateau.

The Eastern Ghats which form the eastern boundary of the peninsula are not 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. The northern boundary of the basin comprises a series of table-lands varying from 600 to 1,200 m 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 and scrub jungles. The delta of Godavari consists of a wide belt of river borne alluvium formed by deposits at the mouth of the river over the ages. The process of silting at the mouth of the river is still continuing and the delta is gradually extending into the sea.

14.2.2. Major Tributaries of Godavari River

The Godavari basin was divided into 12 sub-basins by the Godavari Water Disputes Tribunal. These are: (i) the Upper Godavari (from the source to its confluence with Manjira) (G-1), (ii) the Pravara (G-2), (iii) the Purna (G-3), (iv) the Manjira (G-4), (v) the Middle Godavari (from its confluence with Manjira to its confluence with the Pranhita) (G-5), (vi) the Maner (G-6), (vii) the Penganga (G-7), (viii) the Wardha (G-8), (ix) the Pranhita (G-9), (x) the Lower Godavari (from its confluence with the Pranhita up to the Sea) (G-10), (xi) the Indravati (G-11) and (xii) the Sabari (G-12). A flow diagram of Godavari River is shown as Figure 14.

The largest tributary of the Godavari is the Pranhita (inclusive of Penganga and Wardha) with about 34% coverage of drainage area. The Pravara, Manjira and Maner are right bank tributaries covering about 16.1%, the Purna, Pranhita, Indravathi and Sabari are important left bank tributaries, covering nearly 59.7% of the total catchment area of the basin. The Godavari in the upper, middle, and lower reaches make up for the balance 24.2%. The particulars of the catchment area, length, elevation of the source points of the river and its tributaries in the order of their occurrence along the length of the main river are shown in Table 22.

Major tributaries of Godavari flowing through well-established drainage networks are the Pravara, the Purna, the Manjra, the Penganga, the Wainganaga, the Wardha, the Pranahita, the Indravati, and the Sabari. A brief description of the principal tributaries is given in the following.

The Pravara river

The Pravara River originates in the Western Ghats at an altitude of about 1,067 m. After traversing a distance of about 200 km in the easterly direction it falls into

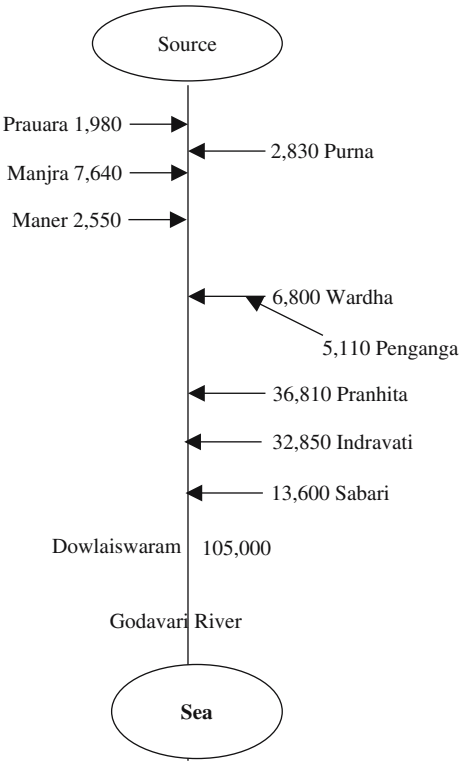

Figure 14. Flow diagram of Godavari River

the Godavari River near Newasa at an altitude of about 457 m. The Mula River is the right bank tributary of Pravara River. The drainage area of the Pravara River is $6,537\,km^2$ lying entirely in Maharashtra, but its principal source of supply is only about 32 km length of the Western Ghats.

Table 22. Important Tributaries of Godavari

SN	Tributary	Elevation of Source	Length (km)	Catchment area (sq. km)
1	Pravara	1, 050	208	6, 537
2	Purna	838	374	15, 579
3	Manjira	823	686	30, 844
4	Maner	533	225	13, 106
5	Pranhita	640	721	109, 079
6	Indravathi	914	536	41, 665
7	Sabari	1, 372	418	20, 427
8	Main Godavari including minor tributaries	1, 067	1, 465	75, 576

The Purna river

The Purna River originates in the Ajanta Range of hills at an altitude of 838 m. It flows in a south-easterly direction for a distance of 373 km before joining the Godavari at an elevation of about 351 m. The Dudna is its longest tributary. The catchment area of the Purna River, including its tributaries is 15,579 km^2 which lies in a low rainfall zone which gets 711 mm to 889 mm of rain in the year.

The Manjara river

The Manjara River is one of the major tributaries of Godavari, which originates in the Balaghat Range of hills in the Bhir district of Maharashtra at an altitude of about 823 m. The river flows in a general east and south easterly direction for 512 km through the Osmanabad district of Maharashtra, the Bidar district of Mysore and the Medak district of Andhra Pradesh before changing its direction Northwards near Sanga Reddipet. After flowing for 75 km further, it enters the Nizamabad district of Andhra Pradesh and from 102 km lower down, it forms the boundary between Maharashtra and Andhra Pradesh. 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 Manjara River are the Tirna, the Karanga, the Halai, the Lendi and the Maner. The catchment area of the Manjra River including its tributaries is 30, 844 km^2 lying in a zone which gets about 635 mm of rain annually.

The Pranhita river

The Pranhita is the most important tributary of the Godavari River which gets water from two important tributaries, namely the Wardha and the Wainganga. The combined waters of the Wainganga and the Wardha are called the Pranhita, which traverses 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 tributaries is 109, 077 km^2 and lies in a medium rainfall zone of 889 mm to 1,600 mm (annual).

The Wardha river

Wardha is one of the right bank tributaries of Pranhita River. The Wardha sub basin lies between latitude 19°18′ N and 21°58′ N and longitudes 77°20′ E and 79°45′ E. Wardha originates at an altitude of 777 m in the Betul district of Madhya Pradesh and enters Maharashtra about 32 km from its source. After traversing a distance of 528 km, it joins the Wainganga at an elevation of 146 m. The major left bank tributaries of the Wardha are the Kar, the Wena, The Jam and the Erai and the right bank tributaries are The Madu, the Bembla and the Penganga. The drainage area of the Wardha River is 24, 087 km^2 and throughout its course, the river flows through dense forests. The average annual rainfall for the entire sub-basin is 1,000 mm approximately.

The Penganga river

The Penganga River originates at an altitude of 686 m in the Buldana Range in Maharashtra and after traversing a distance of 676 km in a generally east-south-east direction, it joins the Wardha River at an elevation of 174 m. Except in its uppermost reaches in which the terrain is barren and hilly, the river passes through dense forests of Yeotmal and Nanded districts. The important tributaries of the Penganga River are the Pus, the Arna, the Aran, and the Waghari. The drainage area of the Penganga River and its tributaries is 23, 898 km^2.

The Wainganga river

The Wainganga River originates at an altitude of 640 m in the Seoni district of Madhya Pradesh. The major tributaries of the Wainganga are the Pench, the Kanhar, the Bagh and the Andhari. The total drainage area of Wainganga and its tributaries is 61, 093 km^2.

The Indravati river

The Indravati originates at an altitude of 915 m in the Thuamul-Rampur plateau in Kalahandi district 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. The important tributaries of the Indravati River are the Podagada, the Kapur, the Muran, the Narangi, the Baordbig, the Kotri, the Bandia and the Nandira (Berudi). After flowing through a number of rapids, the river emerges into plains near Khatiguda village of Nowrangpur district. The total drainage area of Indravati River including its tributaries is 41,665 km^2 lying in a relatively high rainfall zone with about 1,524 mm of annual rainfall. It joins the Godavari River at an elevation of about 82 m at about 531 km from its source.

The Sabari river

The Sabari or the Kalab is the last major tributary of the Godavari. The river originates at an altitude of 1,372 m in the Sinkaram hill range of the Eastern Ghats. It flows for short distances in a north, north-westerly and westerly direction and joins the Godavari, about 418 km from its source, at an altitude of 25 m. The Sileru or Machkund is the most important tributary of the Sabri River originates at an elevation of 1,219 m and flows for a length of about 306 km before joining the Sabari River. The total catchment area of the Sabari including its tributaries is 20, 427 km^2.

14.2.3. Soils

The principal soil types in the Godavari basin and adjoining areas are (i) black soils (regur), (ii) red soils, (iii) laterites and lateritic soils, (iv) alluvium, (v) mixed red and black soils and red and yellow soils and (vi) saline and alkaline soils. The soils in the basin are generally fertile.

14.2.4. Climate of Godavari

The climate of the Godavari drainage basin has high humidity throughout the year effected by the northeast and southwest monsoons. The delta region is semi-arid with an average annual rainfall of 1,042 mm and a maximum temperature in May of 37.3 °C. The coldest month is January with a mean daily maximum temperature of 26.9 °C and a mean daily minimum temperature of 19.2 °C.

Three distinct seasons occur in the Godavari basin, viz. (i) the hot weather, (ii) monsoon and (iii) the winter. The summer season is from mid-February to the end of May. In the hot weather, the heat is unbearable in the central, northern and eastern regions. The weather is comparatively less hot 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 84% of its total annual rainfall. 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.

Temperature

The Godavari basin has a tropical climate. The mean annual surface temperature in the Western Ghats 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, 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 slightly less than 30 °C in the eastern part;

Maximum and minimum temperatures in the basin gradually increase as one moves from west to east. Temperatures are the highest in April-May, which are typical summer months. The maximum temperature 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 temperature increases from 22 °C in the west to 26 °C in the east coast.

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

Rainfall pattern in the basin

The Godavari basin receives its maximum rainfall during the Southwest monsoon. The monsoon currents strike the west coast of the peninsula from west and south-west; meets the Western Ghats or Sahyadri range which presents 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 the easterly course. Rainfall is governed

largely by the orography of the area, which leads to variation in the amount of precipitation. The monsoon currents follow the eastward slope of the country from the crest of the Ghats, which form the watershed. Conditions in the interior are, therefore, somewhat unfavorable for heavy precipitation except in association with the depression from the Bay of Bengal. The Northeast part of the Godavari basin also receives some rain in association with monsoon depressions, which move west-northwest across the Orissa coast.

The Godavari receives flow from a length of about 129 km of the high rainfall zone in the Western Ghats where the annual rainfall varies from 1,000 to 3,000 mm. East of the Western Ghats, the rainfall decreases rapidly to less than 600 mm along a line running approximately from Chitradurga through Sangli and Pune to a point North-east of the line connecting Kurnool, Raichur, Bijapur and Ahmadnagar. East of this line the rainfall again gradually increases to about 900 mm towards the East coast.

The Godavari basin as a whole receives 84% of the annual rainfall on an average, during the Southwest monsoon, which sets in mid June and ends by mid October. 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, rainfall varies from 20 mm to about 50 mm in most parts of the basin. The Indravati and Pranhita sub-basins receive up to 86% and 88% of the annual rainfall during the same period due to influence of the cyclonic storms which predominantly pass through these sub-basins. Particulars of average rainfall in the different sub-basins are given in Table 23.

14.2.5. Water Quality Aspects

Table 24 gives the results of systematic sampling of river water quality carried out by CPCB at different times. It can be seen that at almost all places, the quality

Table 23. Rainfall Pattern in the Sub-basins of Godavari

S.N.	Name of Sub-basin/tributary	Rainfall during		Annual rainfall (mm)	Monsoon rainfall percent of annual rainfall
		June-sept. (mm)	Oct-may (mm)		
1	Upper Godavari	645	125	770	84
2	Pravara	476	130	609	79
3	Purna	660	137	797	83
4	Manjira	696	150	846	82
5	Middle Godavari	809	146	955	85
6	Maner	762	170	932	82
7	Pranhita	1, 196	167	1, 363	88
8	Lower Godavari	929	280	1, 209	77
9	Indravati	1, 366	222	1, 588	86
10	Sabari	1, 137	295	1, 432	79
11	Godavari Basin	953	79	1, 132	84

Table 24. Desired and existing water quality levels of Godavari River (1997–2001)

Location	Desired class	Existing class & critical parameters				
		1997	1998	1999	2000	2001
Godavari at U/S of Gangapur Dam, Nasik, Maharashtra	• B	D DO, BOD	D BOD	D BOD	D BOD	D BOD
Godavari at Panchavati at Ramkund, Maharashtra	B	D DO, BOD	D BOD	D BOD	D BOD	D BOD
Godavari at Nasik D/S, Maharashtra	B	D DO, BOD	D BOD	D BOD	D DO,BOD	D BOD, Totcoli
Godavari at Dhalegaon, Maharashtra	B	D DO, BOD, Totcoli	D BOD, Totcoli	D BOD	D BOD	D BOD
Godavari at Nanded, Maharashtra	B	D DO, BOD	D BOD, Totcoli	D BOD	D BOD	D BOD, Totcoli
Godavari at Raher, Maharashtra	C	D BOD	D BOD	D BOD	D BOD	D BOD
Godavari at Mancherial, A.P.	C	D DO, BOD	NA	NA	NA	NA
Godavari at Polavaram, A.P.	C	B	NA	NA	D BOD	D BOD
Godavari at Rajahmundry U/S, A.P.	C	NA	NA	NA	D BOD	D BOD
Godavari at Rajahmundry D/S, A.P.	C	Below-E BOD, pH	NA	NA	D BOD	D BOD

• NA- Not Available.
Source: Central Pollution Control Board

of Godavari water is below the desired class. For example, at many places, the desired class was B or C while the existing class was D.

14.2.6. Major Water Resources Development Projects in Godavari Basin

The water resources potential in Godavari basin has been assessed by Central Water Commission to be 110.54 km^3. The utilizable surface water is about 76.3 km^3; the replenishable ground water is about 45 km^3. There is a vast potential for irrigation development and hydropower generation in the basin. The present utilization is of the order of only 40 km^3 in the case of surface water and 6 km^3 in the case of ground water.

Water resources of Upper Godavari catchment are fully utilized up to Sriram Sagar Dam. Downstream of this dam, Godavari is joined by many major tributaries, namely, Pranhita, Indravati and Sabari which carry large volumes of flood waters during monsoon. Table 25 gives monsoon yield of some of Godavari's tributaries at selected locations.

Table 25 shows that Pranhita, Indravati and Sabari contribute a huge amount of flow to Godavari in its lower reaches. Since there is no large storage reservoir in this area, most of this water (except a small quantity diverted at Godavari barrage to meet the requirements of delta irrigation) goes to the sea unutilized during the monsoon period. Of course, the scope of additional new irrigation is limited due to typical topography of the lower Godavari basin. Therefore, it is important to construct storages at Inchampalli and Polavaram to utilize huge quantity of water going waste to the sea every year. Potential storage sites for hydropower generation have also been identified on Indravati at Bhopalpatnam and Bodhghat. These storages will also regulate flows for utilization in the downstream areas. The surplus waters of lower Godavari could be transferred to the water deficit areas after meeting all the requirements of the basin in Andhra Pradesh.

Table 25. Annual average observed runoff at Important CWC sites in Godavari basin

Name of the site	Name of the stream	Catchment area (km^2)	Annual average runoff (BCM)
Polavaram	Godavari	307, 800	81.50
Koida	Godavari	305, 460	81.58
Konta	Sabari	19, 550	14.84
Injarum	Sabari	12, 925	11.42
Perur	Godavari	260, 200	54.82
Pathagudem	Indravati	40, 000	21.17
Medadapalli	Indravati	24, 212	40.75
Chindnar	Indravati	17, 270	8.36
Tekra	Pranhita	108, 780	33.85
Sirpur	Pranhita	47, 500	9.89
Bamni	Pranhita	46, 020	1039
Penganga Bridge	Pranhita	18, 441	3.04
Ghugus	Pranhita	21, 429	4.05
Hivra	Wardha	10, 240	0.86
Ashti	Pranhita	50, 990	25.27
Pauni	Pranhita	35, 520	13.50
Satrapur	Kanhan	11, 100	2.19
Somanpally	Maneru	12, 991	1.17
Mancherial	Godavari	102, 900	5.03
Yelli	Godavari	53, 630	1.79
Purna	Purna	15, 000	0.45
G R Bridge	Godavari	33, 934	0.75
Dhalegaon	Godavari	30, 840	0.71

Source: CWC (2002)

Prior to independence, only a few irrigation projects were constructed in Godavari basin. Important among these are Godavari delta system (with Dowlaiswaram weir as head works). Nizamsagar reservoir, Kadana dam and Pravara dam. After independence, under various five-year plans a large number of multi-purpose and irrigation projects were taken up. The most important among them are the Jayakwadi, Sri Ram Sagar and Godavari Barrage (by remodeling the existing Dowlaiswaram) weir. Prominent among the proposed major projects in the basin are Bhopalapatnam on Indravati, Inchampalli and Polavaram on Godavari.

Inchampalli

The Inchampalli project is proposed on the Godavari River about 12 km downstream of the confluence of Indravati with the Godavari River in Andhra Pradesh. It is a joint project among the States of Maharashtra, Madhya Pradesh and Andhra Pradesh. It is a multi purpose project envisaging irrigation benefits for upland areas, generation of hydropower, navigation facilities in the river, development of pisciculture and providing recreation benefits, besides mitigating flood hazards. Flows in abundance are available at Inchampalli, as it is just downstream of the place where two major tributaries, Pranhita and Indravati join the Godavari River. The catchment area of the dam is 269,000 Mm^2. The FRL and MDDL of the reservoir will be 112.77 m and 106.98 m respectively. The gross storage capacity and live storage capacity of the reservoir will be 8,959 and 4,098 MCM respectively. The annual irrigation from the dam is 950 Mm^2 and annual utilization is 620, 000 Mm^2. For hydropower generation install capacity at the dam is 875 MW. The Salient features of Inchampally Project are given in Table 26.

Polavaram

The Polavaram project is planned downstream of Inchampalli after the confluence of another major tributary the Sabari with the Godavari River. It is also a multi-purpose project for irrigation, hydropower, and water supply to Vizag city. The catchment area of the dam is 307, 000 Mm^2. The FRL and MDDL of the reservoir are at 45.72 m and 41.15 m, respectively. The gross storage capacity and live storage capacity of the reservoir is 4,945 and 2, 043 Mm^3 respectively. The project has been planned to utilize the significant quantum of flows that would be received from Sabari and power releases and spills from Inchampalli for its own uses and also for regulating releases for the Godavari delta. The annual irrigation from the dam is 4,720 Mm^2 and annual utilization is 3, 823, 000 Mm^2. For hydropower generation install capacity at the dam is 720 MW. The salient features of Polavaram Project are given in Table 27.

Dowleswaram barrage (cotton barrage)

The Dowleswaram Barrage is the terminal project on Godavari, located downstream of Polavaram, catering to the needs of Godavari delta. This 3,500 m long barrage built in the mid 19th century is supposed to be Asia's largest barrage. It was named as Cotton Barrage after Sir Arthur Cotton, who built the barrage and who is fondly

Table 26. Salient features of Inchampally Project

Particulars	Details
Proposed Utilization from Ayacut in Kharif	635.53 Mm^2
Proposed Utilization from Ayacut in Rabi	700.11 Mm^2
Hydropower production	975 MW
Water Availability	15,885 Mm^3
Water Requirement for Irrigation	2,265.6 Mm^3
Water Requirement for Hydropower	9,912 Mm^3
75% Dependable yield	10,025 Mm^3
Area for submergence at FRL 112.770	970 Mm^2
FRL	112.770 m
M.D.D.L.	106.980 m
Gross storage	10,375.88 Mm^3
Live Storage	9,950.23 Mm^3
Type of Dam	Masonry
Type of Spillway	Ogee
Length of Spillway	1,278 m
No & Type of gates	57, Radial Type
Size of gates	18 m × 12.37 m
Length of R/B Canal	293 km
Irrigation command area	513.95 Mm^2
Number of villages affected	229
Population affected	1 Lakh

Table 27. Salient features of Polavaram Project

Particulars	Details
Catchment area	306, 643 km^2
Proposed Utilisation from Existing Ayacut	NIL
Proposed Utilisation from New Ayacut	2, 910 Mm^2
Hydropower production	720 MW
Water Required for project	8, 535 Mm^3
Water supply to Vishakhapatnam city	663.82 Mm^3
Diversion to Krishna River	2, 265.6 Mm^3
FRL	45.72 m
M.D.D.L.	41.15 m
Gross storage at FRL	3, 388.20 Mm^3
Live Storage at MDDL	3, 381.408 Mm^3
Type of Dam	Earth cum Rock fill
Length of Dam	2,310 m
Type of Spillway	Ogee
Length of Spillway	897.50 m
No & Type of gates	44, Radial Type
Size of gates	16 m × 20 m
Length of L/B Canal	181.50 km
Length of R/B Canal	174 km
Number of villages affected	276
Population affected	117,034

remembered and revered in regard to his yeoman services to the upliftment of the people in the area. This barrage has completely transformed the famine and poverty wracked areas in the Godavari Delta into a prosperous place. Sir Cotton is credited with preparation of a grand plan for development of water resources of Peninsular India but this could not materialize due to some reasons. The catchment area at the barrage is 312,800 million sq. m. The gross storage capacity of the pond at FRL 13.81 m is 10 Mm^3. The annual irrigation from the barrage is for 9, 800 Mm^2 area for which, on an average, annually 777, 400 Mm^3 of water is utilized.

Karanja project

The Karanja Reservoir Project is a major project constructed on Manjra River, a tributary of Godavari River. The dam is located near Byalhalli in Bhalki Taluk in Bidar district. The catchment area of the dam is 2, 025 km^2. The length of the dam is 3,480 m with FRL as 584.15 m. Salient features of the Karanja project are given in Table 28.

Sriram sagar project (SRSP)

Although the Telangana area of Andhra Pradesh State is endowed with great natural water resources, such as the Godavari and Krishna Rivers, their tributaries and

Table 28. Salient features of Karanja Project

Particulars	Details
Yield	271.59 Mm^3
Gross Storage capacity	217.78 Mm^3
Live Storage capacity	207.17 Mm^3
Dead Storage capacity	10.591 Mm^3
Level at top of dam	589.15 m
Maximum Water Level	587.00 m
Crest Level	574.15 m
Sill Level	575.15 m
Peak Spillway Discharge	13,282.36 cumec
Spillway Gates	6 of size 15 m × 10 m
Submergence Area	56.73 Mm^2
Villages affected	7 Full and 2 Partial
Population affected	9,080
Length of Left Bank Canal	31 km
Head Discharge of Left Bank Canal	1.982 Cumec
Ayacut of Left Bank Canal	32.38 Mm^2
Length of Right Bank Canal	131 km
Head Discharge of Right Bank Canal	16.935 Cumec
Ayacut of Right Bank Canal	283.29 Mm^2
Length of Fore Shore Lift Canal	24 km
Head Discharge of Fore Shore Lift Canal	1,756 Cumec
Ayacut of Fore Shore Lift Canal	40.47 Mm^2
Gross Command Area	489.68 Mm^2
Net Command Area	356.14 Mm^2

extensive fertile lands, it largely remains undeveloped partly due to lack of assured irrigation facilities. The extent of Irrigation is small and even this is by means of numerous small tanks, which are dependent on uncertain rainfall. The completion of Sriram Sagar Project Stage-I is expected to make up and set right the shortfalls and imbalances in the economy of the region and would greatly contribute to the well being and prosperity of the people of the region. Thus, this project has great importance for the development of this region.

The Sriram Sagar Project is a multipurpose project, located across the Godavari River near Pochampad of Nizamabad District in Andhra Pradesh at a distance of 200 km from Hyderabad. The dam is located at a latitude of 18°58′ N and a Longitude of 78°20′0″E. The catchment area at the dam site is 91, 760 km^2. The water spread of the reservoir is 453 km^2, with a capacity of 3.17 BCM (Subramanyam, 1979). The reservoir utilizes 1,869 BCM of water to irrigate 0.23 M-ha of land in the Districts of Karimnagar and Nizamabad, of which one-third would be under wet cultivation and the rest under dry crops such as maize, jowar, chillies and pulses.

The masonry spillway is designed for a maximum discharging capacity of 45,307 cumec with MWL at 333.146 m. The arrangement for energy dissipation of the spillway consists of slotted roller bucket for the first 20 spans from left end of the spillway and ski jump bucket in the remaining 22 spans. The left and the right earthen dams are of rolled type. Three $2.438 * 3.657$ m river sluices have been provided to serve for diversion purposes during dam construction and to serve as permanent low level river outlets. Four sluices of $2.438 * 3.657$ m size have been provided for south canal with sill at 307.850 m.

The command area of the SRSP consists of undulating terrain with extensive granite rocks. The area comprises of prominent ridges and valleys formed by gully erosion; it slopes towards the Godavari River and is drained by many small streams that empty into Godavari and its distributaries. The majority of the soils are sandy loams. Though soil conditions support easy drainage, there are a number of low-lying areas which require systematic drainage facilities.

The main rock types occurring in command area are pink and gray granites, with fine to coarse-grained texture. Most of the ridge and relief areas are developed into poorly to moderately weathered formations. Low lying and plain areas are developed into moderately to highly weathered formation. The thickness of weathering extends up to 11 m. It is observed that weathering intensity decreases with depth and generally basement is encountered without fracturing. Hence dug wells are feasible and bore wells are not feasible in general.

The area is drained towards Godavari River. The drainage pattern is dendritic. Undulating topography is characteristic of the area and hence distributaries are aligned on ridges. The maximum and minimum elevations of the area are 300 to 200 m above mean sea level respectively. The normal monsoon rainfall in the area is 986 mm.

The predominant soil type of the area is red sandy loams of good permeability. Black sandy, silty loams are found in low-lying areas stretching along the streams and also in the commands of irrigation tank. Paddy is the principal crop which is grown extensively in the areas receiving irrigation from canal and tank water.

Sugarcane is grown but quite sparsely. In areas that do not receive canal water, paddy is grown under well irrigation.

Water table depth varies from shallow ground level in canal fed areas to 10 m in tail end areas. In the areas receiving canal supplies, the wells existing prior to the project are not being put to use now. These areas are under sugarcane cultivation. Wells are found to be excavated to maximum depths of 2.5–4.0 m to meet the water demand during canal closures. In the tail-end areas, wells are used in both the seasons. The salient features of Sriramsagar project is given in Table 29.

Nizamsagar project

The Nizamsagar project is a multipurpose project, constructed in Nizamabad district in Telengana area of Andhra Pradesh. The project was completed on Manjira River in 1931, a tributary of Godavari, which was a single state river. The canals and distribution system was completed in late 1935. It is a masonry dam, 3.2 km long and 48.15 m high above deep foundation. At the time of its completion, this project was one of the largest in the state but also one of the biggest schemes in India.

The live storage capacity of the reservoir is 724.736 Mm^3, irrigating an ayacut of 967.233 Mm^2. The filling period is generally from July to August and depletion period is from September to June. The installed capacity of the power house at the dam is 15 MW.

Lower manair reservoir

Manair River is a tributary of Godavari River and the reservoir is located at latitude 18°24′ N and longitude 79°8′ E in Karimnagar district of Andhra Pradesh state. The total catchment area of the river up to confluence with Godavari River is 13,106.25 km^2. The lower Manair dam was constructed in 1985 across Manair River at tits 110th km and at its confluence with Mohedamada River. The dam is located at 18°8′24″N and 79°8′6″ E. The total catchment area up to the Lower Manair dam site is 6,464 sq. km; the free catchment area at the Lower Manair Dam is

Table 29. Salient features of Sriramsagar Project

Particulars	Details
Length of Masonry Dam	14.6 km
Bed level	325.240 m
Bed width	51.0 m
Proposed utilization from existing ayacut	890.31 Mm^2
FRL	332.537 m
Gross storage	3,171.84 Mm^3
Live Storage at MDDL	2,322.24 Mm^3
Number of gates	42,
Size of gates	15.24 m × 10 m
Number of villages affected	29
Population affected	38.529

1, 797.46 km^2 and the rest is intercepted. The original capacity of the reservoir at F.R.L. 280.46 m is 680.648 Mm^3. The spillway has 20 gates of 15.24 m × 7.31 m and has been designed for maximum flood of 14,158 cumec.

There are no sediment observation stations on Manair River. Based on Khosla's formula, sediment inflow is assessed at the rate of 4.97 ha.m/year/100 sq. km.

Kaddam reservoir

The Kaddam reservoir was constructed across Kaddam River at its 80th kilometer of run in the Adilabad district of Andhra Pradesh. After traversing a distance of 6.5 km from the dam, Kaddam joins the Godavari River. The latitude and longitude of the dam are 19°07′ N and 78°47′ E. The dam was constructed during the year 1958 and was remodified in the year 1965. The total drainage area of the Kaddam River up to the dam site is 2,631 sq. km. The original capacity of the reservoir at full reservoir level 213.300 m is 215.80 Mm^3.

Upper indravati project

This project, constructed on the Indravati River in Orissa is one of the major multipurpose transbasin diversion projects in India. It involves diversion of the waters of the Indravati River, a tributary of the Godavari River into the Mahanadi basin for power generation and irrigation. The whole scheme envisages construction of 4 dams (Indravati masonry dam; Podagada earth dam; Kapur earth dam; and Muran concrete, masonry and earth dam) and 8 earthen dykes (4 on left and 4 on right). The main dam is on the Indravati River in Nowrangpur and Kalahandi districts of Orissa; the other three being on its three tributaries: the Podagad, the Kapur, and the Muran. All these form a single reservoir, connected together through two link channels, to generate, in all, 1,990 million kWhr of electricity per year and simultaneously to annually irrigate 2, 185 Mm^2 from the releases through the power house. The reservoir has gross storage capacity of 2,300 MCM and live storage of 1,486 MCM. At FRL, the reservoir covers and area of 112 sq. km. At the dam site, the catchment area of Upper Indravati basin is 1,153 sq. km.

The distinct feature of this project is the trans-basin diversion of water from, Godavari Basin up to river Hati (Mahanadi basin) for power generation and irrigation. Tailrace release from powerhouse is picked up at Hati Barrage constructed across river Hati at Mangalpur in Kalahandi district with two canals taking off on either bank. Left main canal is 52 km long and commands an ayacut 49,078 ha. 83 km. long right main canal provides irrigation to 27,191 hectares. Another lift canal is under consideration for irrigating CCA of 33,027 ha.

Water from the reservoir is to be conveyed through a water conductor system for power generation. Thereafter, the release through 7.8 km long tail race channel discharges into the Hati stress, a tributary of the Tel River in Mahanadi basin and is picked up by a weir across the Hati for utilization in irrigation. While designing this project, the aim was to provide as much irrigation as the available resources can provide. With the calculated runoff, the project could provide irrigation of about 1,214.10 Mm^2.

For power generation, the power house is connected to reservoir by a water conductor system consisting of a pressure tunnel, a surge tank and five numbers of penstocks. The tunnel has a length of 4,215 m and is of 7 m diameter. The tunnel discharges into a differential surge tank of 18 m diameter and 96.75 m deep. There are 5 penstocks of 3.05 m diameter each. The annual power potential of this project is 1,990 million KWH at 100 percent load factor. The installed capacity of 600 MW consists of 5 units of 120 MW, each operating under an average load of 374 m. It is a surface power house.

The tail race discharge is utilized for irrigating $1,093\,\mathrm{Mm}^2$ of C.C.A. in Sadon and Dharamgarh subdivisions of Kalahandi District. The intensity of irrigation is 200 percent. The project is located in Kalahandi and Koraput districts which are among the most undeveloped districts of Orissa and are predominantly inhabited by adivasis and tribals. Although there is immense scope of industrial growth and agricultural development, the progress is slow as the rich mineral resources of the districts are not yet properly tapped. When the full potential of this project is utilized, it will undoubtedly accelerate growth of economy of these two districts.

Although droughts are frequent in these districts, even when rainfall in good, rainfall distribution is in variance with the crop water requirements and artificial irrigation is the only means to increase crop production. There is no other project in these districts which has such a high irrigation potential. Further, this region suffers from shortage of electricity. Even after the full utilization of the additional power from the Balimela Power Station (360 MW, 1,980 MKWhr), Talchur Thermal Expansion (220 MW, 1,012 MKWhr) and Rengali Power Station (100 MW, 523 MKWhr) that are now under construction and the Upper Kolab Project, shortage of power with both in energy and capacity will exist. A view of Indravati project has been shown in Figure 15.

Bhopalpatnam Reservoir: This is a proposed reservoir on Indravati River, a tributary of Godavari River. The gross storage, dead storage and live storage capacity of the

Figure 15. A view of Indravati project

reservoir will be 8,368.00, 549.00 and 7, 819.00 Mm^3 respectively. The FRL and MDDL of the reservoir will be 200.254 and 176.48 m respectively. The maximum and minimum dependability has been assessed at 21,969.00 and 3, 290.00 Mm^3 respectively.

Balimela dam

The Balimela Project on the Sileru River in the state of Orissa in India consists of a 70 m high earthfill dam and 3 earthen dykes on the saddles in the left abutment hill. The project is located at a distance of 35 km from Malkangiri in Godhra in Malkangiri District, Orissa. The catchment area at the dam is 4,910 km^2. At FRL 462.7 m, the reservoir has a live storage capacity of 3,610 MCM. The spillway is located on a saddle to the right. Half of the stored water is diverted to another valley and a head of 275 m is created for power generation. The other half quantity of water is used for power generation at successive power stations on the Sileru River itself. Balimela power house has 6 units of 60 MW each, with mean annual inflow of 5,190 MCM. It has a firm power of 161 MW. It was commissioned during 1973–77. A view of Balimela dam is shown in Figure 16.

Mula irrigation project

Mula is a major irrigation project on the Mula River, a tributary of Pravara, which in turn is a tributary of Godavari. The Mula project is located at longitude

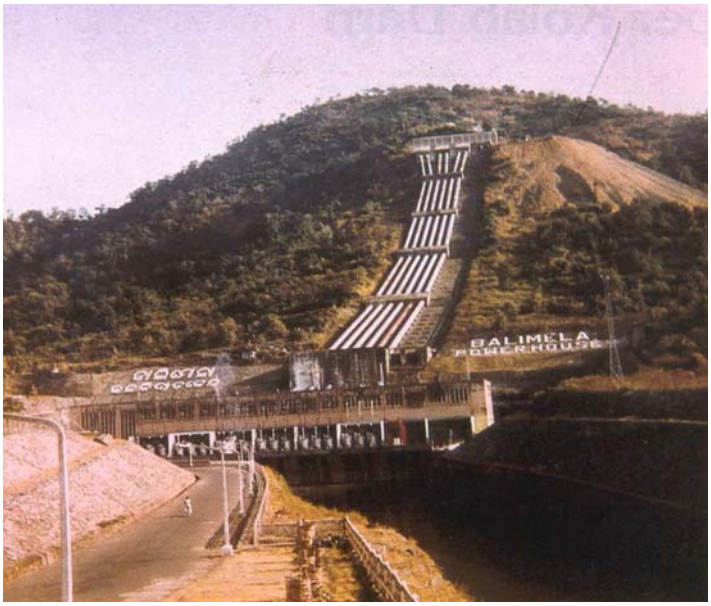

Figure 16. A view of Balimela dam

74°34′30″E and latitudes 19°1′30″N. This multipurpose project caters for irrigation and municipal (Ahemdnagar city) water supply. It provides industrial water supply to defense units, sugar factories, and other industries. The project infrastructure consists of an earthen dam with gated spillway at Baregaon-Nandur in Rahuri Taluka of Ahmednagar district. The FRL, MDDL and MWL of the reservoir are 552.30 m, 534.21 m and 553.21 m respectively. The Gross storage, live storage, and dead storage of the reservoir are 736.32 Mm^3, 608.88 Mm^3 and 127.44 Mm^3 respectively. The water spread area of the reservoir at FRL is 56.397 km^2. Project's right bank and left bank canals with an extensive distribution system provides irrigation to an area of 80,810 ha. Major portion of command has black cotton soil. The rainfall is very scanty in this area; average rainfall is 50 cm in lower catchment and evaporation is moderate.

Pench projects

The Pench River is a tributary of Kanhan River which lies in the Godavari River Basin. There are two major projects on the Pench River. Pench hydropower project comprises of Totaladoh masonry cum concrete dam on Pench River, 3 km from Totaladoh, in Nagpur District, Maharashtra. The catchment area at the dam is 4,275 km^2. The height and length of the dam is 75 m and 680 m respectively. The reservoir has a live storage capacity of 1,249 MCM at FRL 490 m and the MDDL is at 464 m. The power house has 2 units of 80 MW each. It has a firm power of 34 MW with annual inflow of 1,857 MCM in a 75% dependable year. MSEB commissioned the project in 1986–87.

Pench Irrigation Project comprises a storage-cum-diversion dam, 23 km downstream of Totladoh Dam on Pench River to impound releases through the tail race discharge after power generation at Totladoh reservoir. It has lined canals on both the banks, envisaging irrigation of 104,476 ha area in Nagpur and Bhandara districts. Besides irrigation, this project also provides 145 MCM of water for Nagpur water supply and 87 MCM for Koradi Thermal Power Station through its right bank canal. The temperature in the area rises above 36 °C in summer and goes below 20 °C in winter. The average annual rainfall is 1,051 mm. Free catchment area between Totladoh and Kamthi Khedi is 388.0 sq. km with an inflow from free catchment of 112.6 MCM. The Kamthi Khedi diversion dam near Parsheoni Village has a gross storage capacity of 230.00 MCM resulting in live storage of 180.00 MCM. It is 2,248 m long, with height 44.50 m, above cut-off trench in case of earth dam and 45.5 m in case of masonry dam above the lowest foundation level. The dam comprises of a central spillway with earth dam on right flank and earth dam in left saddle. The spillway has 16 gates of size 12 m × 8 m.

Upper kolab

Upper Kolab is a straight masonry gravity dam completed in 1990 on Kolab River, 5 km from Jeyapore in Korapt District, Orissa. The catchment area at the dam is 1,630 km^2. The height and length of the dam is 55 m and 631 m respectively. The reservoir has a gross storage capacity of 1,215 MCM and live storage capacity of 935 MCM at FRL 858 m, and mean annual inflow of 1,803 MCM; its MDDL is at

844 m. At FRL, the reservoir water spread covers 114 sq. km. Peak of design flood hydrograph is 10,020 cumec. The spillway has 11 radial gates of 12.2 m × 12.2 m with crest level at 845.8 m. Two canals take off from the reservoir: right bank canal is known as the Jeyapore main canal which is 58.83 km long with discharge at head 98.1 cumec, and the left bank canal is known as the Padampur canal which is 12.47 km long with 2.79 cumec discharge at the head. Upper Kolab power house has 4 units of 80 MW each. With a design head of 261 m, it has a firm power of 111 MW. OHPC Ltd commissioned the project in 1988–93.

Projects in sileru (machkund) basin

Three important projects of this basin are described here. Machkund project comprises of Kalaput dam, constructed on Machkund River (Sileru River is known by this name in upper reaches). The project is located at a distance of 65 km from Jeypore, in Onukudelli District, Orissa. The catchment area at the power house is 1,932.85 km^2. This 60.7 m high dam has created a reservoir with live storage capacity of 893 MCM at FRL 839 m and the MDDL is at 819 m. At the dam site, mean annual inflow has been estimated at 1,023.7 MCM. For power generation, it has 3 units of 17 MW each and 3 units of 23 MW each respectively. This project, commissioned in 1955–59, has a firm power of 81 MW.

Upper Sileru hydropower project is located on Guntawada masonry gravity dam on Sileru River, 230 km from Visakhapatnam in Andhra Pradesh. The height and length of the dam are 31 m and 625 m respectively. The reservoir has a live storage capacity of 109.5 MCM at FRL 414.5 m and the MDDL is at 406.3 m. The power house has 4 units of 60 MW each. It has a firm power of 58 MW with mean annual inflow of 2,000 MCM.

Lower Sileru hydropower project is located on Donkarayi masonry gravity dam on Sileru River also known as Machkund in upper reaches, 94 km from Bhadrachalam, in Khammam District, Andhra Pradesh. The catchment area at the dam is 2,254 km^2. The height and length of the dam are 71.5 m and 1,399 m respectively. The reservoir has a live storage capacity of 380 MCM at FRL 316 m; its MDDL is at 291.2 m. The power house has 4 units of 115 MW each. It has a firm power of 154 MW with mean annual inflow of 90.6 MCM. This project was commissioned in 1976–78.

Upper wainganga

This project, later renamed as Sanjay Sarovar Project, is a major irrigation scheme in Seoni and Balaghat Districts of Madhya Pradesh. It envisages the construction of a composite earth and masonry dam with maximum height of 42.67 m across Wainganga River near Bhimgarh village at latitude 22°22′51″N and 70°30′20″E. The construction of the dam was completed in 1995. The dam intercepts a catchment area of 2,008 sq. km. At FRL of 519.38 m, the reservoir has gross and live storage capacities of 507 MCM and 410 MCM. In the catchment of the dam, the maximum and minimum annual rainfalls are 1,748 mm and 647 mm, the average being 1,225 mm. The 75% dependable yield at the dam site is 703.1 Mm^3. Ten

radial type gates of size 15.24 m × 10.67 m have been provided at the spillway whose crest lies at 508.71 m.

Other projects

In addition to the above, there are several existing and under construction water resources projects in the basin. Salient features of existing and under construction water resources projects with a live storage capacity of 10 MCM and above have been presented in Table 30 and Table 31, respectively.

14.2.7. Flood of 1986 in Godavari Basin

In the Godavari basin, the normal rainfall over the individual sub-basins varies widely. Godavari basin upstream of Nanded receives about 860 mm in an average year while Indravati sub-basin receives 1,580 mm. During monsoon period, the eastern half of the basin receives about 750 to 1,500 mm of rain every year while in the rest of the area, except a narrow Ghats strip, annual rainfall is between 450 to 750 mm. Consequently eastern half of the basin is more prone to floods as compared to the west.

Floods in the Godavari River are the result of heavy rains over the basin. Severe storms are mostly associated with the depressions/cyclonic storms of Bay of Bengal (BoB) origin. Unprecedented floods occurred in the Godavari basin during 13–20 August 1986 which were caused by a depression originated in the BoB.

The famous flood of 1986 was caused by two storms that occurred in quick succession. A low pressure area was formed over East Madhya Pradesh on 5th August 1986. Moving in a westerly direction, it turned into deep depression on 8th morning and centered close to Surat in Gujarat (Northwest of the Godavari basin). On 10th morning it was centered near latitude 23 °N and longitude 66°30′ E (Pandharinath, 1987). It weakened considerably on 11th August. Although this storm did not cause flooding, it sufficiently saturated the basin. The flood causing storm originated as a low pressure area over North–West BoB on 9th August 1986. This system became well-marked on 10th morning and concentrated into a depression on the same evening, with central region near latitude 18 °N and longitude 88 °E. It moved in a westerly direction and intensified into deep depression and centered near latitude 18 °N and longitude 86°30′ E on 11th morning. Moving in a west-north-westerly direction it crossed north Andhra coast near Kalingapatnam on 12th night. It centered over eastern part of the basin near Karaput on 13th morning. Moving in a north-westerly direction it moved over the extreme eastern part of the basin weakened, into a depression and centered near Raipur on 14th morning. It further weakened and formed as a well marked low over Northwest Madhya Pradesh on 15th morning. To appreciate the relative amounts of rain that fell over the basin in the flood event, Table 33 contains the normal rainfall of monsoon months as well as for the storm events at a few stations over the Godavari basin. Table 32 shows the Flood stages at various gauging sites of Godavari River during August 1986.

Table 30. Salient features of selected existing projects in Godavari basin

Name of the Project	State	Year of completion	Gross storage capacity (MCM)	Live storage capacity (MCM)	Designed annual irrigation (Million sq. m)	Installed capacity (MW)
Boggulavagu	Andhra Pradesh	–	11.52	10.34	20.60	–
Buggavanka	Andhra Pradesh	–	14.32	12.04	34.40	–
Donkaravi Dam	Andhra Pradesh	1974	1, 670.00	1, 252.50	–	25
Jalaput	Andhra Pradesh	1959	970.00	892.00	–	25
Kinnerasani	Andhra Pradesh	–	237.86	207.85	–	–
Lakhnawaram Lake	Andhra Pradesh	1909	60.46	60.46	28.70	–
Nallavagu Project	Andhra Pradesh	1969	21.13	18.49	19.60	–
Peddavagu	Andhra Pradesh	1987	13.85	11.70	64.00	–
Pocharam	Andhra Pradesh	1922	51.55	42.52	40.50	–
Ramadhugu	Andhra Pradesh	1964	18.00	14.84	11.80	–
Ramappa Lake	Andhra Pradesh	1919	–	82.50	21.00	–
Salivagu	Andhra Pradesh	1964	15.87	14.64	12.80	–
Singur	Andhra Pradesh	–	850.00	566.25	160.00	–
Swarna	Andhra Pradesh	1978	42.00	35.83	26.90	–
Vottigedda	Andhra Pradesh	–	89.09	79.93	98.00	–
Ari Tank	Madhya Pradesh	1952	15.30	12.89	42.50	–
Gangulpara Tank	Madhya Pradesh	1958	1, 111.32	10.93	34.50	–
Karad	Madhya Pradesh	1963	15.40	13.69	–	–
Nahaleswara Tank	Madhya Pradesh	1967	16.14	14.55	45.10	–
Oon	Madhya Pradesh	1966	19.80	18.36	1.60	–
Paralkot	Madhya Pradesh	1973	66.30	63.60	145.80	–
Sarathi	Madhya Pradesh	1923	17.06	16.16	34.80	–
Thanwar Project	Madhya Pradesh	1987	139.00	129.00	182.10	–
Adhala	Maharashtra	1974	30.00	27.60	50.90	–
Alandi	Maharashtra	1983	29.52	27.46	44.90	–
Asolamedha	Maharashtra	1918	92.70	74.62	99.20	–
Bagh River Project	Maharashtra	1977	65.08	48.67	336.70	–
Sirpur	Maharashtra	1976	203.77	192.45	–	–
Bhandardara	Maharashtra	1923	312.40	307.31	–	17
Badalkasa	Maharashtra	1923	17.39	16.45	40.50	–
Bor	Maharashtra	1967	138.67	127.40	61.90	–
Chandai	Maharashtra	1978	11.48	10.49	36.10	–
Chandpur	Maharashtra	1915	31.12	23.24	48.60	–
Chargaon	Maharashtra	1976	20.16	17.51	21.20	–
Chorkhamra	Maharashtra	1923	21.05	20.80	40.50	–
Chulband	Maharashtra	1976	19.10	16.54	40.40	–
Darna	Maharashtra	1912	226.87	219.82	258.70	–
Dheku	Maharashtra	1962	13.53	12.16	27.10	–
Dina Nadi Project	Maharashtra	1977	61.17	55.95	113.60	–
Ekburji	Maharashtra	1964	14.12	11.97	24.30	–
Gangapur	Maharashtra	1954	215.76	203.76	232.60	–
Galhati	Maharashtra	1965	16.37	13.83	23.00	–
Ghirani	Maharashtra	1968	25.08	22.46	28.30	–
Ghorazari	Maharashtra	1987	45.19	38.00	38.50	–

(Continued)

Table 30. Continued

Name of the Project	State	Year of completion	Gross storage capacity (MCM)	Live storage capacity (MCM)	Designed annual irrigation (Million sq. m)	Installed capacity (MW)
Girija	Maharashtra	1986	24.50	21.53	38.00	–
Goki	Maharashtra	1980	50.22	42.70	78.00	–
Itiadoh	Maharashtra	1970	288.83	225.12	400.80	–
Jayakwadi	Maharashtra	1976	2, 909.00	2, 171.00	2, 780.00	12
Karadkhed	Maharashtra	1973	12.39	11.01	26.90	–
Karanjwan	Maharashtra	1974	175.56	166.22	448.80	–
Kardwhed	Maharashtra	1977	12.30	11.01	–	–
Kalyan	Maharashtra	1986	15.36	12.22	19.00	–
Karpara	Maharashtra	1976	26.82	24.90	31.10	–
Kanhdi	Maharashtra	1978	22.21	20.48	15.40	–
Khair Bandha	Maharashtra	1915	16.79	15.95		–
Khelna	Maharashtra	1966	12.60	11.08	24.30	–
Koradi	Maharashtra	1980	22.58	15.12	48.00	–
Kundalika	Maharashtra	1986	46.30	34.00	44.00	–
Kundrala	Maharashtra	1974	11.76	10.41	15.60	–
Manar	Maharashtra	1964	138.32	128.68	244.70	–
Mangarh	Maharashtra	1972	210.00	171.50	17.00	–
Makardhokada	Maharashtra	1977	21.35	19.93	33.70	–
Manjra	Maharashtra	1984	250.70	173.32	236.90	–
Masoli	Maharashtra	1982	34.08	26.94	27.50	–
Naleshwar	Maharashtra	1918	12.35	11.18	16.90	–
Navegaon	Maharashtra	1987	45.94	29.59	–	–
Ozarkhed	Maharashtra	1982	67.96	60.32	58.90	–
Palkhed	Maharashtra	1975	–	21.22	549.30	–
Pandharabodi	Maharashtra	1967	13.80	13.04	24.60	–
Pus	Maharashtra	1972	113.92	91.25	93.60	–
Ramtek	Maharashtra	1913	105.15	104.26	109.20	–
Saikheda	Maharashtra	1969	38.51	27.18	31.20	–
Sidheswar	Maharashtra	1962	250.00	81.00	615.00	–
Sindhaphana	Maharashtra	1965	12.59	10.80	17.80	–
Sonal	Maharashtra	1981	20.27	16.93	31.60	–
Sukhana	Maharashtra	1968	21.34	18.49	25.10	–
Tawaraja	Maharashtra	1984	20.50	16.96	40.40	–
Tirana	Maharashtra	1969	22.00	18.62	21.80	–
Tiru	Maharashtra	1974	23.31	15.95	32.90	–
Upper Dudhana	Maharashtra	1965	15.37	13.00	34.90	–
Umari	Maharashtra	1972	231.00	172.10	11.80	–
Waghadi	Maharashtra	1979	41.11	35.37	58.40	–
Wan	Maharashtra	1969	25.18	21.91	52.60	–
Wunna	Maharashtra	1968	23.56	21.64	12.10	18
Yeldari	Maharashtra	1967	966.00	810.00	–	65
Nalkangeri Dam	Orissa	–	39.48	30.84	–	–
Umerkota Project	Orissa	1965	29.61	27.14	50.70	–

Table 31. Salient features of selected under construction projects in Godavari basin

Name of the Project	State	Gross storage capacity (MCM)	Live storage capacity (MCM)	Designed annual irrigation (Million m^2)	Installed capacity (MW)
Sathunal Project	Andhra Pradesh	35.14	28.61	76.80	–
Talliperu	Andhra Pradesh	20.67	14.46	98.00	–
Velleru	Andhra Pradesh	682.40	406.00	580.00	–
Vottivagu	Andhra Pradesh	82.06	74.96	98.00	–
Chulkinala Project	Karnataka	26.57	15.06	40.50	–
Kalisarar	Madhya Pradesh	32.47	27.75	10.00	–
Kanhargaon	Madhya Pradesh	25.50	21.60	389.00	–
Adan	Maharashtra	78.32	67.25	107.20	–
Amal Nalla	Maharashtra	22.70	21.20	39.00	–
Anjana Palsi	Maharashtra	15.55	13.71	25.50	–
Arunavati	Maharashtra	211.85	175.40	310.00	–
Bawanthadi	Maharashtra	298.75	204.79	250.00	–
Bham	Maharashtra	75.42	69.76	–	–
Bhavali	Maharashtra	44.75	40.79	450.00	–
Channa	Maharashtra	14.79	13.99	21.20	–
Dham	Maharashtra	72.46	62.51	102.10	–
Dongargaon	Maharashtra	14.17	12.44	12.50	–
Erdha	Maharashtra	15.27	11.96	25.10	–
Gosikhurd	Maharashtra	732.41	552.44	1, 900.00	–
Human	Maharashtra	304.76	273.26	360.00	–
Isapur	Maharashtra	1, 250.00	950.00	–	–
Karwa	Maharashtra	59.59	52.91	100.00	–
Karwappa	Maharashtra	32.57	31.58	52.50	–
Khekaranala	Maharashtra	26.13	23.71	33.10	–
Lendi	Maharashtra	207.95	159.66	200.00	–
Lower Dudhana	Maharashtra	344.80	242.00	300.00	–
Lower Pus	Maharashtra	81.10	59.67	96.80	–
Lower Terna	Maharashtra	133.56	122.46	200.00	–
Lower Wardha	Maharashtra	253.34	216.87	530.00	–
Majalgaon	Maharashtra	453.64	373.64	938.90	–
Masalga	Maharashtra	14.68	11.95	24.30	–
Mukane	Maharashtra	139.76	122.48	–	–
Nand Storage	Maharashtra	66.00	55.60	–	–
Pakadigudam	Maharashtra	13.31	11.80	37.10	–
Pothra	Maharashtra	38.43	34.73	63.10	–
Punegaon	Maharashtra	20.39	17.58	670.00	–
Shivana Takali	Maharashtra	113.61	42.42	74.90	–
Tambapuri	Maharashtra	21.27	19.63	47.80	–
Tultuli	Maharashtra	186.76	160.45	300.00	–
Upper Pravara	Maharashtra	252.54	244.62	670.00	–
Upper Wardha	Maharashtra	786.40	614.69	800.00	–
Vishnupuri	Maharashtra	–	83.55	–	–
Wedgaon Storage	Maharashtra	160.42	138.72	–	–
Waki	Maharashtra	58.45	55.96	–	–

Table 32. Flood stages at various gauging sites of Godavari River during August 1986

SN	Name of gauging site	Initially level attained	Date & time	Peak level attained	Date and time	Date and time when water level receded below danger level
1	Tekra	DL 13.0 m	12.08.1986 (21.00 hrs)	19.6 m historical	15.08.1986 (03.00 hrs)	18.08.1986 (15.00 hrs)
2	Perur	DL 13.0 m	12.08.1986 (24.00 hrs)	19.3 m	15.08.1986 (03.00 hrs)	18.08.1986 (24.00 hrs)
3	Bhadrachalam	DL 16.2 m	13.08.1986 (03.00 hrs)	23.0 m all time high	16.08.1986	19.08.1986 (12.00 hrs)
4	Kunavaram	DL 13.4 m	12.08.1986 (15.00 hrs)	24.4 m	16.08.1986 (21.00 hrs)	After 20.08.1986
5	Dowlaiswaram	DL 4.3 m	13.08.1986 (09.00 hrs)	6.55 m all time high	16.08.1986	20.08.1986 (03.00 hrs)

Source: Pandharinath (1987).
DL: Danger Level

Table 33. Normal average depth of rainfall and actual flood period rainfall depths in various sub-basins of the Godavari River basin

SN	Name of sub-basin	Normal average depth of rainfall (cm)				Flood period average depth of rainfall (cm)	
		June	July	August	September	9–11 August 1981	8–14 August 1986
1	Godavari basin upstream of Nanded	14.3	19.3	13.9	17.1	2.3	5.47
2	Manjira	12.5	20.0	17.9	22.1	0.6	10.07
3	Penganga	17.5	28.2	20.5	18.1	9.0	16.65
4	Wardha	16.9	33.3	24.2	18.9	10.0	22.77
5	Wainganga	18.9	44.6	35.8	21.1	13.3	23.71
6	Indravati	22.1	45.7	40.6	26.8	11.6	26.35
7	Sabari	20.3	38.9	37.8	25.7	3.5	31.74
8	Godavari basin Downstream of Nanded	16.3	29.5	23.9	20.3	2.8	35.45
9	Whole Godavari basin	17.25	32.67	26.74	21.0	6.77	22.00

Source: Pandharinath (1987).

In addition to the above system, an east-west oriented trough in the lower and mid-troposphere was observed running across the basin on 8th, 9th and 10th. Subsequently this trough was observed only in the mid-troposphere till 12th and became unimportant on 13th. Under the influence of these two systems, heavy to very heavy rain falls were reported at many places over the eastern and central part of the basin.

According to available records since 1881, the highest gauge level recorded at Dowlaiswaram was 5.95 m recorded on 15th August 1953. But this record was surpassed on 16th August 1986 when a gauge level of 6.55 m was recorded. The flood level at Bhadrachalam touched an all time high record of 24.4 m on 16th August 1986.

Available records show that the floods during August 1986 affected 18 districts of Andhra Pradesh. Besides taking a toll of 161 human lives and over 4,000 heads of cattle, it damaged about 12.5 lakh acres of cropped area, affected 2,321 villages and inflicted damage to about 1.05 lakh houses. A 70 m breach took place in the flood embankment of Vasistha River, a tributary of Godavari, at Gopalapuram in East Godavari district. On the night of 18th August 1986 Dowlaiswaram anicut was breached, inundating 12 villages. At Palocole, the railway track was under 2 m of water while Dowlaiswaram approach road was under 3.3 m of water. Polavaram and Kunavaram towns were completely submerged under floodwaters. About 5.5 lakh people had to be evacuated to safer places.