REASSESSMENT OF WATER AVAILABILITY IN INDIA USING SPACE INPUTS

(VOLUME – I)

BASIN PLANNING & MANAGEMENT ORGANISATION

CENTRAL WATER COMMISSION

NEW DELHI - 110 066

NOVEMBER 2018

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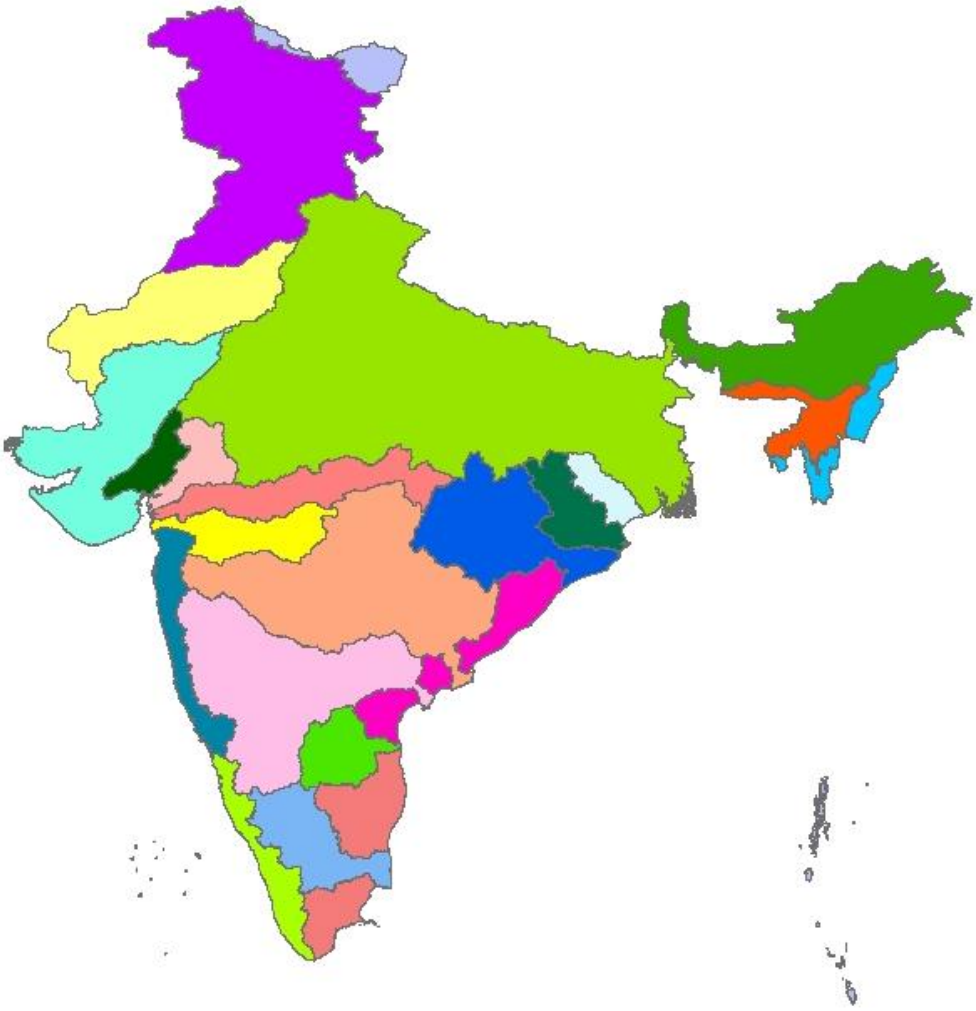

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Project Report Number	No: CWC/BPMO/BP/WRA /November 2018/Vol-1

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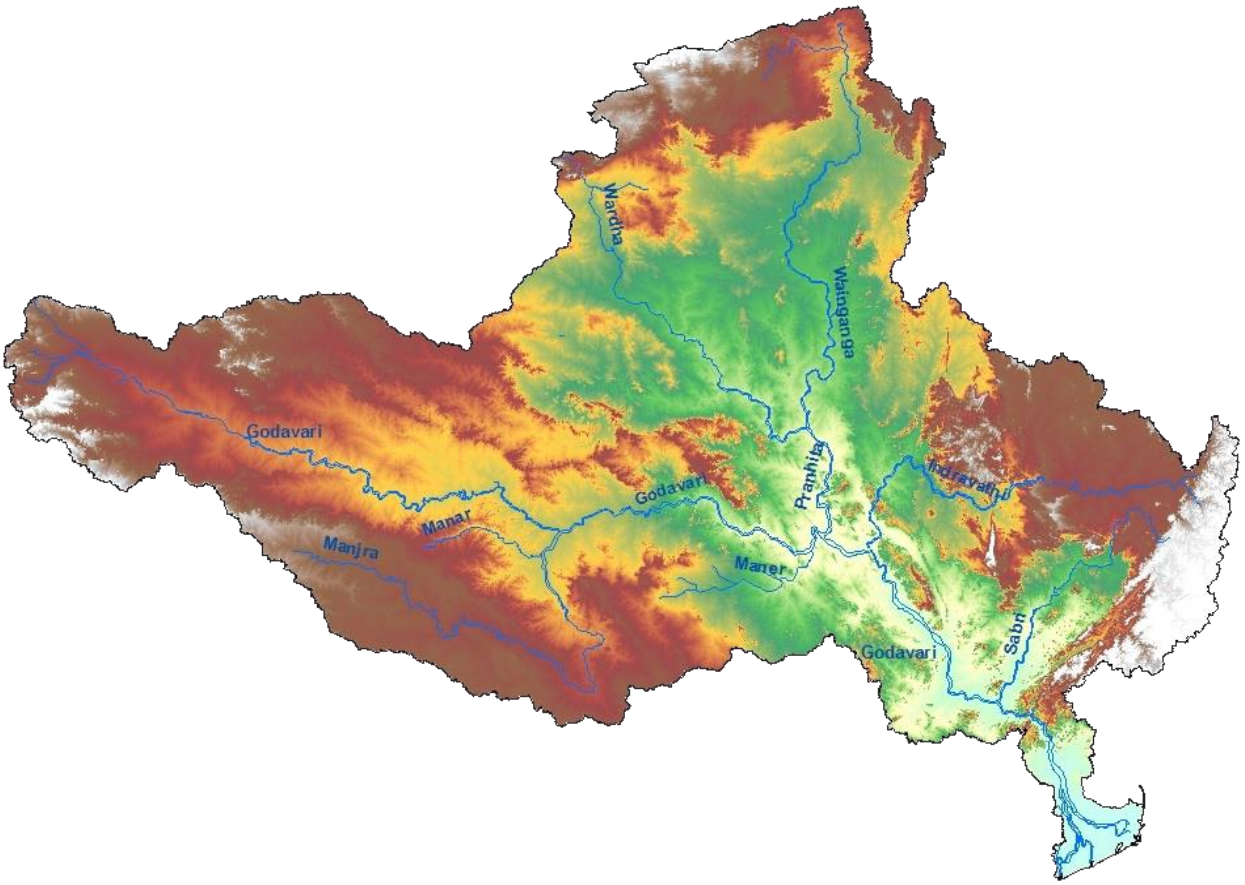
GODAVARI BASIN



1.1 Geo-Spatial Datasets

1.1 .1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of the basin is shown in Figure 1.1. The image corresponds to the 2004-05 year and consists of 17 different classes. The map indicates Kharif only (32.85%), deciduous forest (21.28%) and Double/Triple crop (10.90%) are the major classes in Godavari basin (Figure 1.2).

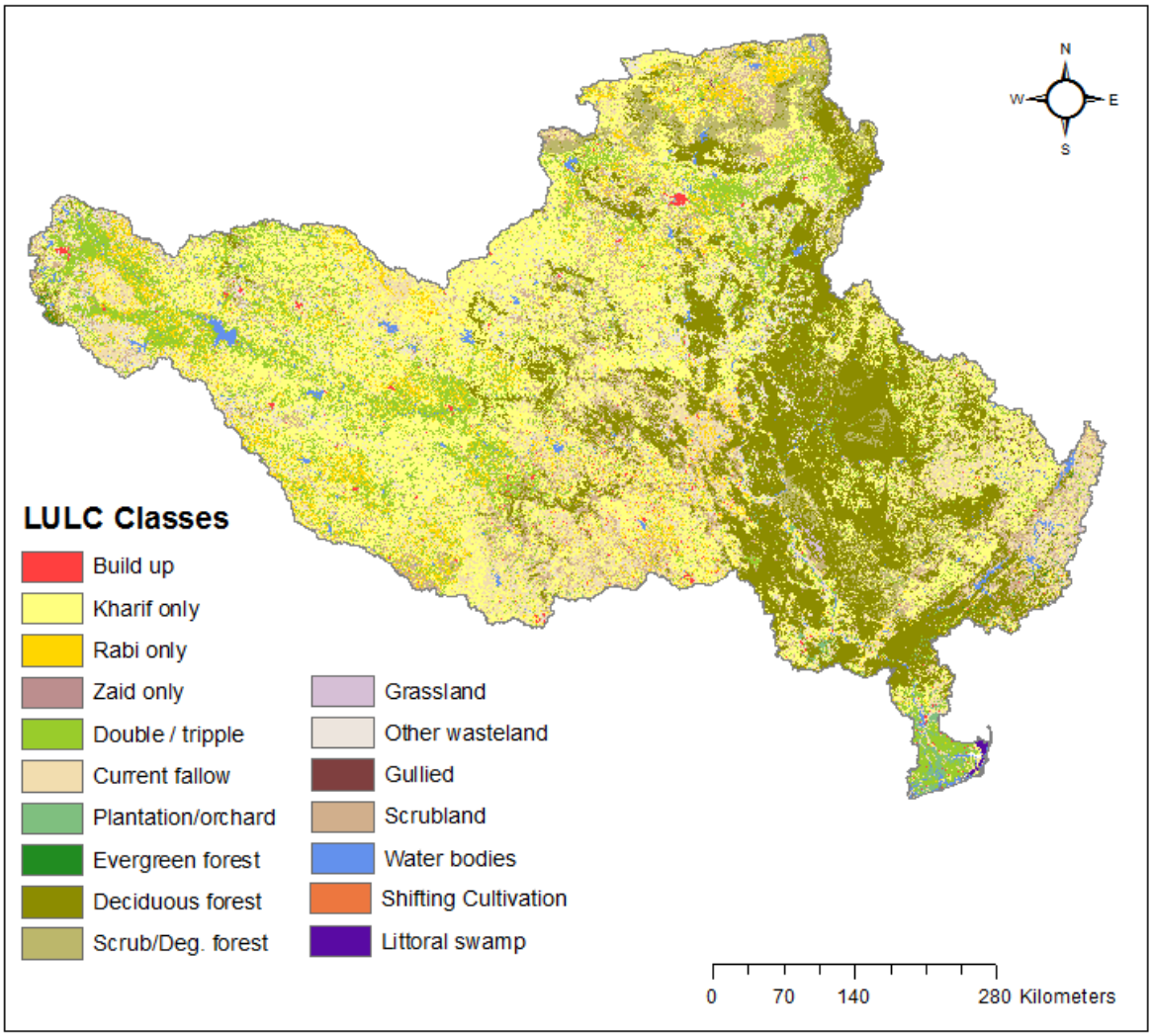


Figure 1.1 LULC map of Godavari basin (2004-05)

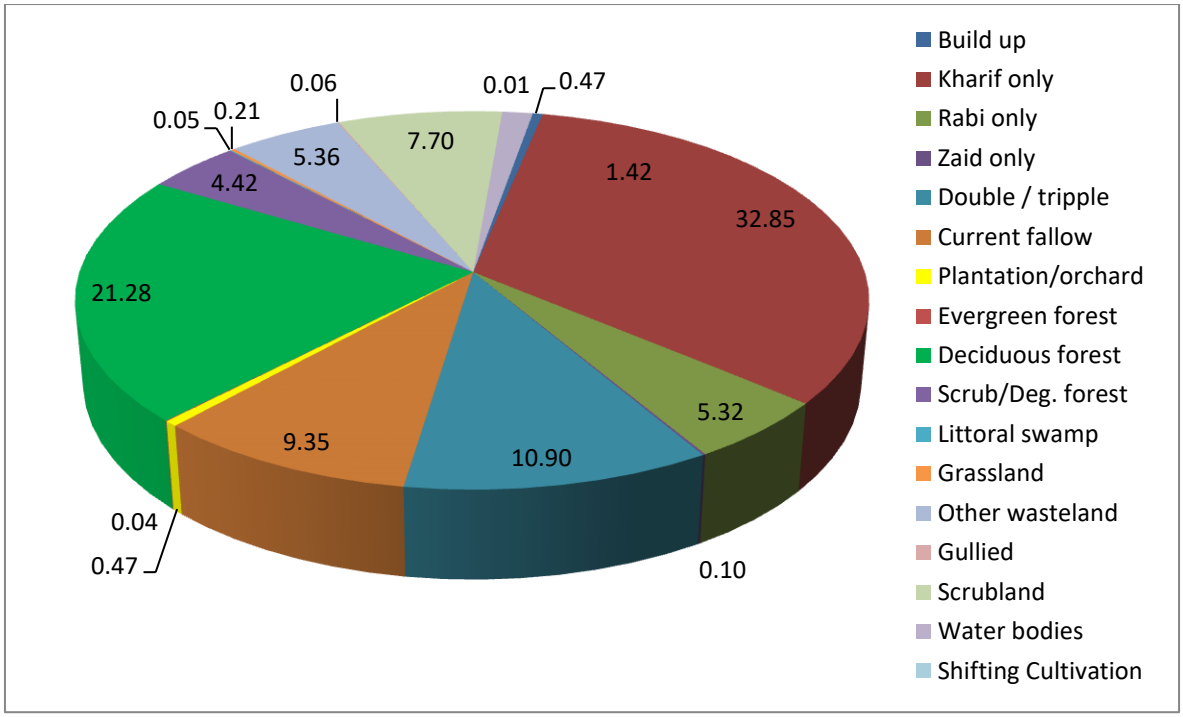


Figure 1.2 Distribution of LULC in Godavari basin (2004-05)

1.1.2 Soil texture

The main soil types found in the basin are sandy, clay and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 1.3 shows various categories of soil in the basin. The soils are classified as sandy, loamy, clayey and rock outcrops based on the soil texture information.

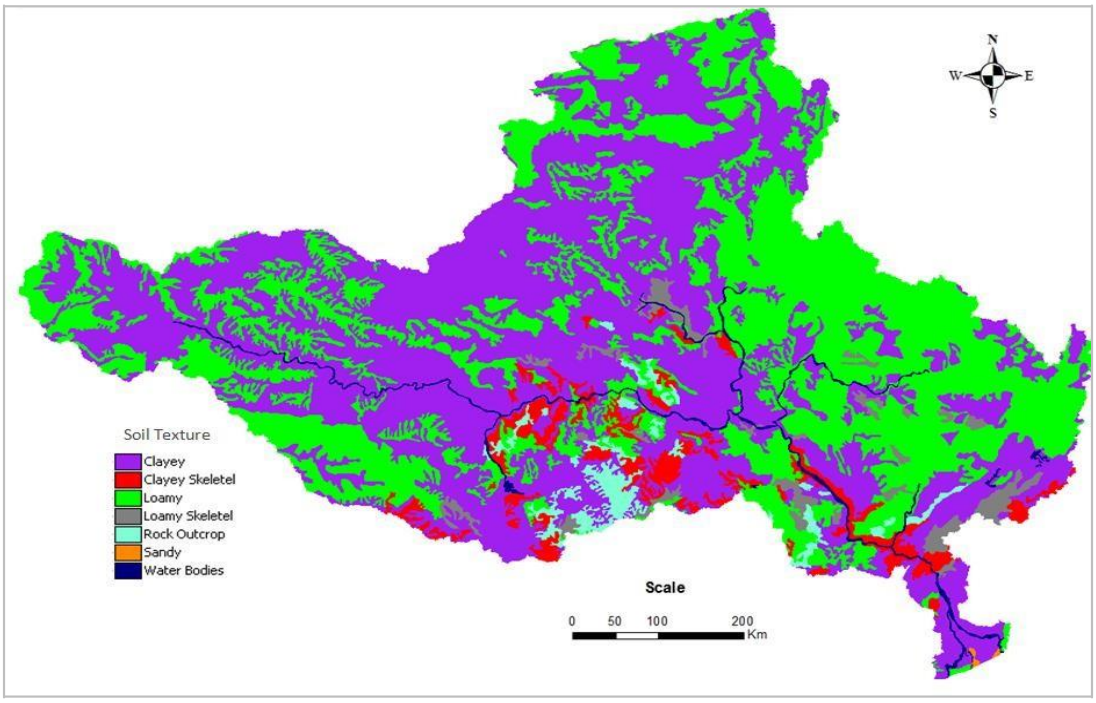


Figure 1.3 Soil texture map of Godavari basin

1.1.3 Topography

The basin is very rugged in the north-eastern part and flat towards downstream side. Slopes in the flood plains are very flat (0 to 3%) causing inundation in the flood plains. The elevation values range from 0 m to 1660 m. Figure 1.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Godavari basin.

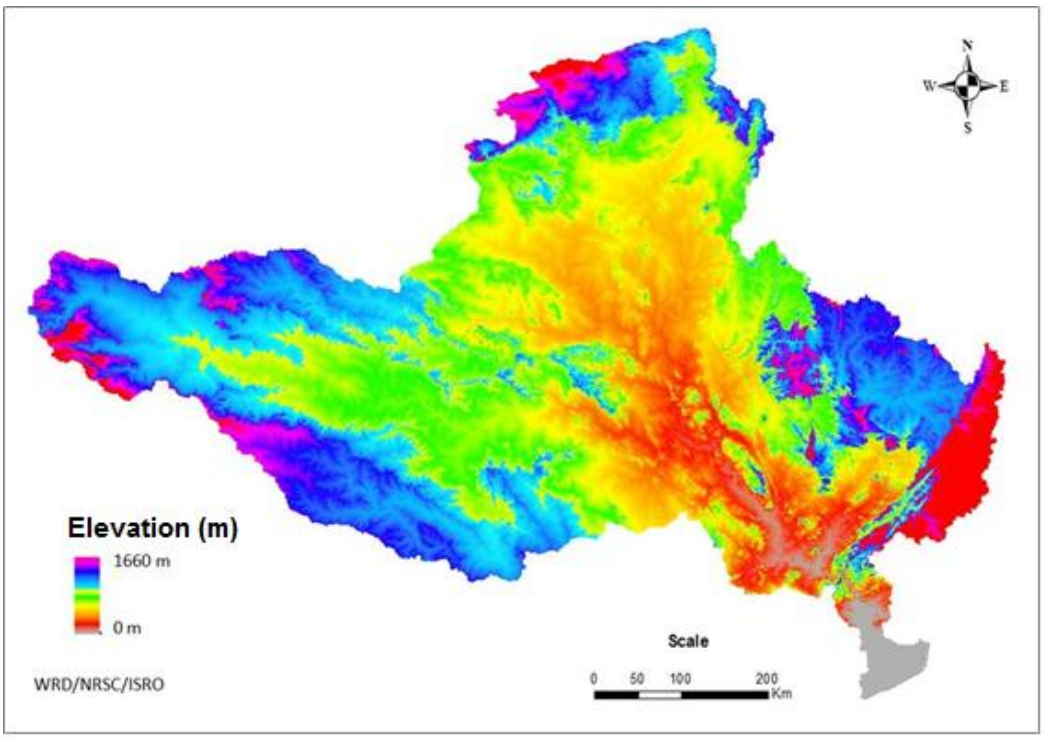


Figure 1.4 SRTM DEM map of Godavari basin

1.2 Hydro-Meteorological and other Input Data

1.2.1 Rainfall grids

Figure 1.5 shows gridded rainfall map of Godavari basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 1.6. Annual rainfall of the basin varies from 877 mm to 1,493 mm and mean rainfall of these 30 years is found to be 1,117 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum annual rainfall of around 848 mm is observed in Mancherial sub-basin, while maximum annual rainfall of 1,503 mm is observed in Konta sub-basin. Of the 30 years, for 13 years annual rainfall is higher than the mean rainfall and for remaining 17 years lower than the mean rainfall.

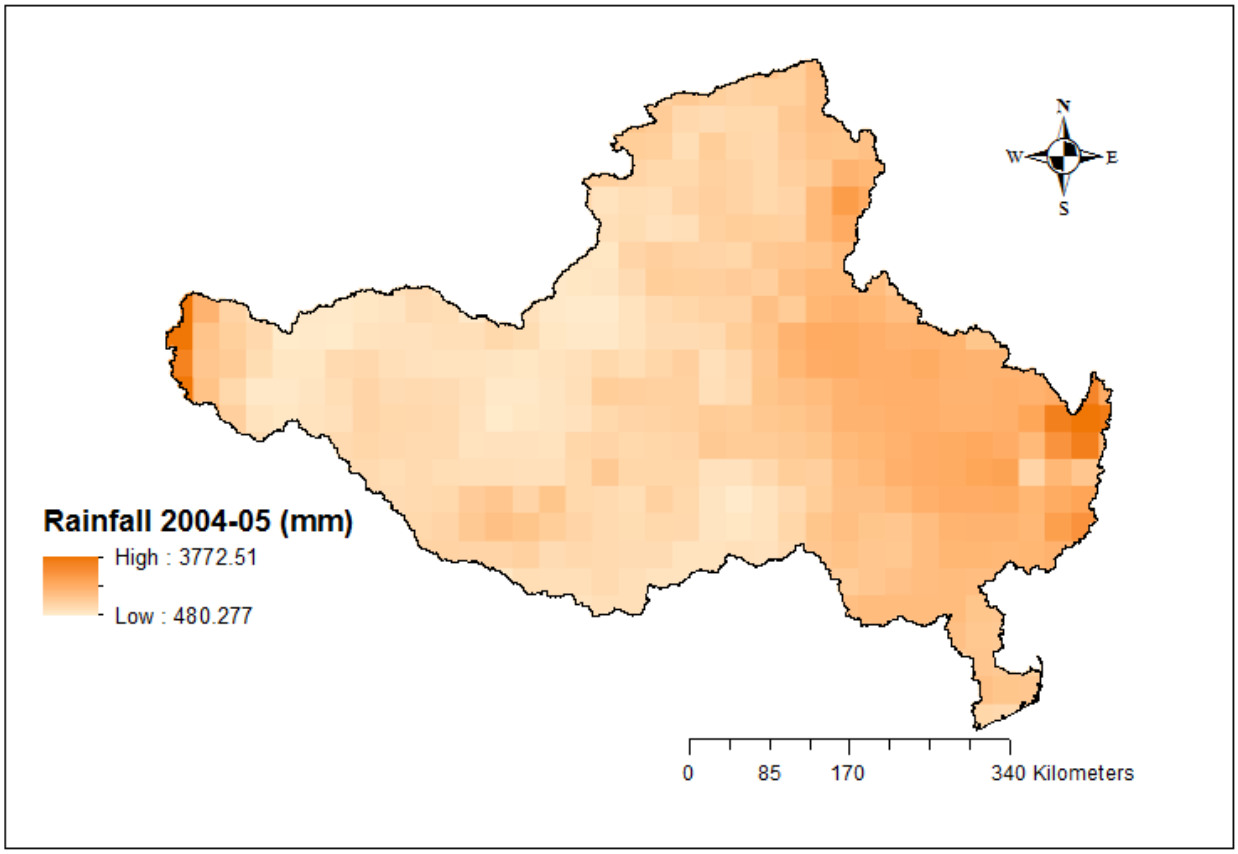


Figure 1.5 Gridded rainfall of Godavari basin (2004-05)

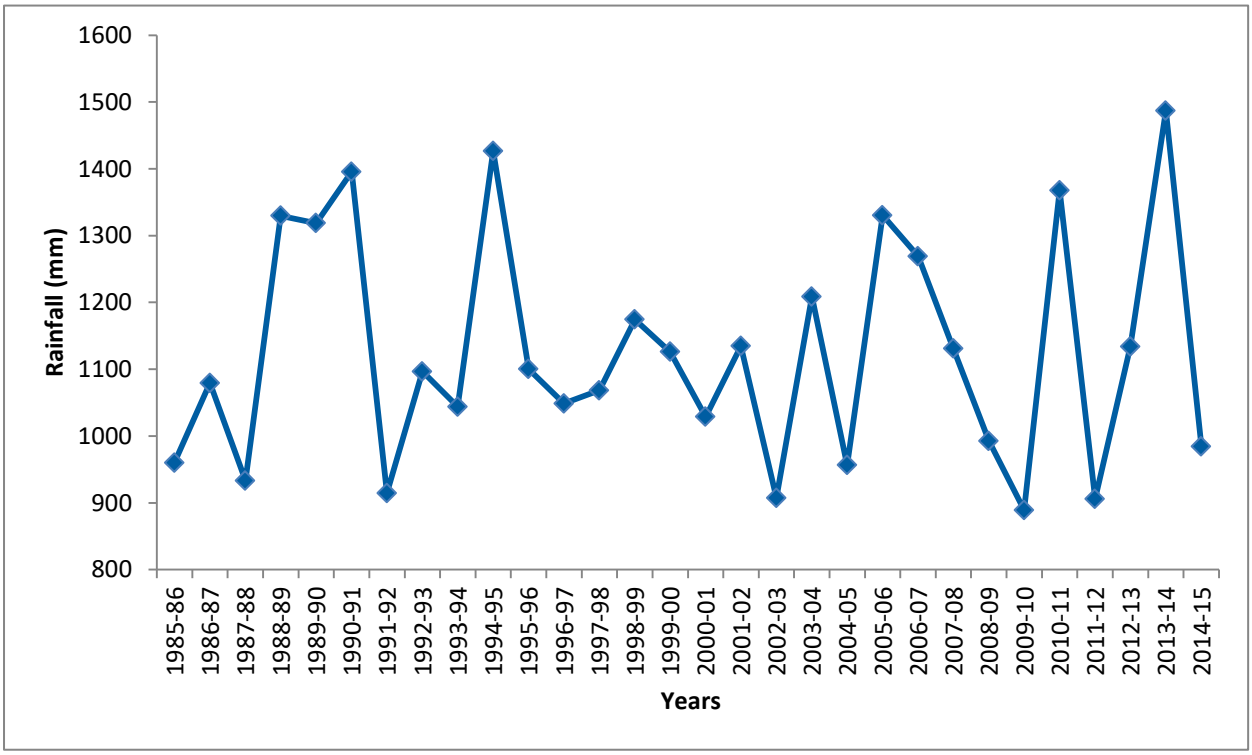


Figure 1.6 Annual rainfall in Godavari basin (1985-86 to 2014-15)

1.2.2 Temperature grids

Gridded mean annual temperature of Godavari basin in 2004-05 varied from 24.62 ^{o}C to 28.61 ^{o}C which is shown in Figure 1.7.

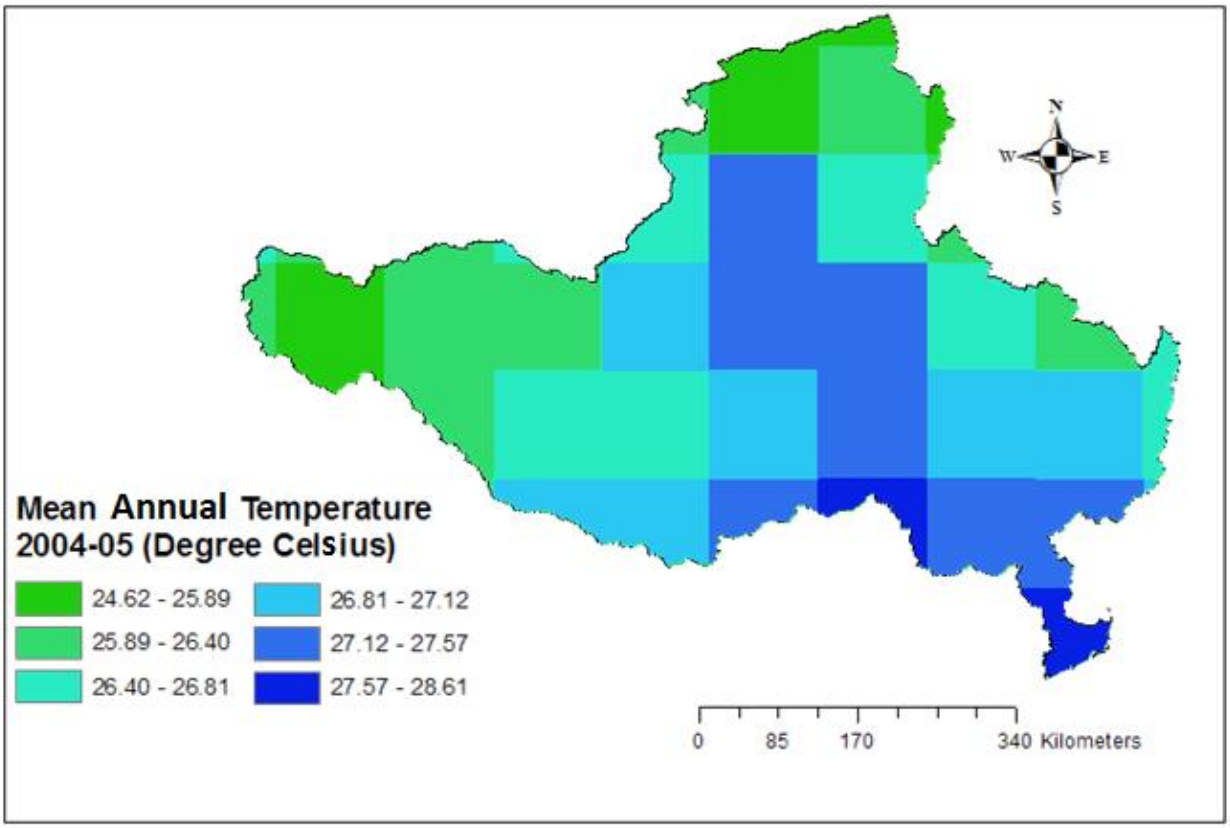


Figure 1.7 Gridded mean annual temperature of Godavari basin (2004-05)

1.2.3 Sub-basins of Godavari basin

The Godavari basin is divided in to nine sub-basins (Figure 1.8) viz. Bamini, Tekra, Yelli, Mancherial, Pathagudem, Somanapally, Konta, Polavaram and combined delta region as one sub-basin. Table - 1.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

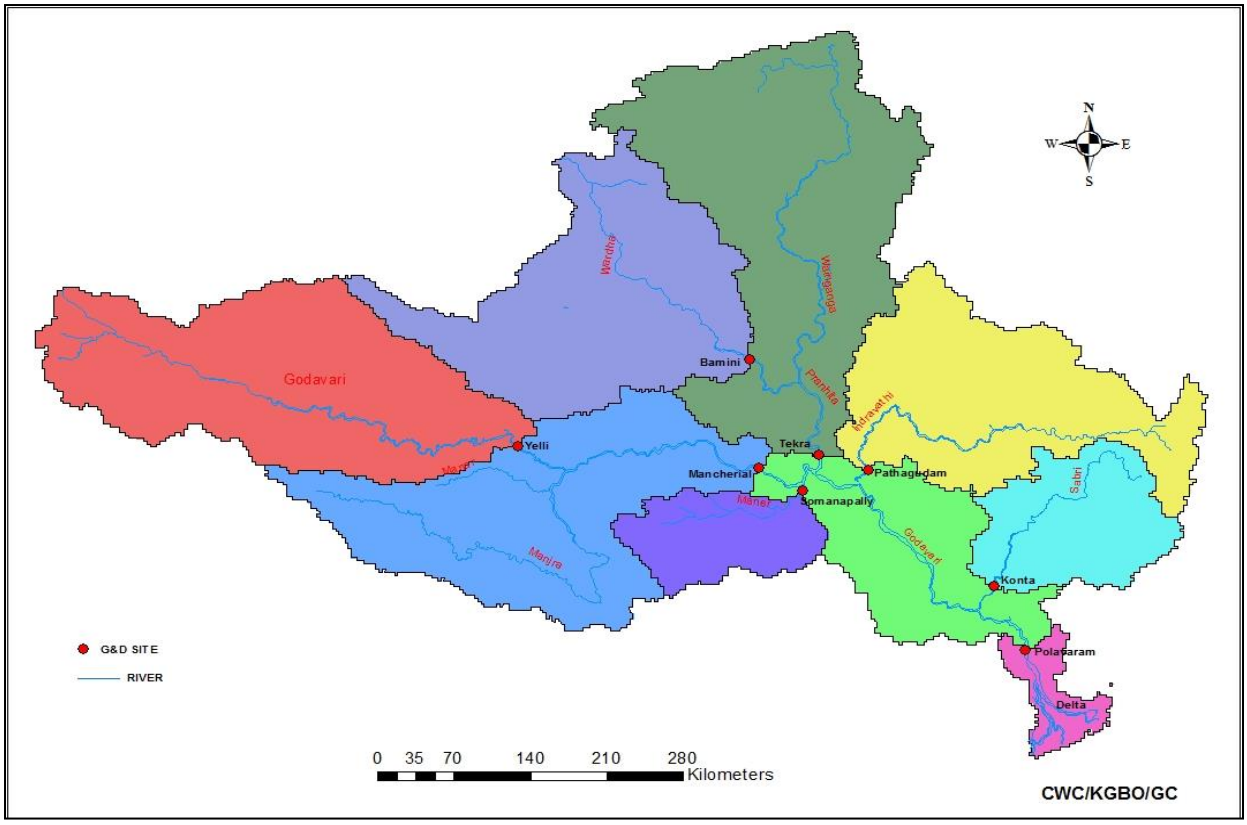


Figure 1.8 Sub-basins of Godavari basin

Table - 1.1 Sub-basin wise details of Godavari basin

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Bamini	Wardha	46,187
2	Tekra	Pranhita	61,779
3	Yelli	Godavari	53,554
4	Mancherial	Godavari	47,724
5	Pathagudem	Indravathi	39,807
6	Somanapally	Maner	12,911
7	Konta	Sabari	19,258
8	Polavaram	Godavari	25,347
9	Delta	Godavari	5,583
	Total basin area		3,12,150

1.2.4 River discharge

The river discharge data was available at all the 8 sites (Yelli, Mancherial and Polavaram on main Godavari, Bamini located on Wardha river, Tekra located on Pranhita river, Pathagudem on Indravathi river, Somanapally on Maner river, and Konta on Sabari river) for the study period of 30 years. The daily discharge data was aggregated to annual scale and was used for calibration and

validation of model computed runoff at sub-basin level except Polavaram for which the hourly discharge data was considered.

1.2.5 Reservoir flux

Figure 1.9 shows the location of some of major reservoirs in Godavari basin. The data of Yeldari Dam, Jayakwadi Dam, Sriram Sagar Project, Upper Indravathi Dam and Lower Manar Dam data received from State Governments were considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation of computed runoff.

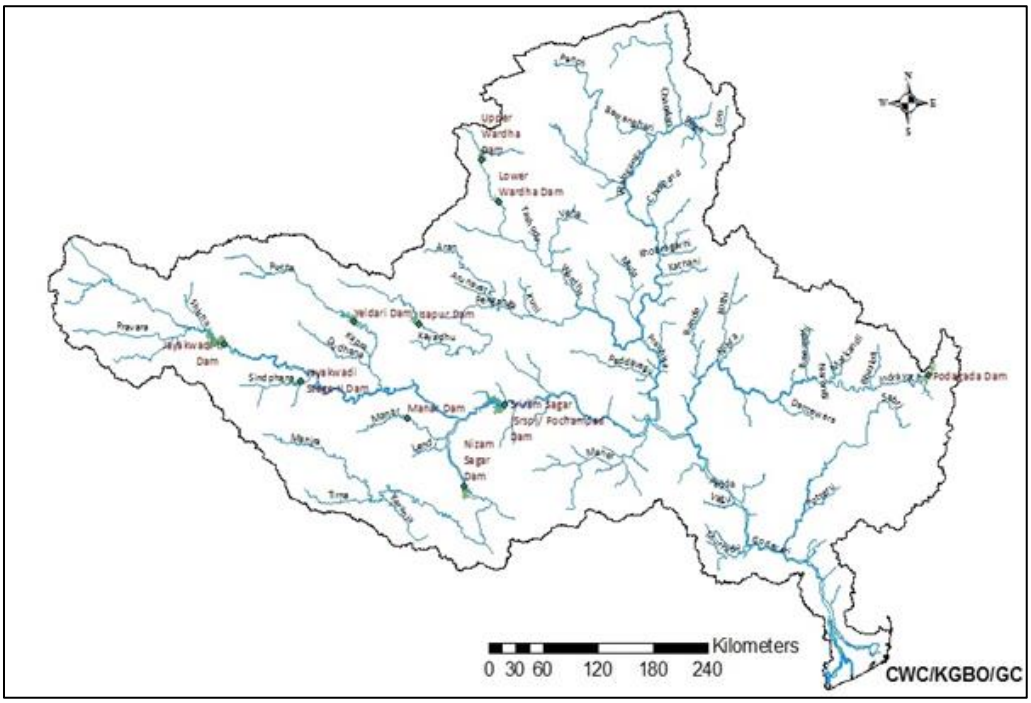


Figure 1.9 Major reservoirs in Godavari basin

1.2.6 Groundwater flux

The spatial annual groundwater flux for the year 2002-03 is shown in Figure 1.10. The annual groundwater flux during the study period is shown in Figure 1.11.

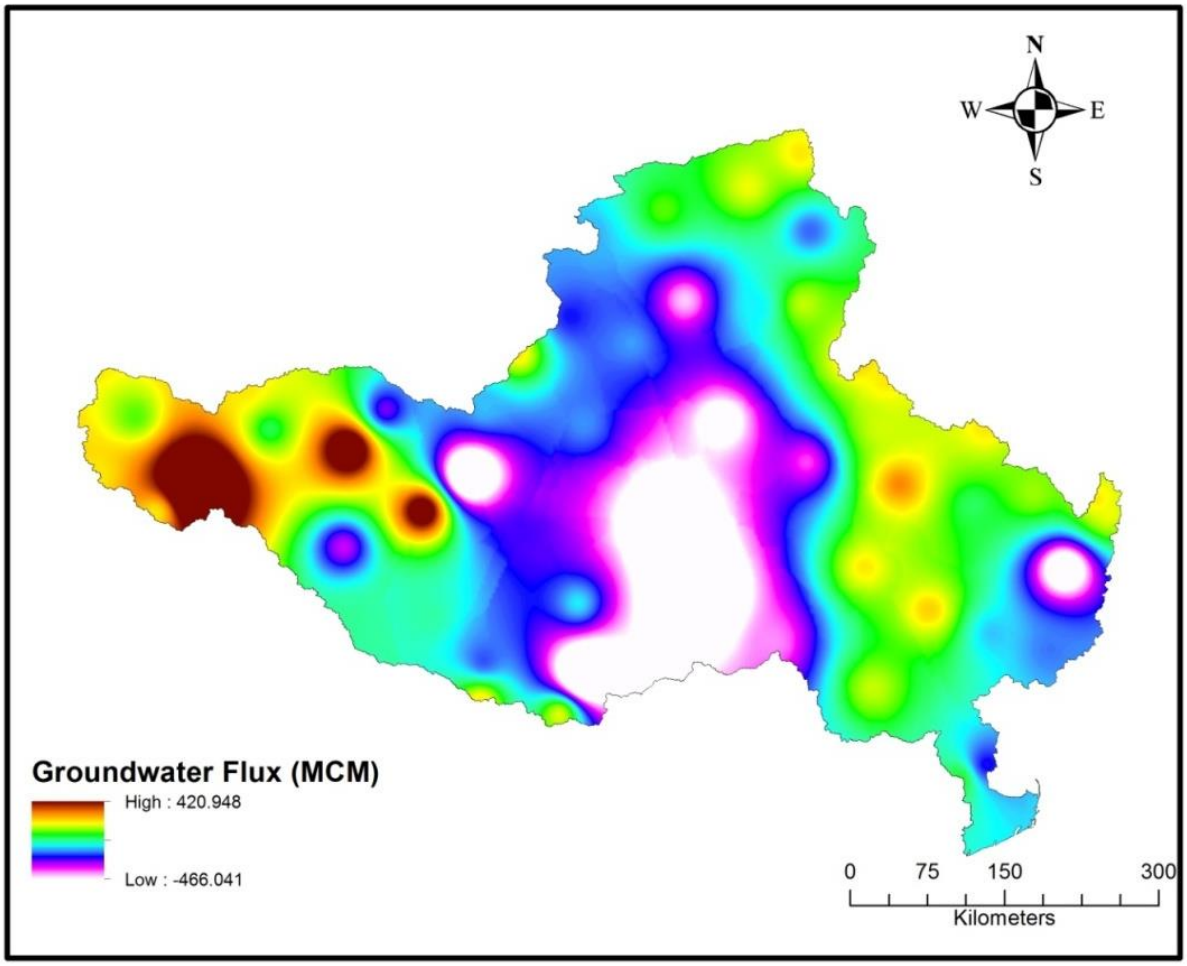


Figure 1.10 Groundwater flux (spatial data) estimated during 2002-03

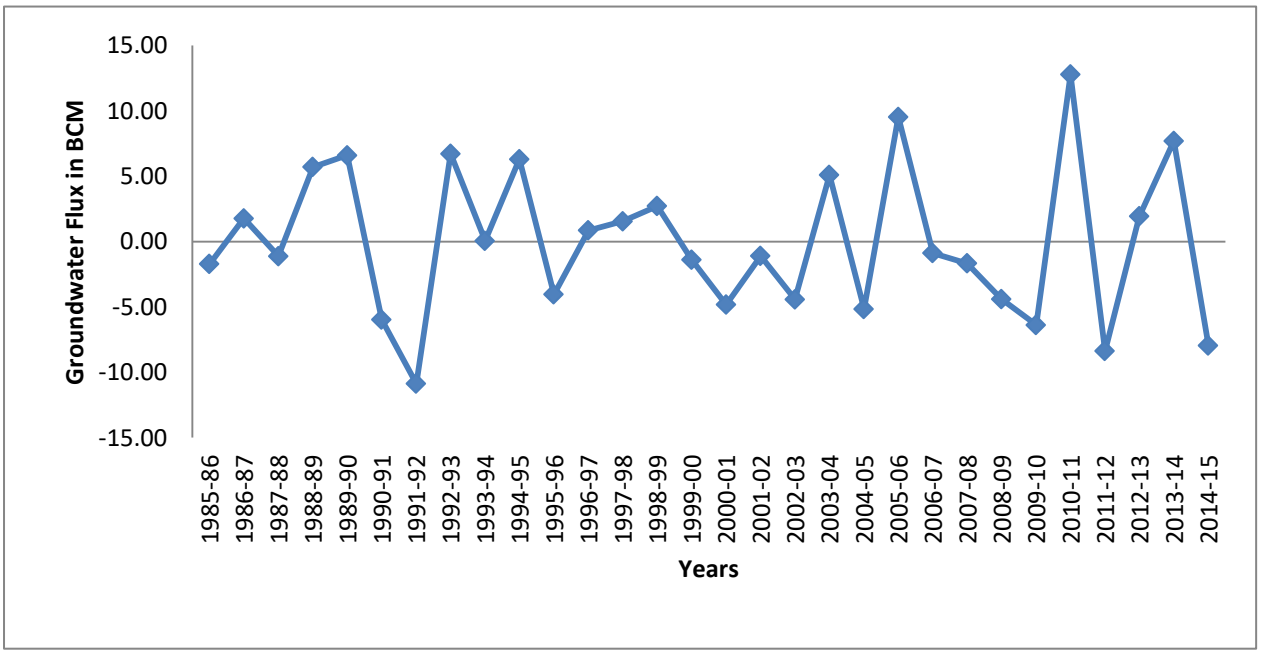


Figure 1.11 Annual groundwater flux of Godavari basin (1985-86 to 2014-15)

1.2.7 Major crops in the basin

Based on the district-wise crop area statistics, district wise major crops for each crop season are identified. Different major crops for each season emerged. Hence the coefficients are taken as per the crop in that particular district. On examining the cropping pattern within the basin, crop growing seasons are decided as Kharif crop during 4 months (July to October), Rabi crop during 4 months (January to April), Double/Triple crop during 8 months (July to October and January to April). Considering all the above factors land use coefficients are taken based on the FAO 56, various sources and earlier studies carried out in the basin.

1.2.8 Irrigation command area

Figure 1.12 shows location of irrigation command boundaries inside and outside the Godavari basin considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence, the command area considered during the year 1985-86 was worked out to be around 45,38,418 hectare, while it was 52,57,004 hectare in 2014-15 (excluding the basin outside command). Basin outside command has been taken uniformly for all years while working out ECII from these areas.

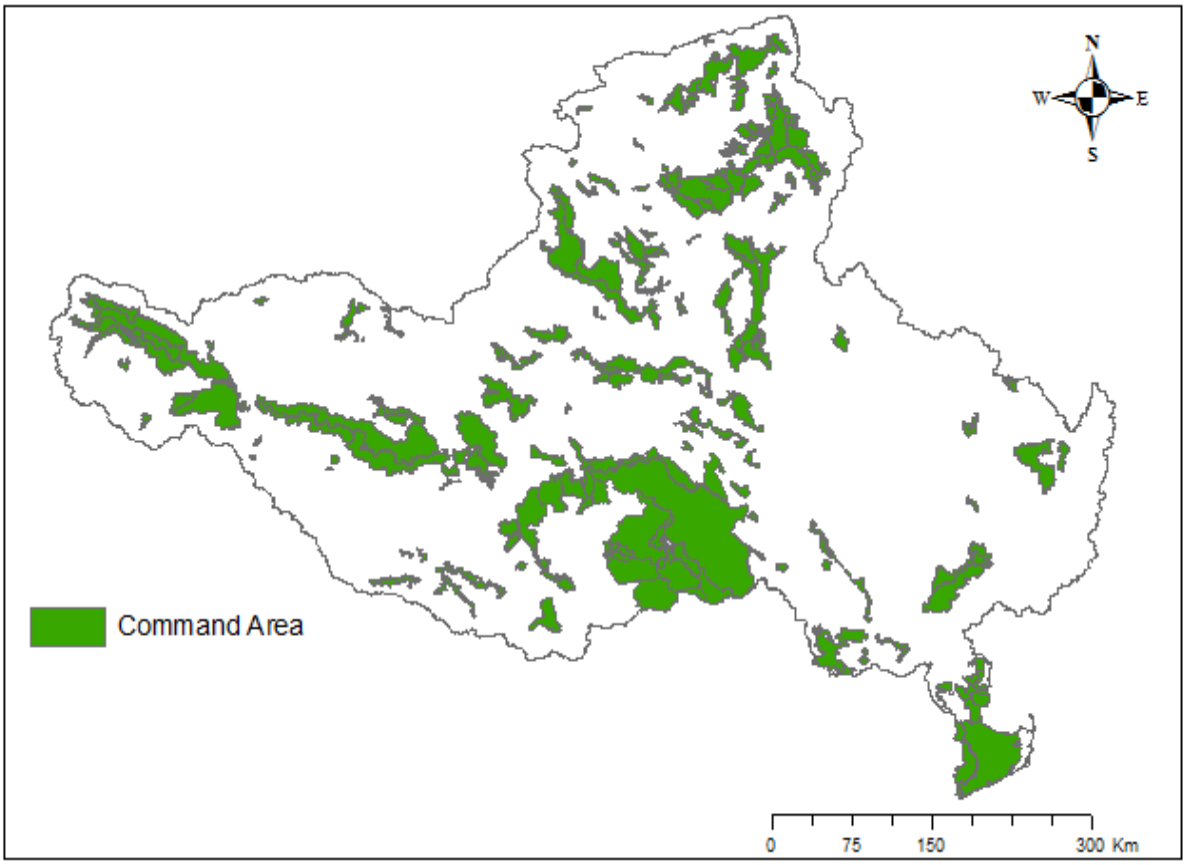


Figure 1.12 Irrigation command boundaries of Godavari basin

1.2.9 Domestic, industrial and livestock demand

Figure 1.13 shows district boundaries layer with district population for the year 2011 census. Population data of census year 1991, 2001, 2011 and livestock census of 1982, 1983, 1987, 1990, 1992, 1993, 1997, 1999, 2003, 2007 and 2012 of basin states were used in the study. The mean annual domestic, industrial and livestock demands are estimated at 1.15 BCM in the basin.

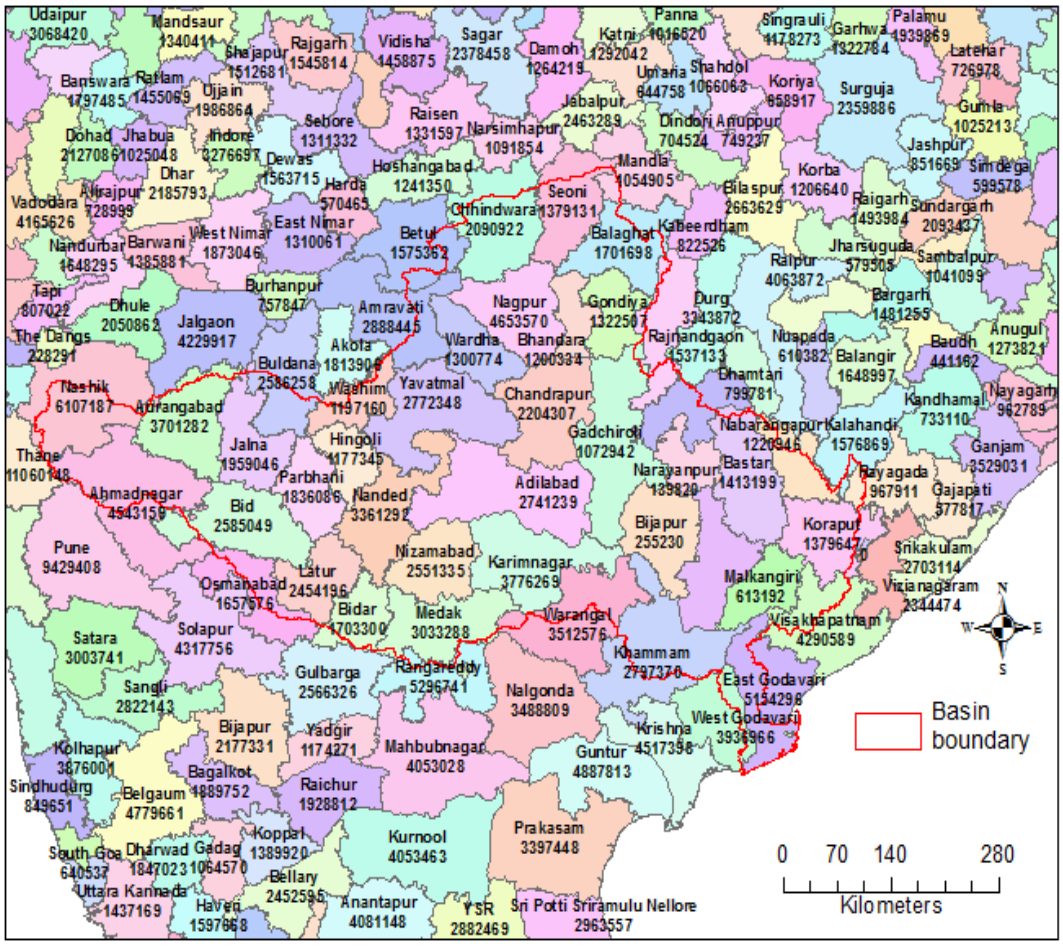


Figure 1.13 District boundaries in Godavari basin

1.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 1.2 provides annual evaporation values from each of sub-basins for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 4.41 BCM. It may be observed from the table that the major reservoirs viz. Sriram Sagar Project in Mancherial and Jaykwadi Dam falling in Yelli and Wardha Dam in Bamini sub-basin contributing more evaporation losses among all sub-basins.

Table - 1.2 Evaporation in reservoirs of Godavari basin

Year	Reservoir Evaporation in each independent sub-basin (in BCM)								
	Bamini	Tekra	Yelli	Mancherial	Pathagudem	Somanapally	Konta	Polavaram	Delta
1985-86	0.96	0.52	0.65	0.37	0.32	0.03	0.43	0.23	0.41
1986-87	1.25	0.68	0.74	0.98	0.28	0.22	0.39	0.55	0.71
1987-88	0.82	0.50	0.84	0.39	0.34	0.03	0.45	0.21	0.39
1988-89	0.86	0.52	0.80	0.86	0.35	0.15	0.33	0.50	0.50
1989-90	0.84	0.54	0.89	0.90	0.39	0.19	0.42	0.59	0.81
1990-91	0.67	0.49	0.78	0.79	0.36	0.18	0.36	0.53	0.56
1991-92	0.84	0.37	0.60	0.28	0.31	0.03	0.37	0.22	0.47
1992-93	1.11	0.55	0.82	1.17	0.29	0.23	0.38	0.61	0.75
1993-94	0.88	0.53	0.90	0.38	0.34	0.03	0.40	0.22	0.38
1994-95	0.84	0.54	0.75	0.88	0.39	0.16	0.43	0.56	0.73
1995-96	1.07	0.64	0.77	1.23	0.31	0.26	0.37	0.61	0.75
1996-97	0.97	0.47	0.79	0.38	0.27	0.03	0.36	0.25	0.91
1997-98	1.16	0.76	0.88	1.32	0.28	0.25	0.37	0.62	0.71
1998-99	0.90	0.57	0.95	1.21	0.41	0.24	0.36	0.63	0.77
1999-00	1.10	0.65	0.88	1.07	0.27	0.24	0.38	0.57	0.68
2000-01	0.83	0.43	0.66	0.33	0.31	0.03	0.41	0.05	0.43
2001-02	1.07	0.59	0.81	1.14	0.27	0.23	0.38	0.04	0.77
2002-03	0.85	0.48	0.75	0.33	0.30	0.02	0.37	0.05	0.31
2003-04	0.85	0.45	0.67	0.84	0.39	0.17	0.40	0.05	0.68
2004-05	0.84	0.51	0.79	0.39	0.31	0.02	0.42	0.03	0.40
2005-06	0.78	0.25	0.48	0.57	0.17	0.10	0.37	0.05	0.51
2006-07	0.69	0.17	0.52	0.56	0.11	0.09	0.30	0.04	0.55
2007-08	0.73	0.25	0.56	0.63	0.13	0.11	0.35	0.05	0.56
2008-09	0.68	0.23	0.44	0.39	0.11	0.09	0.21	0.05	0.36
2009-10	0.74	0.18	0.35	0.32	0.11	0.04	0.25	0.03	0.45
2010-11	0.73	0.68	0.62	0.69	0.16	0.11	0.38	0.08	0.64
2011-12	1.39	0.66	0.47	0.43	0.09	0.07	0.22	0.06	0.35
2012-13	1.47	0.73	0.48	0.68	0.14	0.12	0.33	0.08	0.50
2013-14	1.28	0.99	0.70	0.81	0.15	0.13	0.30	0.08	0.47
2014-15	1.42	1.35	0.27	0.38	0.02	0.06	0.03	0.03	0.13
Avg.	0.95	0.54	0.69	0.69	0.26	0.12	0.35	0.26	0.55
								Avg.	4.41

1.3 Previous Estimates

A gist of earlier assessments on Godavari river system made by different authorities over a period of time has been presented in Table 1.3.

The water potential of the Godavari river system has been assessed at different times by different authorities. The very first assessment was made by the First Irrigation Commission. This Commission used past records of the surface flow of the Godavari from the greater part of its catchment covering a number of years to estimate the average flow. It assessed the total annual surface flow in the Godavari river system to be 116.77 BCM. In 1949 when the assessment of the basin wise water resources of the country was worked out on the basis of Khosla's formula, the annual runoff of the Godavari river system was estimated to be 125.52 BCM. In 1960 when the irrigation potential studies of the country were completed by the Central Water & Power Commission, the total annual runoff of the Godavari was assessed at 115.33 BCM. In 1962 Krishna-Godavari Commission set up by the Government of India gave a figure of 117.99 BCM as the total yield from the catchment. CWC's publication No. 30/88 "Water Resources of India", April 1988 mentions water availability of the basin as 117.99 BCM.

In 1993 study, the Godavari basin had a total catchment area of 3,12,800 sq.km. Flow data at Polavaram (catchment area of 3,07,800 sq.km.) available for the period 1967-68 to 1984-85 were used. Data on abstractions for irrigation were obtained from Irrigation Project Authorities wherever available and in other cases, the abstractions were estimated from the irrigated area statistics and by adopting suitable delta. All major and medium irrigation projects and other minor irrigation projects were considered in that study. Withdrawal for domestic use was based on population statistics assuming requirement of 70 LPCD for rural population, 200 LPCD for urban population and 50 LPCD for the livestock. Industrial water requirement was estimated to be as domestic water requirement. The total available water resource was estimated as 110.54 BCM in the basin. 75 % dependable flow was estimated as 80.545 BCM.

Table - 1.3 Earlier assessments on Godavari river system

S. No.	Year	Authority/Method of estimation	Quantity (BCM)
1.	1901 - 03	First Irrigation Commission/using coefficients of runoff	116.76
2.	1949	Khosla's empirical formula	125.52
3.	1960	CW & PC/Statistical analysis of flow data wherever available and rainfall-runoff relationships wherever data were meagre.	115.33
4.	1962	Krishna Godavari Commission/Aggregation of average annual yields of all sub-basins	117.99
5.	1988	Central Water Commission/General water balance approach	117.99
6.	1993	Central Water Commission	110.54

1.4 Runoff Estimation

The observed discharges are available for sites Yelli, Mancherial and Polavaram on river Godavari; site Bamini on river Wardha; site Tekra on river Pranhita; site Pathagudem on river Indravathi; site Somanapally on river Maner and site Konta on river Sabari. The model estimated runoff is calibrated against the observed discharge at all these eight locations. Computed runoff at deltaic region is added to the whole basin without any calibration, since it does not have any observed discharge. Tables - A.1 to A.8 at Annexure - A give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for these discharge stations. Figures 1.14 to 1.21 show comparative graphs of calibrated and observed discharge at these discharge stations. From the graphs, it may be observed that model estimated runoff and observed discharge at almost all the sites are matching very well for the 30 year period.

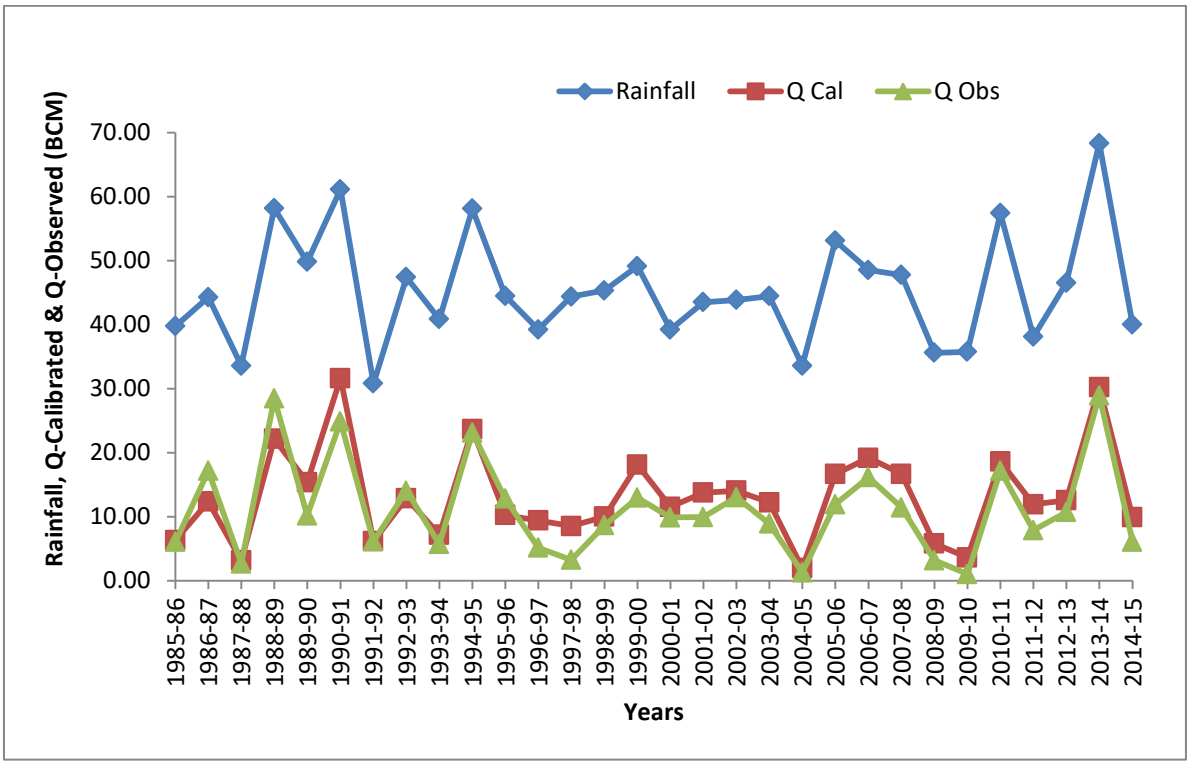


Figure 1.14 Calibrated runoff and observed discharge at Bamini

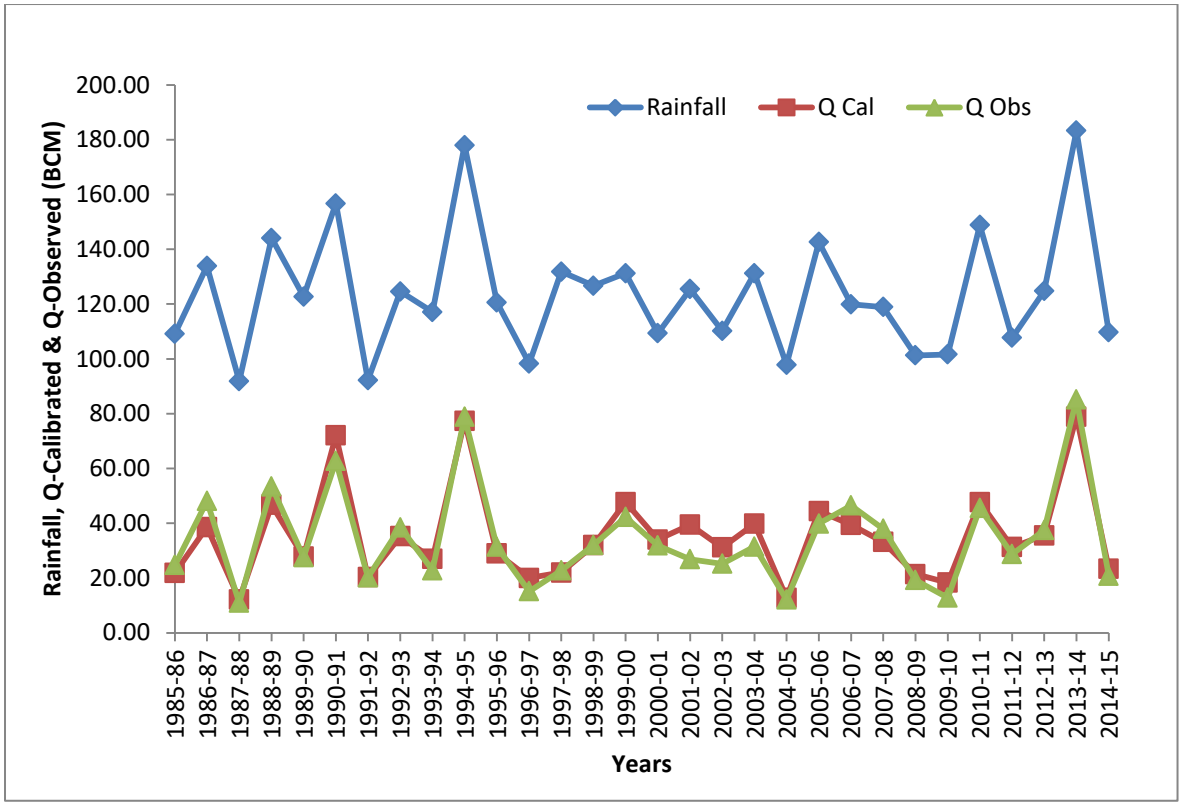


Figure 1.15 Calibrated runoff and observed discharge at Tekra

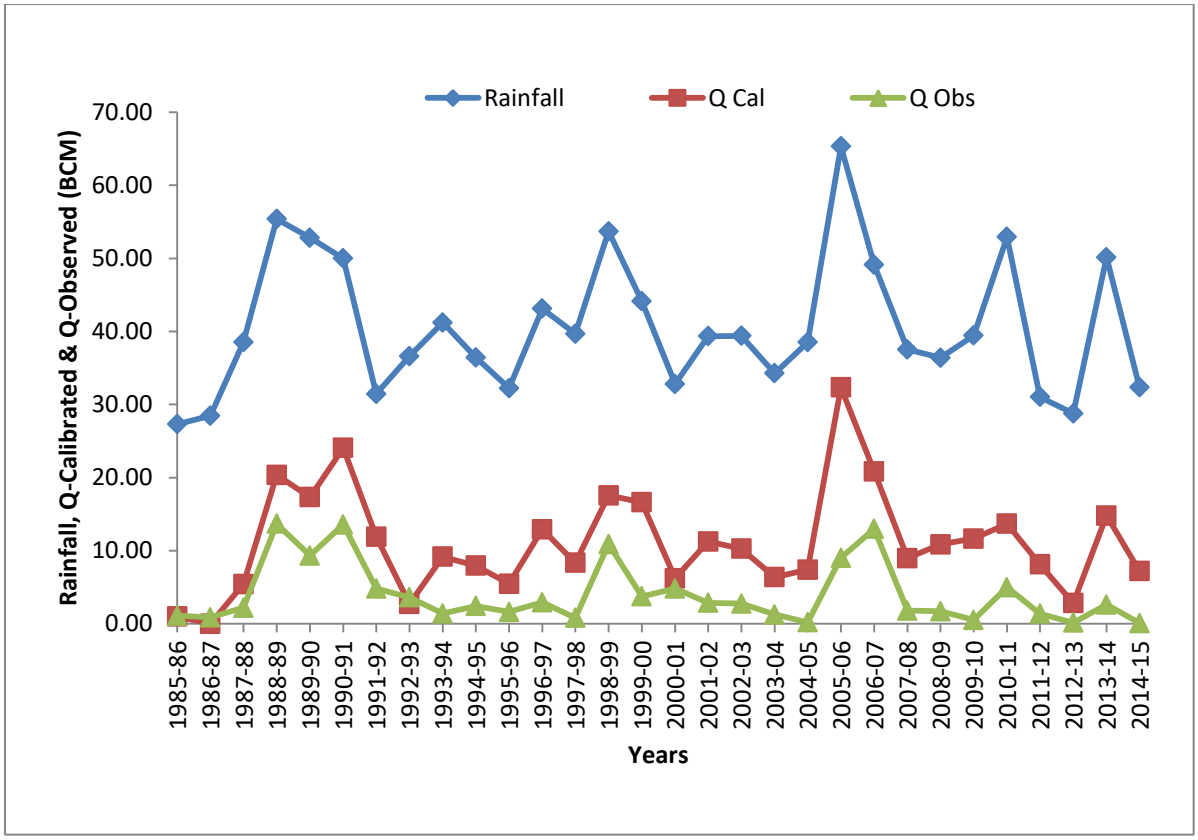


Figure 1.16 Calibrated runoff and observed discharge at Yelli

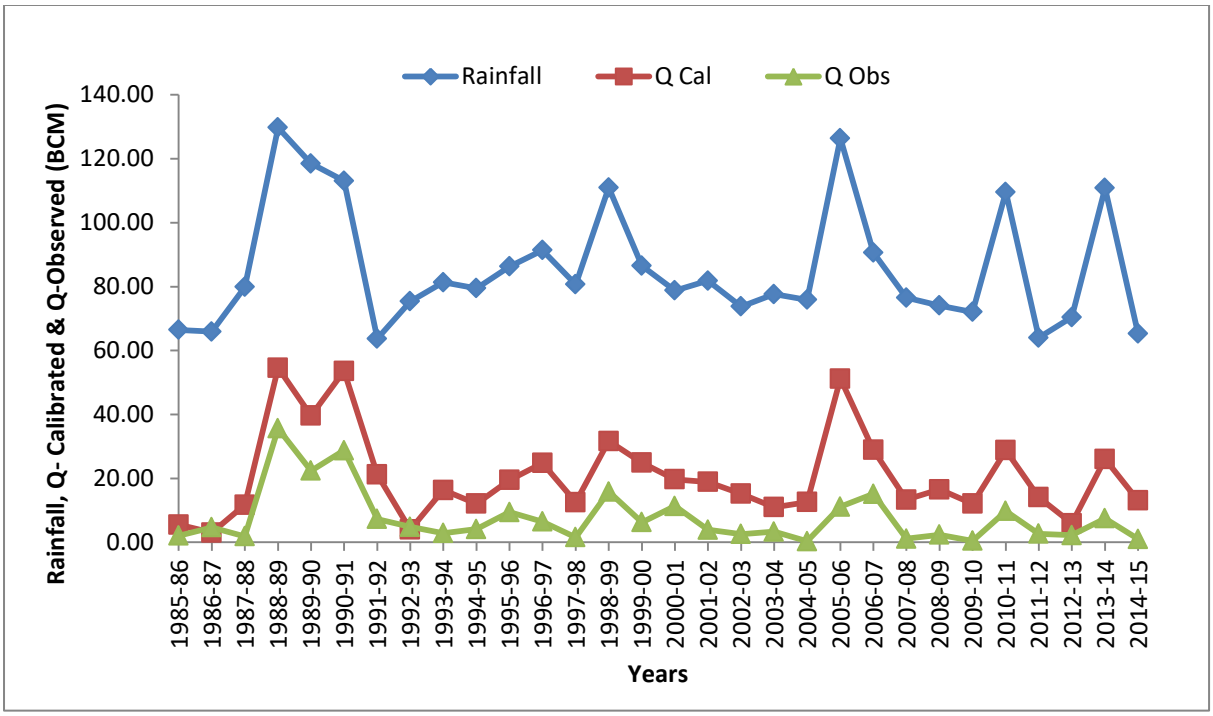


Figure 1.17 Calibrated runoff and observed discharge at Mancherial

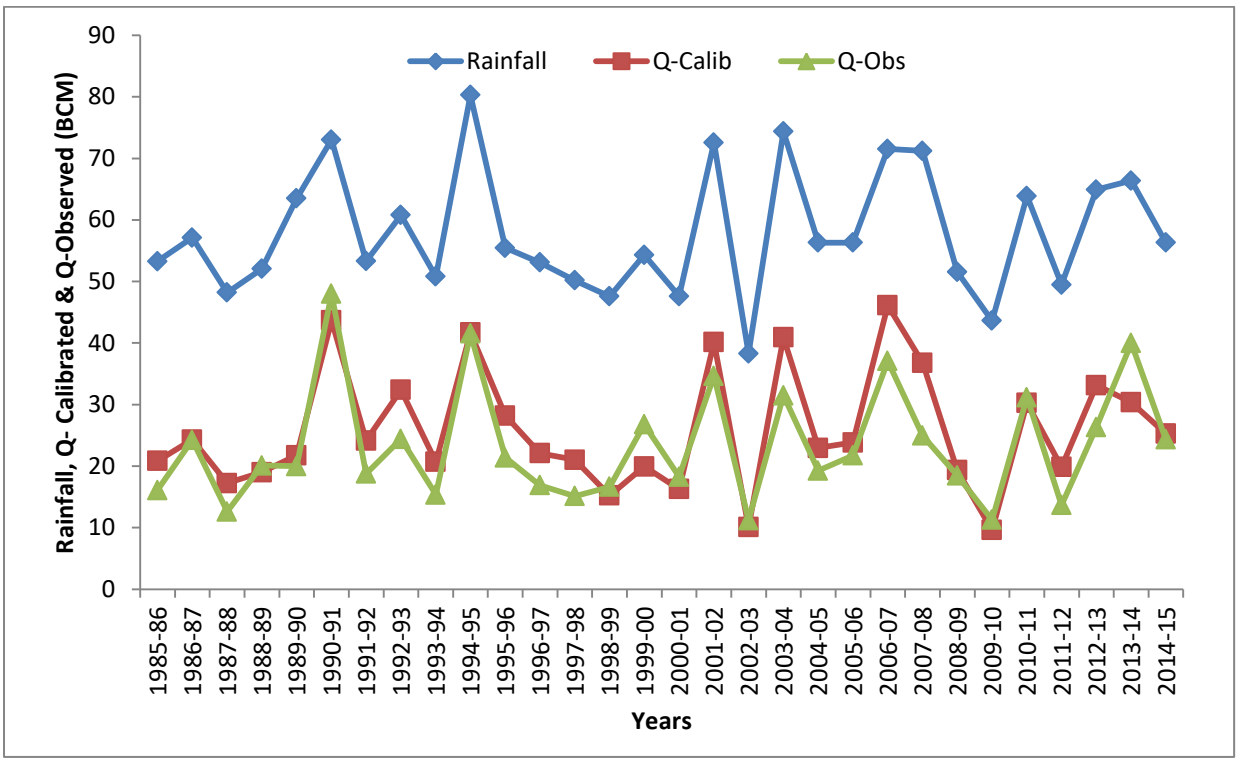


Figure 1.18 Calibrated runoff and observed discharge at Pathagudem

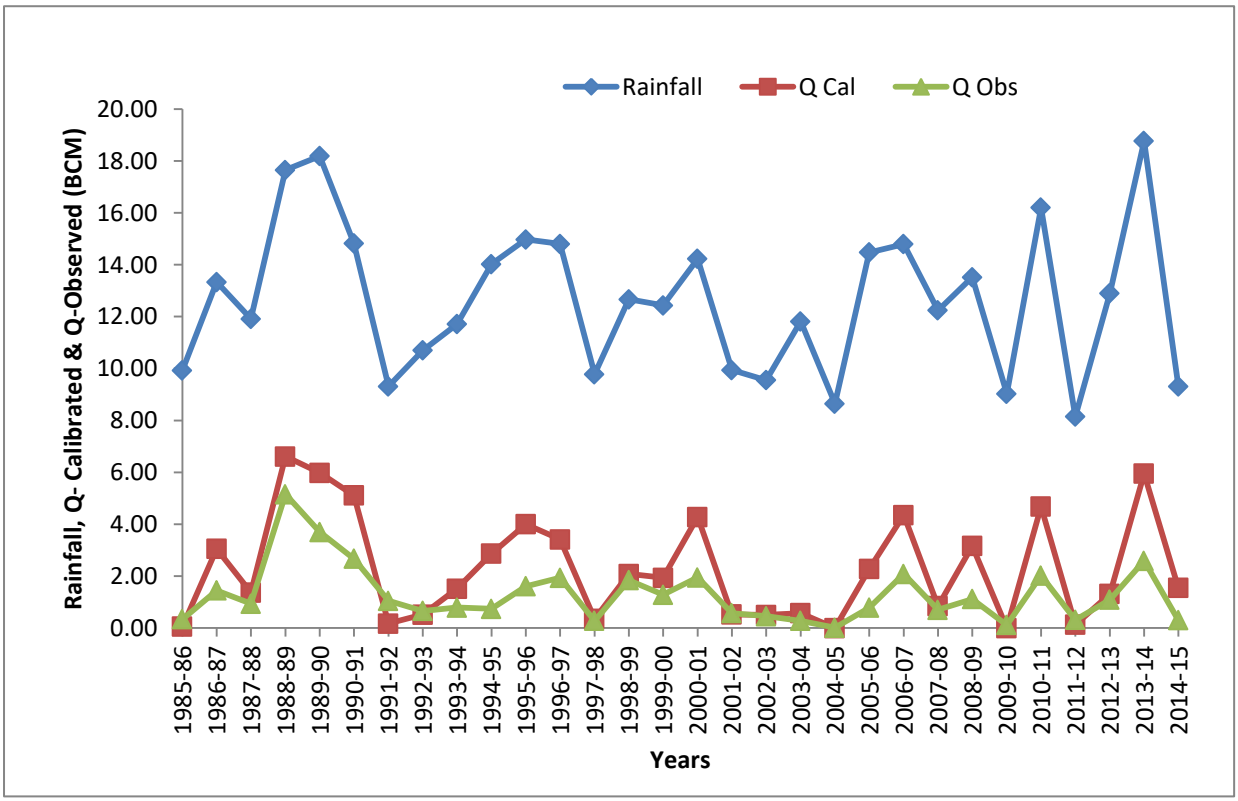


Figure 1.19 Calibrated runoff and observed discharge at Somanapally

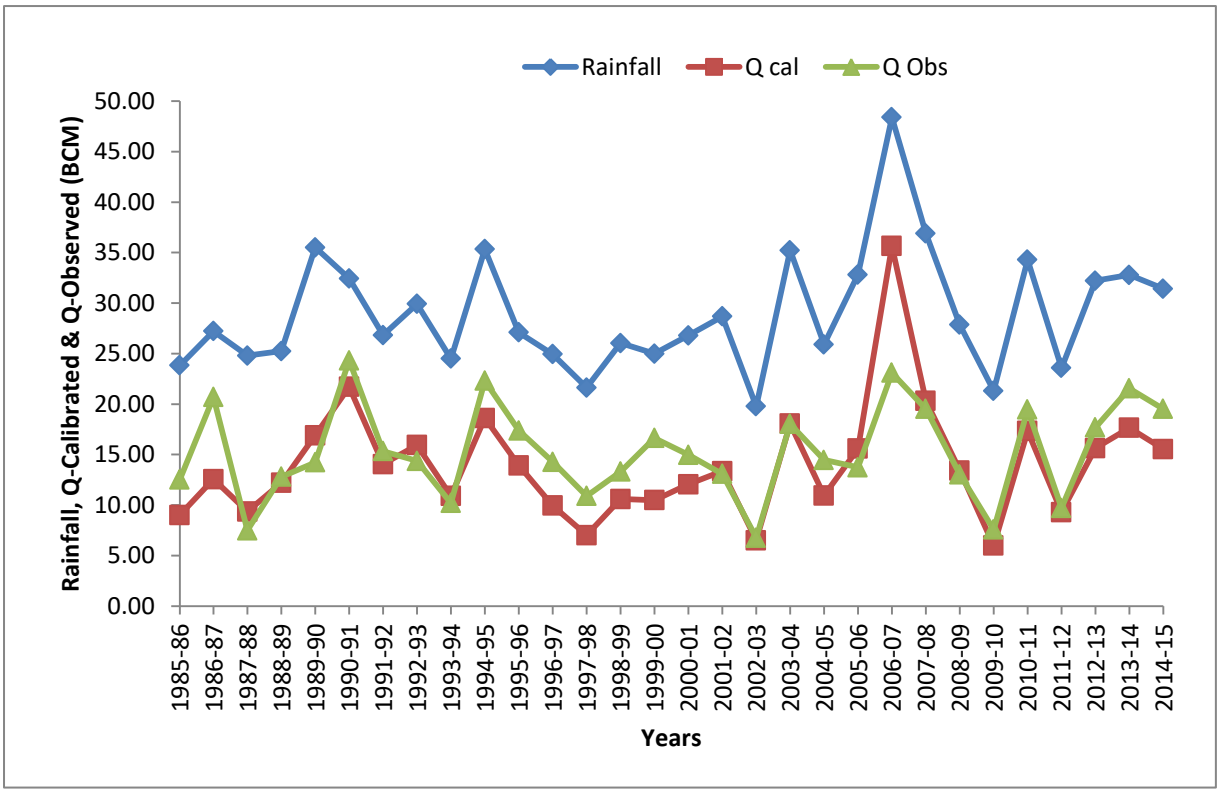


Figure 1.20 Calibrated runoff and observed discharge at Konta

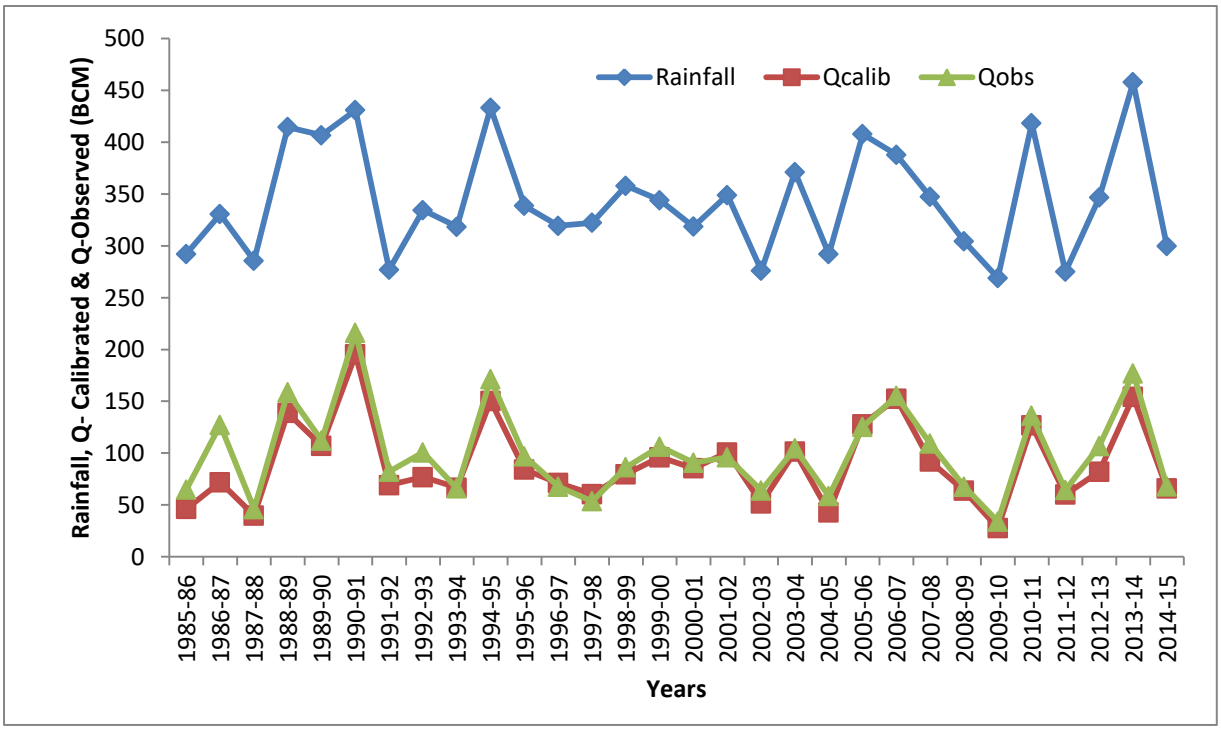


Figure 1.21 Calibrated runoff and observed discharge at Polavaram

Table - A.8 at Annexure - A gives calibrated runoff of Godavari basin up to Polavaram for 30 years. It may be observed from the Table that the mean annual calibrated runoff is 89.61 BCM. The maximum annual calibrated runoff is 195.34 BCM during 1990-91. The minimum annual calibrated runoff is 27.64 BCM during 2009-10. The average annual ECII is about 16.70 BCM. The maximum annual ECII is about 26.77 BCM during 2009-10. The minimum annual ECII is about 3.27 BCM during 2013-14.

1.5 Annual Water Resources Availability of Godavari basin

- It is observed that the model estimated runoff is very well matching for the entire study period for all the sites except Yelli, Mancherial and Somanapally.
- A correlation is noticed in observed runoff and rainfall at Yelli and Mancherial, which are adjacent sub-basins. The runoff coefficients with respect to model estimated runoff and observed runoff are 0.27 and 0.10 at Yelli and 0.24 and 0.09 at Mancherial. Hence, there may be any major diversions/storages at the upstream of Yelli for which no field data is available. This results in the higher difference between observed and calibrated runoff at Yelli. The same difference is carried forward at Mancherial.
- Also, a correlation is noticed in observed runoff and rainfall at Somanapally sub-basin. The runoff coefficients with respect to model estimated runoff and observed runoff are 0.18 and 0.10 at Somanapally, but it is negligible as the difference between observed and calibrated runoff is 0.98 BCM. Consequently, it may be observed that the calibrated and observed discharges are more or less equal during lean rainfall years and only differ during high rainfall years.
- In Konta sub-basin, the rainfall for the year 2006-07 (48.39 BCM) is abnormal, which is 20 BCM more than average rainfall (28.94 BCM) for the study period. During this year, the observed discharge is less compared to the calibrated runoff as at the high discharges banks has over flown and the same has been taken from the S-D curve.

Table - A.9 at Annexure - A shows the year-wise water resource availability in the Godavari basin. In the study period, the minimum annual available water resource is 56.98 BCM for the year 2004-05 and the maximum annual available water resource is 201.74 BCM for the year 1990-91. The mean available water resource is 117.74 BCM for the basin. The mean water availability from the **pilot model study** of Godavari basin (1988-89 to 2007-08) has been incorporated and for the remaining years, the model has been simulated. The mean available water resources of Godavari basin accounts about 32.25% of mean annual rainfall during 1985-86 to 2014-15. The population of the basin in 2011 was estimated as 7,29,55,636, which results in the per capita water availability in 2011 for the basin as 1,613 m^3 per year.

1.5.1 Annual water resources of Godavari basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 2013-14 and 2009-10, extreme wet and dry rainfall conditions occurred in Godavari basin. The annual water resources of Godavari basin during these two extreme rainfall conditions are 196.47 BCM and 73.29 BCM, respectively as shown in Table - 1.4. The water balance components during these years are presented in Figures 1.22 and 1.23.

Table - 1.4 Water resources availability in Godavari basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources availability (BCM)
Maximum Rainfall	2013-14	482.94	196.47
Minimum Rainfall	2009-10	288.33	73.29

Water Resources availability-rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.41 and 0.26 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years, potential evapotranspiration is less compared to the dry years which will have cumulative effect in runoff. It is found that the ECII during 2013-14 is less than the year 2009-10.

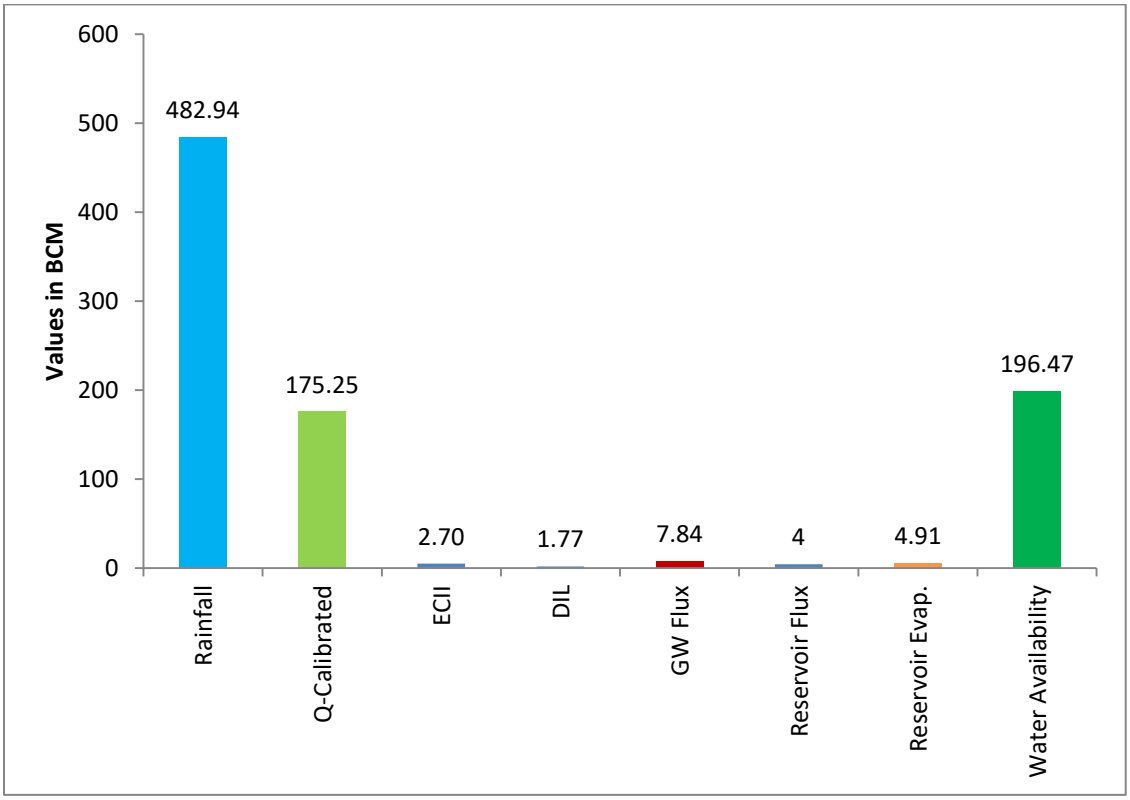


Figure 1.22 Water balance components of Godavari basin during extreme high rainfall (2013-14)

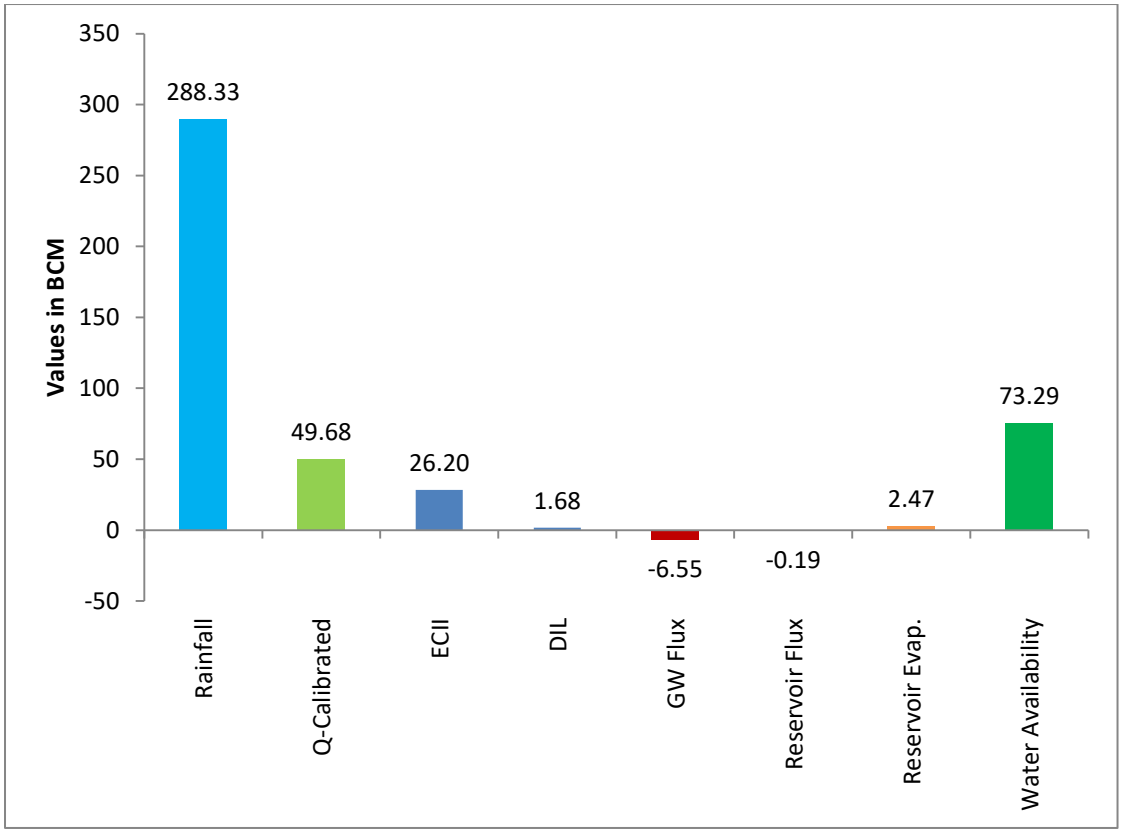


Figure 1.23 Water balance components of Godavari basin during extreme low rainfall (2009-10)

1.5.2 Mean water resources of Godavari basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation

Input + Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Evaporation from Reservoirs) = 96.57 + 16.13 + 1.15 + (-0.60) + 0.09 + 4.41 = 117.74 BCM

The mean water resource availability of the Godavari Basin for the study period of 1985-86 to 2014-15 is 117.74 BCM. Figure 1.24 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

75 % dependable flow for the whole Godavari basin = 87.67 BCM

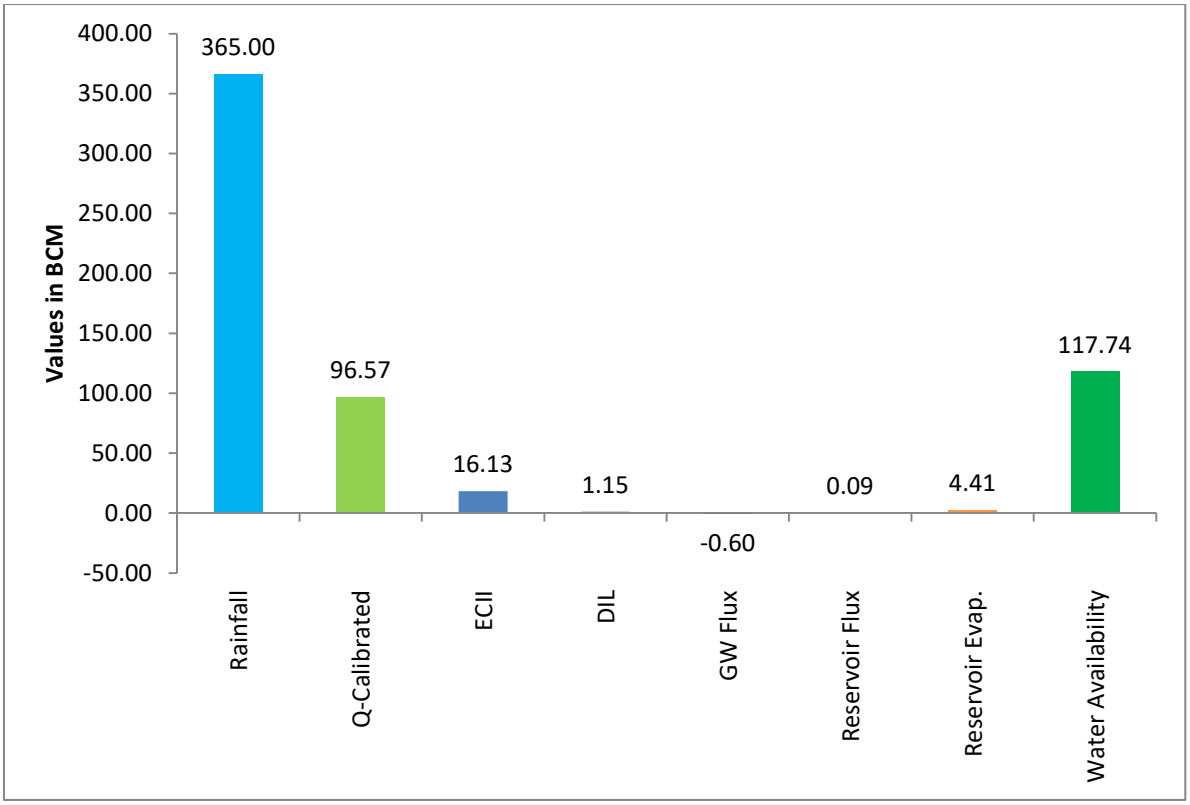
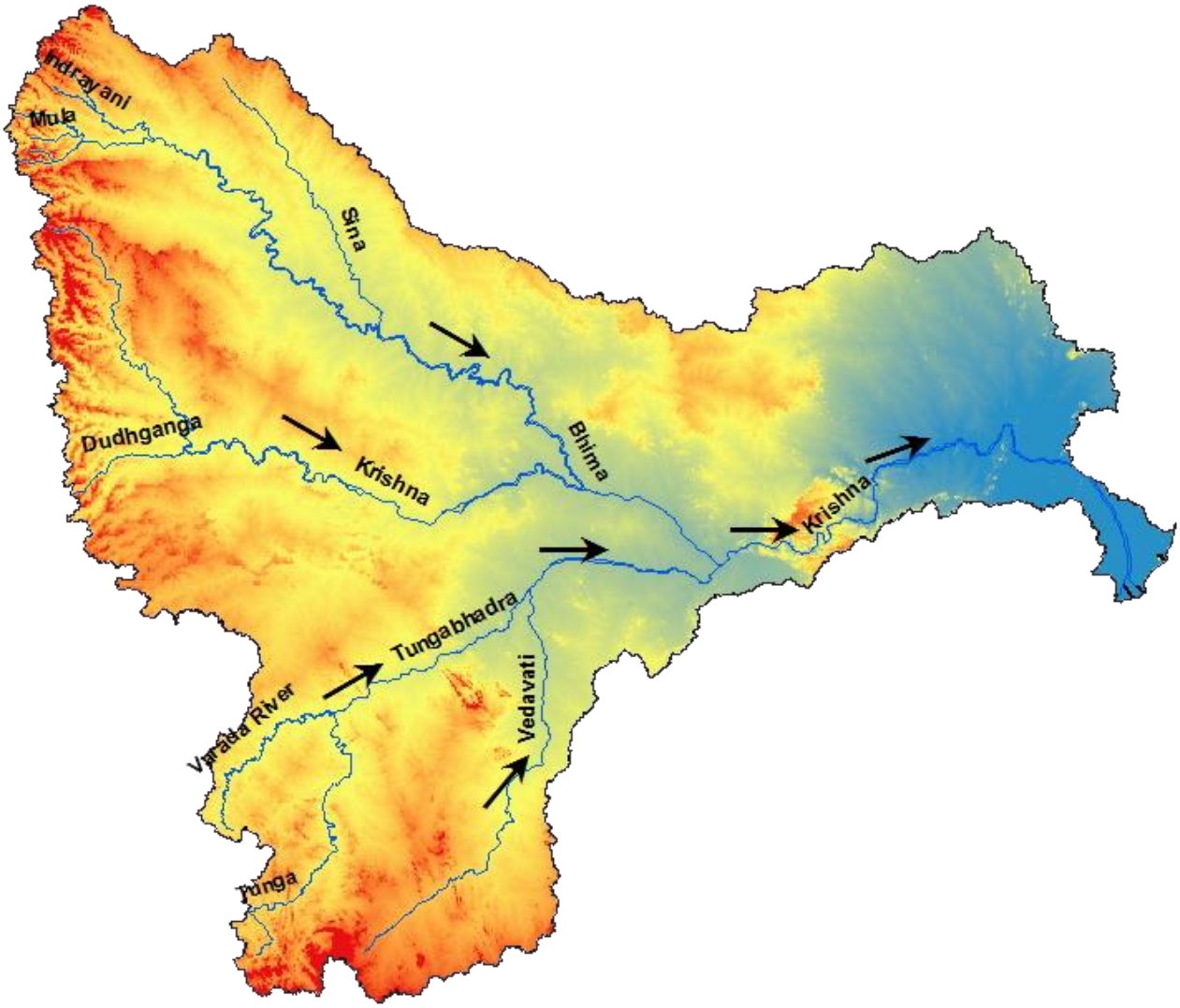


Figure 1.24 Mean water balance components of Godavari basin

HIGHLIGHTS

- *Mean available water resources of Godavari basin is 117.74 BCM.*
- *Maximum annual water availability is 201.74 BCM during 1990-91.*
- *Minimum annual water availability is 56.98 BCM during 2004-05.*
- *Annual rainfall in the basin varies from 877 mm to 1,493 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1,117 mm.*
- *Godavari basin is divided into nine sub-basins for the reassessment study viz. Bamini, Tekra, Yelli, Mancherial, Pathagudem, Somanapally, Konta, Polavaram and Combined Delta region as one sub-basin.*
- *Average annual domestic, industrial and livestock demand in the basin is 1.15 BCM.*
- *Average annual evaporation from water bodies in the basin is 4.41 BCM.*

KRISHNA BASIN



2.1 Geo-Spatial Datasets

2.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of the basin is shown in Figure 2.1. The image corresponds to the 2004-05 year and consists of 16 different classes. The map indicates current fallow (27.95%), Kharif only (23.87%) and Double/Triple crop (13.29%) are the major classes in Krishna basin (Figure 2.2).

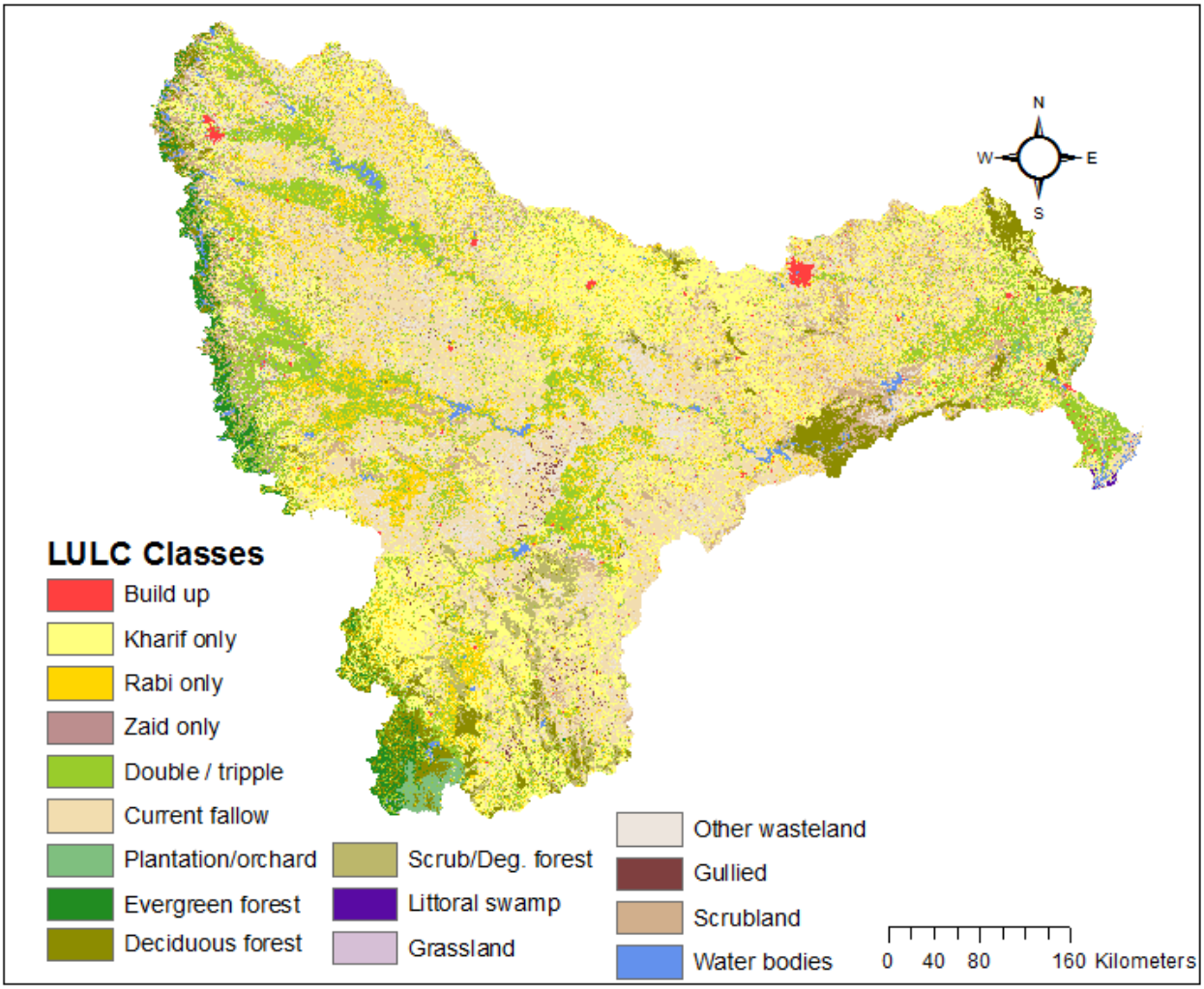


Figure 2.1 LULC map of Krishna basin (2004-05)

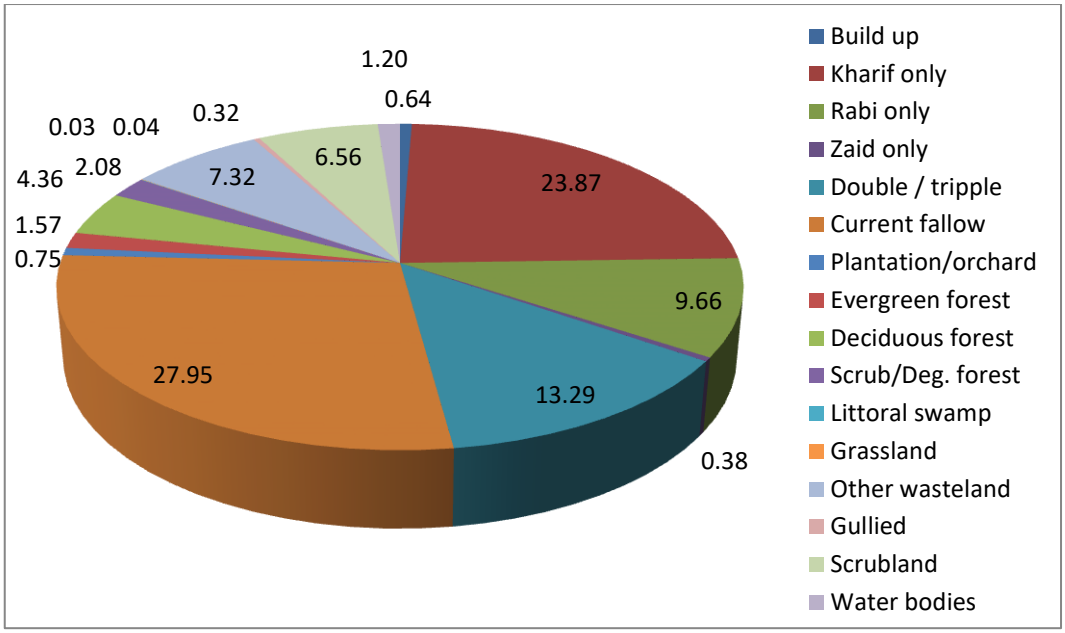


Figure 2.2 Distribution of LULC in Krishna basin (2004-05)

2.1.2 Soil texture

The main soil types found in the basin are sandy, clay and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 2.3 shows various categories of soil in the basin. The soils are classified as sandy, loamy, clayey and rock outcrops based on the soil texture information.

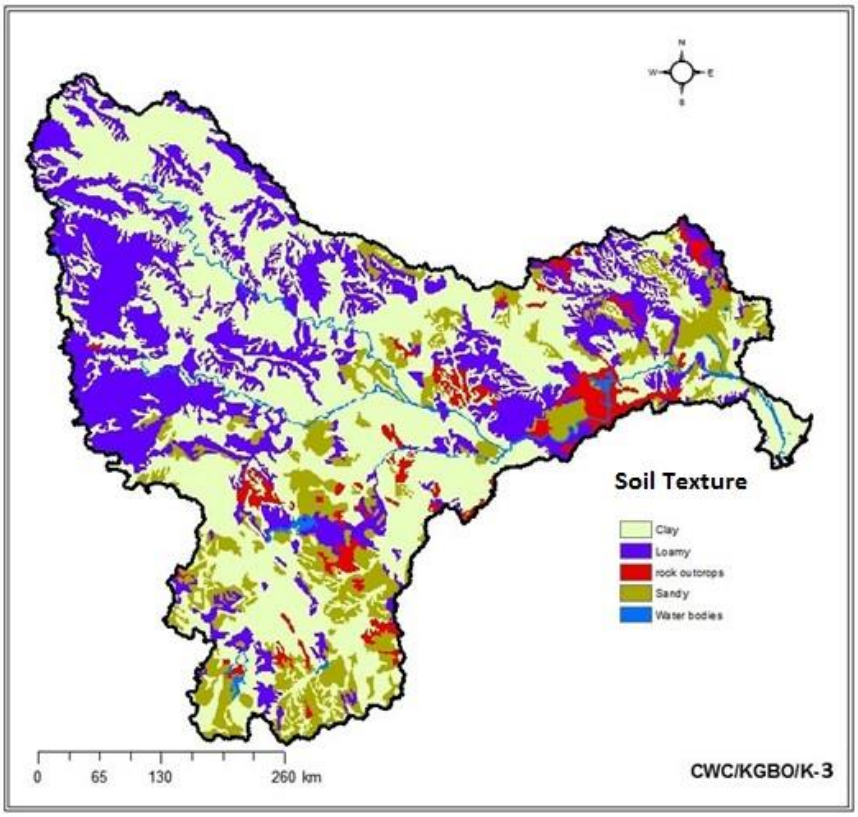


Figure 2.3 Soil texture map of Krishna basin

2.1.3 Topography

The topography of the basin consists of ghat areas, plateau and the coastal plains. The upper regions of the basin are mostly hilly and forested. The lower region of the basin is deltaic plains. The elevation values ranges from a minimum of 0 m to a maximum of 1,787 m. The average elevation is about 444 m in the basin. Figure 2.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Krishna basin.

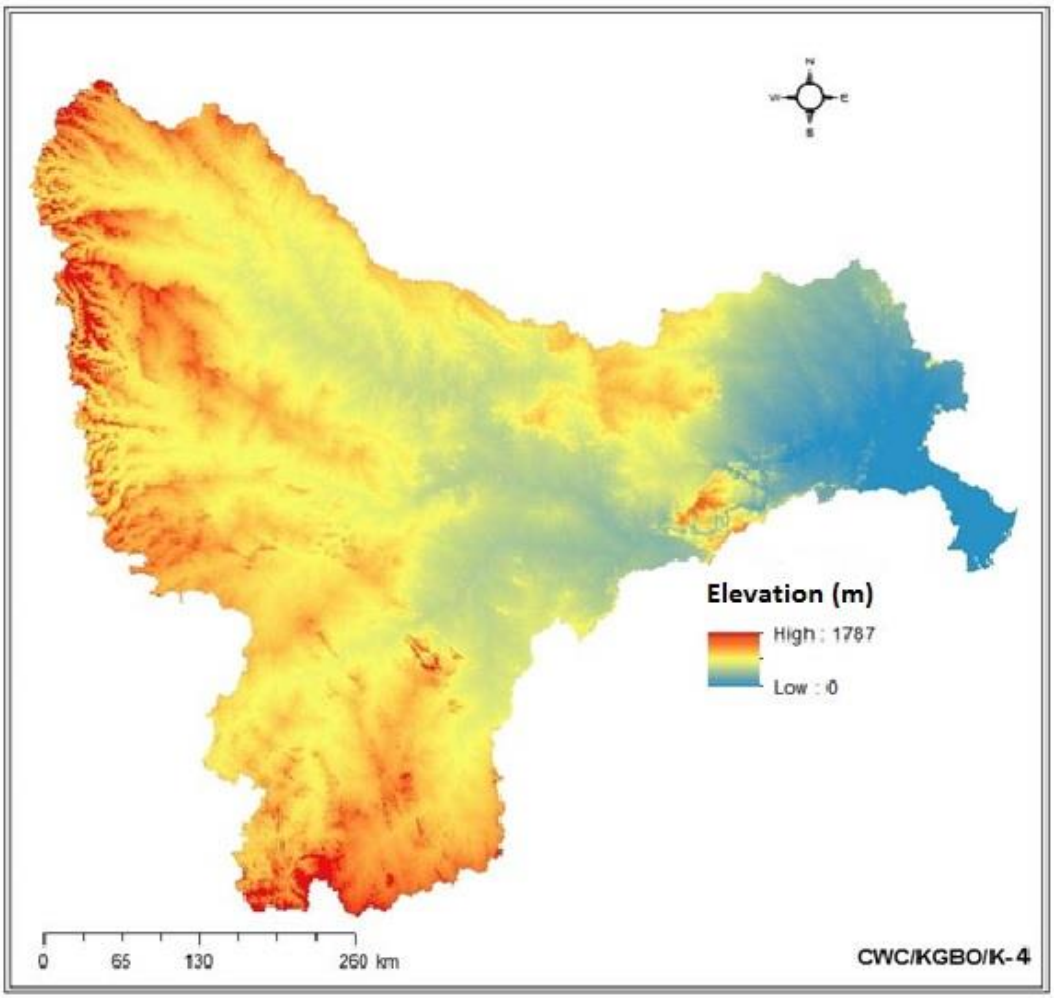


Figure 2.4 SRTM DEM map of Krishna basin

2.2 Hydro-Meteorological and other Input Data

2.2.1 Rainfall grids

Figure 2.5 shows gridded rainfall map of Krishna basin for the year 2010-11. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 2.6 (2005-06 rainfall was not considered in the study as it is found to be abnormally high). Annual rainfall of the basin varies from 604 mm to 1,045 mm and mean rainfall of these 29 years is found to be 857 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum annual rainfall of around 686 mm is observed in Yadgir sub-basin (area between Takli and Yadgir) while maximum annual rainfall of 1,496 mm is observed in Kurundwad sub-basin. Central part of the

basin receives less rainfall. Of the 29 years, for 16 years annual rainfall is higher than the mean rainfall and for remaining 13 years lower than the mean rainfall.

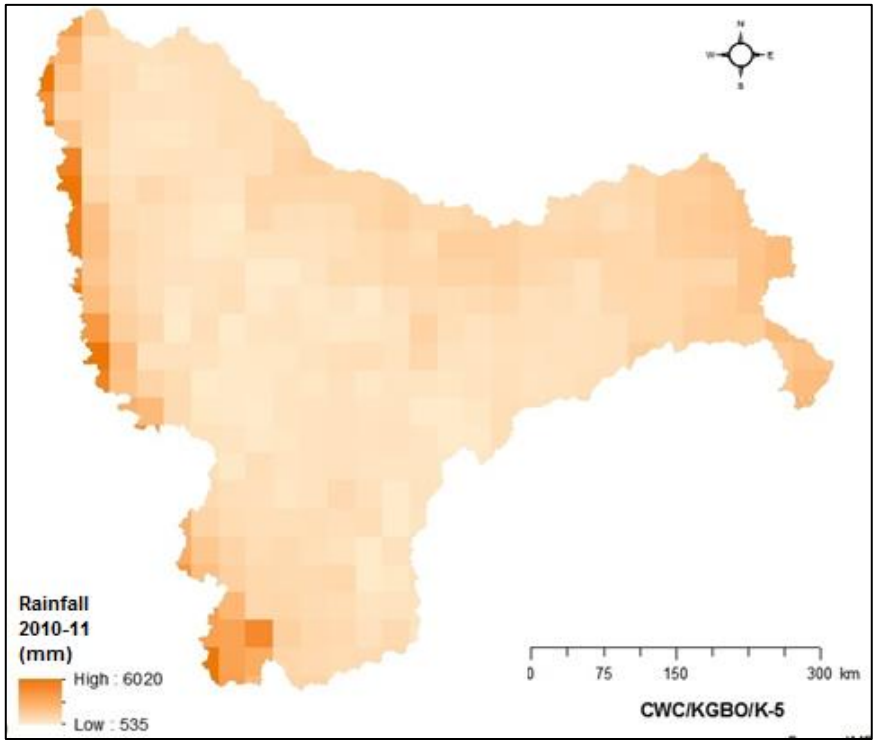


Figure 2.5 Gridded rainfall of Krishna basin (2010-11)

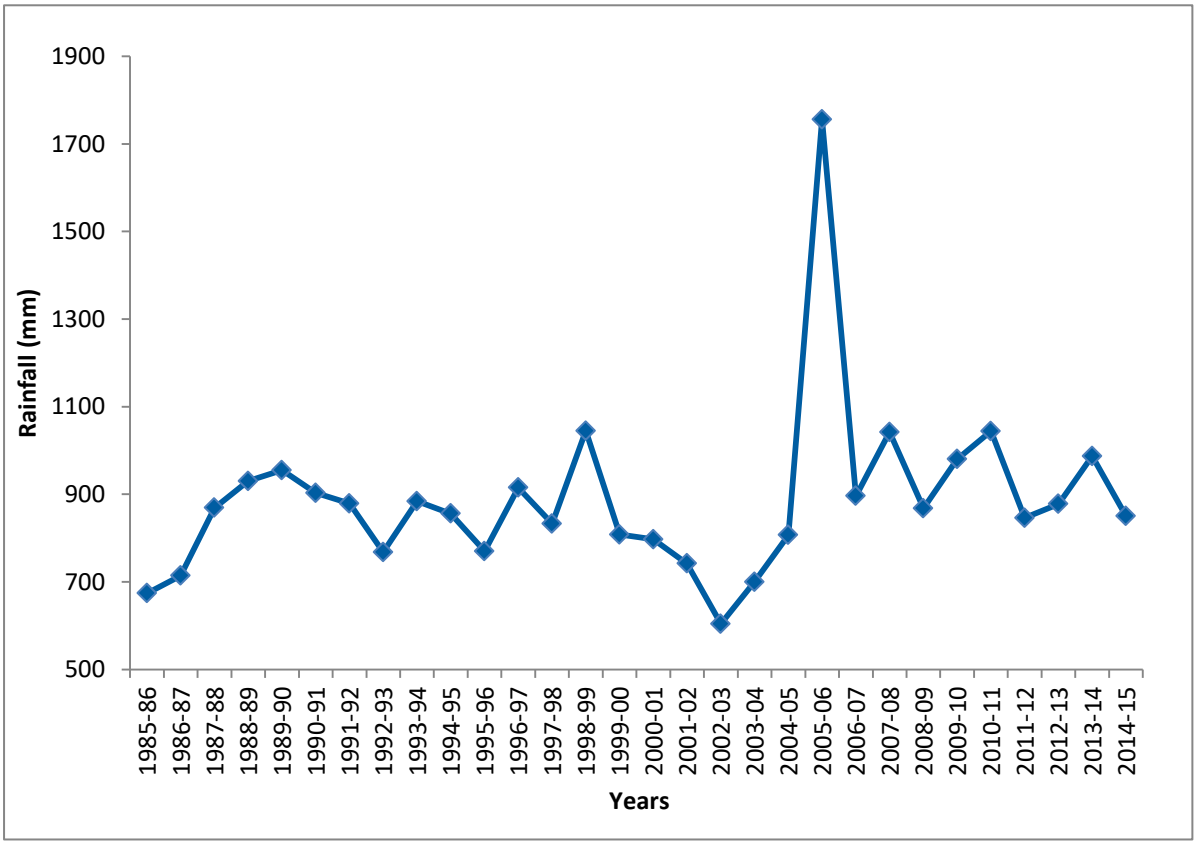


Figure 2.6 Annual rainfalls in Krishna basin (1985-86 to 2014-15)

2.2.2 Temperature grids

Gridded mean annual temperature of Krishna basin in 2009-10 is shown in Figure 2.7. The mean annual temperature during 2009-10 was about 27 ^{0}C.

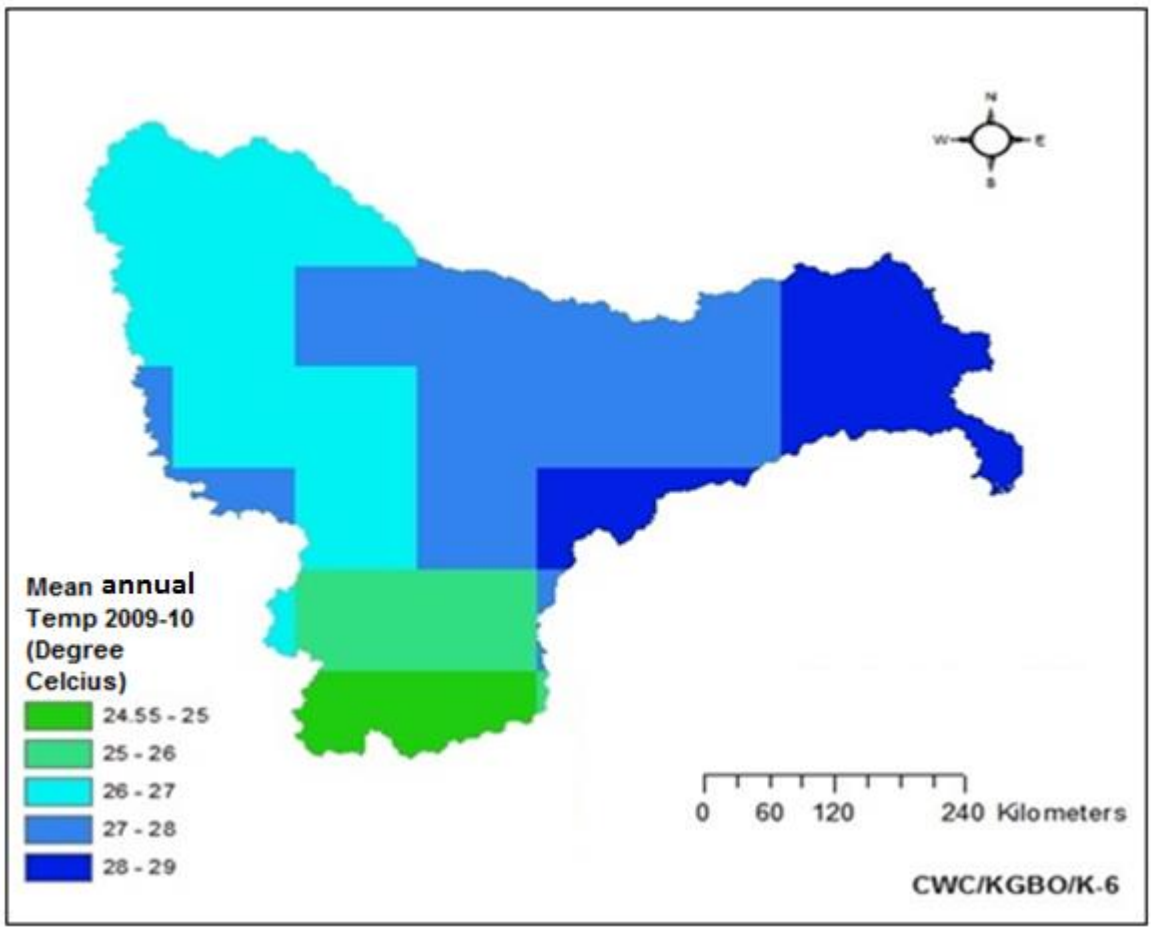


Figure 2.7 Gridded mean annual temperature of Krishna basin (2009-10)

2.2.3 Sub-basins of Krishna basin

The Krishna basin is divided in to eight sub-basins (Figure 2.8) viz. Kurundwad, Huvinhedgi, Takli, Yadgir, Bawapuram, Wadinepalli, Vijayawada and combined delta region as one sub-basin. Table - 2.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

Figure 2.8 Sub-basins of Krishna basin

Table - 2.1 Sub-basin wise details of Krishna basin

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Kurundwad	Krishna	15,352
2	Huvinhedgi	Krishna	38,951
3	Takli	Bhima	33,398
4	Yadgir	Bhima	36,135
5	Bawapuram	Tungabhadra	66,653
6	Wadinepalli	Krishna	52,663
7	Vijayawada	Krishna	13,240
8	Delta	Krishna	3,047
		Total basin area	2,59,439

2.2.4 River discharge

The river discharge data was available at all the 7 sites (Kurundwad, Huvinhedgi, Wadinepalli and Vijayawada located on main Krishna, Takli and Yadgir located on left flank tributary Bhima and Bawapuram on right flank tributary Tungabhadra) for the study period of 30 years. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level.

2.2.5 Reservoir flux

Figure 2.9 shows the location of some of major reservoirs in Krishna basin. The data of 13 major reservoirs such as Nagarjuna Sagar, Srisailam, Tungabhadra, Narayanpur, Almatti, Ujjani, etc. maintained by CWC and 9 medium projects received from State Governments were considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed runoff.

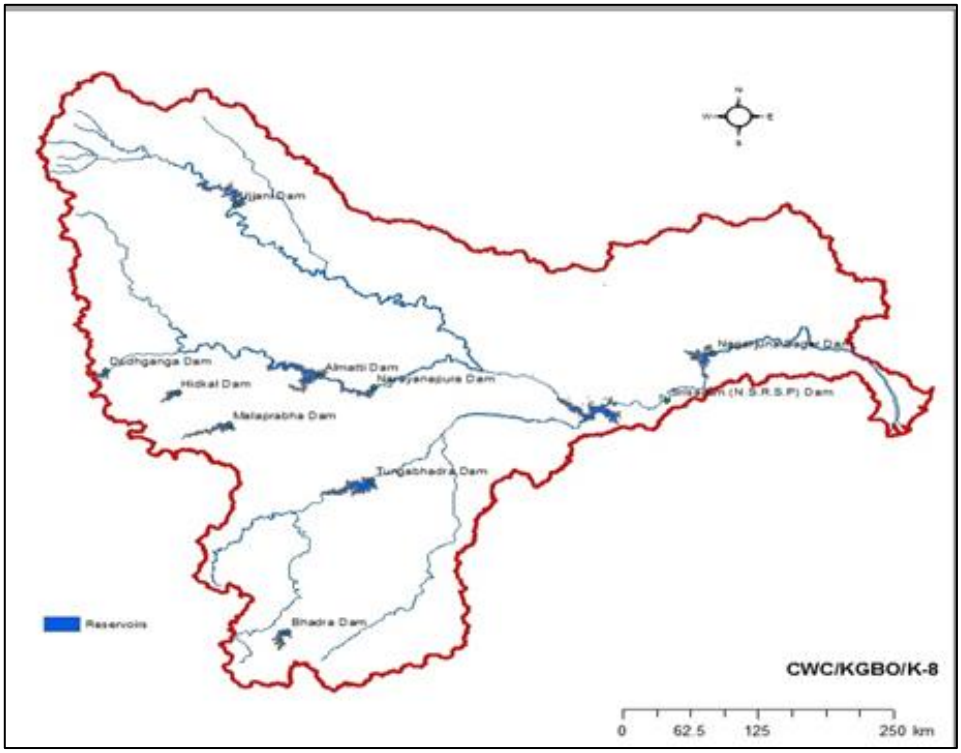


Figure 2.9 Major reservoirs in Krishna basin

2.2.6 Groundwater flux

The spatial annual groundwater flux for the year 2002-03 is shown in Figure 2.10. The annual groundwater flux during the study period is shown in Figure 2.11.

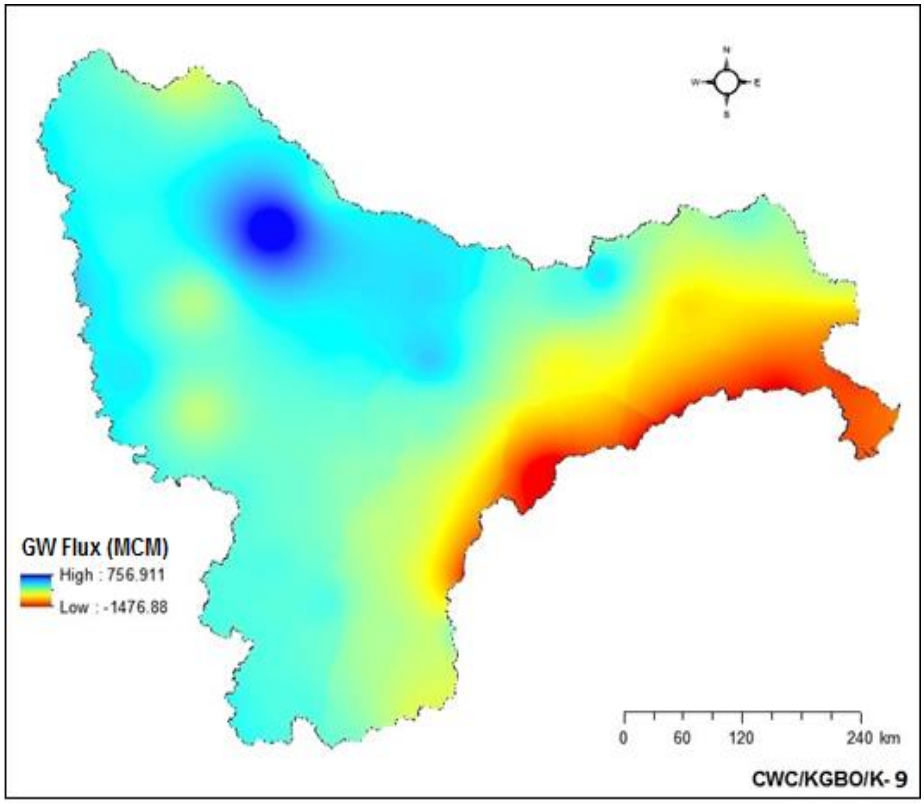


Figure 2.10 Groundwater flux (spatial data) estimated during 2002-03

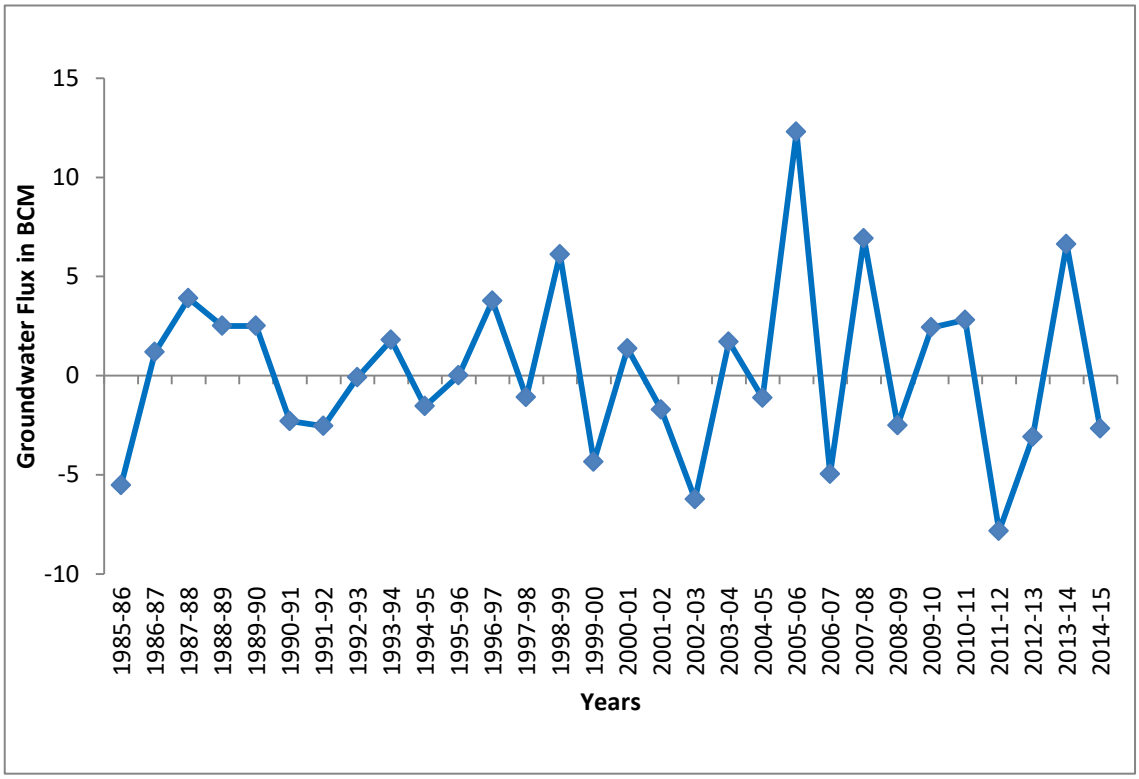


Figure 2.11 Annual groundwater flux of Krishna basin (1985-86 to 2014-15)

2.2.7 Major crops in the basin

The Krishna basin was divided in 39 regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if rice is a major crop, it may be jowar or bajra in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if rice is a major crop in Kharif only season, it may be jowar or bajra during 2005-06.

2.2.8 Irrigation command area

Figure 2.12 shows location of irrigation command boundaries inside and outside the Krishna basin considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence the command area considered during the year 1985-86 was worked out to be around 70,72,365 hectare, while it was 81,69,157 hectare in 2014-15 (excluding the basin outside command). Basin outside command has been taken uniformly for all years while working out ECII from these areas.

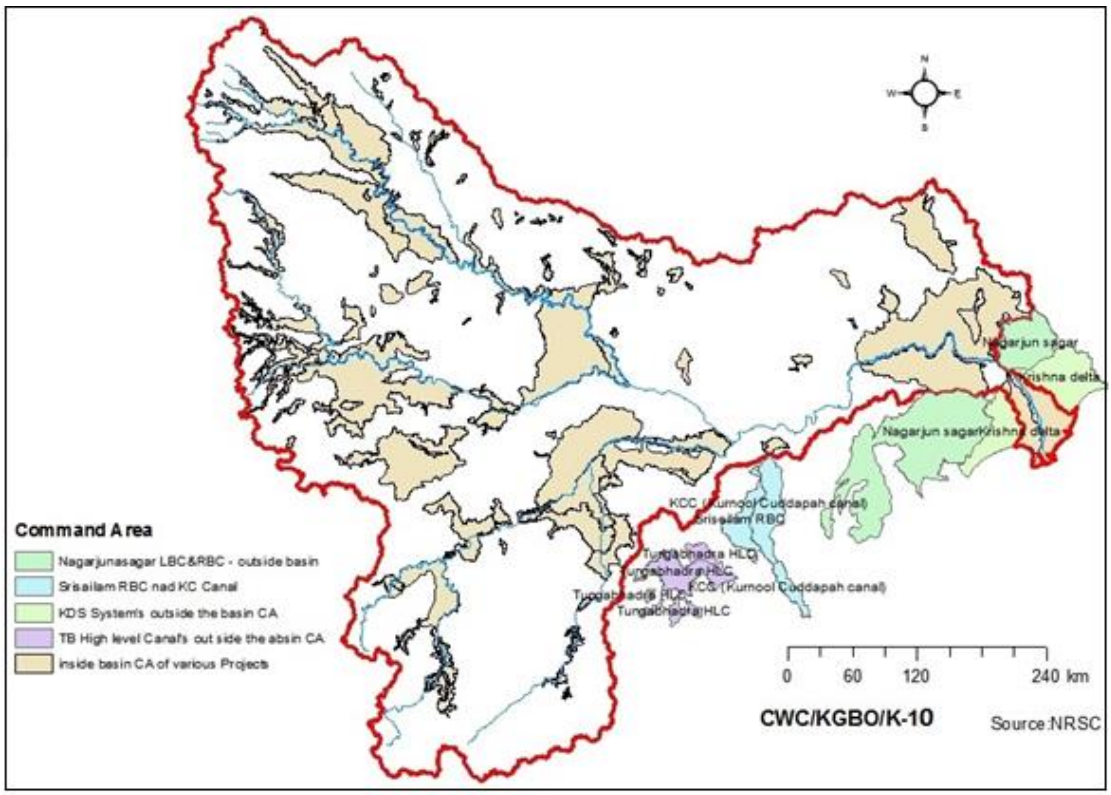


Figure 2.12 Irrigation command boundaries of Krishna basin

2.2.9 Domestic, industrial and livestock demand

Figure 2.13 shows district boundaries layer with district population for the year 2011 census. Population data of census year 1991, 2001, 2011 and livestock census of 1982, 1983, 1987, 1990, 1992, 1993, 1997, 1999, 2003, 2007 and 2012 of basin states were used in the study. Population statistics for intervening period and beyond were calculated using geometric progression method. The mean annual domestic, industrial and livestock demands are estimated at 1.65 BCM in the basin.

Figure 2.13 District boundaries in Krishna basin

2.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 2.2 provides annual evaporation values from each of sub-basins for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 2.05 BCM. It may be observed from the table that two major reservoirs viz. Nagarjuna Sagar and Srisailam falling in Wadinepalli sub-basin are contributing more evaporation losses among all sub-basins.

Table - 2.2 Evaporation in reservoirs of Krishna basin

Year	Reservoir evaporation in each independent sub-basin (in BCM)							
	Kurundwad	Huvinhedgi	Takli	Yadgir	Bawapuram	Wadinepalli	Vijayawada	Delta
1985-86	0.1121	0.0819	0.2789	0.0714	0.1492	0.2894	0.0504	0.1023
1986-87	0.1262	0.1142	0.3042	0.0720	0.1716	0.2751	0.0436	0.0352
1987-88	0.1516	0.1484	0.3553	0.0934	0.1963	0.3164	0.0465	0.0976
1988-89	0.1141	0.1172	0.3147	0.0826	0.1481	0.3570	0.0467	0.1023
1989-90	0.1269	0.1413	0.3653	0.0972	0.1615	0.3956	0.0616	0.1371
1990-91	0.1309	0.1362	0.3517	0.0875	0.1806	0.3525	0.0561	0.0942
1991-92	0.1076	0.1320	0.2820	0.0629	0.1791	0.3787	0.0563	0.1155
1992-93	0.1244	0.1304	0.3257	0.0817	0.1827	0.3290	0.0514	0.0987
1993-94	0.1535	0.1466	0.4007	0.0949	0.1815	0.3359	0.0459	0.0324
1994-95	0.1365	0.1266	0.3005	0.0753	0.1397	0.3124	0.0488	0.1117
1995-96	0.1199	0.1305	0.3238	0.0848	0.1555	0.4133	0.0516	0.0999
1996-97	0.1658	0.2649	0.3942	0.0966	0.1837	0.4346	0.0570	0.1395
1997-98	0.1595	0.2214	0.4016	0.0995	0.1855	0.3127	0.0164	0.1266
1998-99	0.1868	0.3053	0.4876	0.1326	0.1968	0.4123	0.0542	0.1246
1999-00	0.1586	0.1916	0.3960	0.1043	0.1484	0.2815	0.0501	0.1101
2000-01	0.1623	0.2162	0.3723	0.0995	0.1785	0.3754	0.0459	0.1238
2001-02	0.1645	0.1874	0.4241	0.0988	0.1462	0.3581	0.0505	0.1194
2002-03	0.1390	0.1832	0.3402	0.0996	0.1343	0.2938	0.0516	0.0733
2003-04	0.1535	0.0045	0.3335	0.0925	0.1436	0.3915	0.0369	0.1150
2004-05	0.1564	0.2209	0.4337	0.1194	0.1584	0.3122	0.0594	0.0889
2005-06	0.1815	0.6689	0.5043	0.1751	0.6927	0.8096	0.0507	0.5368
2006-07	0.1528	0.4183	0.4409	0.1359	0.4933	0.5883	0.3042	0.4238
2007-08	0.1469	0.6112	0.4074	0.1909	0.7205	0.9187	0.1199	0.7809
2008-09	0.1690	0.4379	0.4144	0.1636	0.5404	0.6731	0.2921	0.6088
2009-10	0.1892	0.6295	0.5889	0.2067	0.7359	0.6645	0.2053	0.4806
2010-11	0.1935	0.6410	0.5808	0.2722	0.7213	0.8663	0.2950	0.4830
2011-12	0.1825	0.4858	0.4537	0.1867	0.6190	0.6026	0.1628	0.3674
2012-13	0.2020	0.5108	0.4393	0.2025	0.5650	0.8626	0.2516	0.5118
2013-14	0.2261	0.5612	0.5665	0.2663	0.7098	1.0231	0.2251	0.4257
2014-15	0.2664	0.3750	0.3254	0.1715	0.6032	0.6021	0.1383	0.1900
Avg	0.1587	0.2847	0.3969	0.1273	0.3241	0.4846	0.1009	0.2286
Avg. excluding High variance year 2005-06	0.1579	0.2714	0.3932	0.1256	0.3114	0.4734	0.1026	0.2179

2.3 Previous Estimates

A gist of earlier assessments on Krishna river system made by different authorities over a period of time has been presented in Table 2.3.

The water potential of the Krishna river system has been assessed at different times by different authorities. The first assessment was made by the First Irrigation Commission. This Commission used past records of the surplus flow of the Krishna from the greater part of its catchment extending back for a sufficient number of years to estimate the average flow as accurately as possible. The Commission assessed the total annual surface flow in the Krishna river system as 84.86 BCM. In 1949 when the assessment of the basin wise water resources of the country (basin wise) was made on the of Khosla's formula, the annual runoff of the Krishna river system was estimated to be 44.92 BCM. The Technical Committee for the optimum utilization of Krishna and Godavari waters, in its report dated 1953 estimated the average annual runoff of the Krishna river system at Vijayawada based on Khosla's formula to be 46.87 BCM. The Central Water & Power Commission, when conducting the irrigation potential studies of the country assessed the total annual runoff of the Krishna river system to be 57.76 BCM. The Krishna Godavari Commission set up by the Government of India in their report dated July/August, 1962, estimated the average annual yield, sub-basin wise and reported that the aggregate yield of all the sub-basins of the Krishna system is 62.78 BCM. The Krishna Water Disputes Tribunal (1973) gave the assessment of water resources potential of Krishna basin as 67.79 BCM.

In 1993 study, the Krishna basin had a total catchment area of 2,58,948 sq.km. Flow data at Vijayawada (catchment area of 2,51,369 sq.km.) available for the period 1971-72 to 1984-85 were used. Data on abstractions for irrigation were obtained from Irrigation Project Authorities wherever available and in other cases, the abstractions were estimated from the irrigated area statistics and by adopting suitable delta. In all 67 major and medium irrigation projects and other minor irrigation projects were considered in that study. Withdrawal for domestic use was based on population statistics assuming requirement of 70 LPCD for rural population, 200 LPCD for urban population and 50 LPCD for the Livestock. Industrial water requirement was estimated to be as domestic water requirement. The total water resource available was estimated at 78.12 BCM in the basin.

Table - 2.3 Earlier assessments on Krishna river system

S. No.	Year	Authority/Method of estimation	Quantity (BCM)
1.	1901 - 03	First Irrigation Commission / using runoff coefficients	84.86
2.	1949	Khosla's empirical formula	44.92
3.	1953	The Technical committee for the optimum utilisation of Krishna and Godavari waters	46.87
4.	1960	CW & PC / Statistical analysis of flow data wherever available and rainfall-runoff relationships wherever data were meagre	57.76
5.	1962	The Krishna Godavari Commission-aggregation of average annual yields of all sub-basins	62.78
6.	1973	Krishna Water Disputes Tribunal	67.79
7.	1993	Central Water Commission	78.12

2.4 Runoff Estimation

The observed discharges are available for sites Kurundwad, Huvinhedgi, Wadinepalli, Vijayawada on river Krishna and Takli and Yadgir on river Bhima and Bawapuram on river Tungabhadra. The model estimated runoff is calibrated against the observed discharge at all the seven locations. Computed runoff at Deltaic region is added to the whole basin without any calibration, since it does not have any observed discharge. Tables – B.1 to B.7 at Annexure - B give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for these discharge stations. Figures 2.14 to 2.20 show comparative graphs of calibrated runoff and observed discharge at these discharge stations. From the graphs, it may be observed that the model estimated runoff and observed discharge at almost all the sites (Kurundwad, Huvinhedgi, Wadinepalli, Vijayawada and on River Bhima, Takli and Yadgir and on river Tungabhadra) is matching very well for the 30 year period. In case of Bawapuram site, it is matching well for almost all the years except for 4 years 2009-10 to 2012-13.

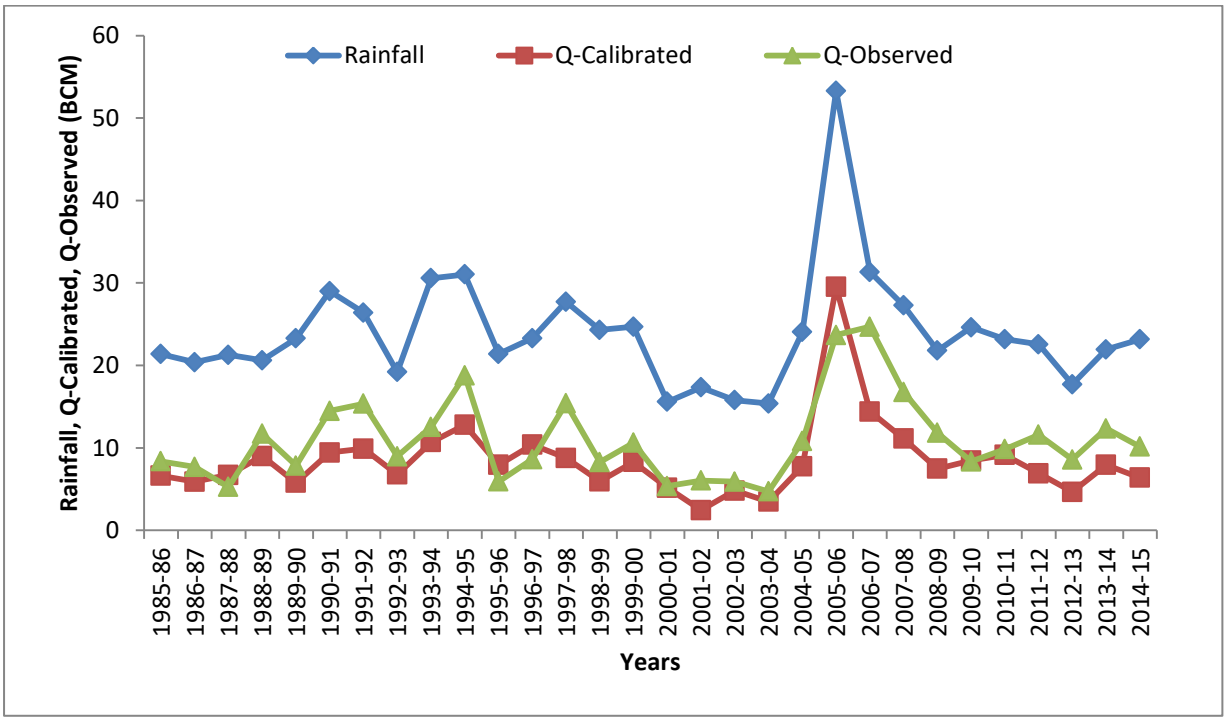


Figure 2.14 Calibrated runoff and observed discharge at Kurundwad

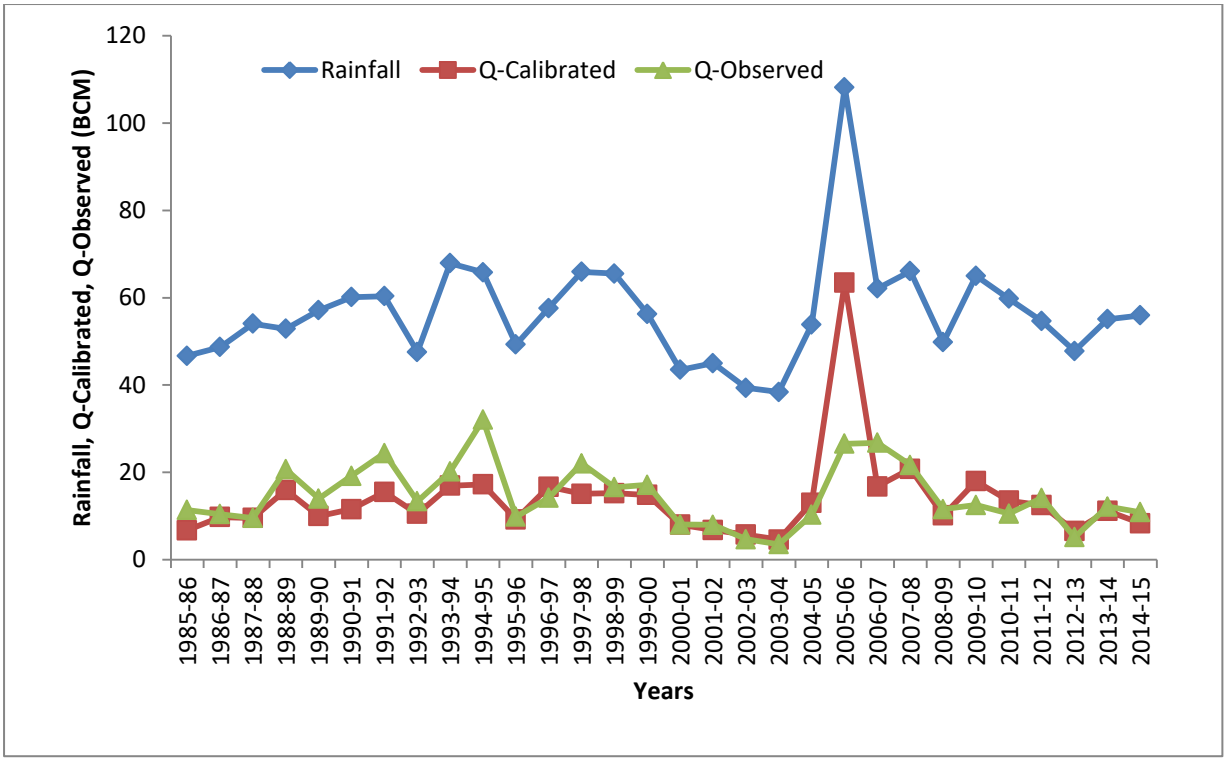


Figure 2.15 Calibrated runoff and observed discharge at Huvinhedgi

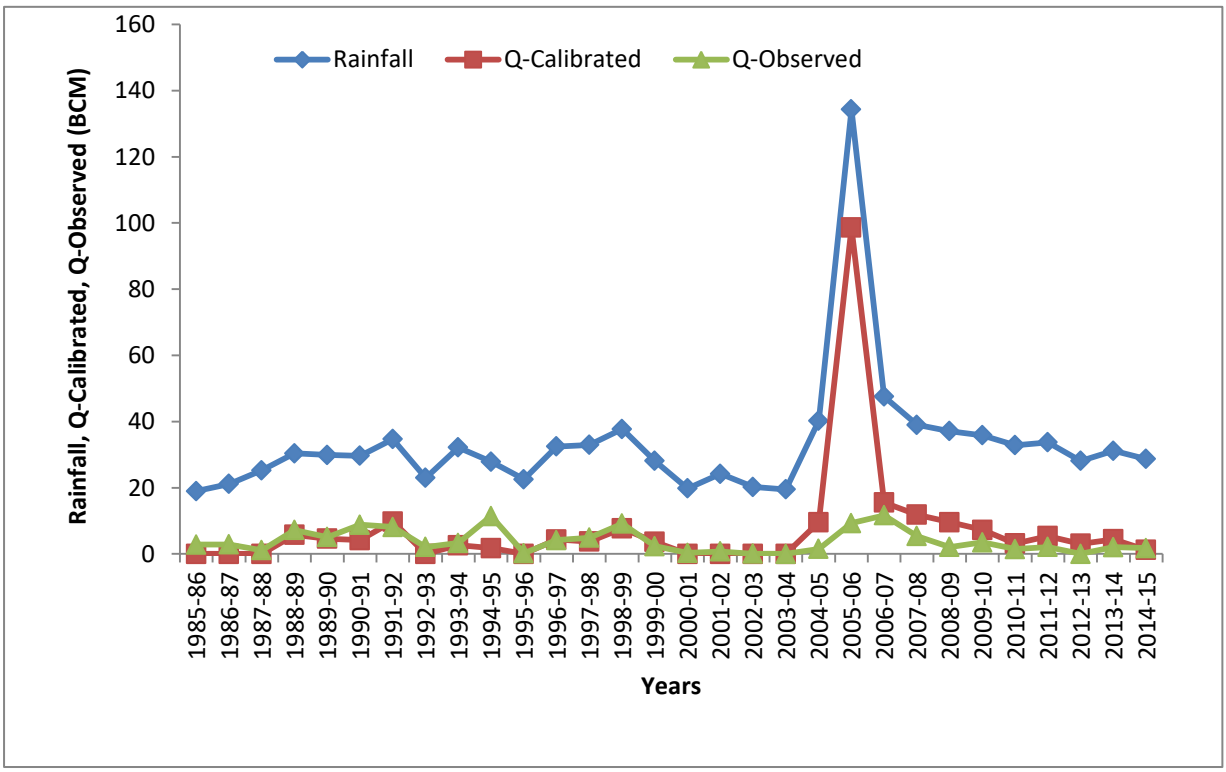


Figure 2.16 Calibrated runoff and observed discharge at Takli

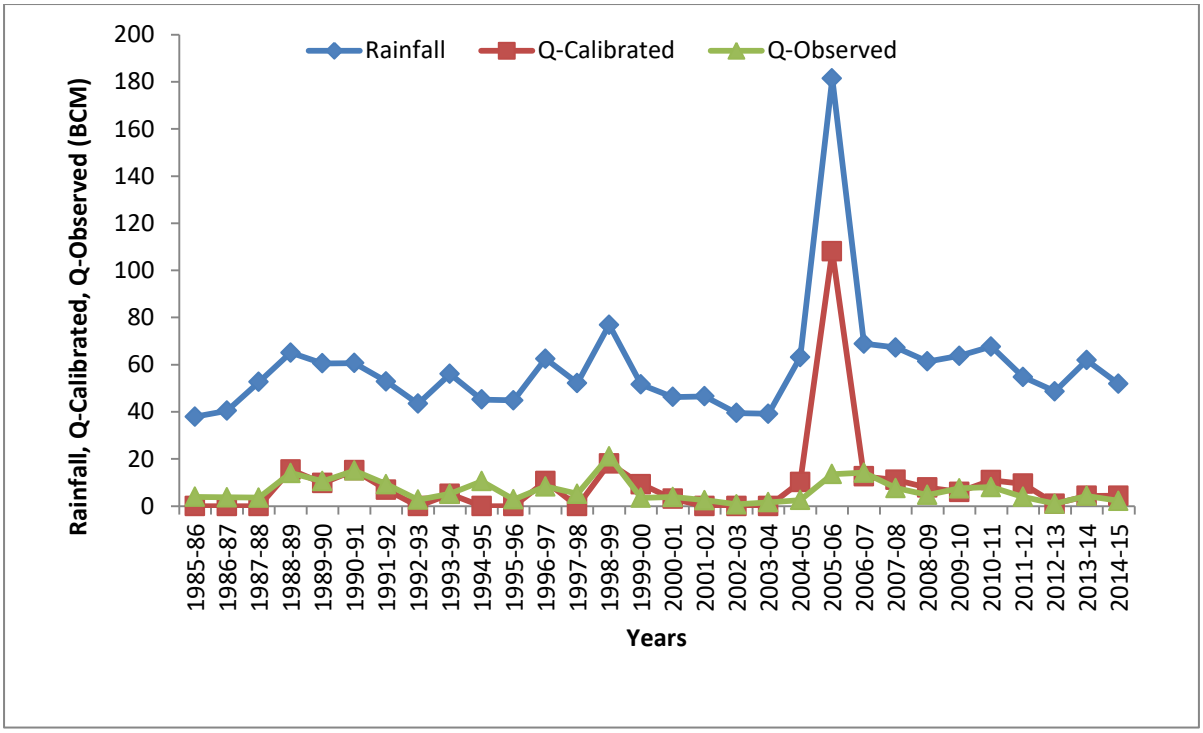


Figure 2.17 Calibrated runoff and observed discharge at Yadgir

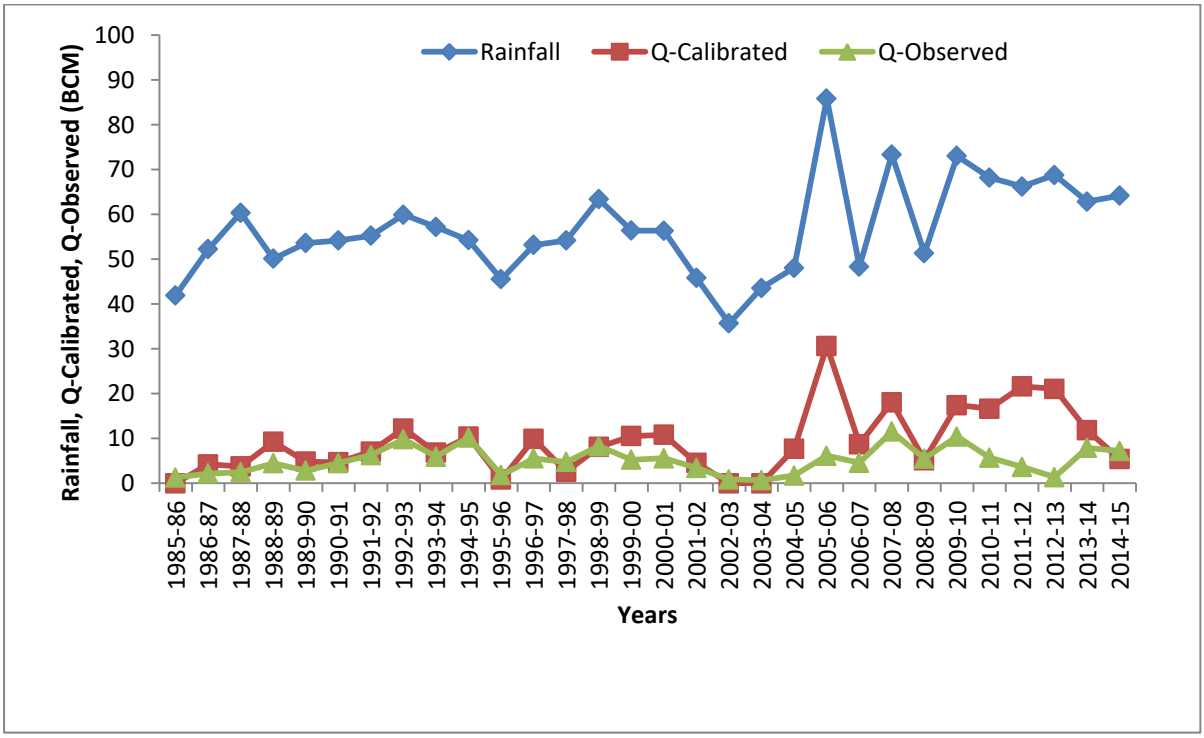


Figure 2.18 Calibrated runoff and observed discharge at Bawapuram

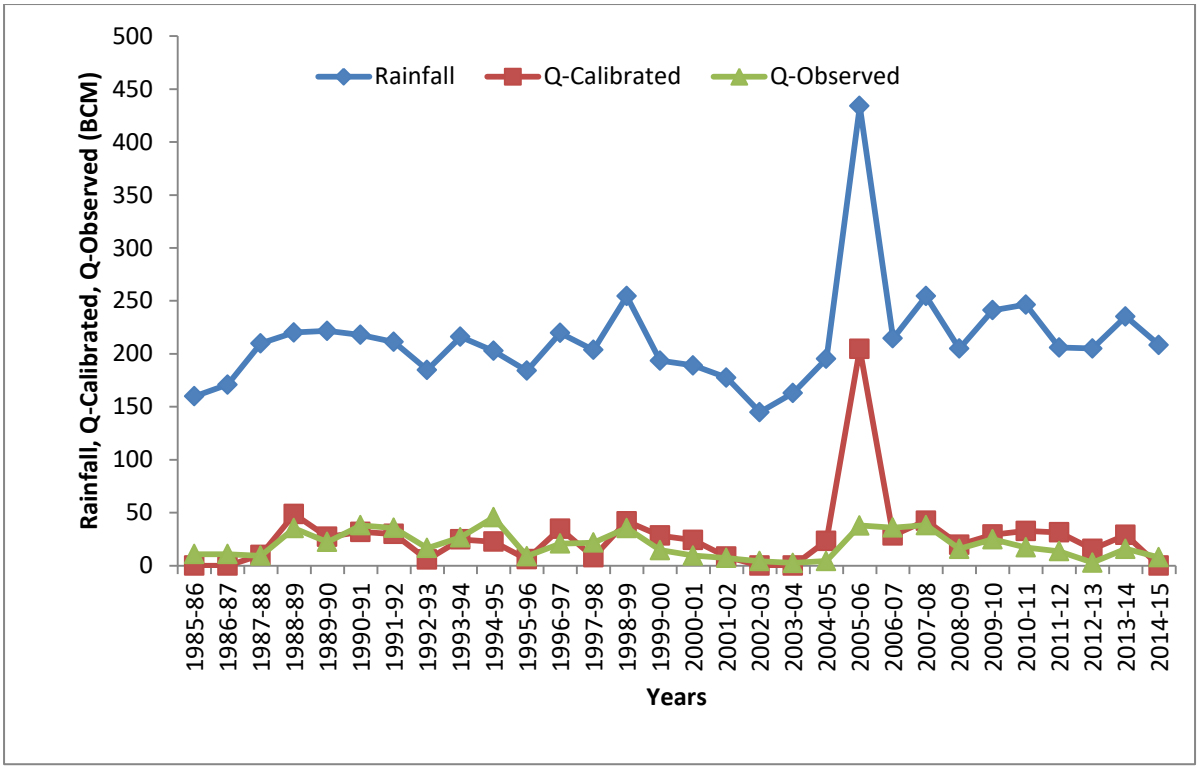


Figure 2.19 Calibrated runoff and observed discharge at Wadinepalli

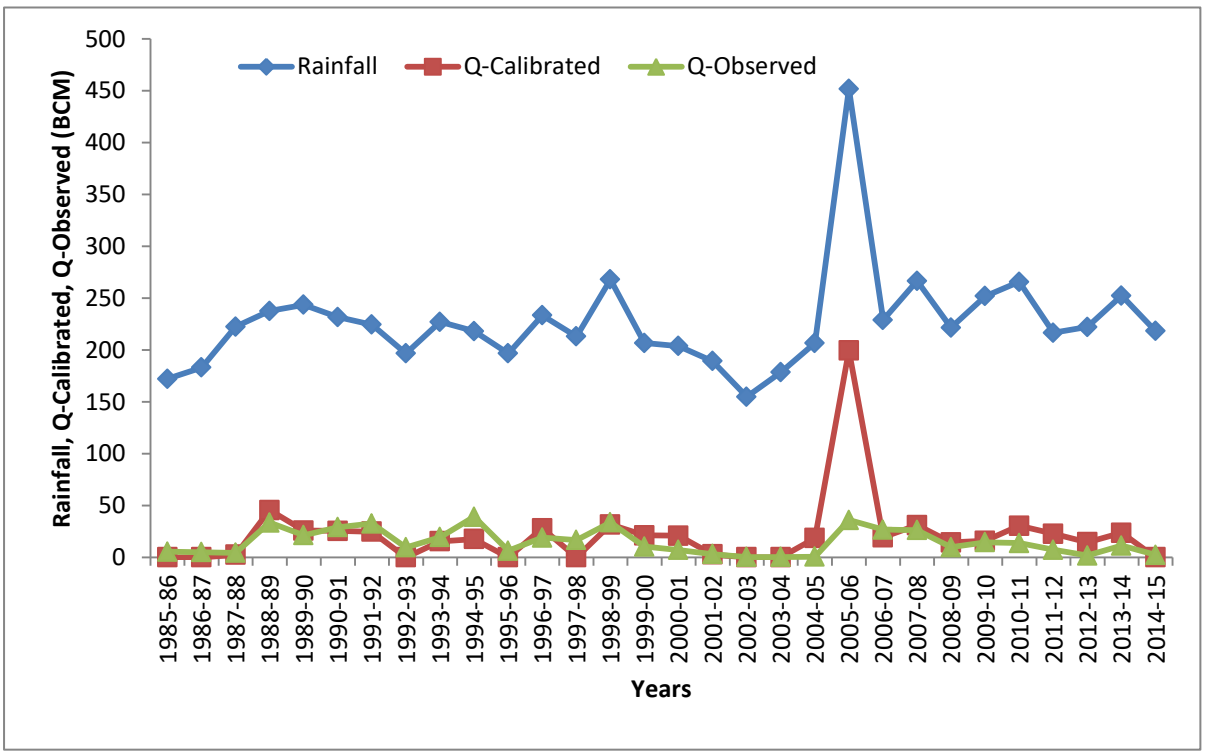


Figure 2.20 Calibrated runoff and observed discharge at Vijayawada

Table - B.8 at Annexure - B gives calibrated runoff of Krishna basin for the period 1985-86 to 2014-15. The mean annual calibrated runoff is about 16.33 BCM. The maximum annual calibrated runoff is 46.79 BCM during 1988-89. The minimum annual calibrated runoff occurred on several occasion as zero during 1985-86, 1986-87, 1992-93, 1997-98, 2002-03, 2003-04 and 2014-15. The

mean annual ECII is about 57.49 BCM. The maximum annual ECII is about 79.47 BCM during 2014-15. The minimum annual ECII is about 43.95 BCM during 2000-01.

2.5 Annual Water Resources Availability of Krishna basin

Table - B.8 at Annexure - B shows the different components required to estimate the basin level water resources of Krishna for 29 years. The maximum annual water availability is 126.41 BCM during 2007-08. The minimum annual water availability is 54.79 BCM during 2002-03. The mean available water resource is 89.04 BCM. The mean available water resource of Krishna basin accounts about 39.40 % of mean annual rainfall during 1985-86 to 2014-15 (excluding the year 2005-06).

2.5.1 Annual water resources of Krishna basin during extreme rainfall conditions

Out of the total 29 years of meteorological data base of study period, during the years 2010-11 and 2002-03, extreme wet and dry rainfall conditions occurred in Krishna basin. The annual water resources of Krishna basin during these two extreme rainfall conditions are 117.95 BCM and 54.79 BCM, respectively as shown in Table - 2.4. The water balance components during these years are presented in Figures 2.21 and 2.22.

Table - 2.4 Water resources availability in Krishna basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources Availability (BCM)
Maximum Rainfall	2010-11	272.10	117.95
Minimum Rainfall	2002-03	154.59	54.79

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.43 and 0.35 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years, potential evapotranspiration is less compared to the dry years this will have cumulative effect in runoff. It is found that the ECII during 2002-03 is less than the year 2010-11.

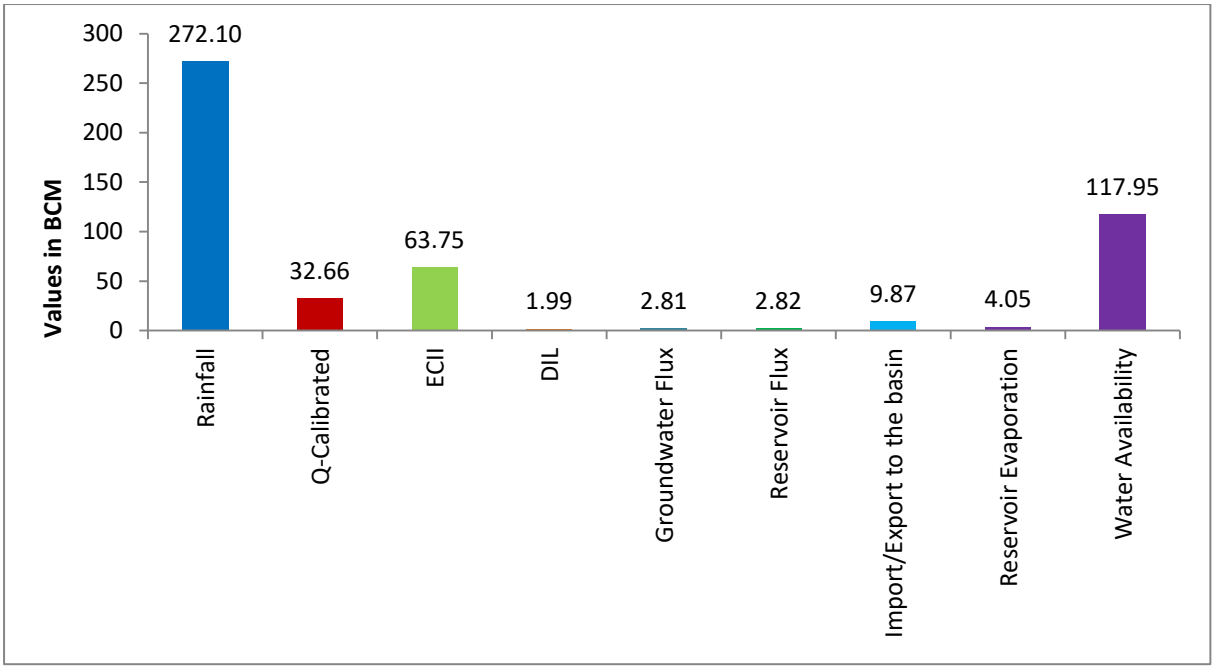


Figure 2.21 Water balance components of Krishna basin during extreme high rainfall (2010-11)

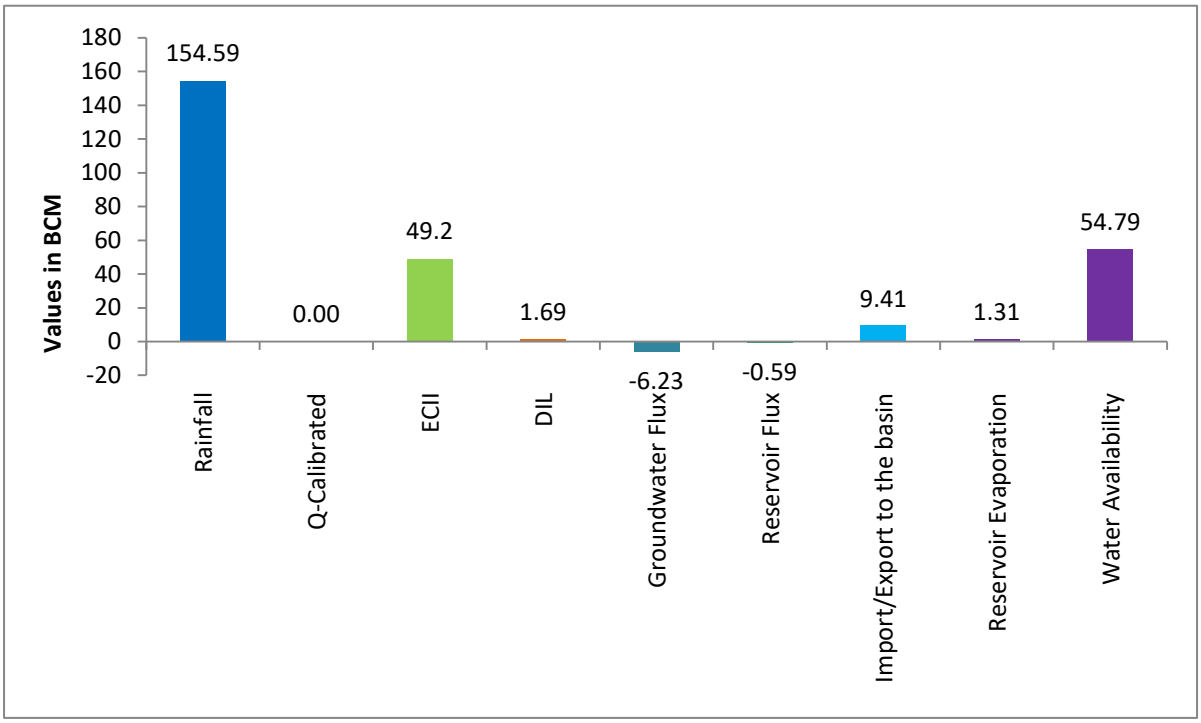


Figure 2.22 Water balance components of Krishna basin during extreme low rainfall (2002-03)

2.5.2 Mean water resources of Krishna basin

The mean water resources of the basin is computed by taking mean of the 30 years (excluding year 2005-06) water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Export from basin + Evaporation from Reservoirs)

= 16.33 + 57.49 + 1.65 + (-0.13) + (-0.25) + 11.90 + 2.05 = 89.04 BCM

75% dependable flow of Krishna basin = 71.43 BCM

The mean available annual water resource of the basin is 89.04 BCM. Figure 2.23 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15 (excluding the year 2005-06).

It is observed that the computed runoff factors varies from 0.01 (865 mm rainfall) to 0.19 (930 mm rainfall). The mean runoff factor for 30 year period is 0.10.

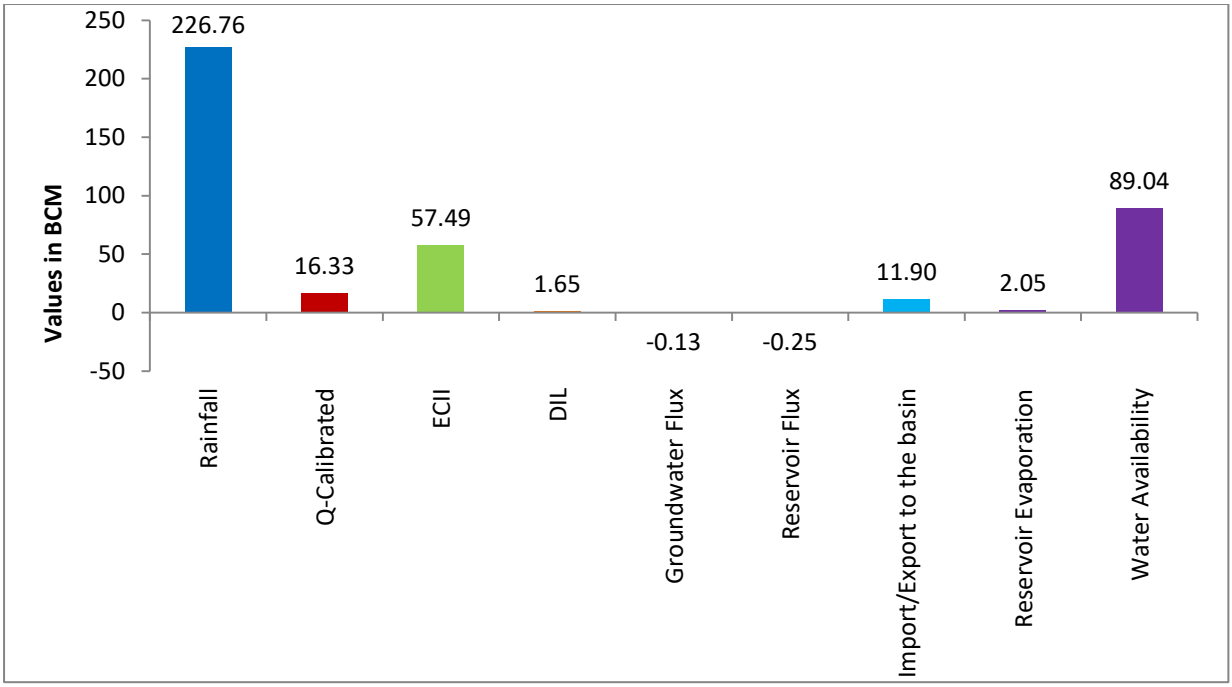
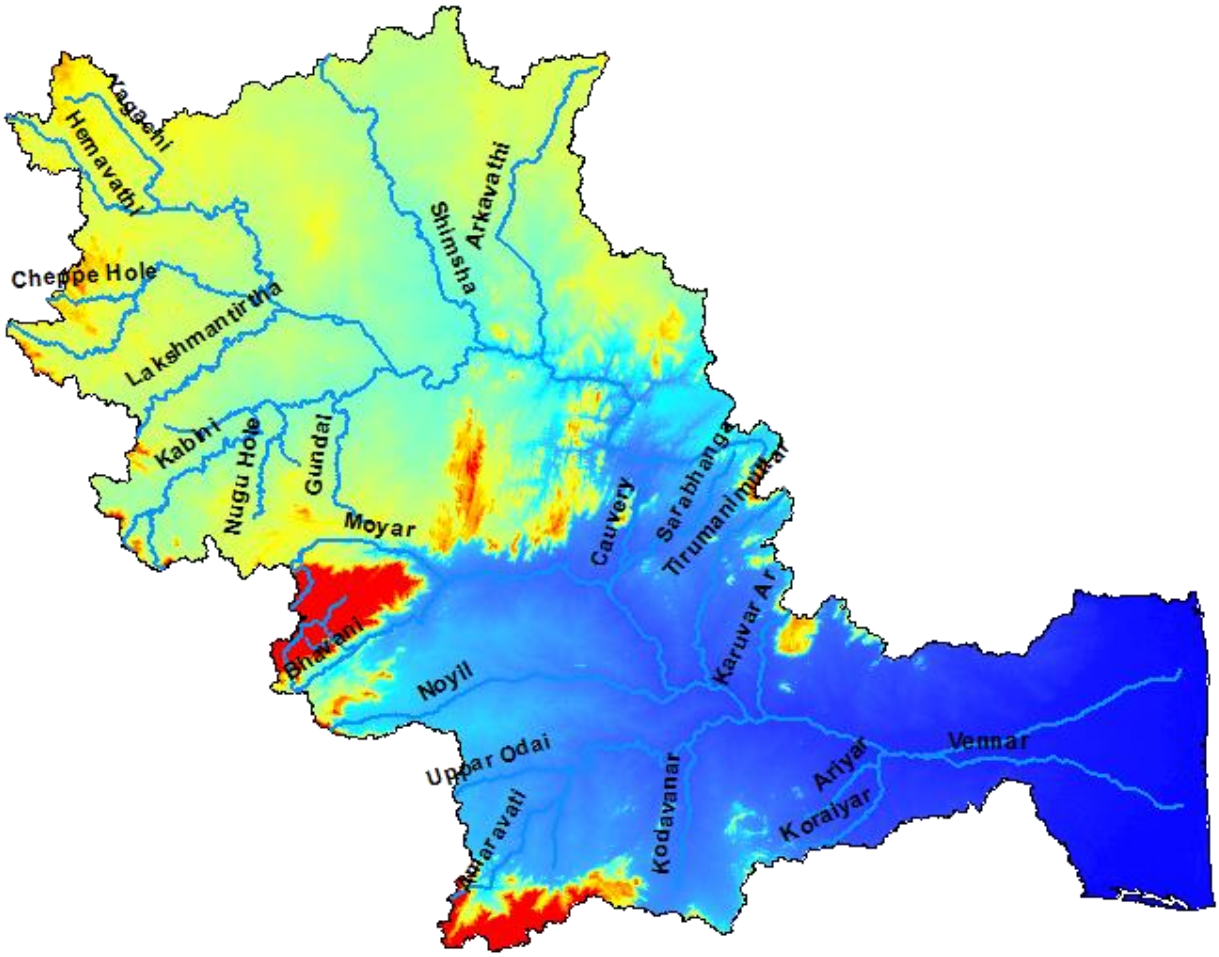


Figure 2.23 Mean water balance components of Krishna basin (mean of 29 years)

HIGHLIGHTS

- *Mean available water resources of Krishna basin is 89.04 BCM.*
- *Maximum annual water availability is 126.41 BCM during 2007-08.*
- *Minimum annual water availability is 54.79 BCM during 2002-03.*
- *Annual rainfall in the basin varies from 604 mm to 1,045 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 857 mm.*
- *Krishna basin is divided into eight sub-basins for the reassessment study viz. Kurundwad, Huvinhedgi, Takli, Yadgir, Bawapuram, Wadinepalli, Vijayawada and combined delta region as one sub-basin.*
- *Average annual domestic, industrial and livestock demand in the basin is 1.65 BCM.*
- *Average annual evaporation from water bodies in the basin is 2.05 BCM.*

CAUVERY BASIN



3.1 Geo-Spatial Datasets

3.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of the basin is shown in Figure 3.1. The image corresponds to the 2004-05 year and consists of 16 different classes. The map indicates Kharif only (30.85%), deciduous forest (14.27%) and Double/Triple (13.15%) are the major classes in Cauvery basin (Figure 3.2).

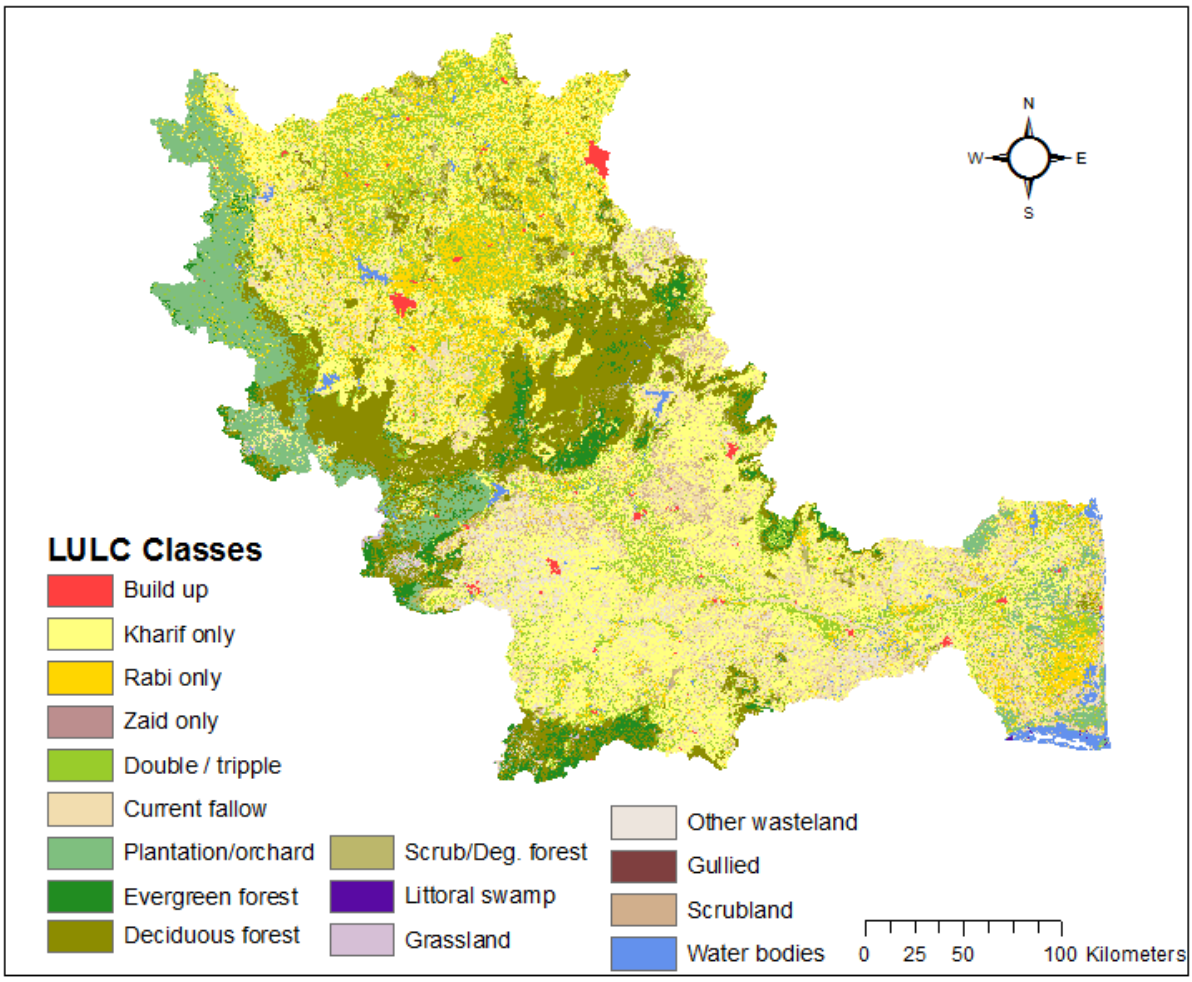


Figure 3.1 LULC map of Cauvery basin (2004-05)

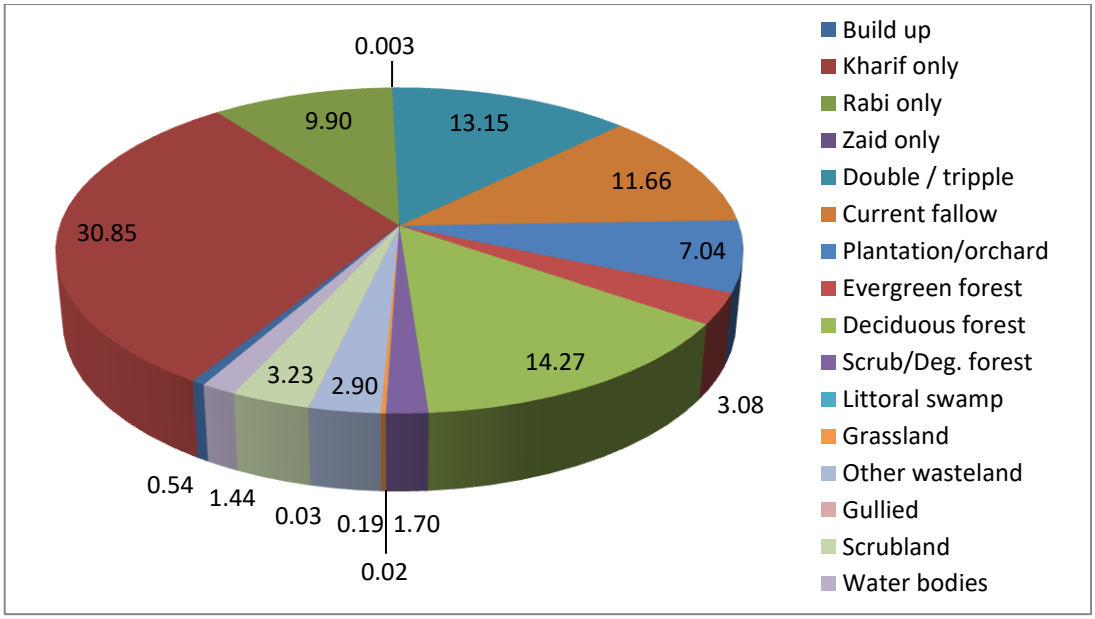


Figure 3.2 Distribution of LULC in Cauvery basin (2004-05)

3.1.2 Soil texture

The main soil types found in the basin are clay, clayey skeletal and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 3.3 shows various categories of soil in the basin. The soils are classified as sandy, loamy, clayey and rock outcrops based on the soil texture information.

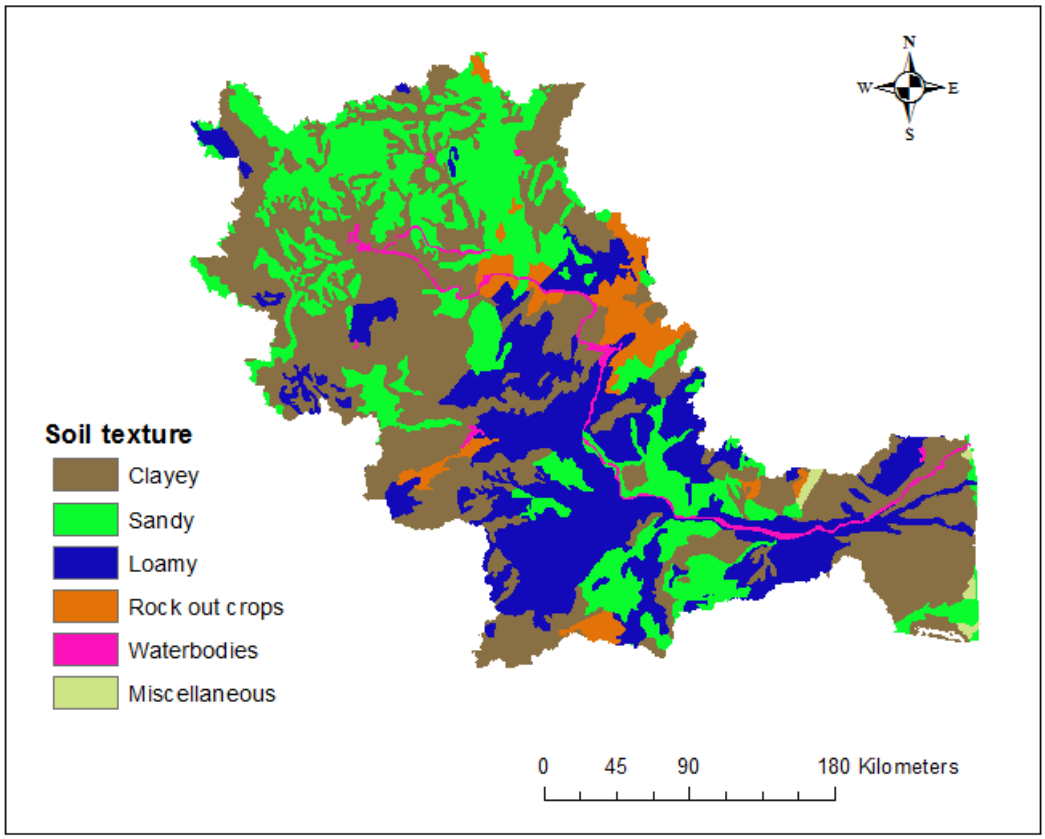


Figure 3.3 Soil texture map of Cauvery basin

3.1.3 Topography

The topography of the basin consists of ghat areas, plateau and the coastal plains. The upper regions of the basin are mostly hilly and forested. The lower region of the basin is deltaic plains. The elevation values ranges from a minimum of 0 m to a maximum of 2,629 m. The average elevation is about 568 m in the basin. Figure 3.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Cauvery basin.

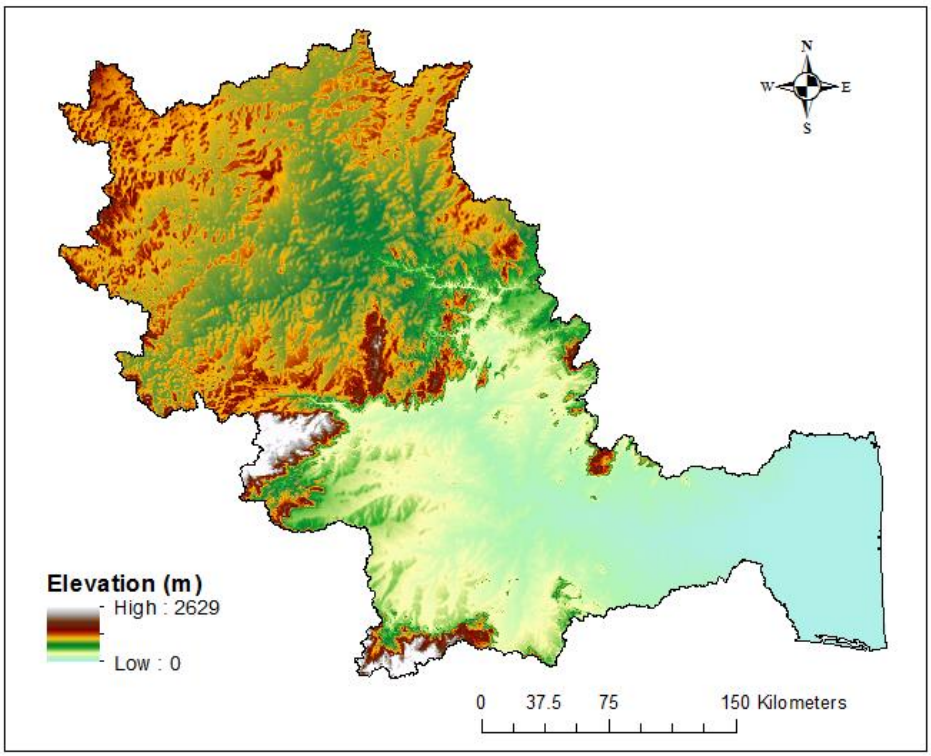


Figure 3.4 SRTM DEM map of Cauvery basin

3.2 Hydro-Meteorological and other Input Data

3.2.1 Rainfall grids

Figure 3.5 shows gridded water year wise rainfall of Cauvery basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 3.6. Annual rainfall of the basin varies from 457 mm in 2002-03 to 1,266 mm in 2010-11 and mean rainfall of these 30 years is found to be 949 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum annual rainfall of around 954.11 mm is observed in Musiri sub-basin, while maximum annual rainfall of 1,017.87 mm is observed in Biligundlu sub-basin. Of the 30 years, for 17 years annual rainfall is higher than the mean rainfall and for remaining 13 years lower than the mean rainfall.

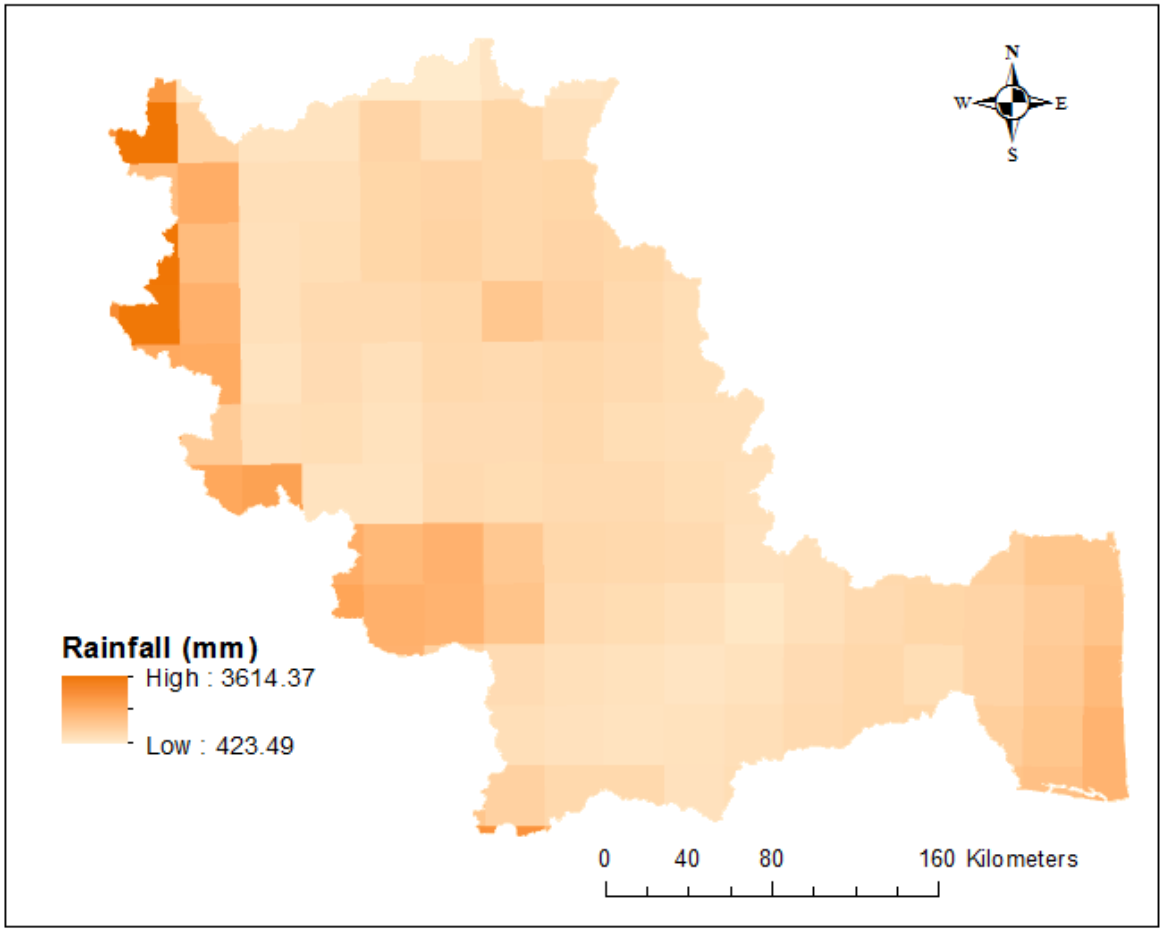


Figure 3.5 Gridded rainfall of Cauvery basin (2004-05)

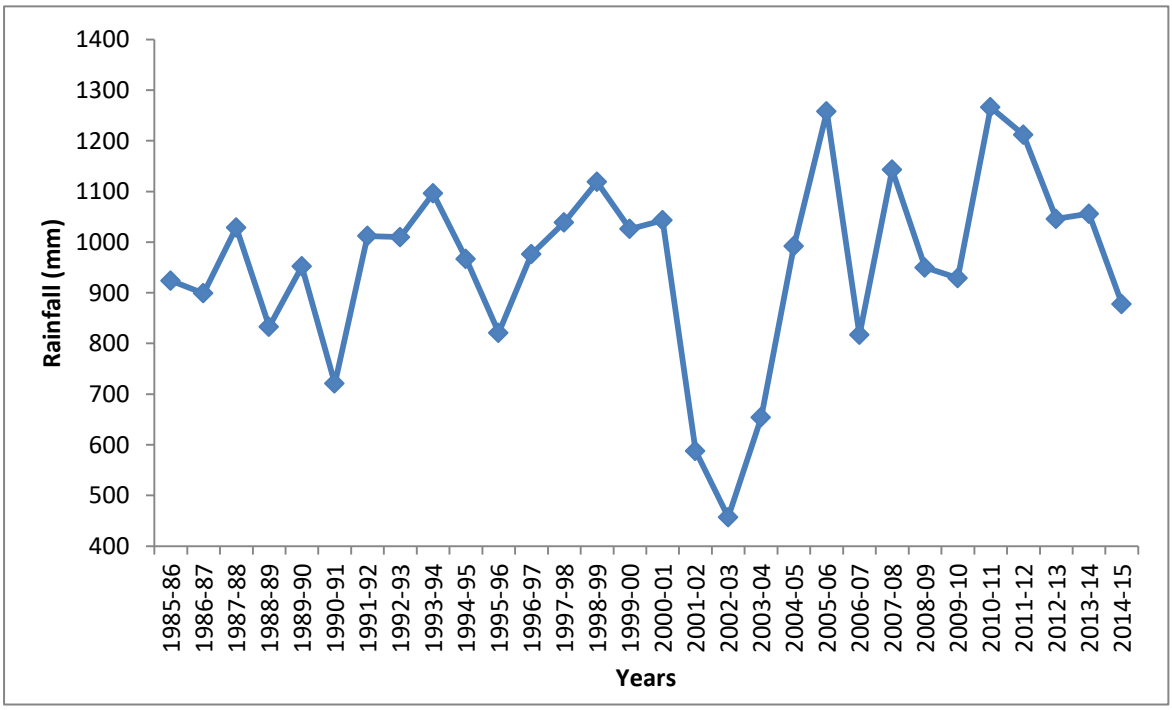


Figure 3.6 Annual rainfall of Cauvery basin (1985-86 to 2014-15)

3.2.2 Temperature grids

Gridded mean annual temperature of Cauvery basin in 2004-05 varied from 22.26 °C to 28.96 °C which is shown in Figure 3.7.

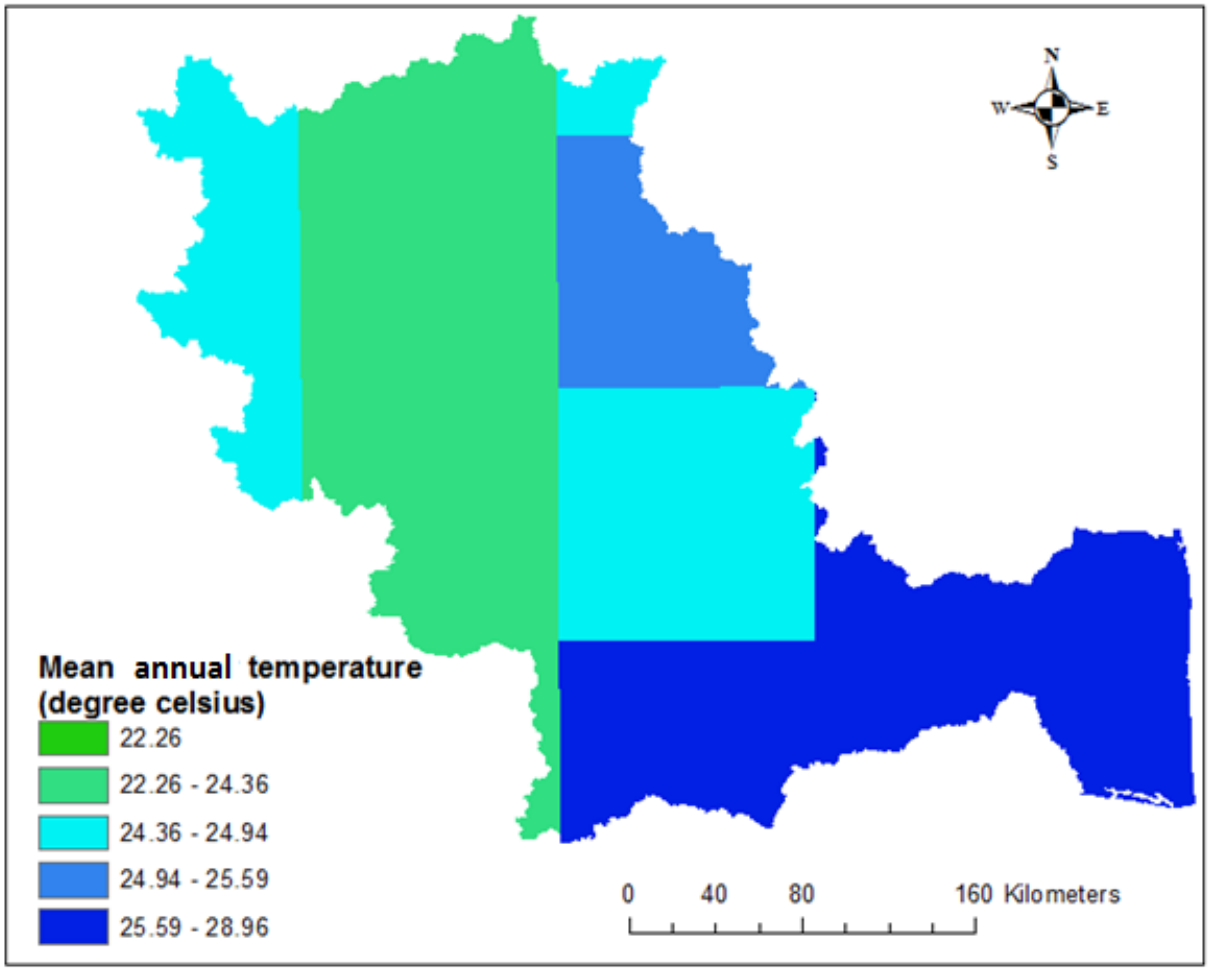


Figure 3.7 Gridded mean annual temperature of Cauvery basin (2004-05)

3.2.3 Sub-basins of Cauvery basin

The Cauvery basin is divided in to three sub-basins (Figure 3.8) viz. Biligundulu, Musiri and Delta. Table - 3.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

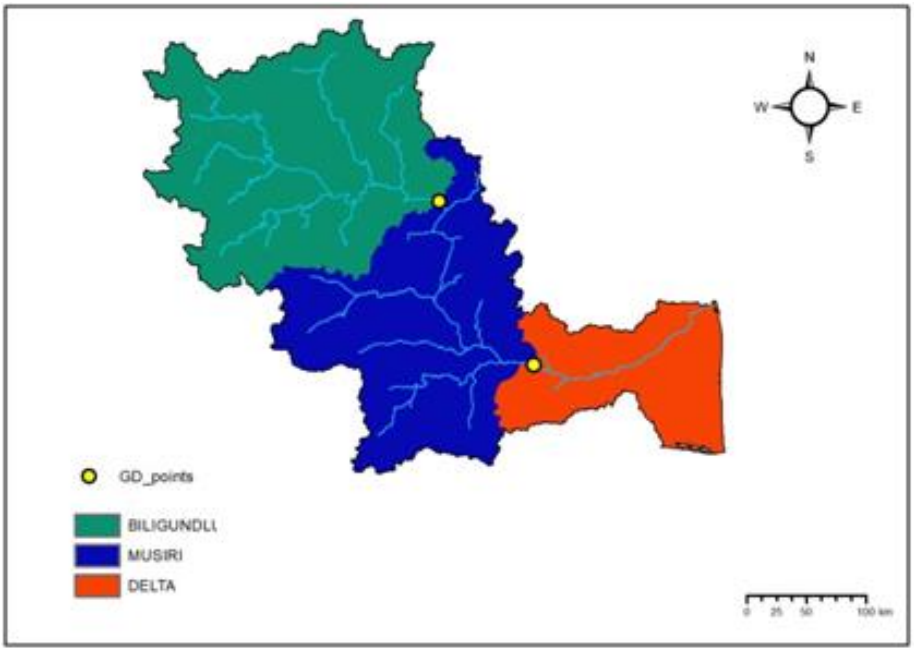


Figure 3.8 Sub-basins of Cauvery basin

Table - 3.1 Sub-basin wise details of Cauvery basin

Sl. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Biligundulu	Cauvery	37,468
2	Musiri	Cauvery	32,056
3	Delta	Cauvery	15,643
	Total basin area		85,167

3.2.4 River discharge

The river discharge data was available at both the sites (Biligundulu and Musiri) for the study period of 30 years. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level.

3.2.5 Reservoir flux

Figure 3.9 shows the location of some of major reservoirs in Cauvery basin. The data of 6 major and medium reservoirs such as Hemavathi, Harangi, Kabini, Krishnaraj Sagara, Lower Bhavani and Mettur were considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed runoff.

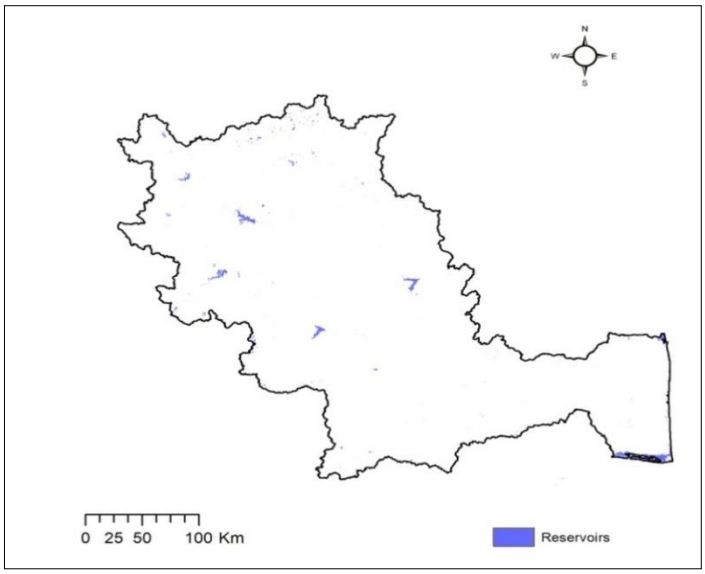


Figure 3.9 Major reservoirs in Cauvery basin

3.2.6 Groundwater flux

The spatial annual groundwater flux for the year 2004-05 is shown in Figure 3.10. The annual groundwater flux during the study period is shown in Figure 3.11.

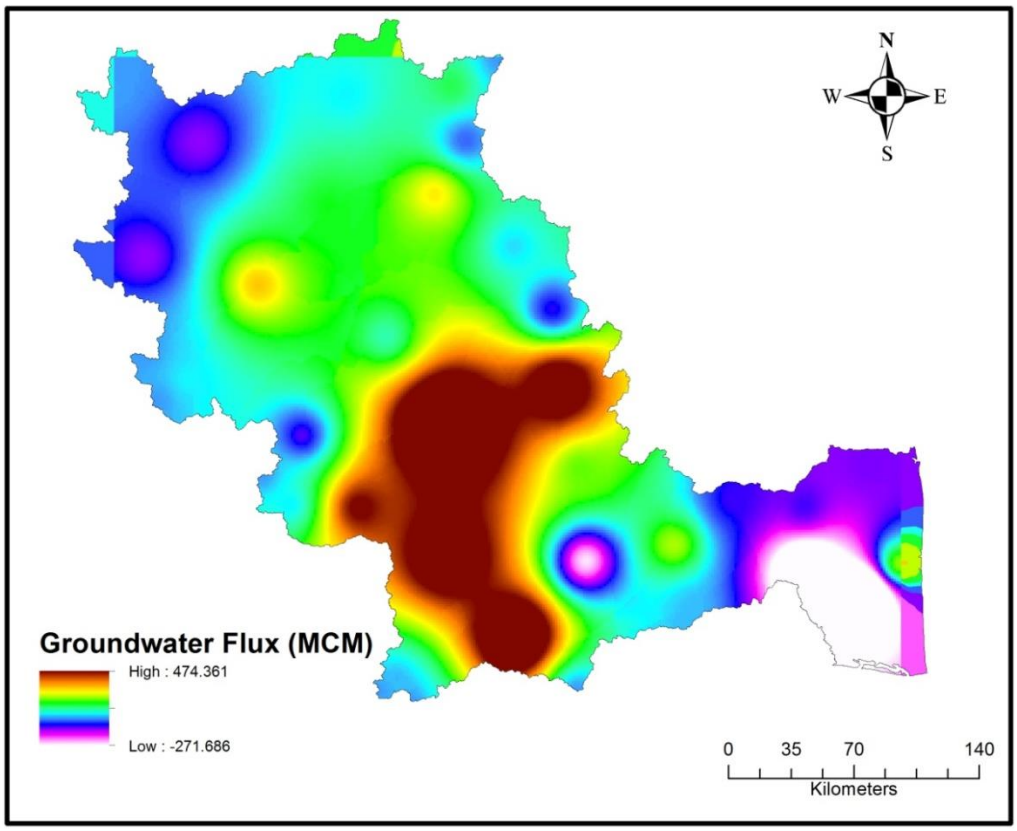


Figure 3.10 Groundwater flux (spatial data) estimated during 2004-05

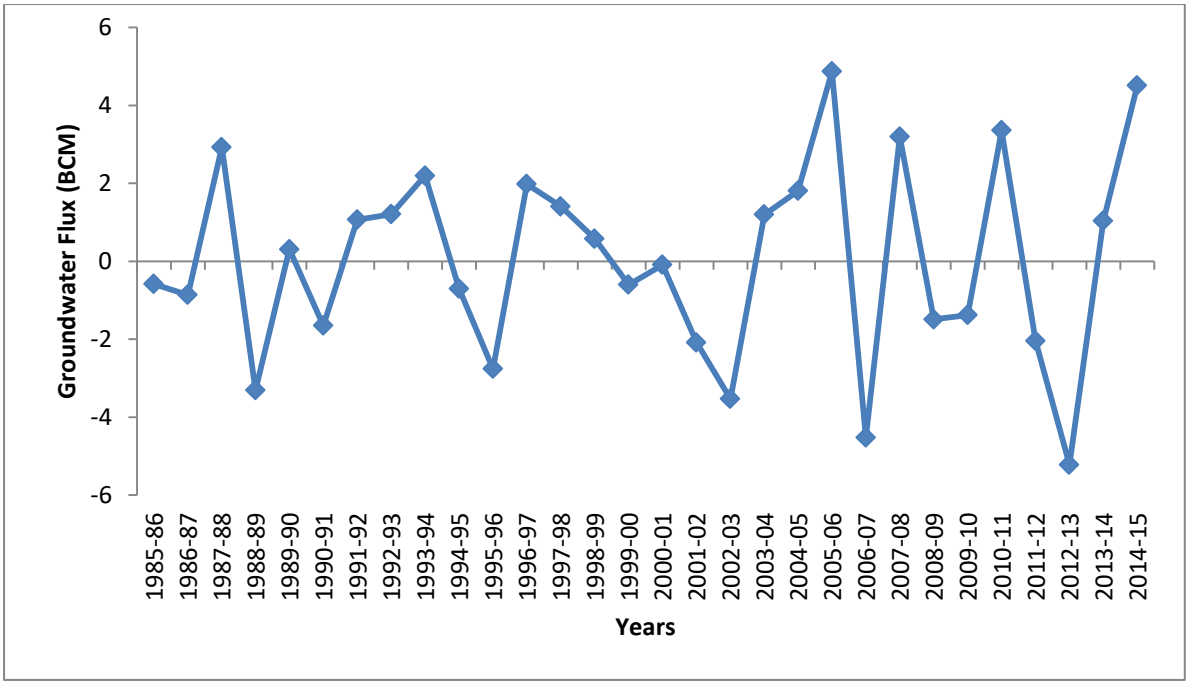


Figure 3.11 Annual groundwater flux of Cauvery basin (1985-86 to 2014-15)

3.2.7 Major crops in the basin

The Cauvery basin was divided in seven regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if rice is a major crop, it may be ragi or jowar in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if rice is a major crop in Kharif only season, it may be jowar or bajra during 2005-06.

3.2.8 Irrigation command area

Figure 3.12 shows location of irrigation command boundaries inside and outside the Cauvery basin considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence the command area considered during the year 1985-86 was worked out to be around 20,91,163 hectare, while it was 21,05,874 hectare in 2014-15 (excluding the basin outside command). Basin outside command has been taken uniformly for all years while working out ECII from these areas.

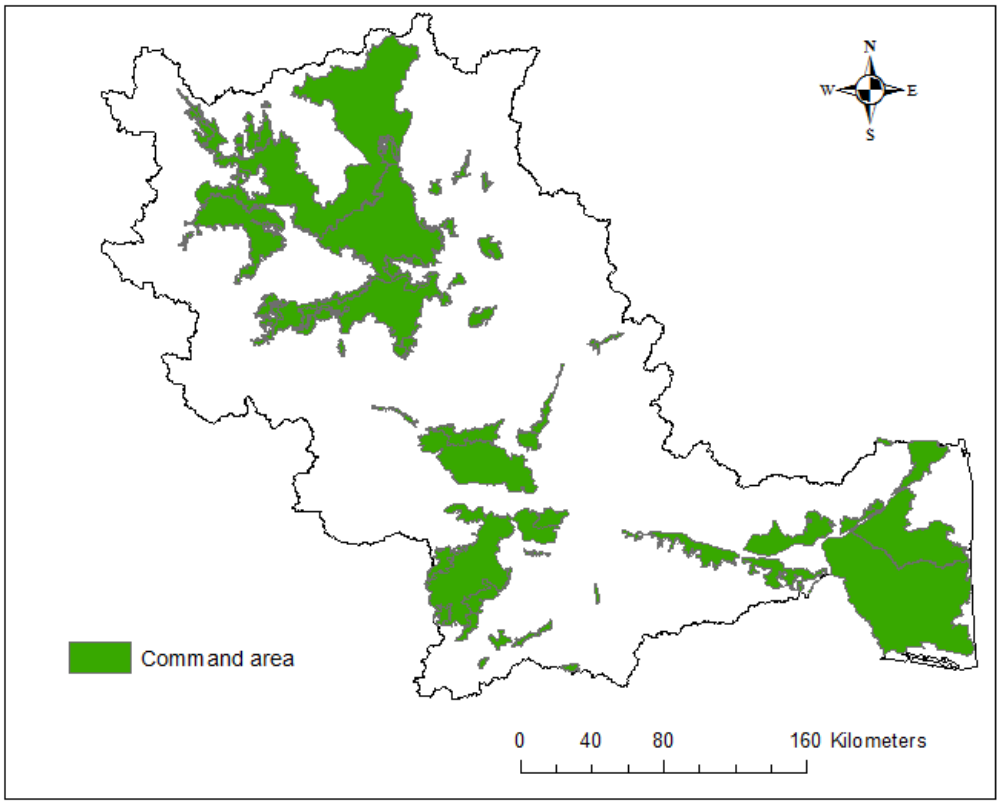


Figure 3.12 Irrigation command boundaries of Cauvery basin

3.2.9 Domestic, industrial and livestock demand

Figure 3.13 shows district boundaries layer with district population for the year 2011 census. Population data of census year 1991, 2001, 2011 and livestock census of 1982, 1983, 1987, 1990, 1992, 1993, 1997, 1999, 2003, 2007 and 2012 of basin states were used in the study. The mean annual domestic, industrial and livestock demands are estimated as 0.78 BCM in the basin.

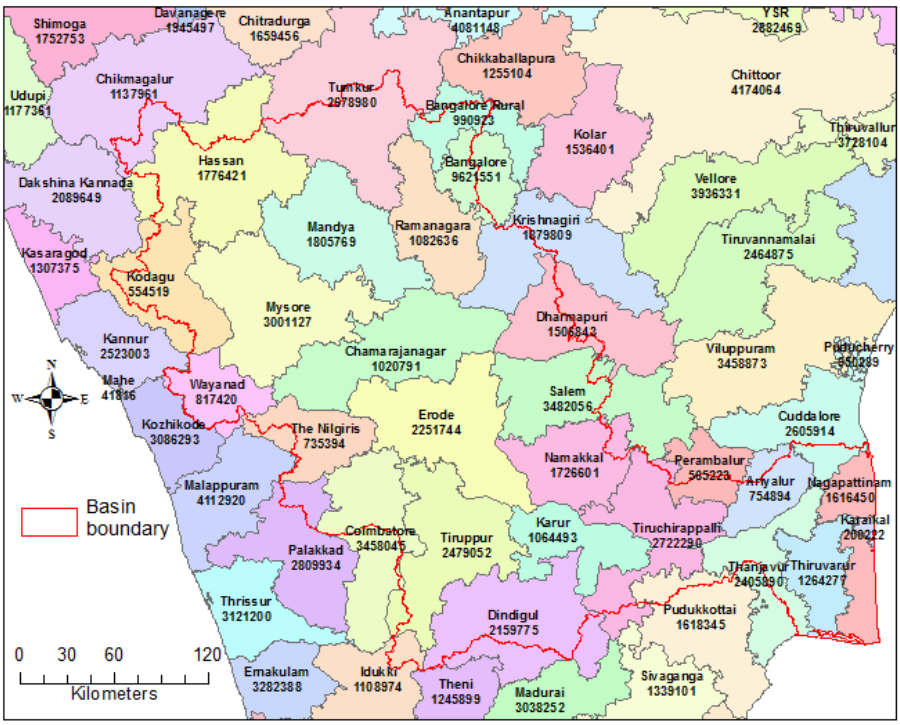


Figure 3.13 District boundaries in Cauvery basin

3.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 3.2 provides annual evaporation values from the Cauvery basin for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 0.65 BCM.

Table - 3.2 Evaporation in reservoirs of Cauvery basin

Year	Evaporation from reservoirs (BCM)	Year	Evaporation from reservoirs (BCM)
1985-86	0.91	2001-02	0.39
1986-87	0.74	2002-03	0.29
1987-88	0.84	2003-04	0.44
1988-89	0.46	2004-05	0.88
1989-90	0.88	2005-06	0.71
1990-91	0.49	2006-07	0.44
1991-92	0.78	2007-08	0.68
1992-93	0.71	2008-09	0.63
1993-94	0.85	2009-10	0.47
1994-95	0.71	2010-11	0.77
1995-96	0.55	2011-12	0.87
1996-97	0.59	2012-13	0.82
1997-98	0.80	2013-14	0.61
1998-99	0.60	2014-15	0.26
1999-00	0.53	Avg.	0.65
2000-01	0.83		

3.3 Previous Estimates

A gist of earlier assessments on Cauvery river system made by different authorities over a period of time has been presented in Table 3.3.

The water potential of the Cauvery river system has been assessed at different times by different authorities. The first assessment was made by the First Irrigation commission. This Commission used past records of the surplus flow of the Cauvery from the greater part of its catchment extending back for a sufficient number of years to estimate the average flow as accurately as possible. The Commission assessed the total annual surface flow in the Cauvery river system as 56.634 BCM. In 1949 when the assessment of the basin wise water resources of the country (basin wise) was made on the of Khosla's formula, the annual runoff of the Cauvery river system was estimated to be 9.99 BCM.

In 1993 and 2007, CWC and CWDT have not undertaken the assessment of water resources in Cauvery basin instead they decided to stick to the assessment done by Cauvery Fact Finding Committee (CFFC) constituted by the Government of India in 1972. The assessment made was at Lower Anicut across Coleroon, a branch of Cauvery in the Delta. An area of near 8000 sq.km in the delta was not accounted for in this assessment. The potential at Lower Anicut has been taken as the potential for the entire basin.

According to the CFFC, total geographical area of Cauvery basin was worked out to be 87,144 sq.km. The values of observed inflow, utilisation and withdrawals due to minor, medium and major irrigation projects for 38 years (1934-35 to 1971-72) were collected from the concerned State Governments of Karnataka, Kerala and Tamil Nadu. 50%, 75% and 90% yield of the basin at Krishnarajasagar, Mettur Reservoir and Grand Anicut was determined. Withdrawal for domestic and industrial consumptive use by all the three states were calculated to be about 0.292 BCM (10 TMC). The total water resource availability was estimated to be 20.954 BCM (740 TMC) with 50% dependability in the whole basin.

Table - 3.3 Earlier assessments on Cauvery river system

S. No.	Year	Authority/Method of estimation	Quantity (BCM)
1.	1901 - 03	First Irrigation Commission/ using coefficients of runoff	56.634 BCM including Vennar and Palar basins
2.	1949	Khosla's empirical formula	9.99
3.	1960	CW & PC/Statistical analysis of flow data wherever available and rainfall-runoff relationships wherever data were meagre.	18.60
4.	1972	Cauvery Fact Finding Committee	20.95 BCM with 50% dependability 18.97 BCM with 75 % dependability 17.64 BCM with 90% dependability
5.	1993	Central Water Commission	Same as the Cauvery Fact Finding Committee
6.	2007	Cauvery Water Disputes Tribunal	Same as the Cauvery Fact Finding Committee

3.4 Runoff Estimation

On river Cauvery, Biligundulu and Musiri discharge sites are located and the model estimated runoff is calibrated against the observed discharge at both the locations. Computed runoff at

Deltaic region is added to the whole basin without any calibration, since it does not have any observed discharges. Tables - C.1 and C.2 at Annexure - C give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for the two discharge stations. Figures 3.14 and 3.15 show comparative graphs of calibrated runoff and observed discharge at these discharge stations. From the graphs, it is observed that the model estimated runoff and observed discharge at both the sites (Biligundlu and Musiri) are matching very well for the 30 year period.

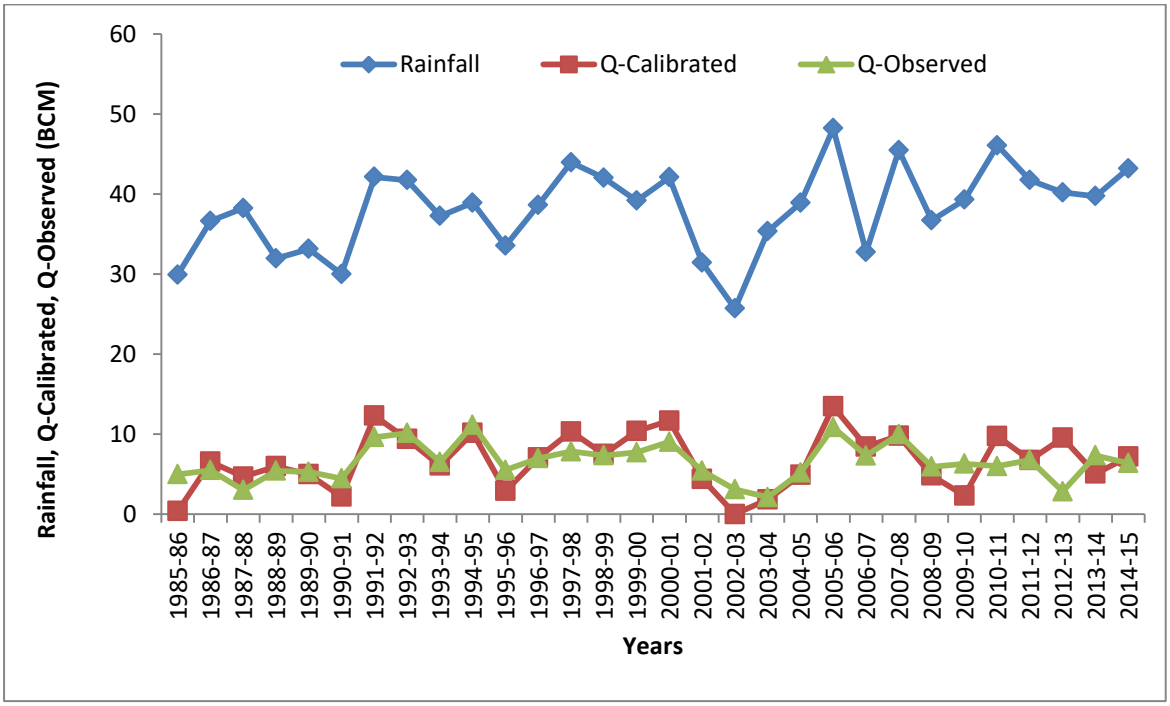


Figure 3.14 Calibrated runoff and observed discharge at Biligundlu

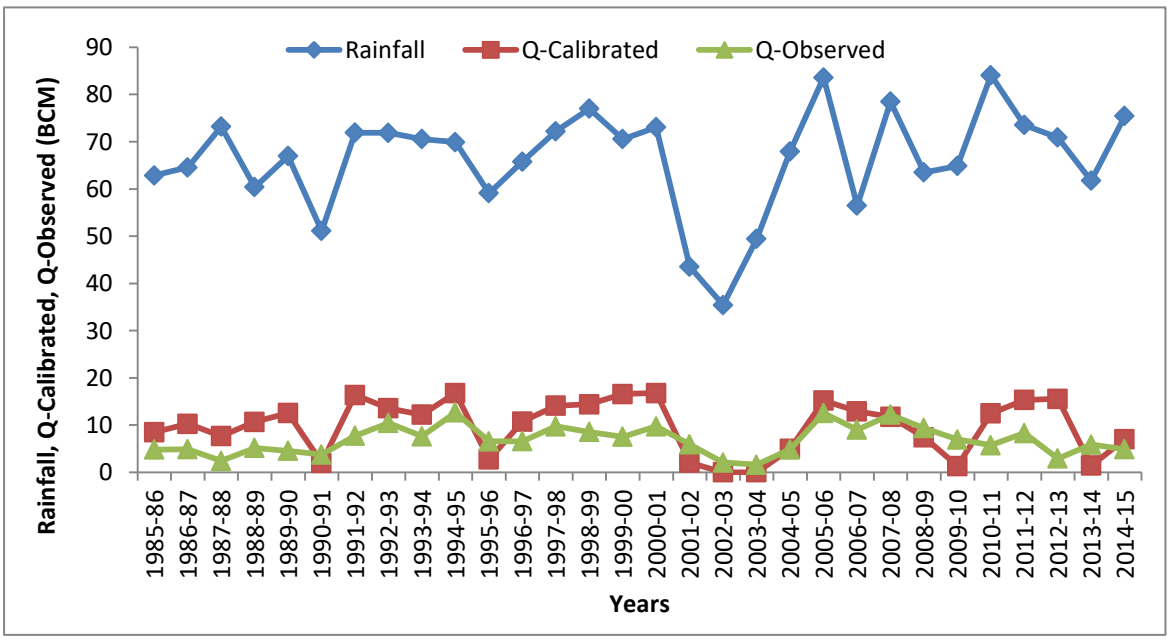


Figure 3.15 Calibrated runoff and observed discharge at Musiri

Table - C.3 at Annexure - C gives calibrated runoff of Cauvery basin for 30 years. The mean annual calibrated runoff is about 11.08 BCM. The maximum annual calibrated runoff is 20.16 BCM during 2005-06. The minimum annual calibrated runoff occurred on several occasion as zero during 1990-91, 1995-96, 2001-02, 2002-03, 2003-04 and 2013-14. The mean annual ECII is about 15.19 BCM. The maximum annual ECII is about 29.15 BCM during 2002-03 which is the driest year in 30 years. The minimum annual ECII is about 8.27 BCM during 1993-94.

3.5 Annual Water Resources Availability of Cauvery Basin

Table - C.3 at Annexure - C shows the different components that are required to estimate the basin level water resources of Cauvery for 30 years. The maximum annual water resource is 42.31 BCM during 2005-06. The minimum annual water resource is 17.19 BCM during 1990-91. The mean available basin water resource is 27.67 BCM. The mean available water resource of Cauvery basin accounts about 34.03 % of mean annual rainfall during 1985-86 to 2014-15.

3.5.1 Annual water resources of Cauvery basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 2010-11 and 2002-03, extreme wet and dry rainfall conditions occurred in Cauvery river basin. The annual water resources of Cauvery basin during these two extreme rainfall conditions are 34.93 BCM and 26.56 BCM, respectively as shown in Table - 3.4. The water balance components during these years are presented in Figures 3.16 and 3.17.

Table - 3.4 Water resources availability in Cauvery basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources Availability (BCM)
Maximum Rainfall	2010-11	107.81	34.93
Minimum Rainfall	2002-03	38.93	26.56

Water resources availability - rainfall ratio during the extreme maximum and extreme minimum rainfall years is found to be 0.32 and 0.68 respectively. During higher rainfall years PET is less compared to the dry years, this will have cumulative effect in runoff. It is found that the ECII during 2010-11 is less than the year 2002-03.

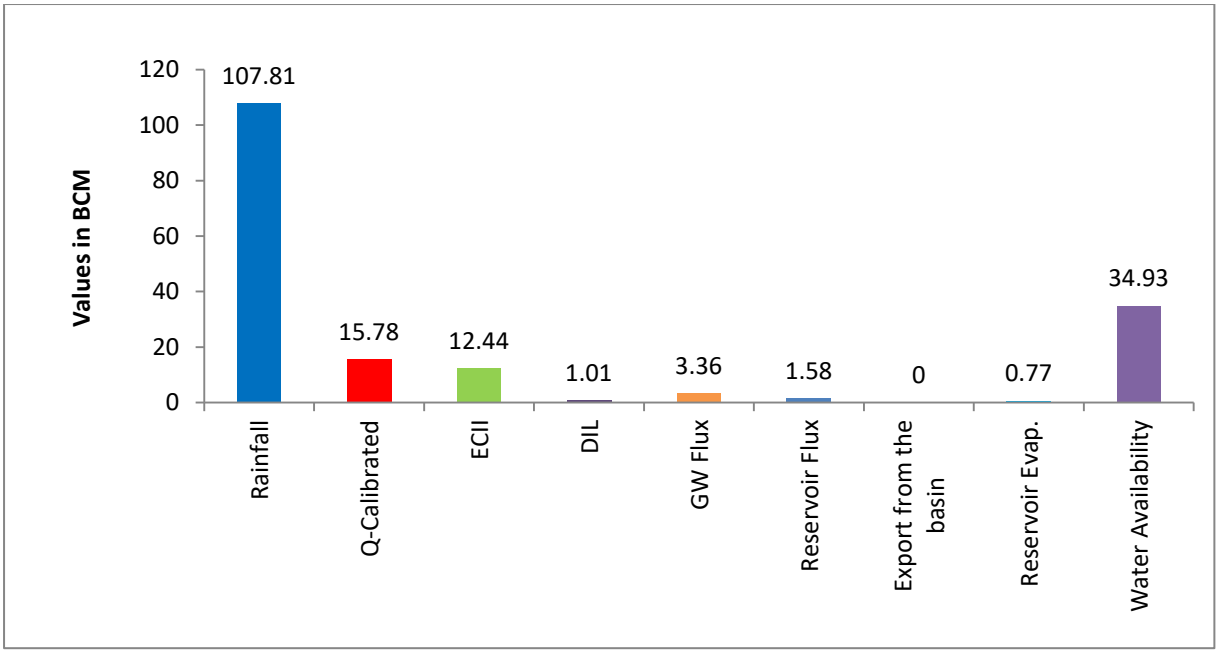


Figure 3.16 Water balance components of Cauvery basin during extreme high rainfall (2010-11)

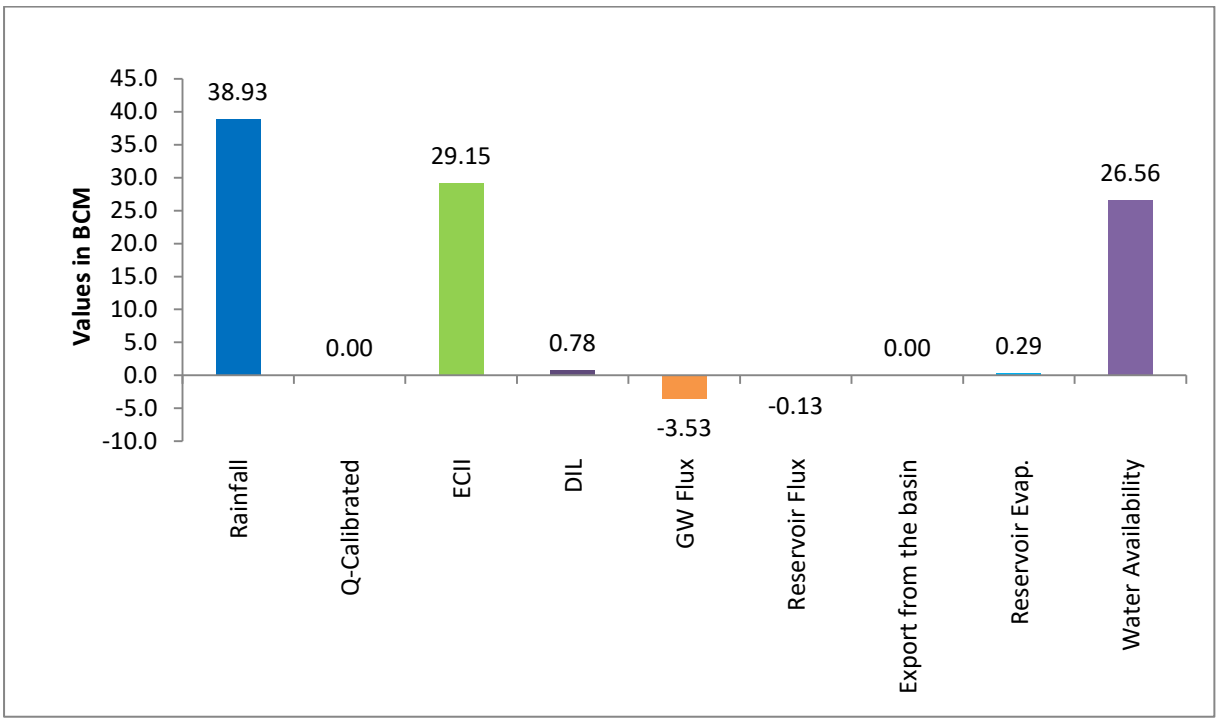


Figure 3.17 Water balance components of Cauvery basin during extreme low rainfall (2002-03)

3.5.2 Mean water resources of Cauvery basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industrial and livestock consumption + Groundwater Flux + Reservoir Flux + Evaporation from Reservoirs)

= 11.08 + 15.19 + 0.78 + 0.03 + (-0.06) + 0.65 = 27.67 BCM

The mean available water resource of the Cauvery basin is 27.67 BCM and 75% dependable flow is 22.62 BCM. Figure 3.18 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

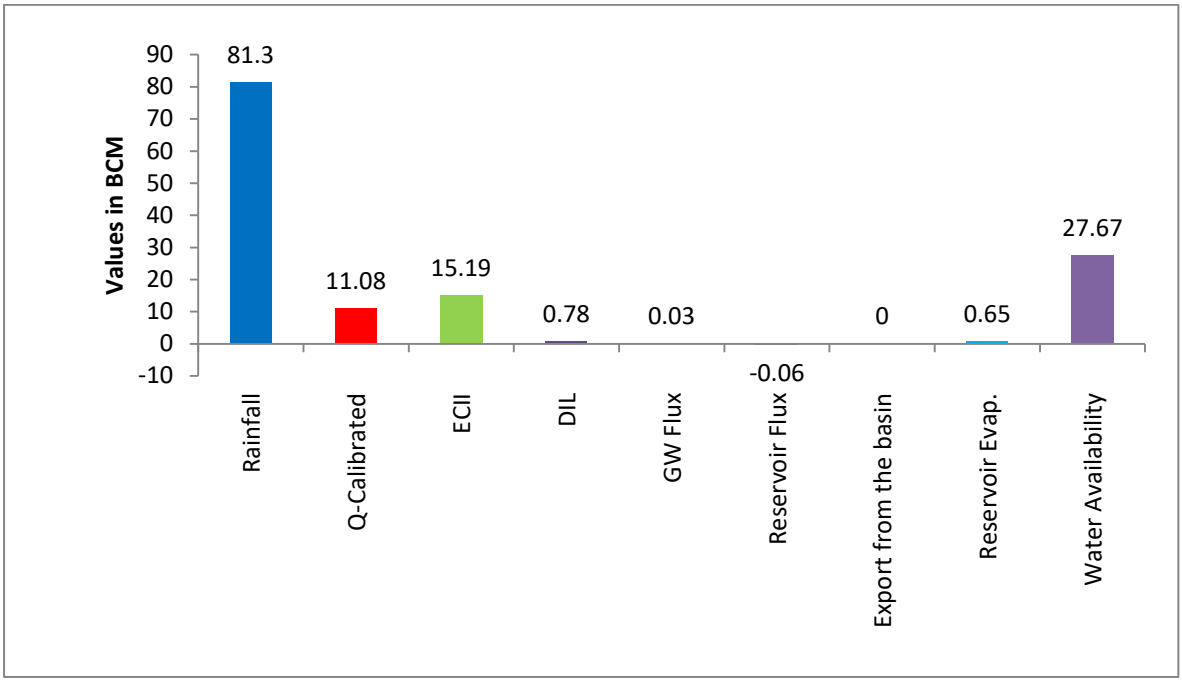
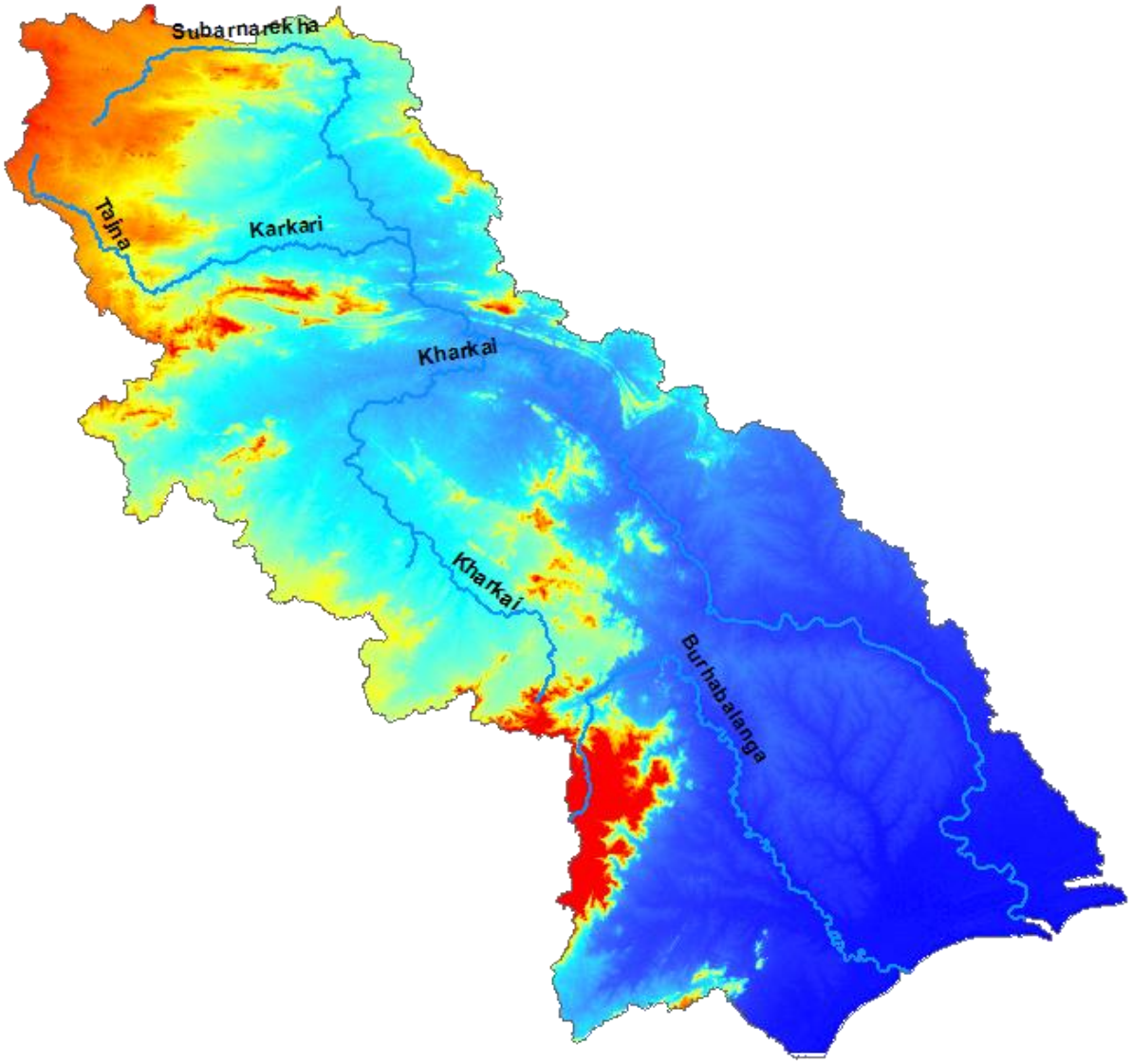


Figure 3.18 Mean water balance components of Cauvery basin

HIGHLIGHTS

- *Average annual available water resources of Cauvery basin is 27.67 BCM.*
- *Maximum annual water availability is 42.31 BCM during 2005-06.*
- *Minimum annual water availability is 17.19 BCM during 1990-91.*
- *Annual rainfall in the basin varies from 457 mm to 1,266 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 949 mm.*
- *Cauvery basin is divided into three sub-basins for the reassessment study viz. Biligundlu, Musiri and Delta.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.78 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.65 BCM.*

SUBERNAREKHA BASIN



4.1 Geo-Spatial Datasets

4.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of the basin is shown in Figure 4.1. The image corresponds to the 2004-05 year and consists of 17 different classes. The map indicates Kharif only (24.01%), Rabi only (3.60 %), current fallow (28.72%) and Deciduous Forest (22.12%) are the major classes in Subernarekha basin (Figure 4.2).

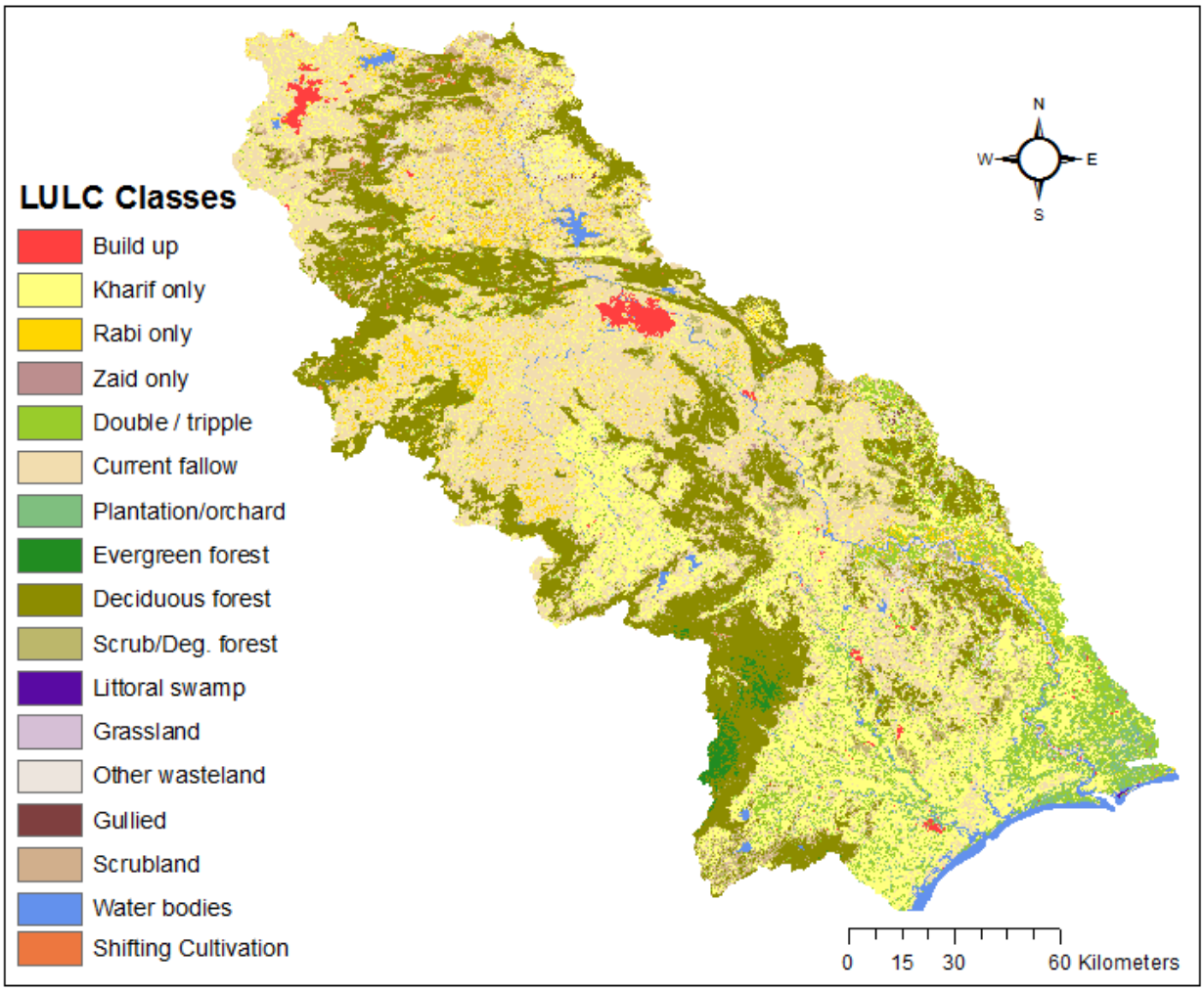


Figure 4.1 LULC map of Subernarekha basin (2004-05)

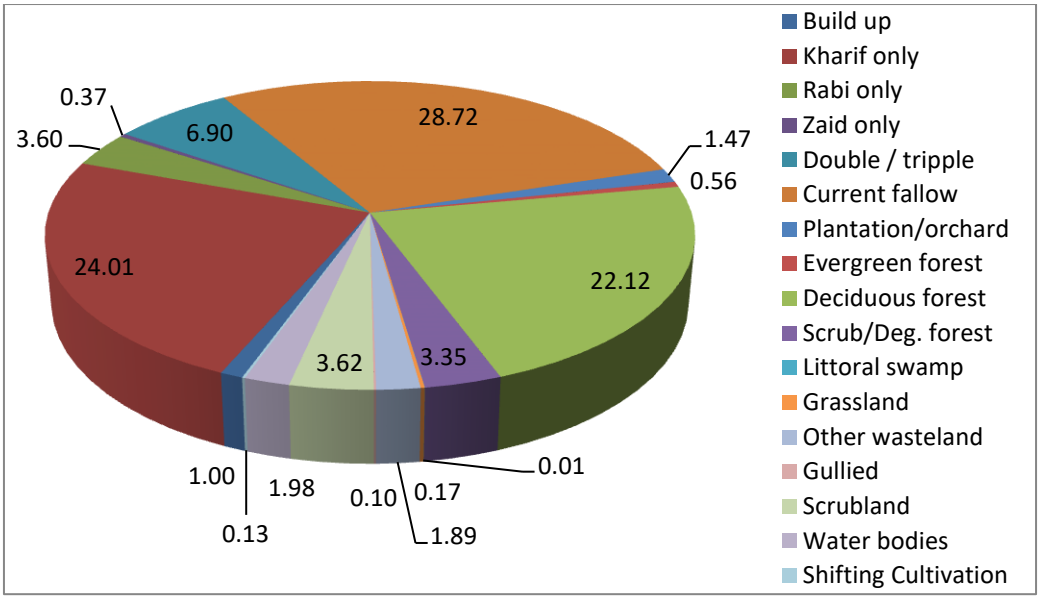


Figure 4.2 Distribution of LULC in Subernarekha basin (2004-05)

4.1.2 Soil texture

The main soil types found in the basin are sandy, clay and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 4.3 shows various categories of soil in the basin. The soils are classified as loamy, clay and loamy skeletal based on the soil texture information.

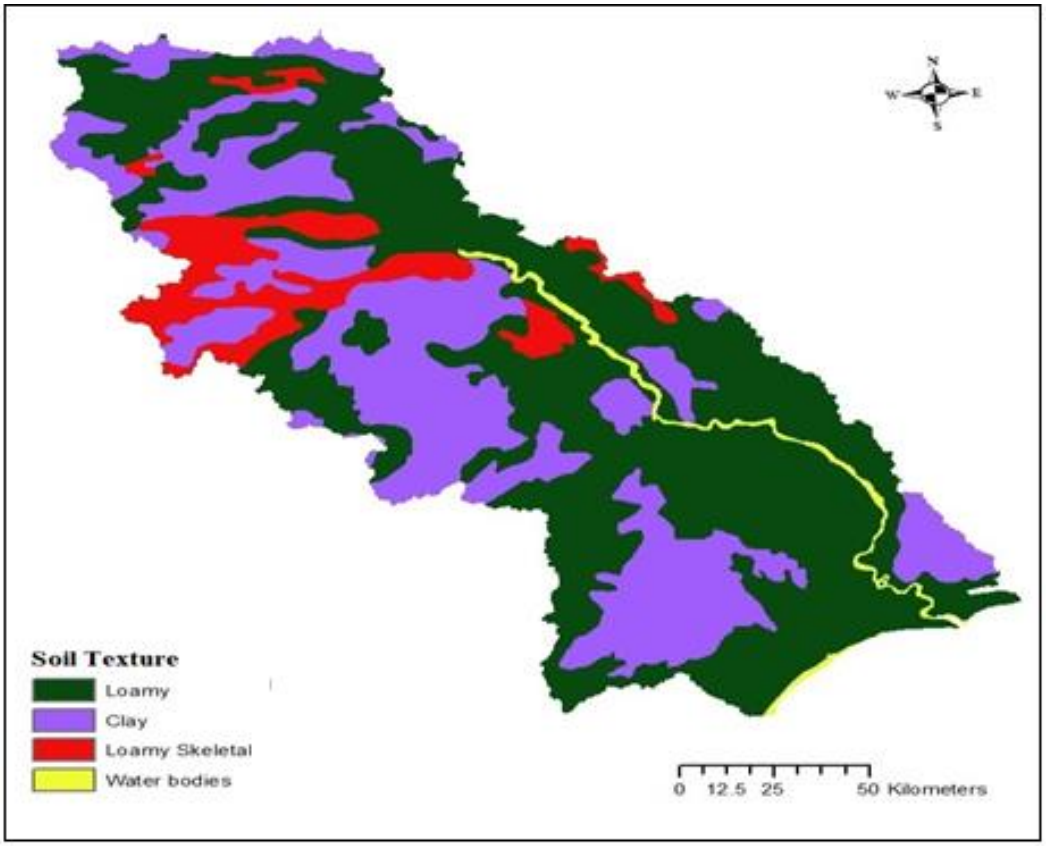


Figure 4.3 Soil texture map of Subernarekha basin

4.1.3 Topography

The topography of the basin covers Pre-Cambrian or Achaean (ii) Tertiary and (iii) Alluvium plains. Out of these, Pre-Cambrian formations mostly cover Jharkhand and West Bengal regions and Tertiary and Alluvium plains cover the basin area in Odisha. The elevation values ranges from a minimum of 0 m to a maximum of 1,172 m. The average elevation is about 321 m in the basin. Figure 4.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Subernarekha basin.

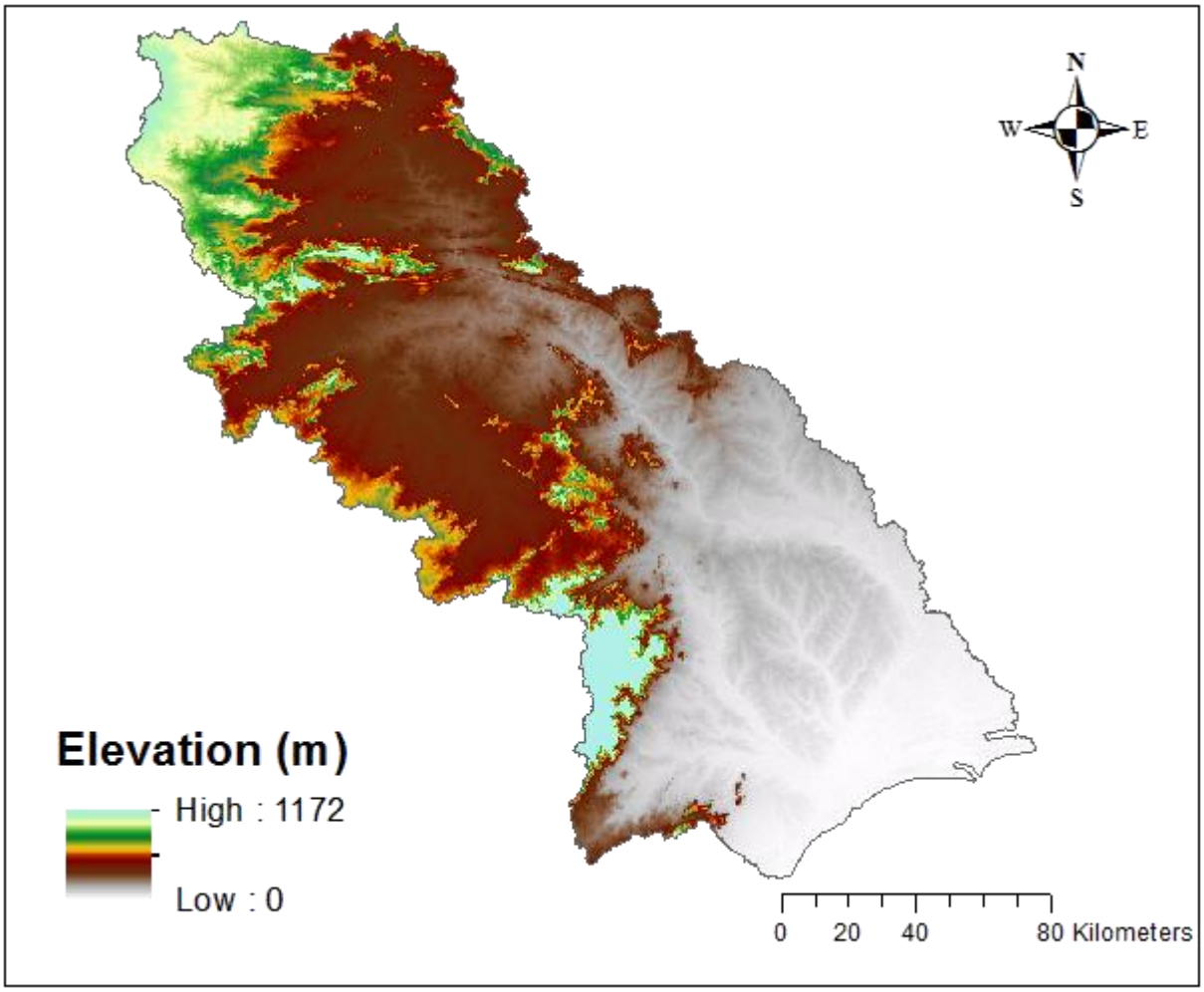


Figure 4.4 SRTM DEM map of Subernarekha basin

4.2 Hydro-Meteorological and other Input Data

4.2.1 Rainfall grids

Figure 4.5 shows gridded rainfall map of Subernarekha basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 4.6. Annual rainfall of the basin varies from 1,006.75 mm to 1,810.29 mm and mean rainfall of these 30 years is found to be 1,427 mm. Of the 30 years, for 14 years annual rainfall is higher than the mean rainfall and for remaining 16 years lower than the mean rainfall.

4.2.2 Temperature grids

Gridded mean annual temperature of Subernarekha basin in 2004-05 is shown in Figure 4.7. The mean annual maximum and minimum temperatures during 2004-05 were about 27.44°C and 25.97°C respectively.

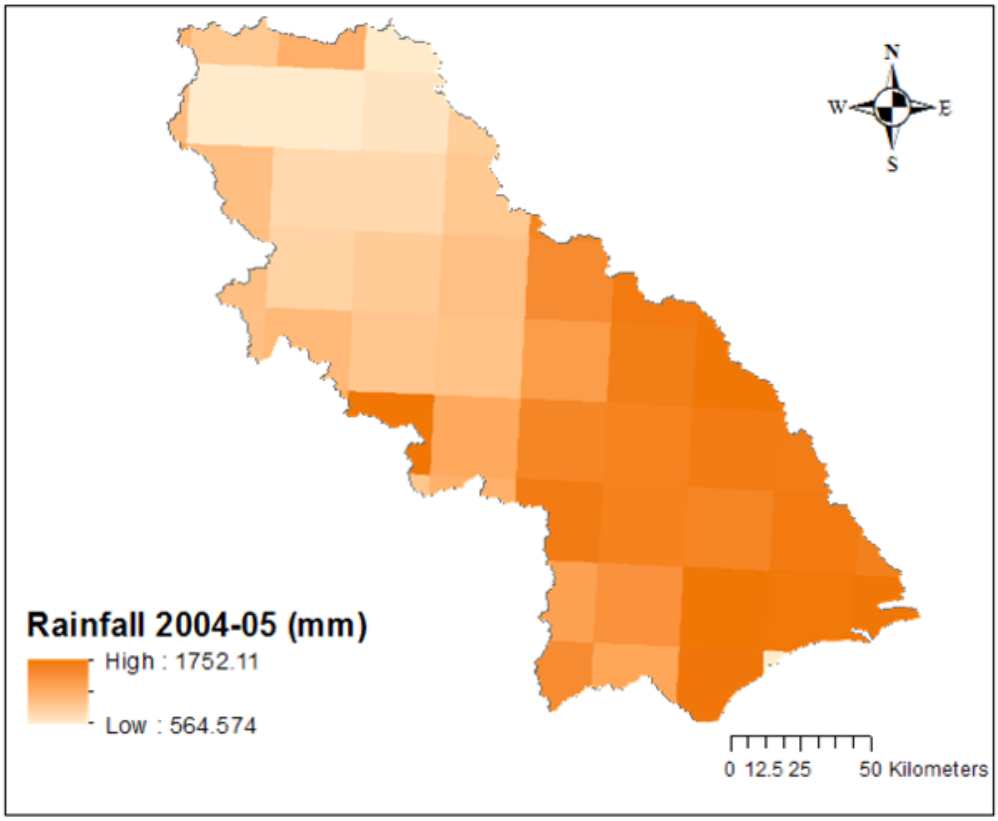


Figure 4.5 Gridded rainfall of Subernarekha basin (2004-05)

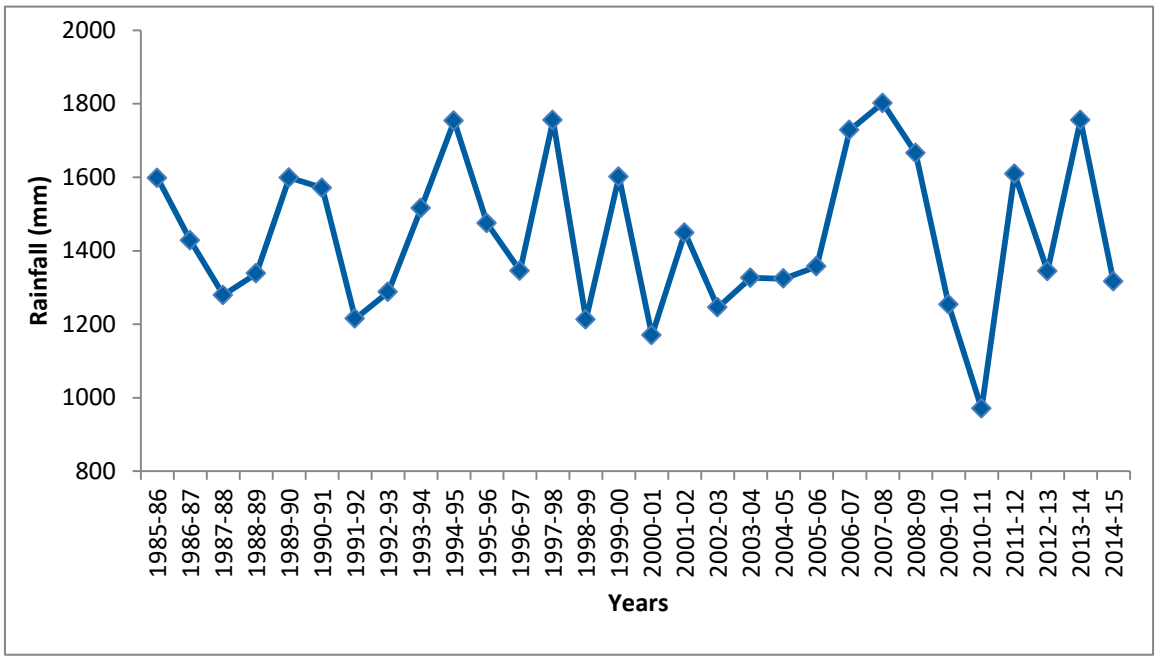


Figure 4.6 Annual rainfalls in Subernarekha basin (1985-86 to 2014-15)

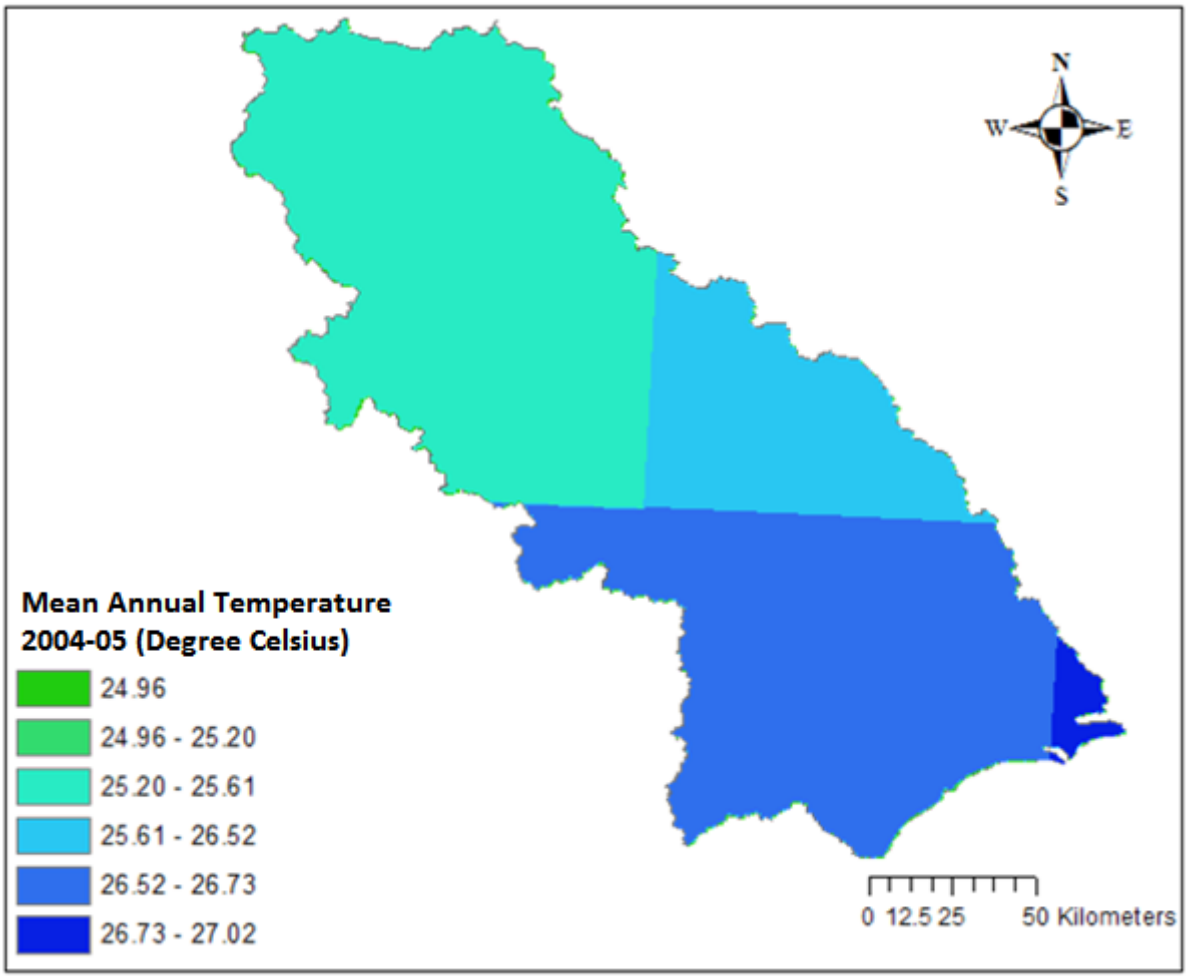


Figure 4.7 Gridded mean annual temperature of Subernarekha basin (2004-05)

4.2.3 Sub-basins of Subernarekha basin

Subernarekha basin is divided in to 6 sub-basins (Figure 4.8) viz. Muri, Adityapur, Jamshedpur, Ghatsila, Govindpur and combined delta region as one sub-basin. Table - 4.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

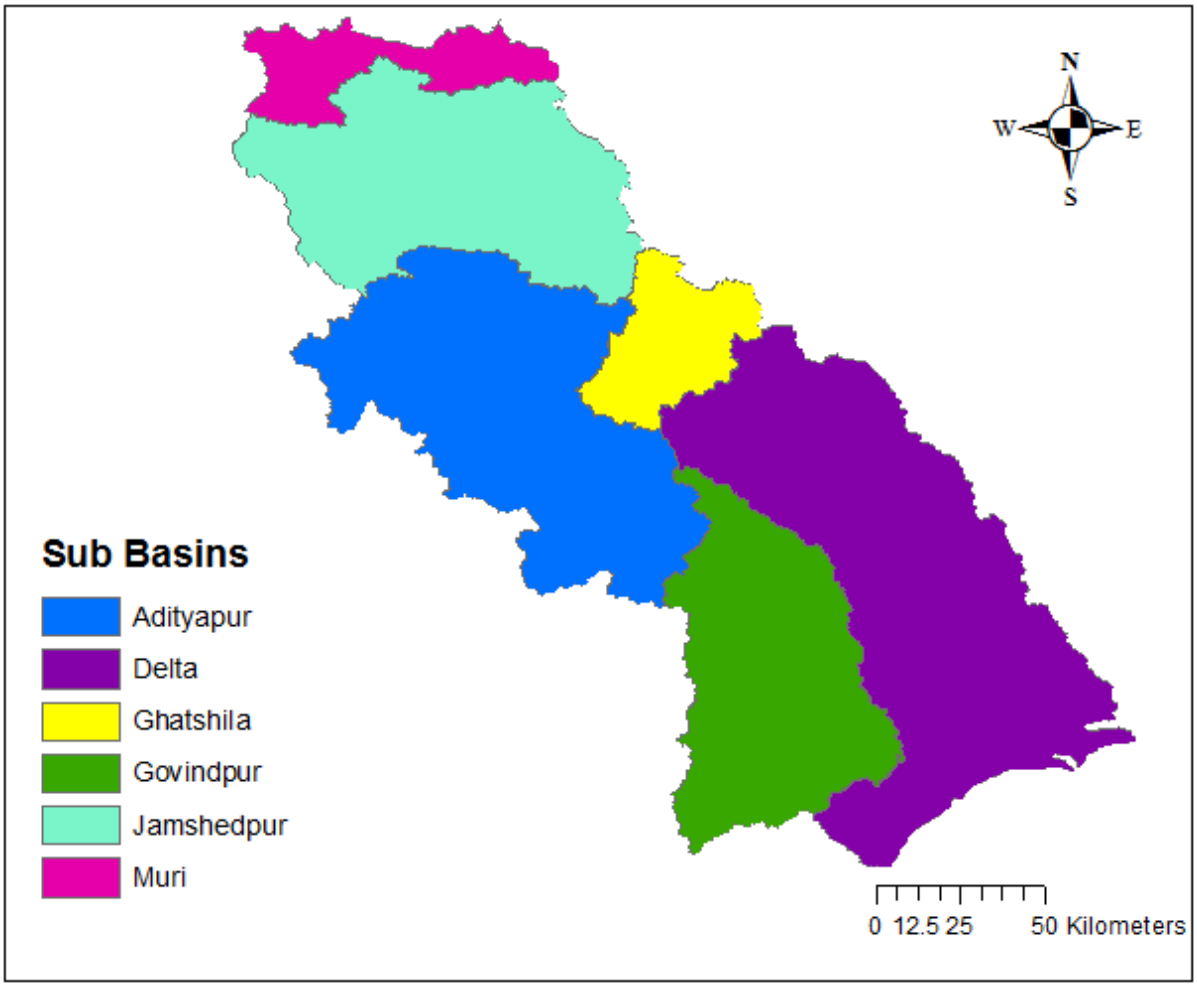


Figure 4.8 Sub-basins of Subernarekha basin

Table - 4.1 Sub-basin wise details of Subernarekha basin

Sl. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Muri	Subernarekha	1343.50
2	Adityapur	Subernarekha	6235.08
3	Jamshedpur	Subernarekha	5080.94
4	Ghatsila	Subernarekha	1488.00
5	Govindpur	Burhabalang	4418.45
6	Delta	Subernarekha	8238.03
	Total basin area		26,804

4.2.4 River discharge

The river discharge data was available at all the 5 sites (Muri, Adityapur, Jamshedpur, Ghatsila located on Subernarekha and Govindpur located on Burhabalang) for the study period of 30 years. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model discharge at sub-basin level.

4.2.5 Reservoir flux

Figure 4.9 shows the location of some of major reservoirs in Subernarekha basin. The data of reservoirs such as Chandil, Sunei, Kalo, Kharkai and Haladia were considered for estimating storage fluxes changes for each water year for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed discharge.

Figure 4.9 Major reservoirs in Subernarekha basin

4.2.6 Groundwater flux

The spatial groundwater flux for the period of 2004-05 is shown in Figure 4.10. The annual groundwater flux during the study period is shown in Figure 4.11.

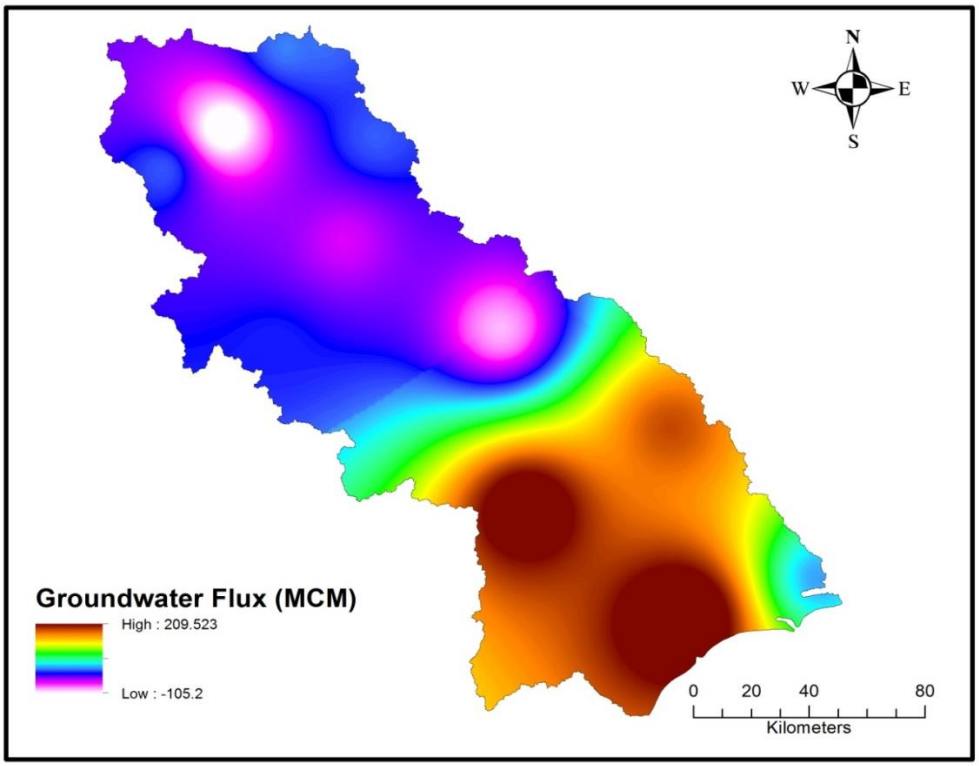


Figure 4.10 Groundwater flux (spatial data) estimated during 2004-05

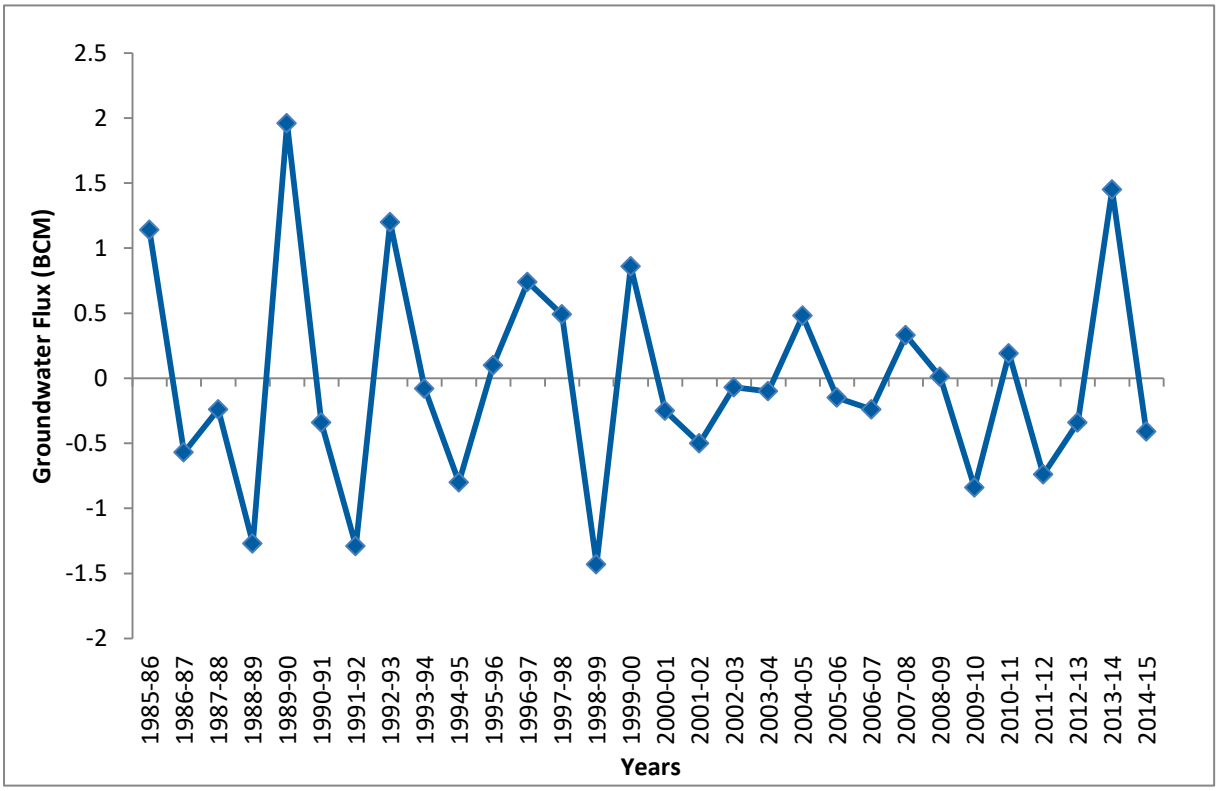


Figure 4.11 Annual groundwater flux of Subernarekha basin (1985-86 to 2014-15)

4.2.7 Major crops in the basin

The Subernarekha basin was divided in 7 (varying from year to year) regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if rice is a major crop, it may be maize in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if wheat is a major crop in Rabi only season, it may be linseed during 2006-07.

4.2.8 Irrigation command area

Figure 4.12 shows location of irrigation command boundaries inside and outside the basin considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Basin outside command has been taken uniformly for all years while working out ECII from these areas.

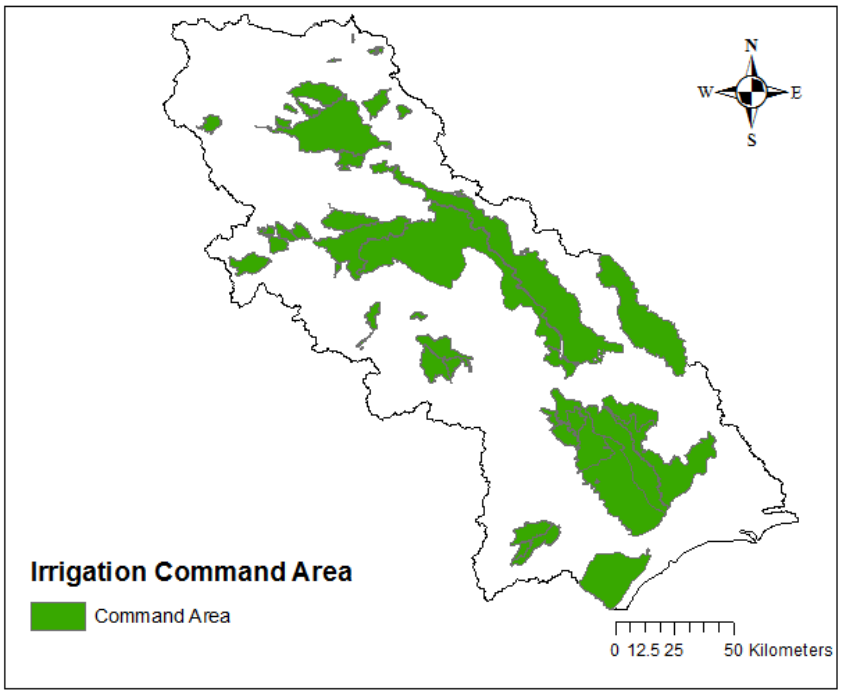


Figure 4.12 Irrigation command boundaries of Subernarekha basin

4.2.9 Domestic, industrial and livestock demand

The population of each district (2011 census) is provided as an attribute in the layer (Figure 4.13). The domestic demand is estimated taking into account the district boundaries of the year 2011. Population data of census year 1991, 2001, 2011 and livestock census of 1982, 1983, 1987, 1990, 1992, 1993, 1997, 1999, 2003, 2007 and 2012 of basin states were used in the study. The mean annual domestic, industrial and livestock demands are estimated at 0.16 BCM in the basin.

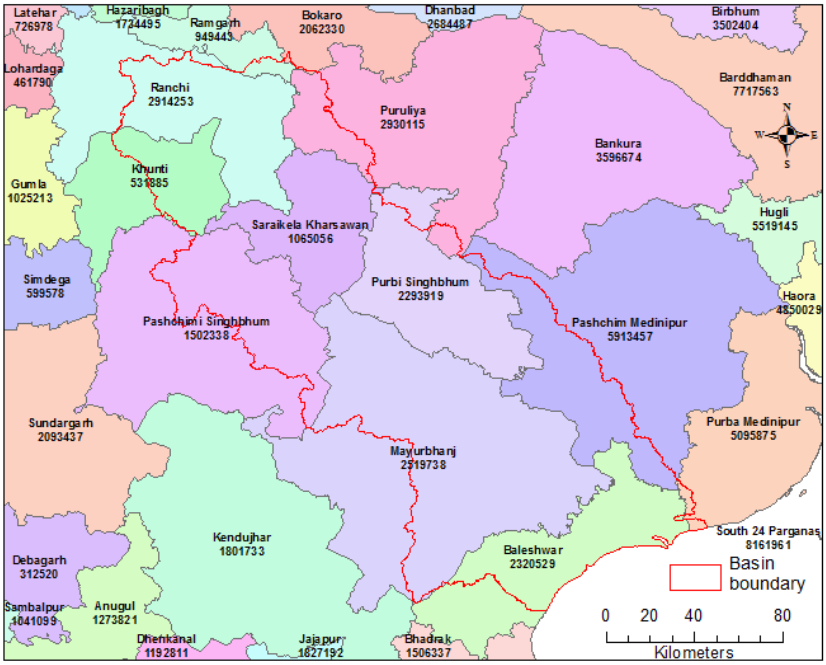


Figure 4.13 District boundaries in Subernarekha basin

4.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 4.2 provides annual evaporation values from each of sub-basins for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 0.54 BCM.

Table - 4.2 Evaporation in reservoirs of Subernarekha Basin

Year	Reservoir evaporation (BCM)	Year	Reservoir evaporation (BCM)
1985-86	0.53	2000-01	0.51
1986-87	0.52	2001-02	0.58
1987-88	0.52	2002-03	0.53
1988-89	0.57	2003-04	0.58
1989-90	0.59	2004-05	0.57
1990-91	0.56	2005-06	0.47
1991-92	0.55	2006-07	0.49
1992-93	0.59	2007-08	0.54
1993-94	0.51	2008-09	0.4
1994-95	0.53	2009-10	0.47
1995-96	0.49	2010-11	0.46
1996-97	0.59	2011-12	0.47
1997-98	0.59	2012-13	0.53
1998-99	0.59	2013-14	0.56
1999-00	0.54	2014-15	0.66
		Avg.	0.54

4.3 Previous Estimates

In 1949 when the basin wise assessment of the water resources of the country was made on the basis of Khosla's formula, the total annual runoff of the river systems in the basin was estimated to be 20.33 BCM. In 1960, the Central Water and Power Commission, while conducting irrigation potential studies, assessed the total annual runoff of the river systems in the basin to be 14.81 BCM on the basis of Strange's rainfall-runoff coefficients for average catchments. This figure has been revised to 10.79 BCM in CWC's Publication No.30/88 "Water Resources of India", April 1988 (based on rainfall-runoff relationship).

4.4 Runoff Estimation

In Subernarekha basin, Muri, Adityapur, Jamshedpur and Ghatsila sites are located on Subernarekha river and Govindpur site on river Burhabalang. The model estimated runoff is calibrated against the observed discharge at all the five locations. Computed discharge at Deltaic region is added to the whole basin without any calibration, since it does not have any observed discharge. Tables - D.1 to D.5 at Annexure - D give calibrated runoff along with observed discharge, rainfall, ECII, etc, during 30 years for these discharge stations. Figures 4.14 to 4.18 show comparative graphs of calibrated and observed discharge at these discharge stations. From the graphs, it may be observed that the model estimated runoff and observed discharge at almost all the sites (Muri, Adityapur, Jamshedpur, Ghatsila and Govindpur) are matching very well for the 30 year period.

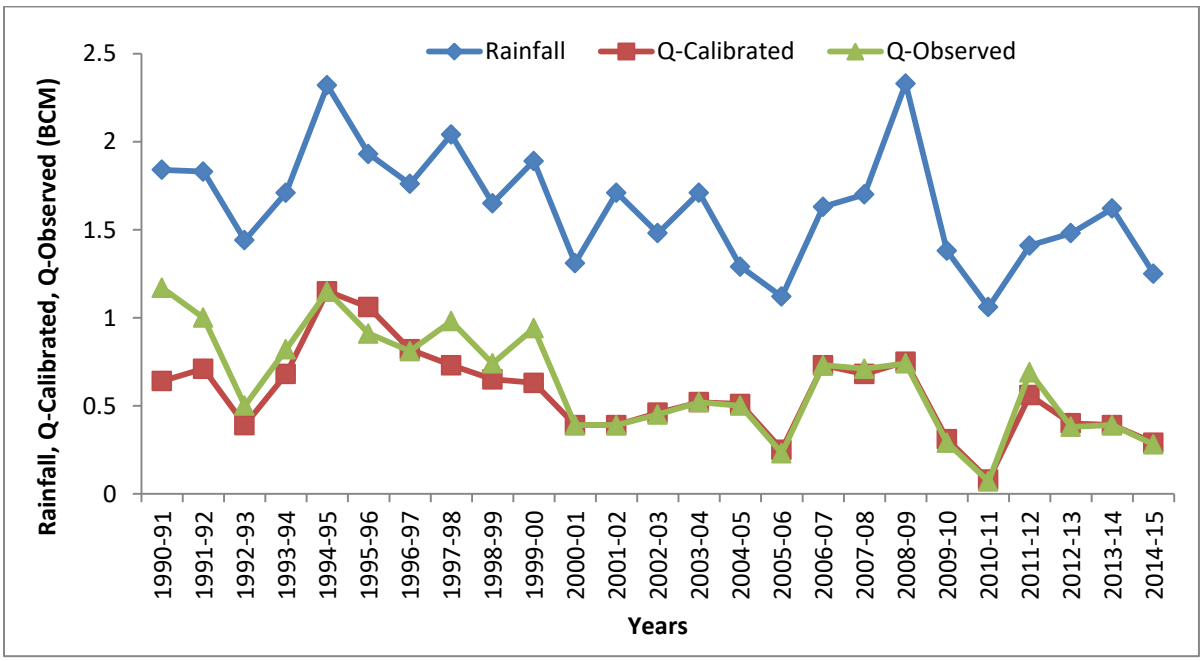


Figure 4.14 Calibrated runoff and observed discharge at Muri

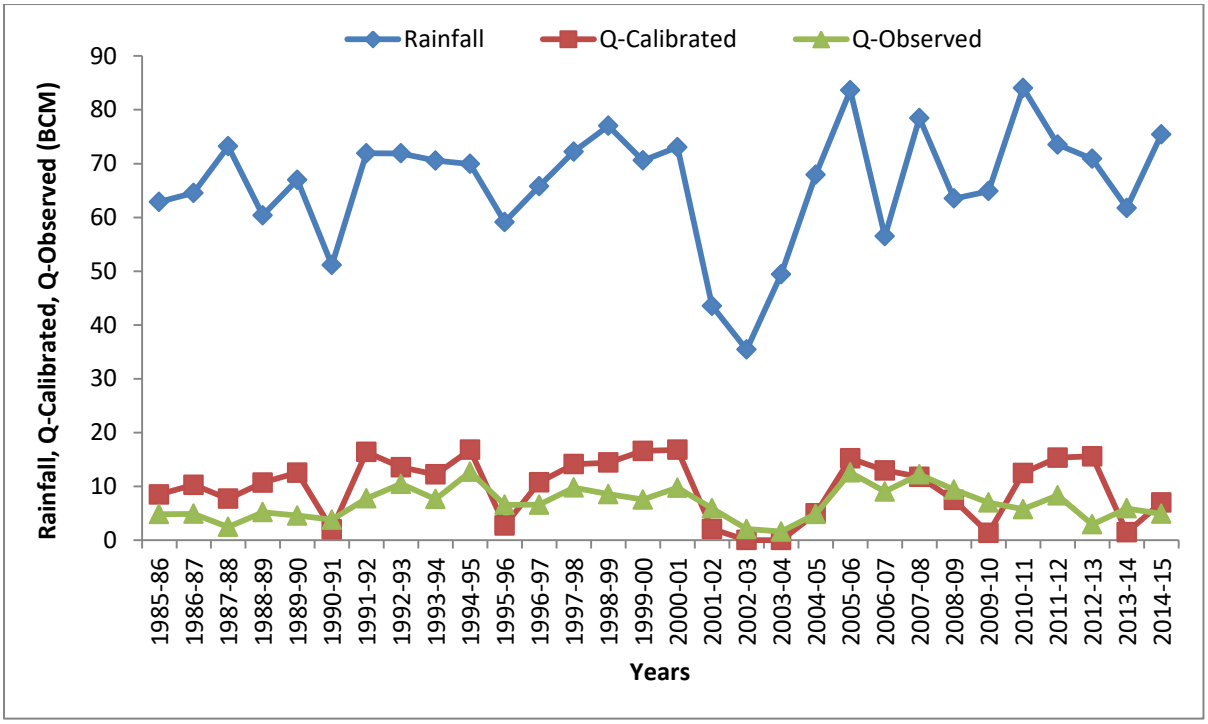


Figure 4.15 Calibrated runoff and observed discharge at Adityapur

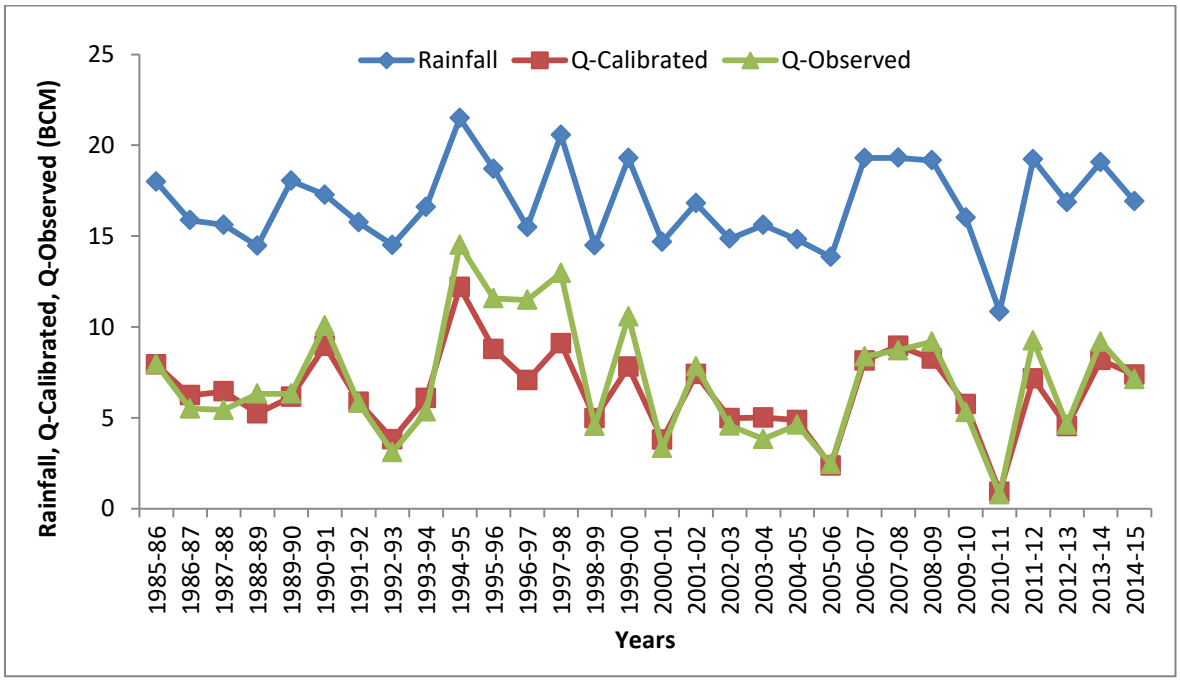


Figure 4.16 Calibrated runoff and observed discharge at Jamshedpur

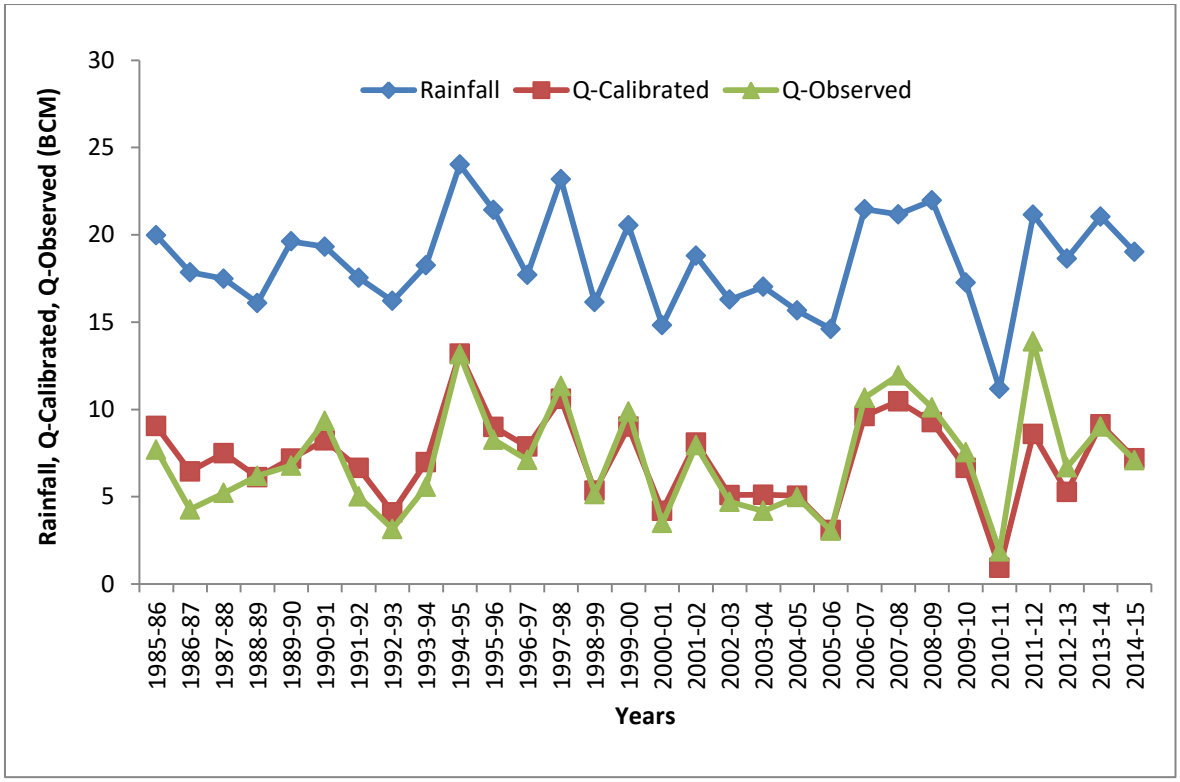


Figure 4.17 Calibrated runoff and observed discharge at Ghatsila

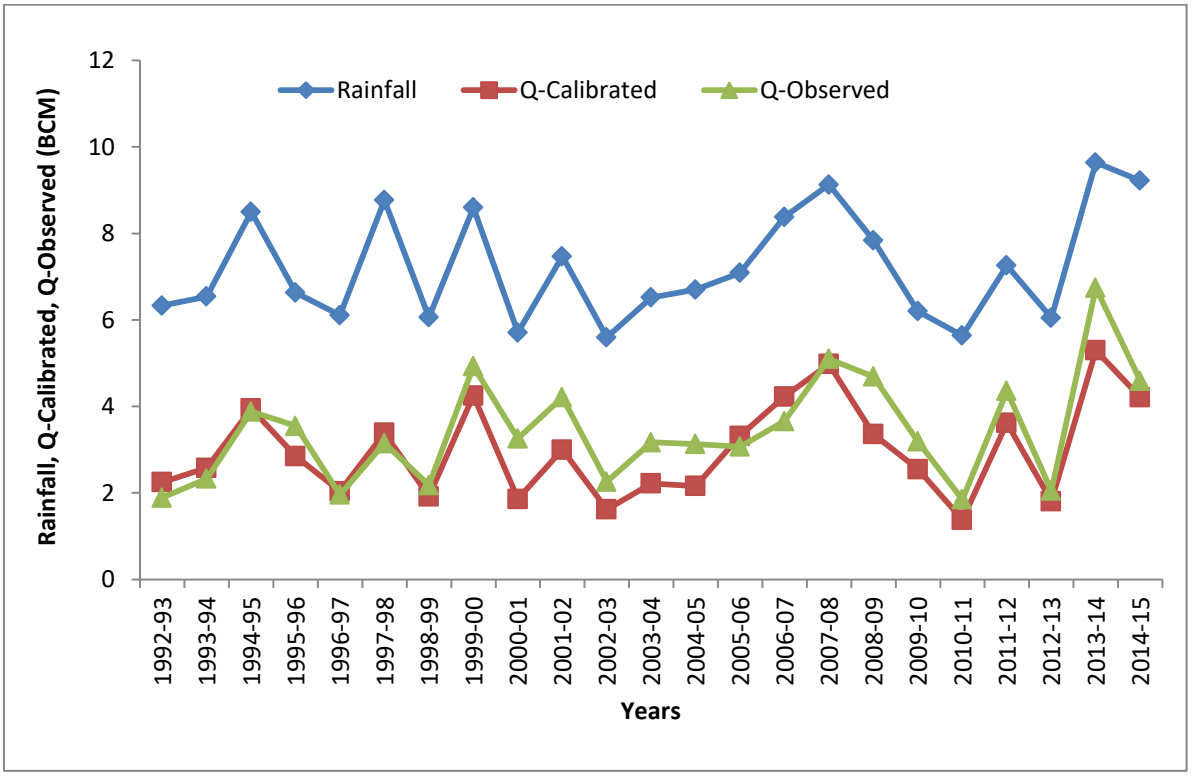


Figure 4.18 Calibrated runoff and observed discharge at Govindpur

Table D.6 at Annexure - D gives calibrated runoff of Subernarekha basin for years 1985-86 to 2014-15. The mean annual calibrated runoff is 12.26 BCM. The maximum annual calibrated runoff is 21.71 BCM during 1994-95. The minimum annual calibrated runoff is 1.42 BCM during 2010-11. The mean annual ECII is about 2.11 BCM. The maximum annual ECII is about 8.34 BCM during 2014-15. The minimum annual ECII is about 0.61 BCM during 1990-91.

4.5 Annual Water Resources Availability of Subernarekha Basin

Table - D.6 at Annexure - D shows the different components required to estimate the basin level water resources of Subernarekha for 30 years. The maximum annual water resource is 23.46 BCM during 2007-08 in 30 years. The minimum annual water resource is 5.49 BCM during 2010-11 in 30 years. The mean available water resource of the Subarnarekha basin is 15.05 BCM. The mean available water resource of Subernarekha basin accounts to about 37.57 % of mean annual rainfall during 1985-86 to 2014-15.

4.5.1 Annual water resources of Subernarekha basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 2007-08 and 2010-11, extreme wet and dry rainfall conditions occurred in Subernarekha river basin. The annual water resources of Subernarekha basin during these two extreme rainfall conditions are 23.46 BCM and 5.49 BCM, respectively as shown in Table - 4.3**.** The water balance components during these years are presented in Figures 4.19 and 4.20.

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.47 and 0.20 respectively. During high rainfall years, potential evapo-transpiration is less compared to the dry years which will have cumulative effect in runoff. It is found that the ECII during 2007-08 is less than the year 2010-11.

Table - 4.3 Water resources availability of Subernarekha basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources Availability (BCM)
Maximum Rainfall	2007-2008	50.26	23.46
Minimum Rainfall	2010-2011	26.61	5.49

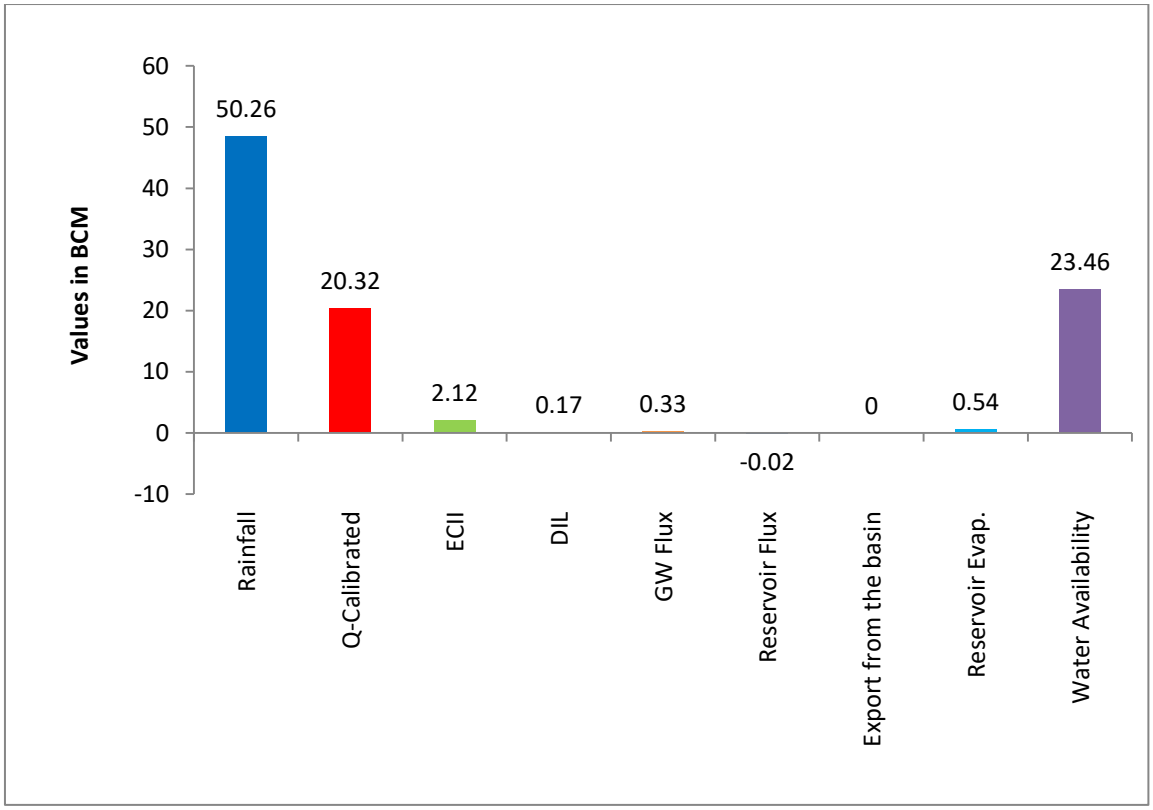


Figure 4.19 Water balance components of Subernarekha basin during extreme high rainfall (2007-08)

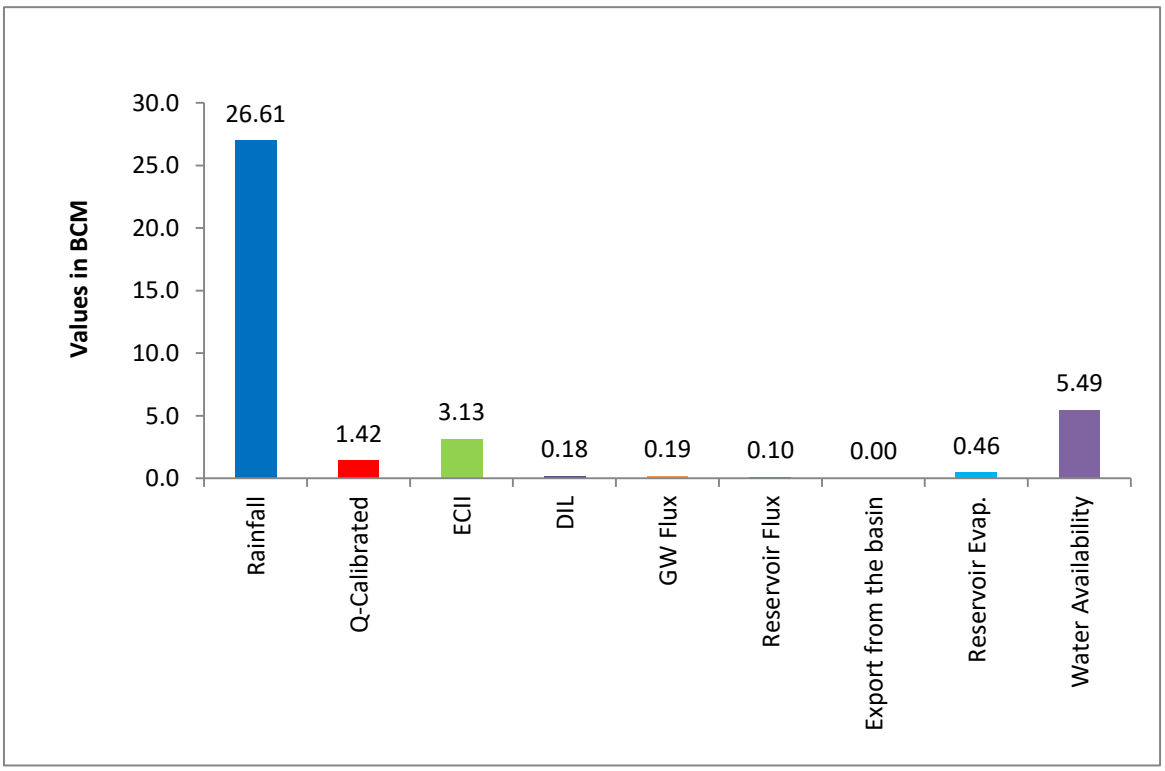


Figure 4.20 Water balance components of Subernarekha basin during extreme low rainfall (2010-11)

4.5.2 Mean water resources of Subernarekha basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Export from basin + Evaporation from Reservoirs) = 12.26 + 2.11 + 0.16 + (-0.02) + (0.01) + 0 + 0.54 = 15.05 BCM

75% dependable flow of Subernarekha basin = 12.00 BCM

The mean available annual water resource of the Subernarekha basin is 15.05 BCM. Figure 4.21 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

It is observed that the computed runoff factors varies from 0.05 (1,007 mm rainfall) to 0.49 (1,646 mm rainfall). The mean runoff factor for 30 year period is 0.31.

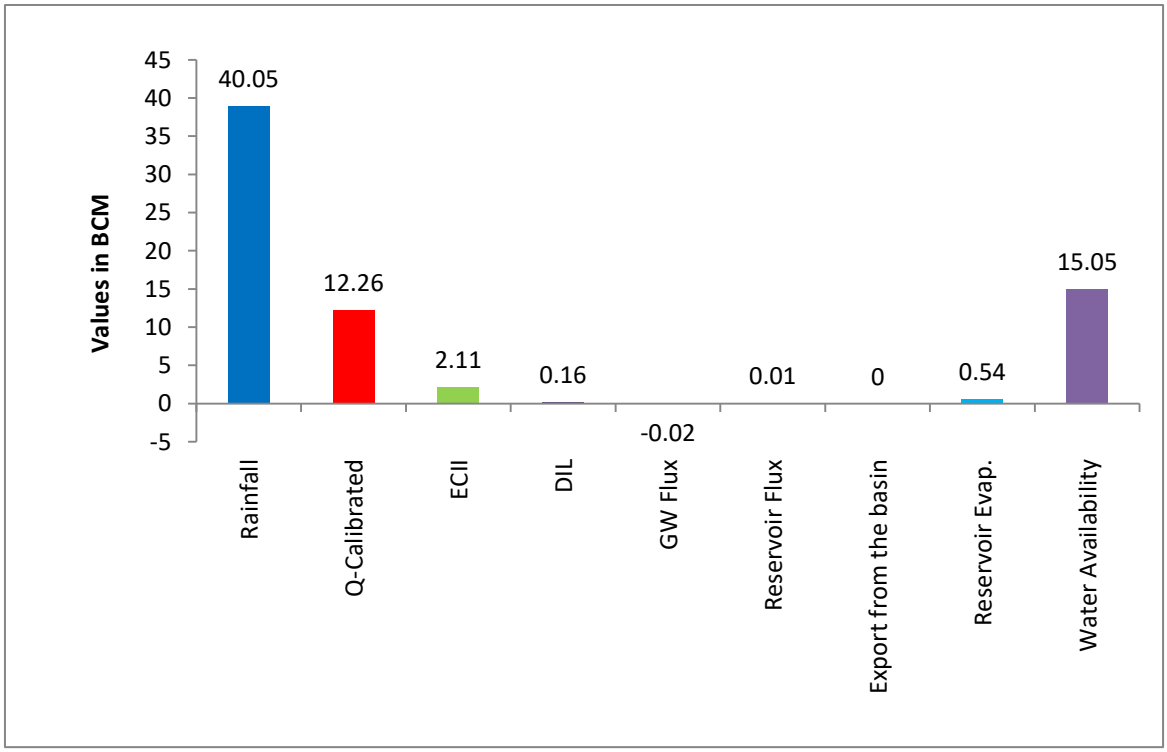
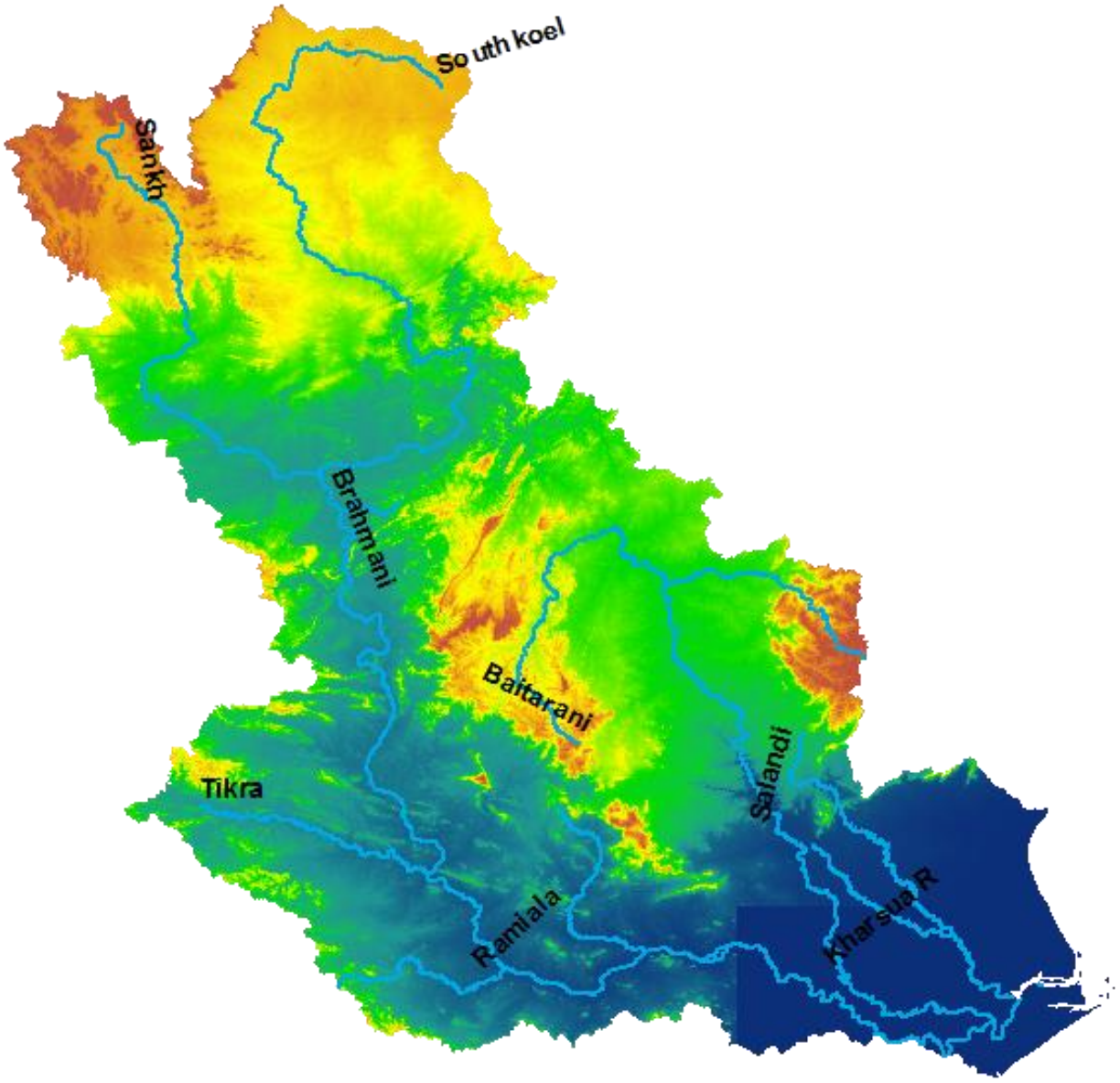


Figure 4.21 Mean water balance components of Subernarekha basin

HIGHLIGHTS

- *Average annual available water resources of Subernarekha basin is 15.05 BCM.*
- *Maximum annual water availability is 23.46 BCM during 2007-08.*
- *Minimum annual water availability is 5.49 BCM during 2010-11.*
- *Annual rainfall in the basin varies from 1,006.75 mm to 1,810.29 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1427 mm.*
- *Subernarekha basin is divided into six sub-basins for the reassessment study viz. Muri, Adityapur, Jamshedpur, Ghatsila, Govindpur and Combined Delta region as one sub-basin.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.16 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.54 BCM.*

BRAHMANI-BAITARANI BASIN



5.1 Geo-Spatial Datasets

5.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of Brahmani-Baitarani basin is shown in Figure 5.1. The image corresponds to the 2004-05 year and consists of 17 different classes. Forest cover forms as the major constituent (31.9%), followed by crop area (30%) and current fallow (28.25%). The remaining 10.7% of basin area is covered by built up land, plantation, littoral swamp, grassland, gullied land, scrubland, other waste land and water bodies (Figure 5.2). The crop area is further categorised as Kharif only (23.64%), Rabi only (0.9%), Zaid only (0.26%) and Double/Triple (4.35%) classes.

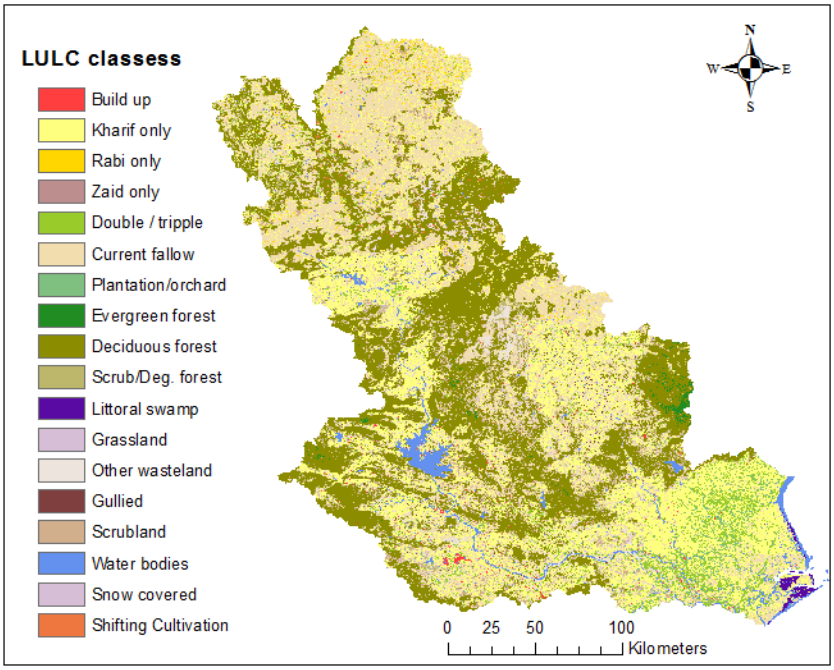


Figure 5.1 LULC map of Brahmani-Baitarani basin (2004-05)

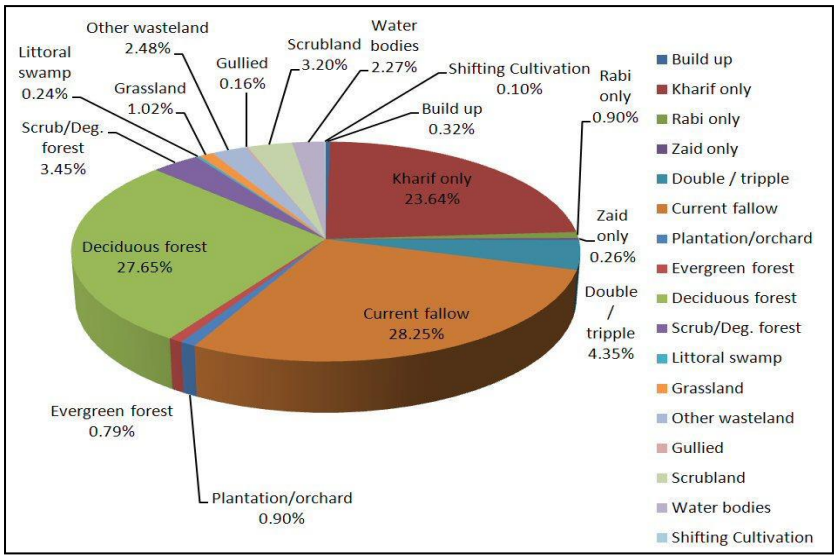


Figure 5.2 Distribution of LULC in Brahmani-Baitarani basin (2004-05)

5.1.2 Soil texture

The main soil types found in the basin are red and yellow soils, red sandy and loamy soils, mixed red and black soils and coastal alluvium. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 5.3 shows various categories of soil in the basin. The soils are classified as sandy, loamy, clayey, loamy skeletal, clay skeletal based on the soil textural information.

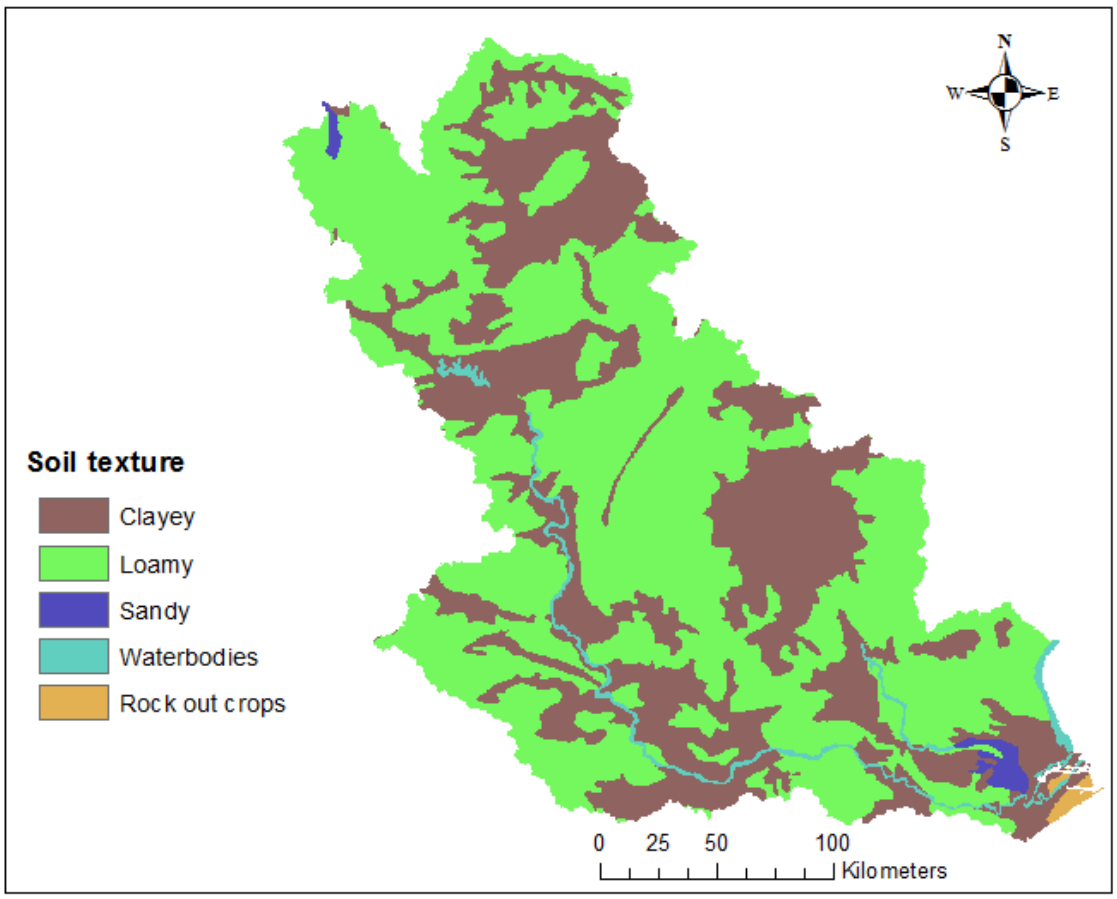


Figure 5.3 Soil texture map of Brahmani-Baitarani basin

5.1.3 Topography

The topography of the basin consists of ghat areas, northern plateau, central table land and the coastal plains. The upper regions of the basin are mostly hilly and forested. The lower region of the basin is deltaic plains. The elevation values ranges from a minimum of 0 m to a maximum of 1,181 m. The average elevation is about 341 m in the basin. Figure 5.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Brahmani-Baitarani basin.

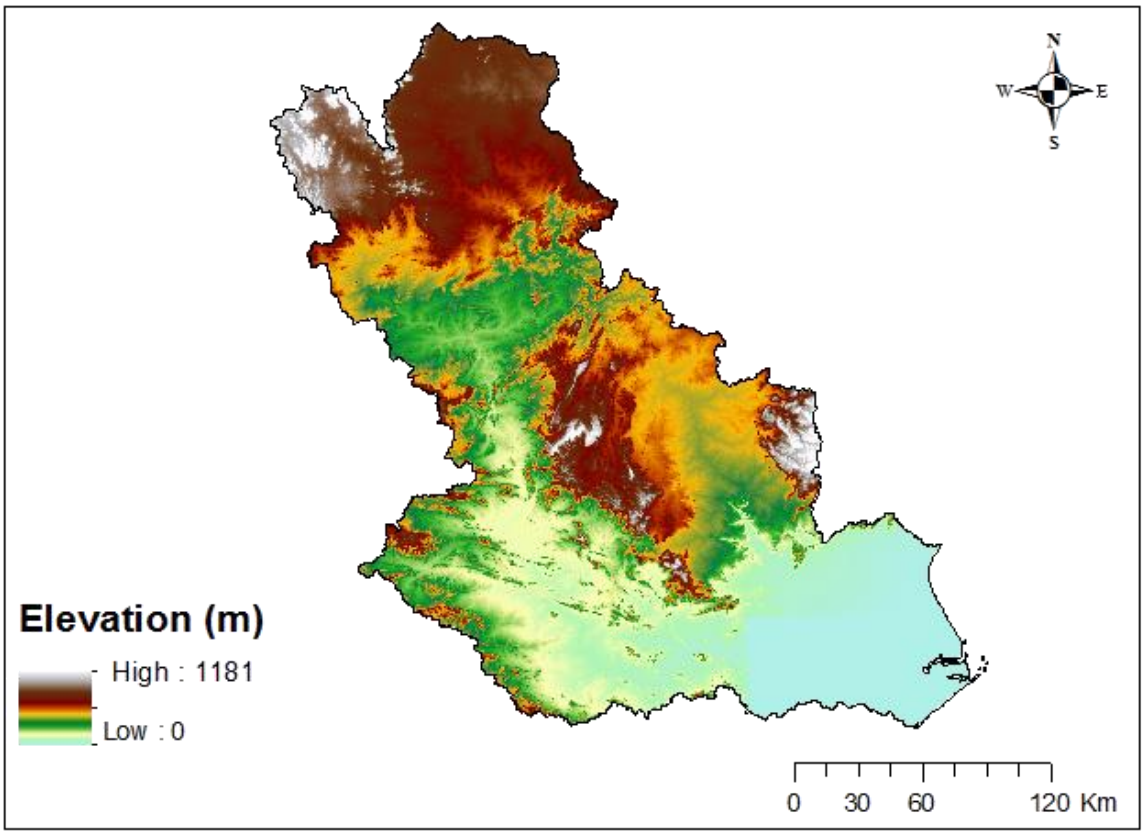


Figure 5.4 SRTM DEM map of Brahmani-Baitarani Basin

5.2 Hydro-Meteorological and other Input Data

5.2.1 Rainfall grids

Figure 5.5 shows gridded rainfall map of Brahmani-Baitarani basin for the water year 2004-05. Figure 5.6 shows annual rainfall variations of the basin during the 30 years (1985-86 to 2014-15). Among these 30 years, the lowest annual rainfall is 1,108 mm (2002-03) and highest annual rainfall is 1,891 mm (1994-95). Rainfall analysis during the study period of 1985-2015 (30 years) indicated the mean rainfall is 1,456 mm. Of the 30 years, for 16 years annual rainfall is higher than the mean rainfall and for remaining 14 years lower than the mean rainfall**.**

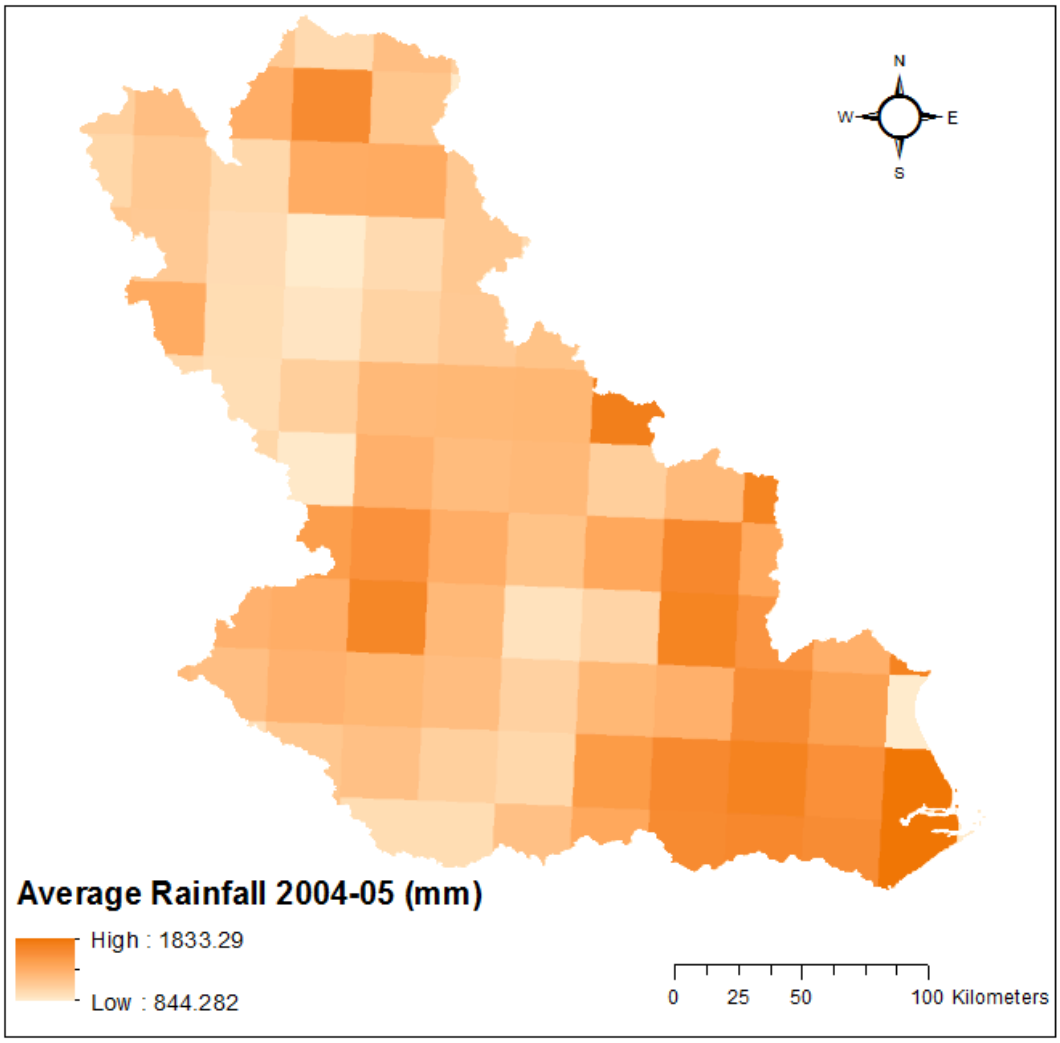


Figure 5.5 Gridded rainfall of Brahmani-Baitarani basin (2004-05)

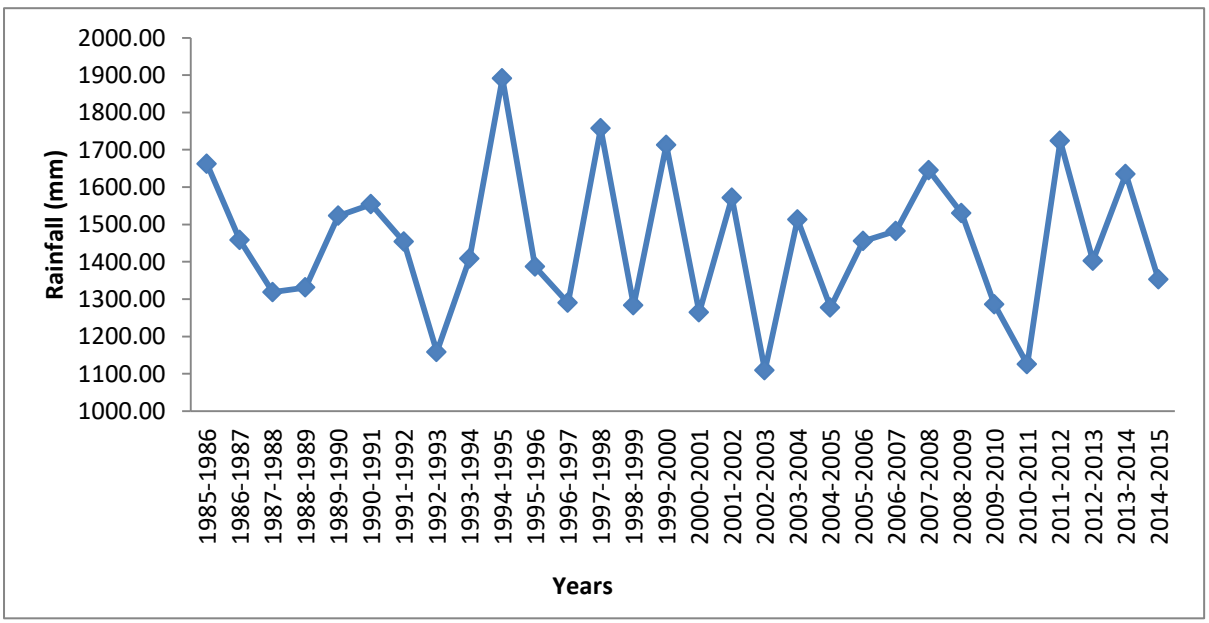


Figure 5.6 Annual rainfall in Brahmani-Baitarani basin (1985-86 to 2014-15)

5.2.2 Temperature grids

Gridded mean annual temperature of Brahmani-Baitarani basin in 2004 is shown in Figure 5.7. The highest mean annual temperature is observed in May which is about 32^{o}C and lowest mean monthly temperature about 19^{o}C in January.

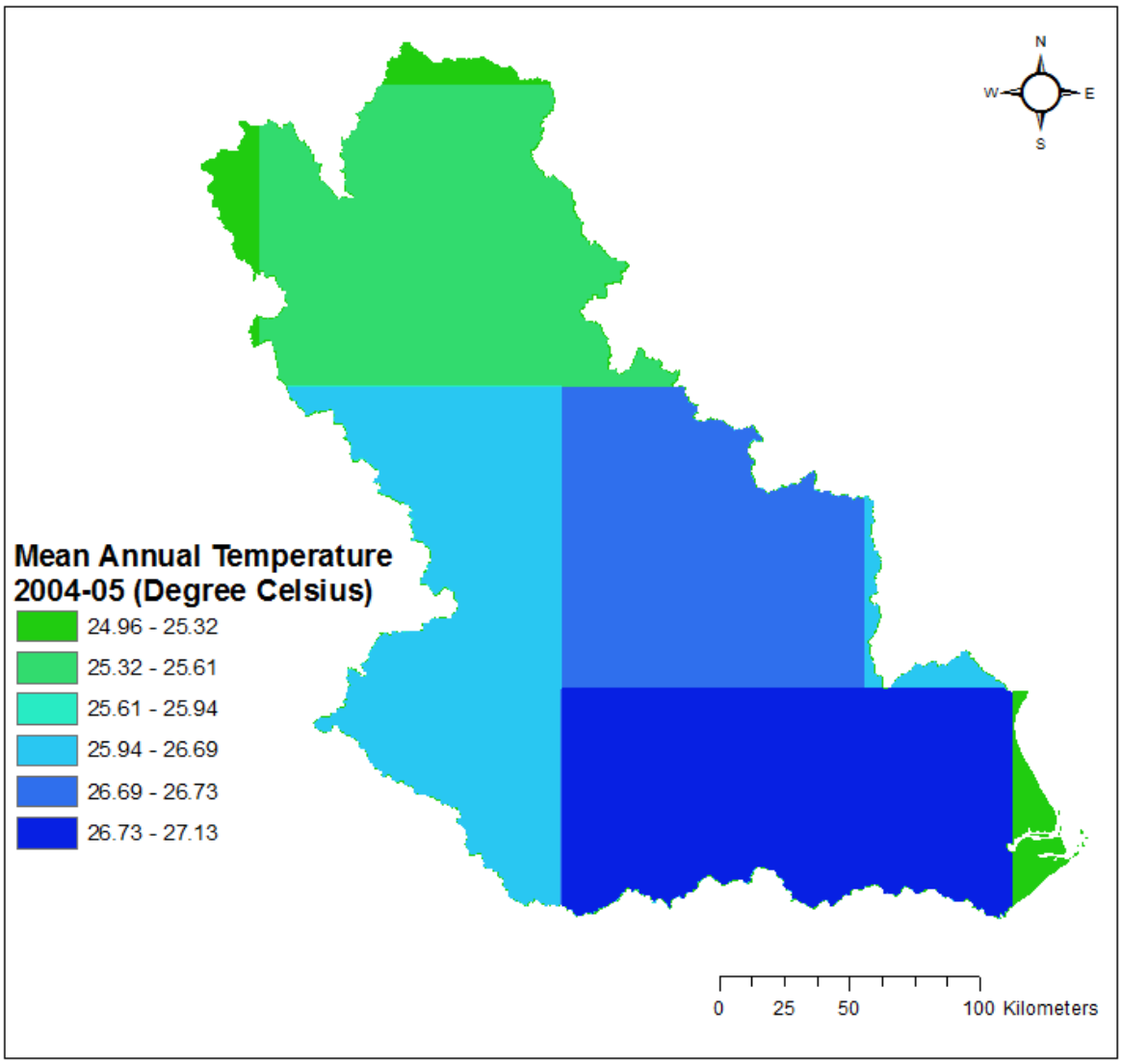


Figure 5.7 Gridded mean annual temperature of Brahmani-Baitarani basin (2004-05)

5.2.3 Sub-basins of Brahmani-Baitarani basin

The Brahmani-Baitarani basin is divided in to eight sub-basins (Figure 5.8) viz. Tilga, Jaraikela, Panposh, Gomlai and Jenapur in Brahmani basin and Champua and Anandapur in Baitarani basin and combined delta region as one sub-basin. Table 5.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

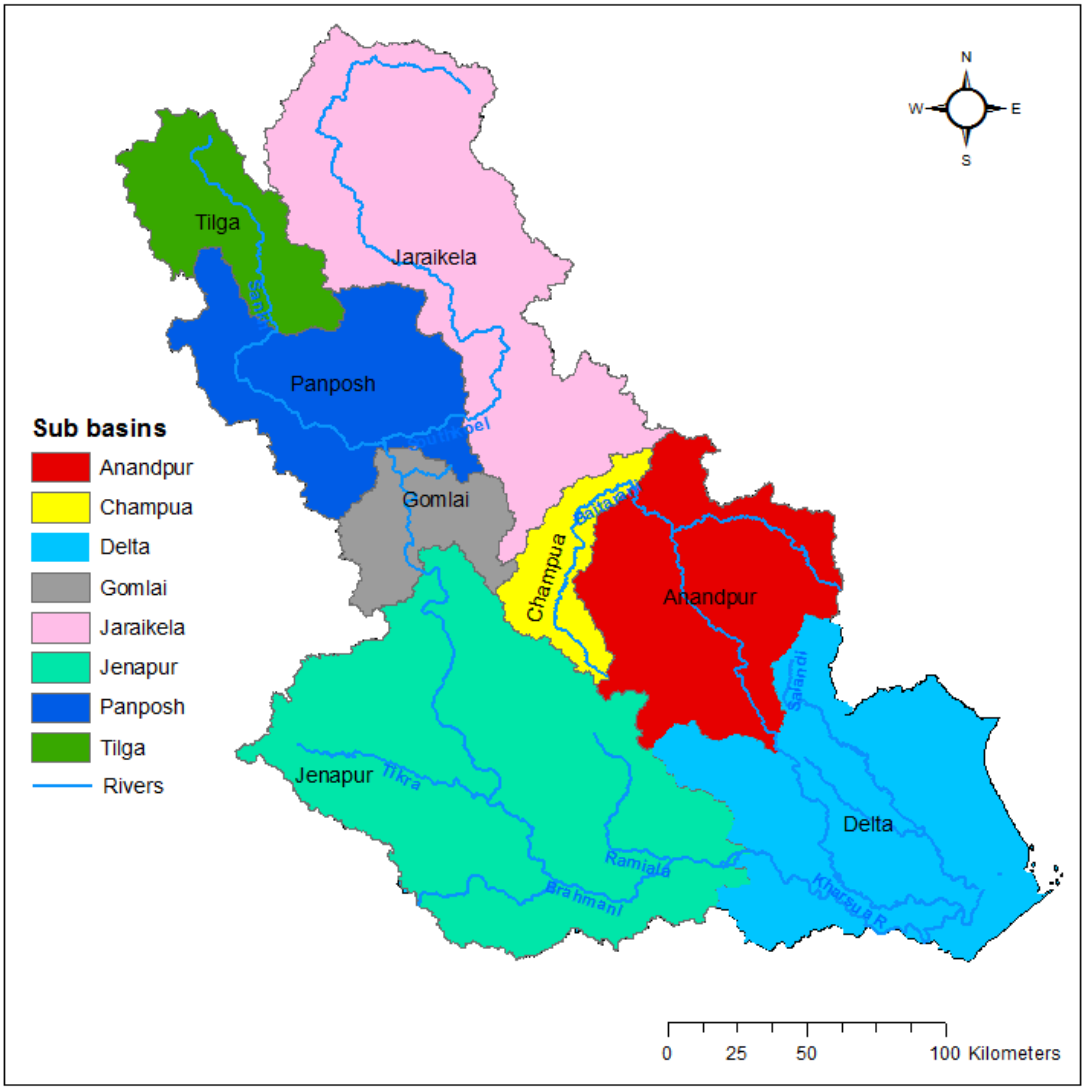


Figure 5.8 Sub-basins of Brahmani-Baitarani basin

Table - 5.1 Sub-Basin wise details of Brahmani-Baitarani basin

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Tilga	Sank	3,182
2	Jarikela	Koel	10,605
3	Panposh	Brahmani	5,537
4	Gomlai	Brahmani	2,317
5	Jenapur	Brahmani	14,272
6	Champua	Baitarani	1,802
7	Anandapur	Baitarani	6,825
8	Delta area		9,362
	Total basin area		53,902

5.2.4 River discharge

The river discharge data was available at all the 7 sites (Tilga, Jaraikela, Panposh, Gomlai, Jenapur on Brahmani and its tributaries and Champua and Anandapur on Baitarani river) for the study period of 30 years except Panposh and Champua.

5.2.5 Reservoir flux

Figure 5.9 shows the location of 3 main reservoirs in Brahmani-Baitarani basin. Mandira dam was constructed during 1957-1959 on Sankh river, a tributary of Brahmani river. The dam is exclusively meant for the purpose of storing water for supply to the Rourkela Steel Plant located about 24 km downstream along the river course.

Rengali dam was constructed across Brahmani river during 1974-1985. This is a multipurpose reservoir for flood control, irrigation and power generation. The gross capacity and live storage capacity of reservoir at Full Reservoir Level (FRL) is 4.40 BCM and 3.45 BCM respectively (Dam Safety Report, 2007). Salandi dam was built across Salandi river, a tributary of Baitarani river with main purpose of irrigation. The data of major reservoirs such as Rengali and Salandi received from State Government were considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed runoff.

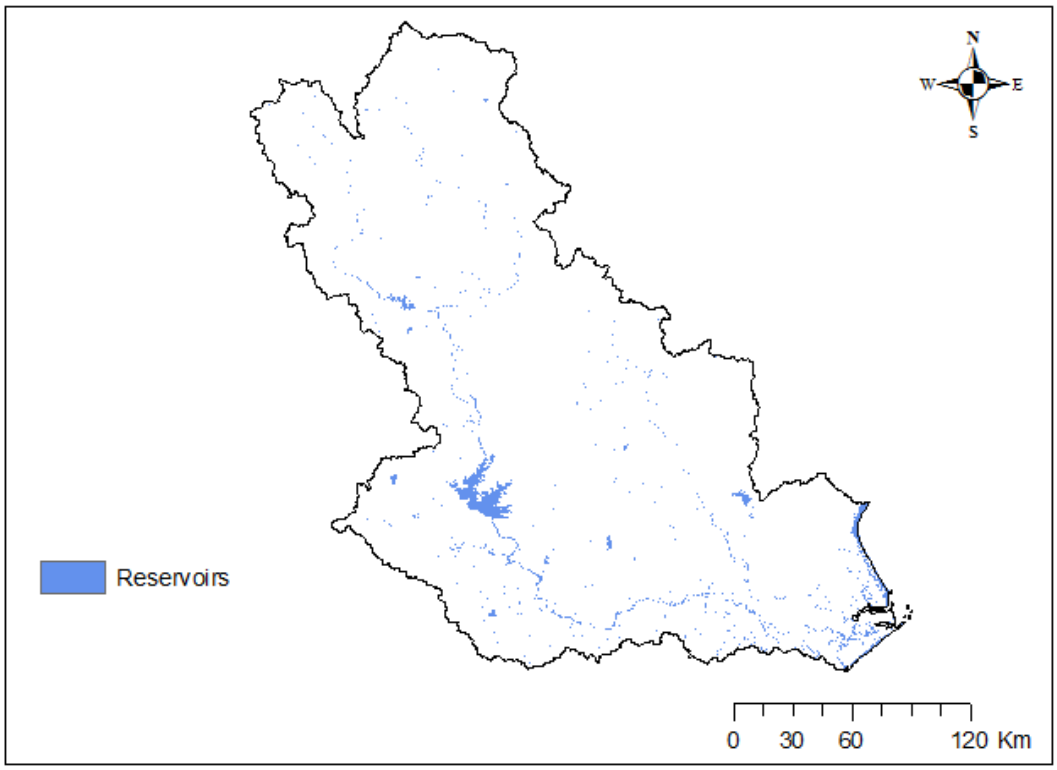


Figure 5.9 Major reservoirs in Brahmani-Baitarani basin

5.2.6 Groundwater flux

Spatial variation of annual groundwater flux for year 2014-15 is shown in Figure 5.10 and annual groundwater Flux variation for 1985-86 to 2014-15 is shown in Figure 5.11.

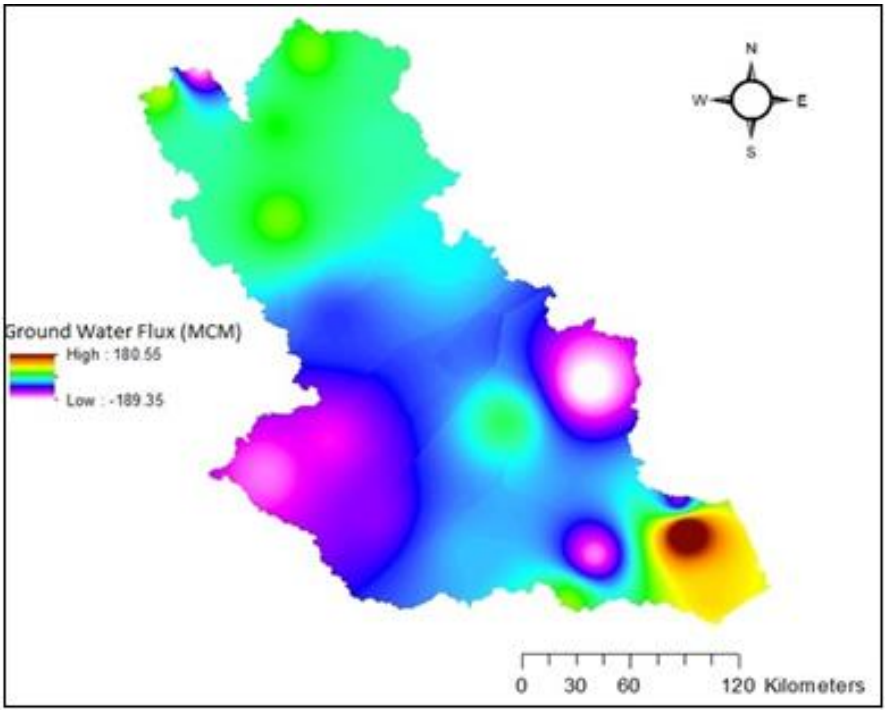


Figure 5.10 Groundwater flux (spatial data) estimated during 2014-15

The spatial annual groundwater flux in the basin varies from 180.55 MCM to -189.35 MCM during year 2014-15 as shown Figure 5.11. The mean annual groundwater flux from 1984-85 to 2014-15 of Brahmani-Baitarani river basin is estimated at 0.0068 BCM.

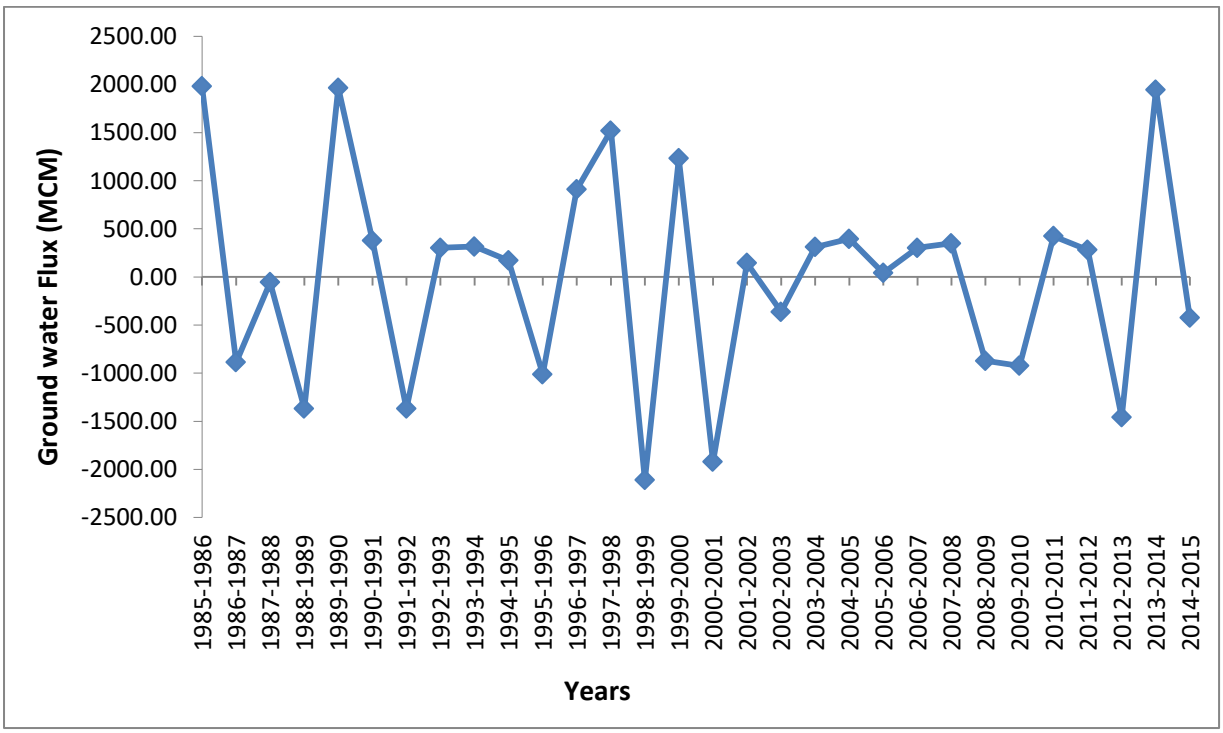


Figure 5.11 Annual groundwater flux of Brahmani-Baitarani basin (1985-86 to 2014-15)

5.2.7 Major crops in the basin

The basin was divided in 12 regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if rice is a major crop, it may be jowar or bajra in the neighbouring district. Similarly, temporal variation indicates for example during 2010-11, if mustard seed is a major crop in Rabi only season, it may be sesame during 2011-12.

5.2.8 Irrigation command area

Figure 5.12 shows location of irrigation command boundaries inside the basin and outside the Brahmani-Baitarani basin considered for the year 2014-15. Basin outside command has been taken uniformly for all years while working out ECII from these areas.

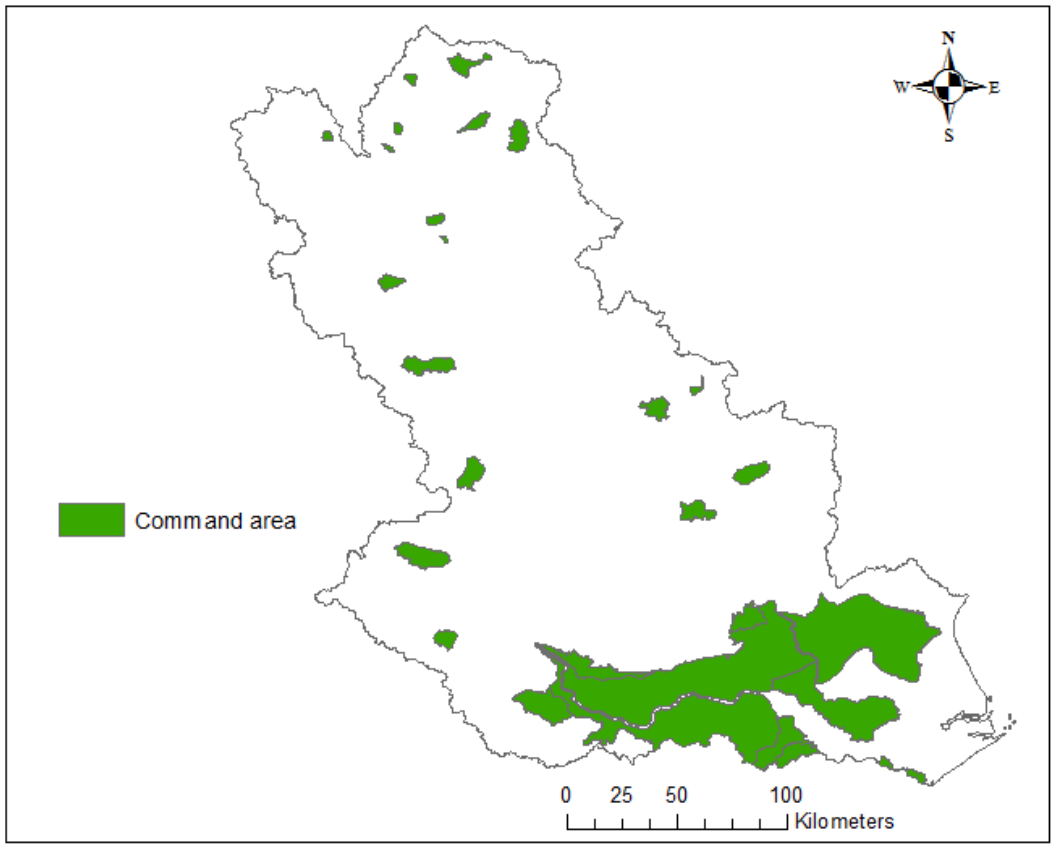


Figure 5.12 Irrigation command boundaries of Brahmani-Baitarani basin

5.2.9 Domestic, industrial and livestock demand

Figure 5.13 shows district boundaries layer for the year 2011. Population data of census year 1991, 2001, and 2011 of basin were used in the study. The livestock demand for water was also considered in estimating the total water requirements for this sector. As per the 18th census data of National Dairy Development Board, it was estimated that livestock population in the country is about 50% (529 million as per 2007 data) to the human population. The mean annual domestic, industrial and livestock demands are estimated at 0.18 BCM in the basin.

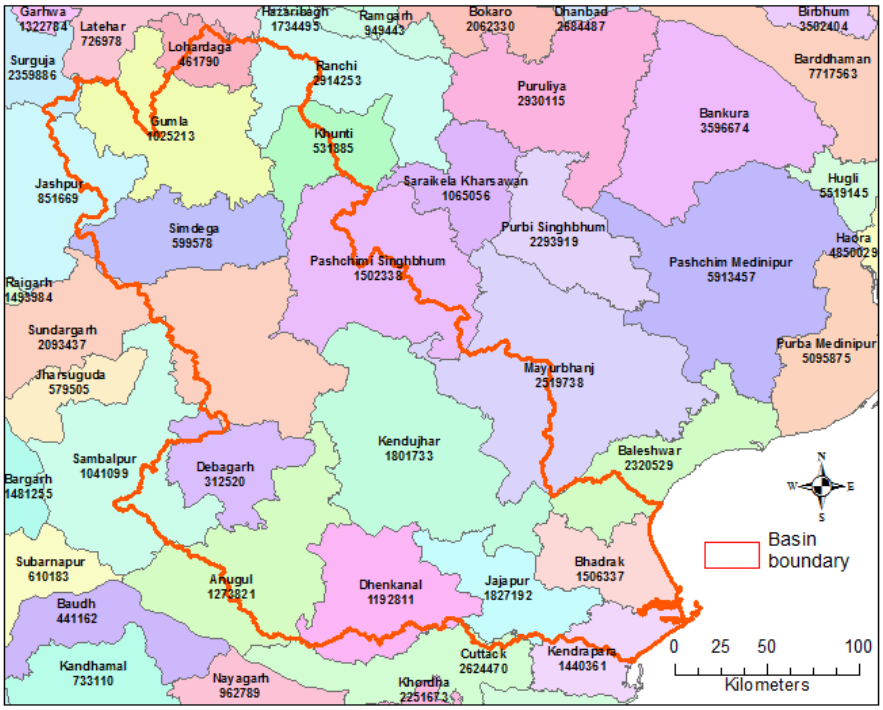


Figure 5.13 District boundaries in Brahmani-Baitarani basin

5.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 5.2 provides annual evaporation values from Brahmani-Baitarani basin for the period of 1985-86 to 2014-15 (30 years). Major reservoirs Rengali, Salandi and Mandira are the main sources of evaporation losses from the surface storage in the basin. The average total evaporation volume for basin amounts to about 0.93 BCM.

Table - 5.2 Evaporation in the reservoirs of Brahmani-Baitarani basin

Year	Evaporation (BCM)	Year	Evaporation (BCM)
1985-86	0.98	2000-01	1.10
1986-87	0.96	2001-02	0.45
1987-88	1.12	2002-03	0.76
1988-89	1.11	2003-04	0.95
1989-90	0.98	2004-05	1.11
1990-91	0.95	2005-06	0.99
1991-92	0.92	2006-07	0.75
1992-93	0.74	2007-08	0.96
1993-94	0.92	2008-09	0.72
1994-95	0.71	2009-10	0.80
1995-96	0.91	2010-11	0.85
1996-97	1.11	2011-12	0.61
1997-98	1.14	2012-13	1.00
1998-99	1.09	2013-14	1.10
1999-00	1.01	2014-15	0.91
		Avg	0.93

5.3 Previous Estimates

In 1949, using Khosla's empirical formula basin-wise water resources assessment of the Brahmani-Baitarani basin was estimated as 39.225 BCM. In 1960, Central Water & Power Commission while conducting irrigation potential studies assessed the total annual runoff of the basin as 28.69 BCM on the basis of Strange's rainfall-runoff coefficients. In 1988, CWC reported 36.23 BCM as average water resources of the Brahmani-Baitarani basin using Khosla's formula.

In 1993 study, the Brahmani-Baitarani basin has a total catchment area of 51,822 sq.km. For the Brahmani portion of the basin, flow data at Jenapur (CWC discharge station with catchment area of 36,300 sq.km) available for the period 1964-65 to 1984-85 and for the Baitarani portion of the basin, flow data at Biridi (catchment area of 10,120 sq. km) available for the period 1964-65 to 1984-85 were used. The discharge flows were proportionately taken based on the areas with respect to Jenapur to the total Brahmani basin (catchment area of 39,030 sq. km) and Biridi to the total Baitarani basin (catchment area of 10,982 sq.km).

Withdrawal for irrigation was calculated based on the year-wise irrigation potential created assuming an average delta of 0.82 m. Withdrawal for domestic use was based on population statistics assuming requirement of 70 LPCD for rural population and 140 LPCD for urban population. The change in storage in the reservoirs in the basin was neglected. The total water resource available was estimated as 28.48 BCM in the basin.

5.4 Runoff Estimation

The observed discharges are available for the sites Tilga on Sankh river, Jarikela on Koel river, Panposh, Gomlai, Jenapur on main Brahmani river and Champua and Anandapur located on Baitarni River. The model estimated runoff is calibrated against the observed discharge at all the seven locations. Computed runoff at deltaic region is added to the whole basin without any calibration, since it does not have any observed discharges. Tables E.1 to E.7 at Annexure - E give calibrated runoff along with observed discharge, rainfall, ECII, etc during 30 years for these discharge stations. Figures 5.14 to 5.20 show comparative graphs of calibrated and observed discharge at these discharge stations. From the graphs, it may be observed that the model estimated runoff and observed discharge at almost all the sites are matching very well for the 30 year period.

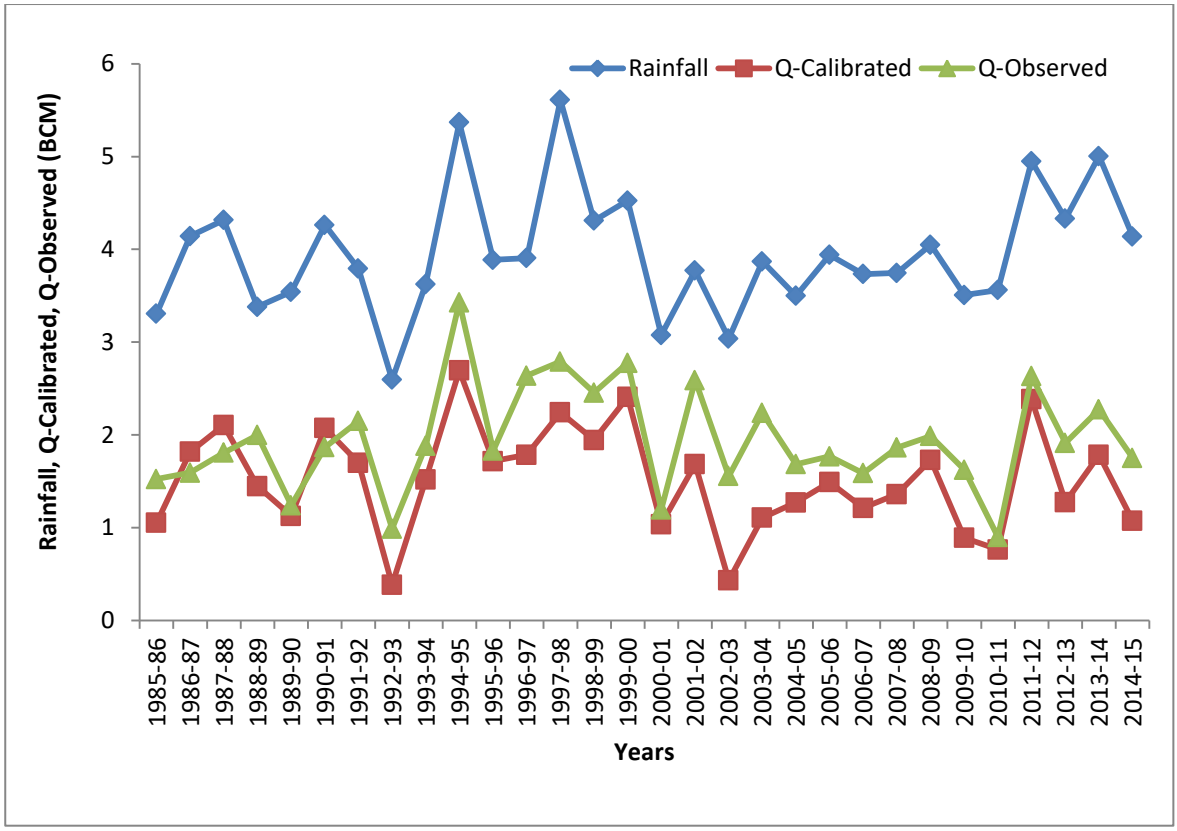


Figure 5.14 Calibrated runoff and observed discharge at Tilga

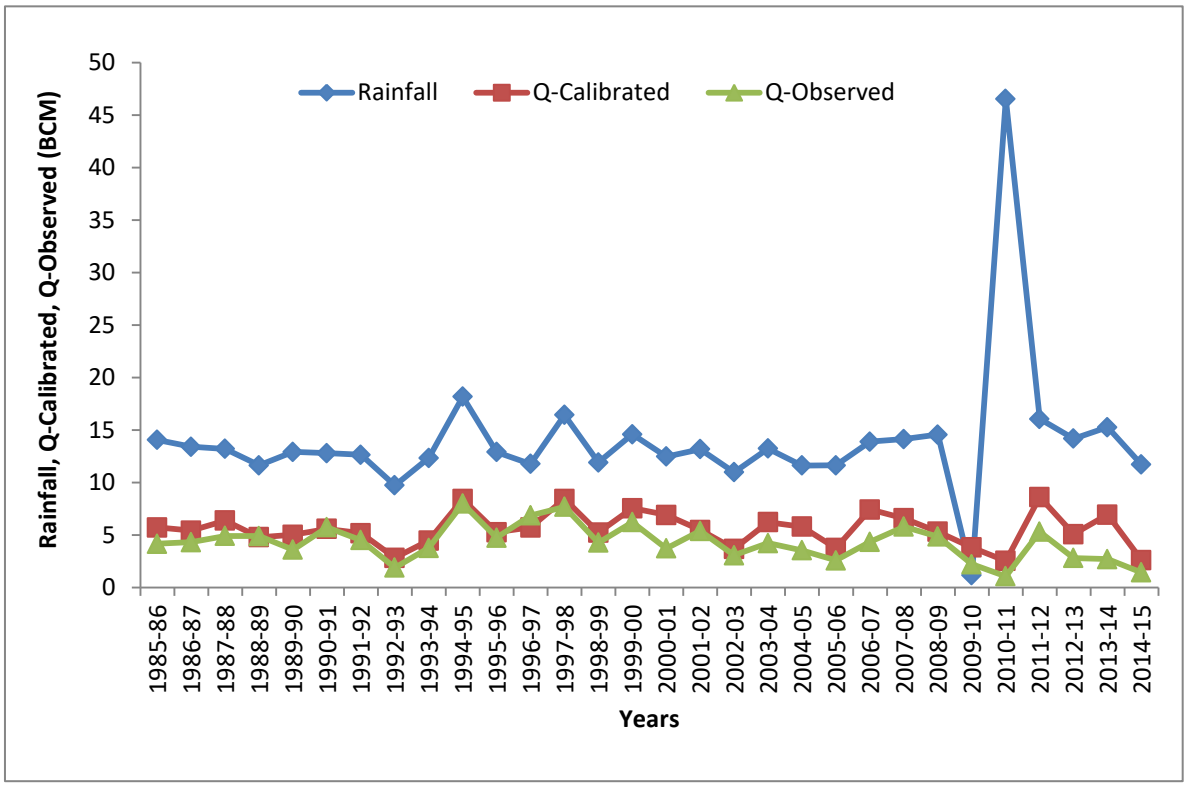


Figure 5.15 Calibrated runoff and observed discharge at Jarikela

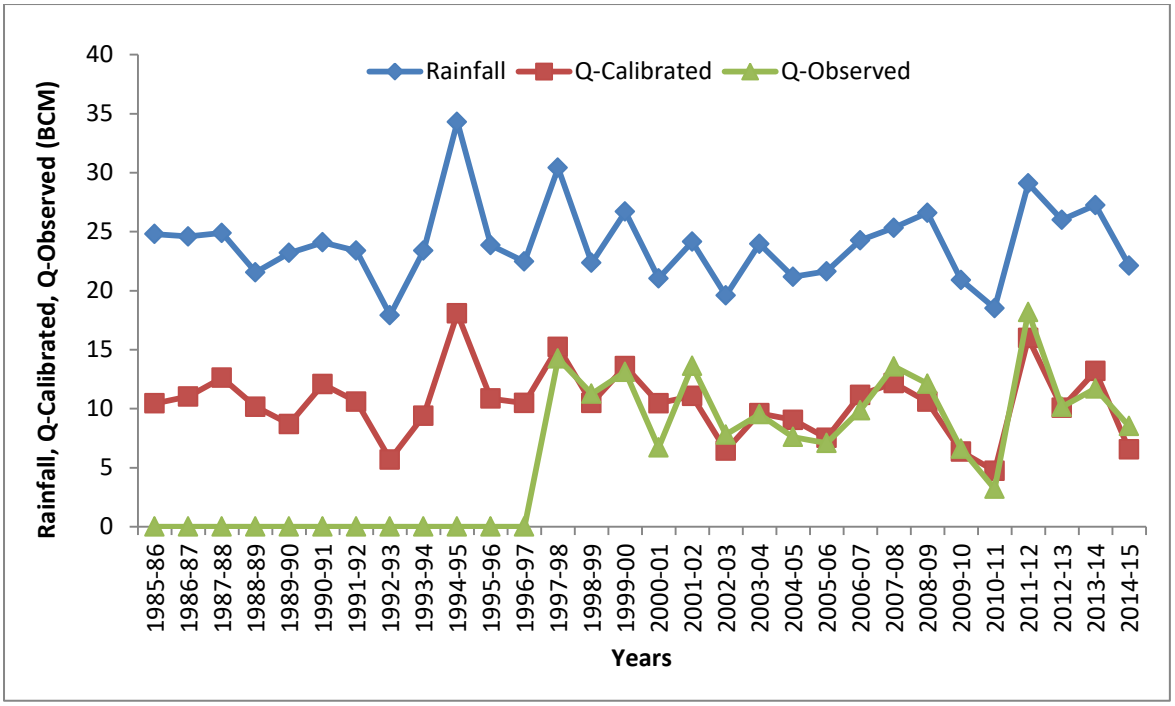


Figure 5.16 Calibrated runoff and observed discharge at Panposh

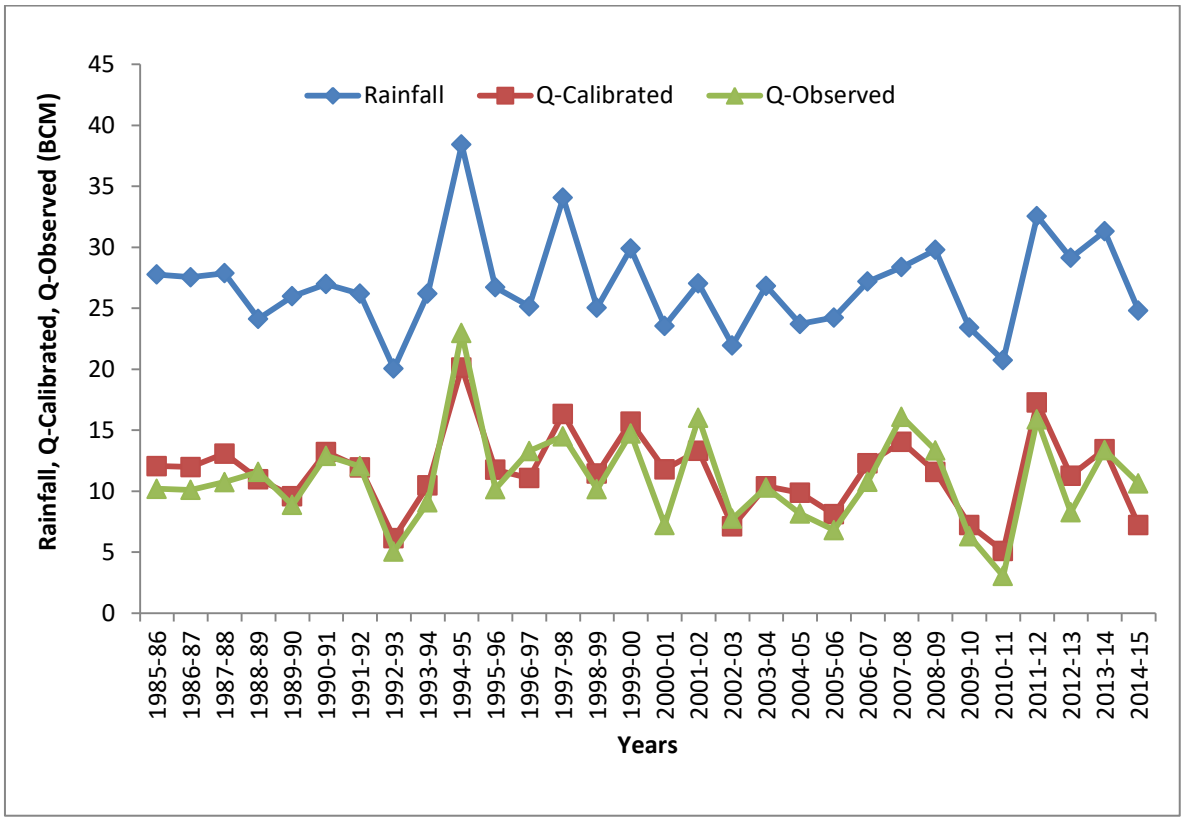


Figure 5.17 Calibrated runoff and observed discharge at Gomlai

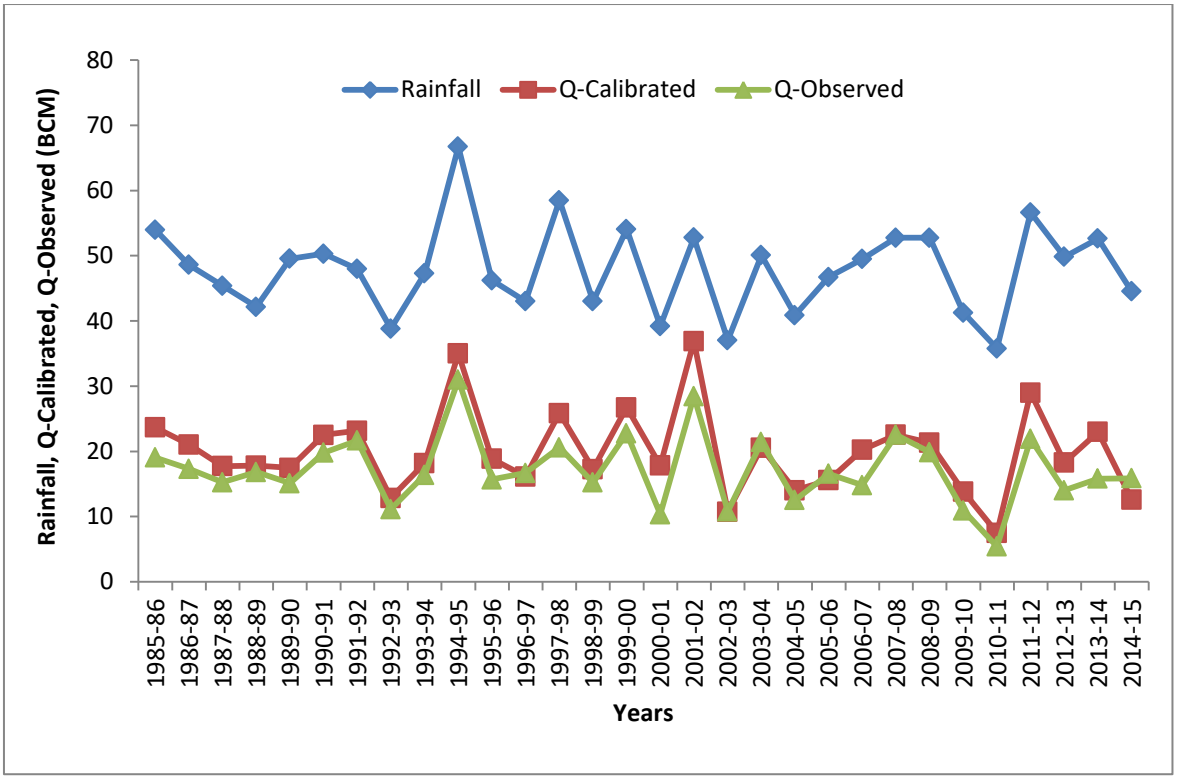


Figure 5.18 Calibrated runoff and observed discharge at Jenapur

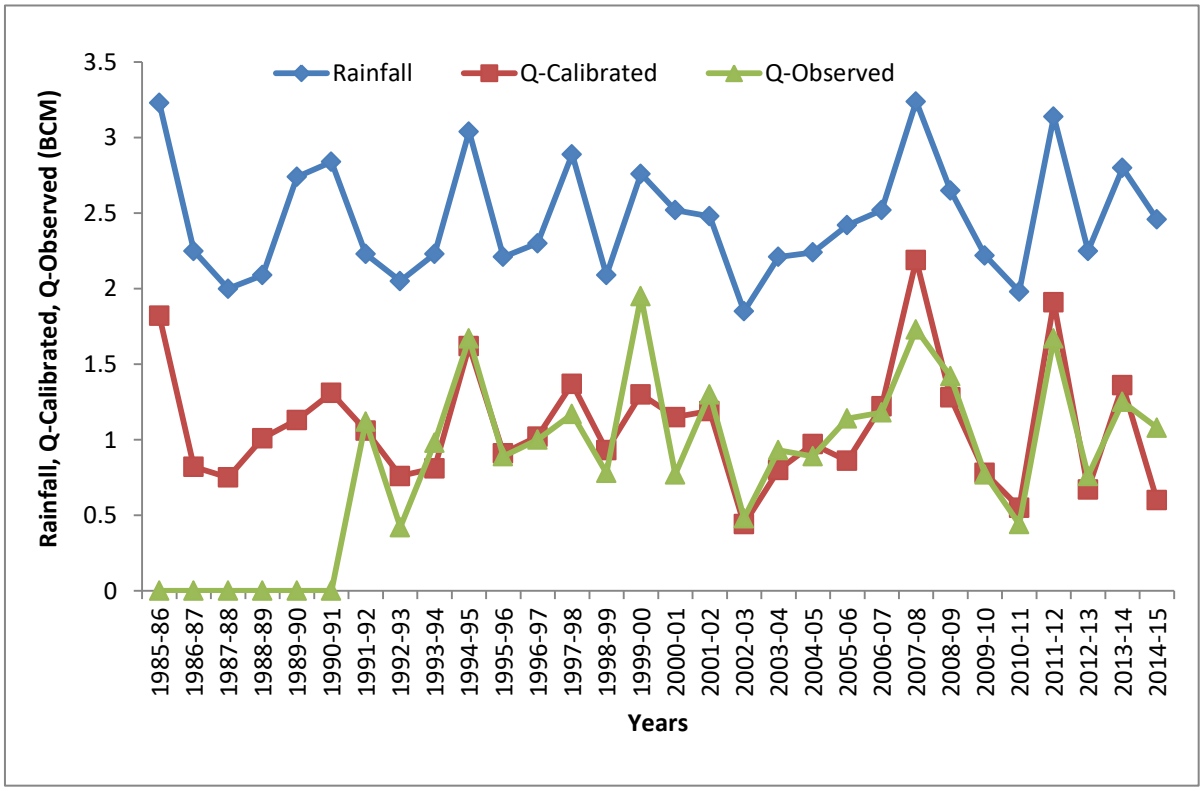


Figure 5.19 Calibrated runoff and observed discharge at Champua

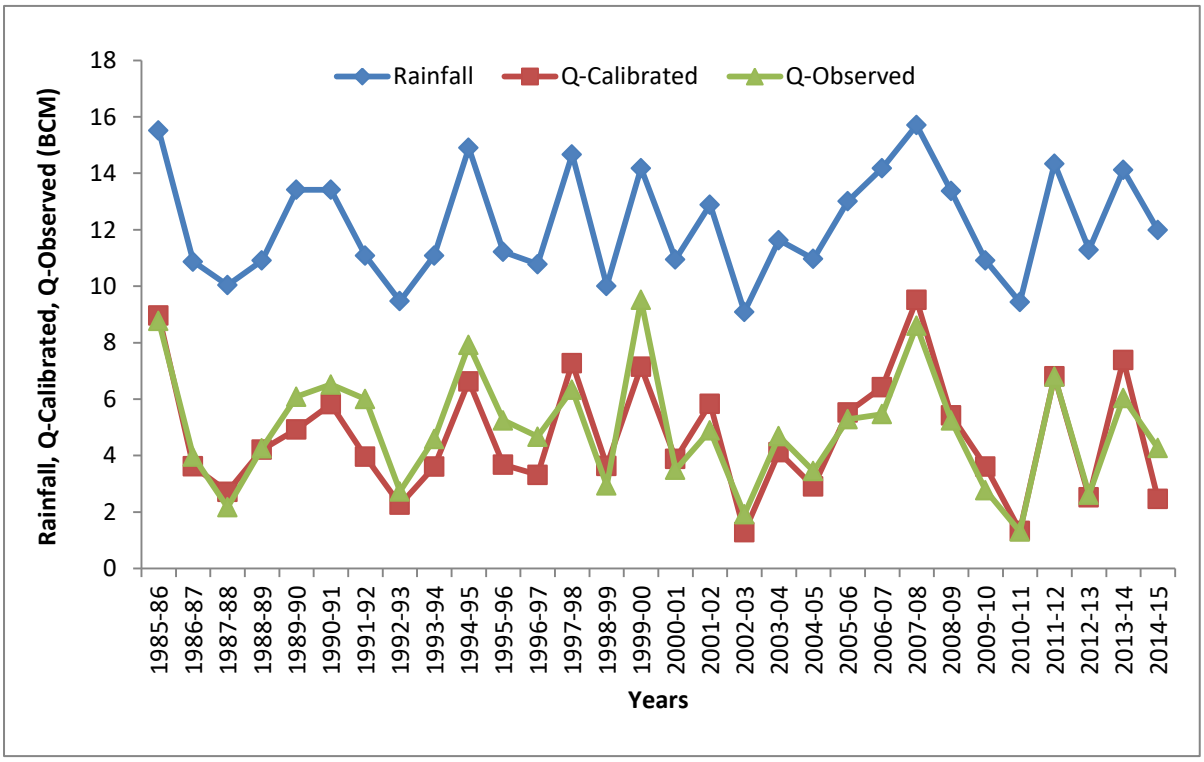


Figure 5.20 Calibrated runoff and observed discharge at Anandapur

Table - E.8 at Annexure - E gives calibrated runoff of Subernarekha basin for 30 years. The mean annual calibrated runoff is about 29.50 BCM. The maximum annual calibrated runoff is 48.90 BCM during 1994-95. The average annual ECII is about 5.05 BCM. The maximum annual ECII is about 7.94 BCM during 1996-97. The minimum annual ECII is about 2.82 BCM during 1985-86.

5.5 Annual Water Resources Availability of Brahmani-Baitarani Basin

Table - E.8 at Annexure - E shows the different components required to estimate the basin level water resources for 30 years. The maximum annual water resource is 54.78 BCM during 1994-95 in the 30 years. The minimum annual available water resource is 21.68 BCM during 2002-03 which is the driest year in the 30 years. The mean available basin water resource is 35.65 BCM. The mean available water resource of Brahmani-Baitarani basin accounts about 42.96% of mean annual rainfall during 1985-86 to 2014-15.

5.5.1 Annual water resources of Brahmani-Baitarani basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 1994-95 and 2002-03, extreme wet and dry rainfall conditions occurred in basin. The annual water resources of basin during these two extreme rainfall conditions are 54.78 BCM and 21.68 BCM, respectively as shown in Table - 5.3. The water balance components during these years are presented in the Figures 5.21 and 5.22.

Table - 5.3 Water resources availability in Brahmani-Baitarani basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources Availability (BCM)
Maximum Rainfall	1994-95	108.45	54.78
Minimum Rainfall	2002-03	63.39	21.68

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.51 and 0.34 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During high rainfall years, potential evapotranspiration is less compared to the dry years which will have cumulative effect in runoff. It is found that the ECII during 1994-95 is less than the year 2002-03.

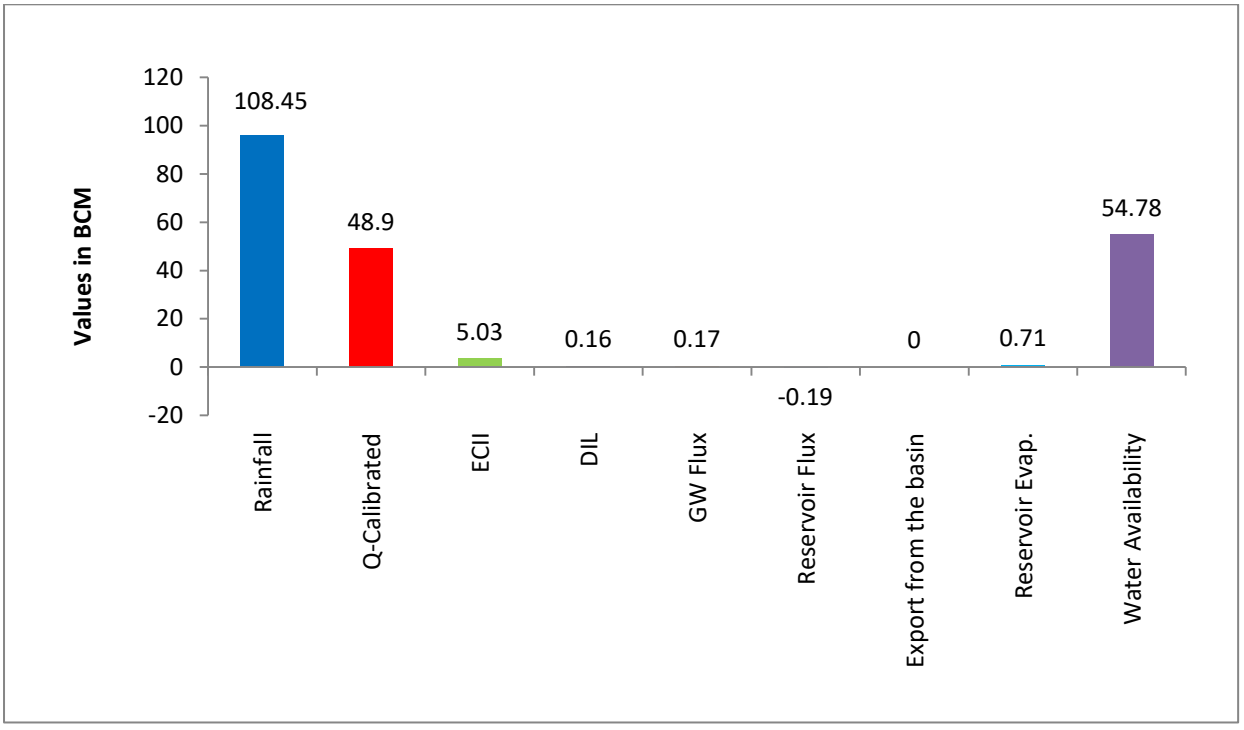


Figure 5.21 Water balance components of Brahmani-Baitarani basin during extreme high rainfall (1994-95)

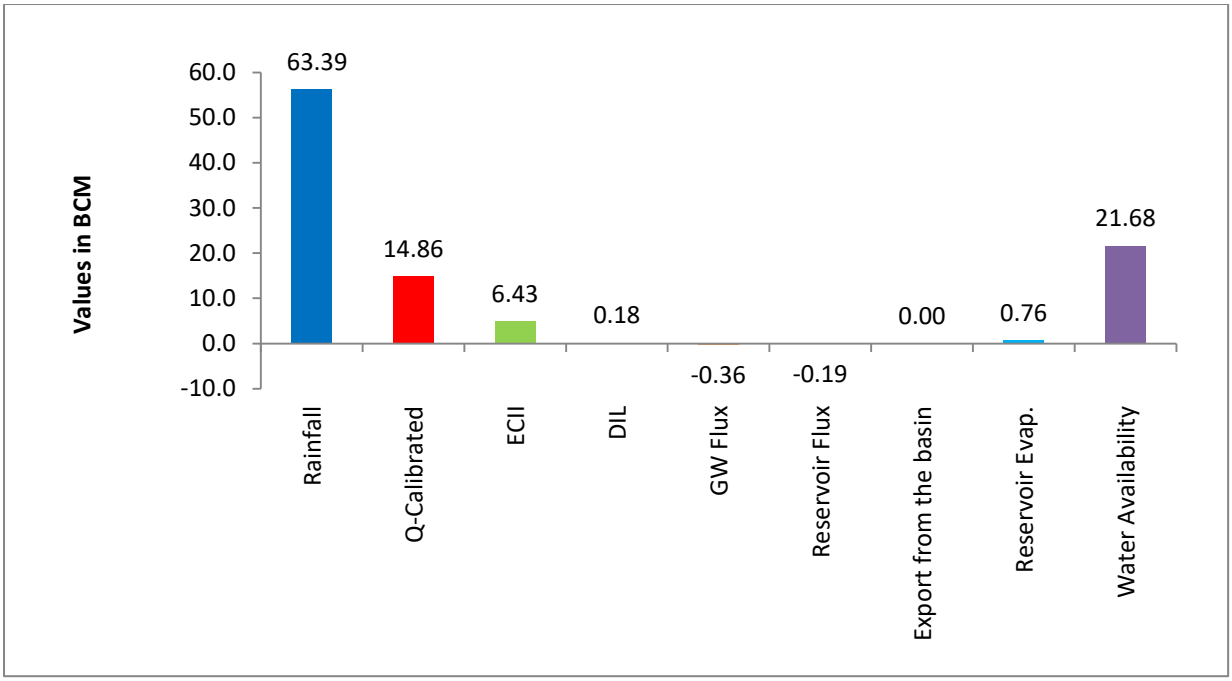


Figure 5.22 Water balance components of Brahmani-Baitarani basin during extreme low rainfall (2002-2003)

5.5.2 Mean water resources of Brahmani-Baitarani basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input with field preparation+ Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Evaporation from Reservoirs)

= 29.50 + 5.05 + 0.18 + 0.01 - 0.02 + 0.93 = 35.65 BCM

75% dependable flow of Brahmani-Baitarani basin = 25.00 BCM

Figure 5.23 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

It is observed that the computed runoff factors varies from 0.20 (1125 mm rainfall) to 0.50 (1891 mm rainfall). The mean runoff factor for 30 year period is 0.39.

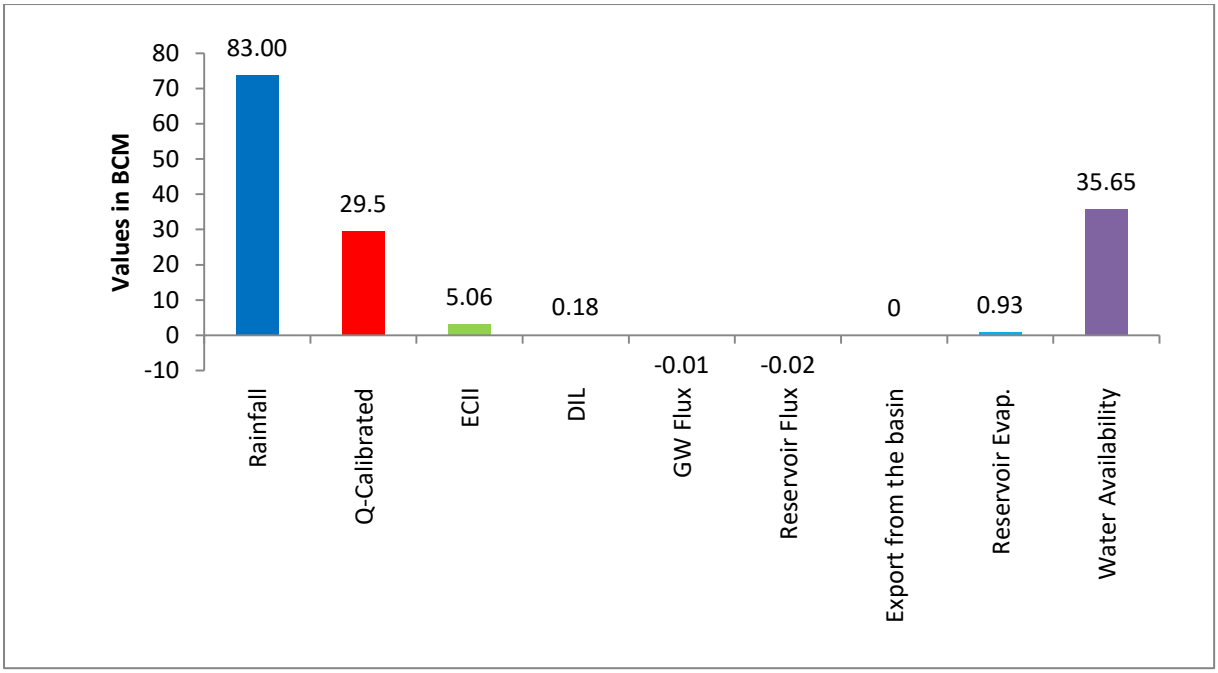
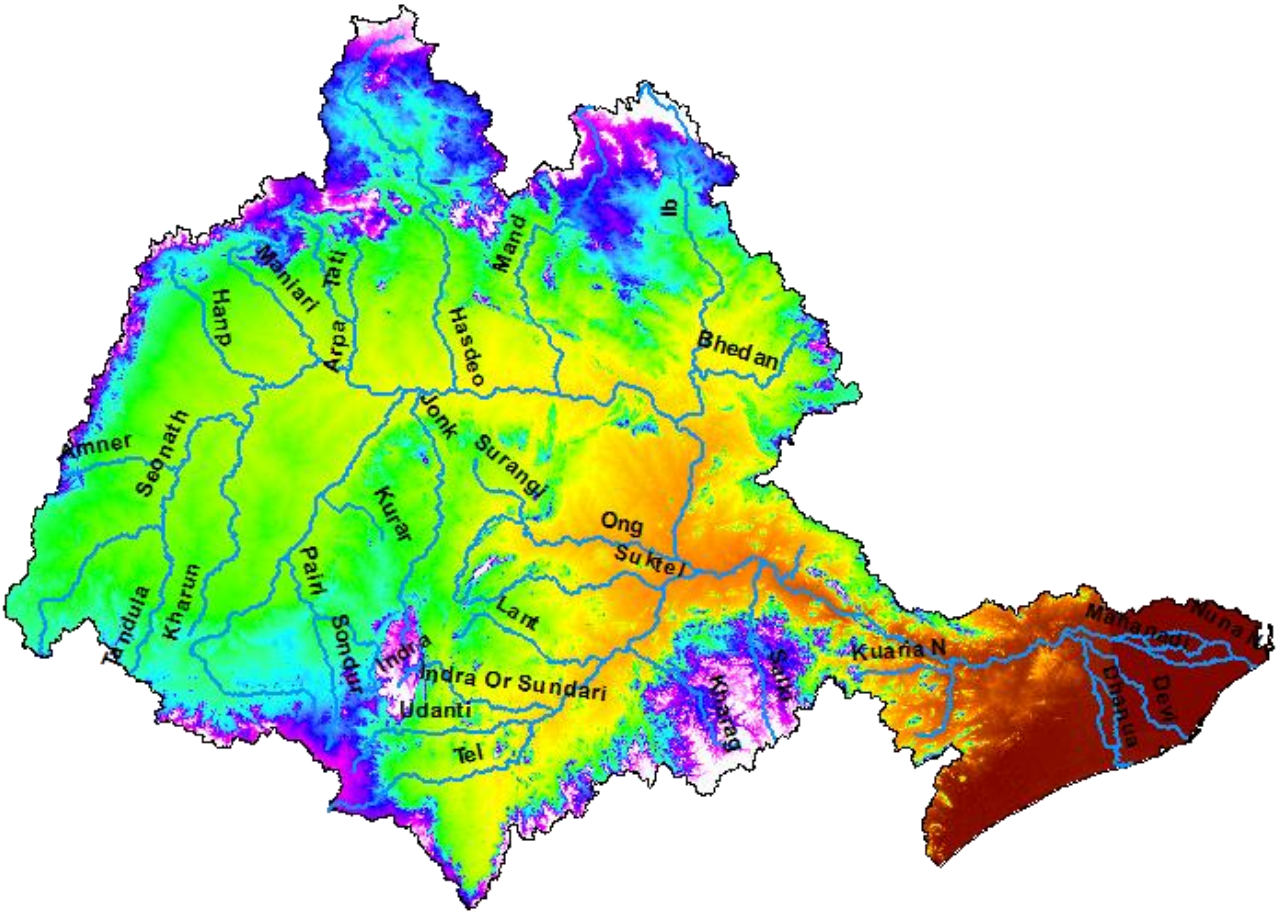


Figure 5.23 Mean water balance components of Brahmani-Baitarani basin

HIGHLIGHTS

- *Mean available water resource of Brahmani-Baitarani basin is 35.65 BCM.*
- *Maximum annual water availability is 54.78 BCM during 1994-95.*
- *Minimum annual water availability is 17.96 BCM during 2010-11.*
- *Annual rainfall in the basin varies from 1,108 mm to 1,891 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1,456 mm.*
- *Brahmani-Baitarani basin is divided into six sub-basins for the reassessment study viz. Tilga, Jaraikela, Panposh, Gomlai and Jenapur in Brahmani basin and Champua and Anandapur in Baitarani basin and combined delta region as one sub-basin.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.18 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.93 BCM.*

MAHANADI BASIN



6.1 Geo-Spatial Datasets

6.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of the basin is shown in Figure 6.1. The image corresponds to the 2004-05 year and consists of 17 different classes. The map indicates Double/Triple crop (25.99%) current fallow (25%) and Scrub/Deg Forest (11.80) are the major classes in Mahanadi basin (Figure 6.2).

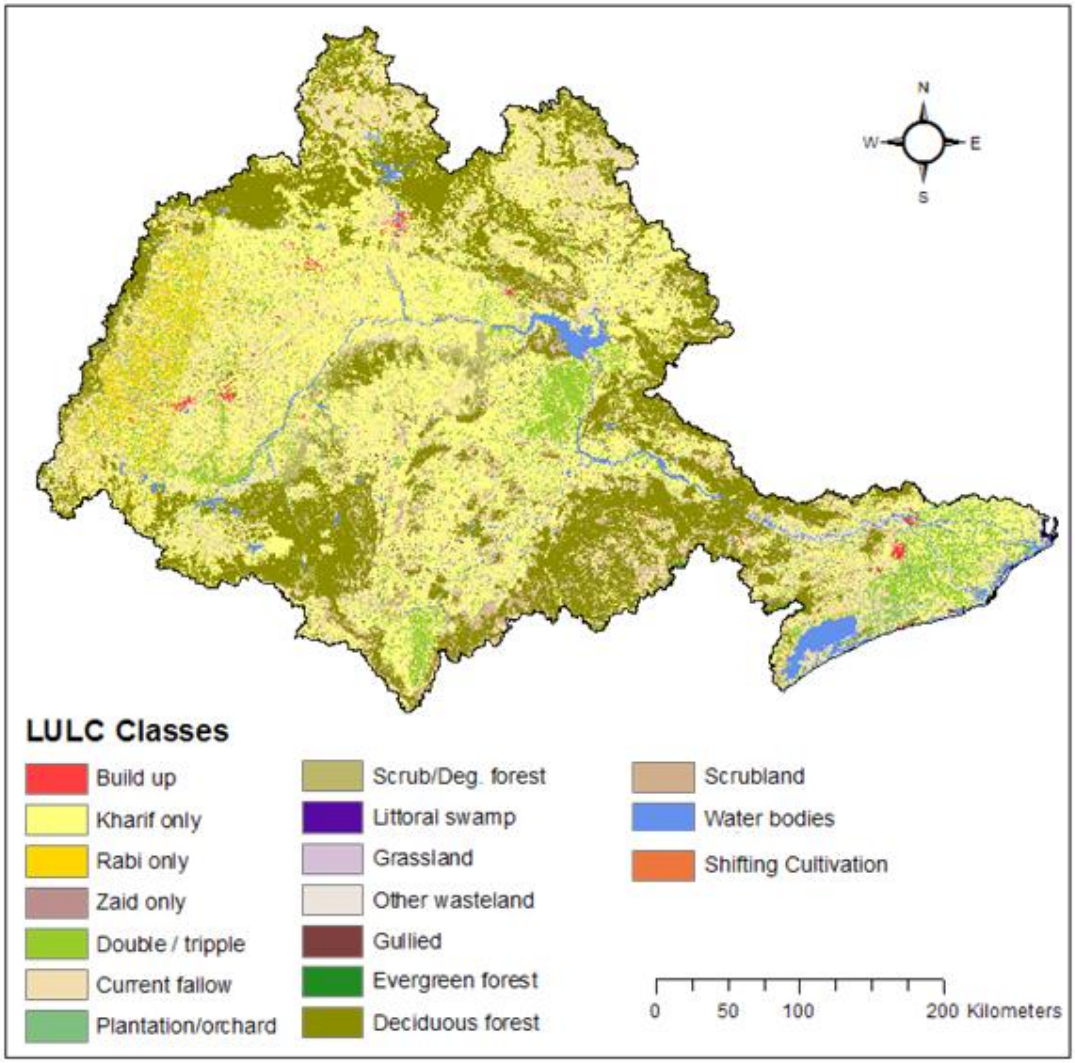


Figure 6.1 LULC map of Mahanadi basin (2004-05)

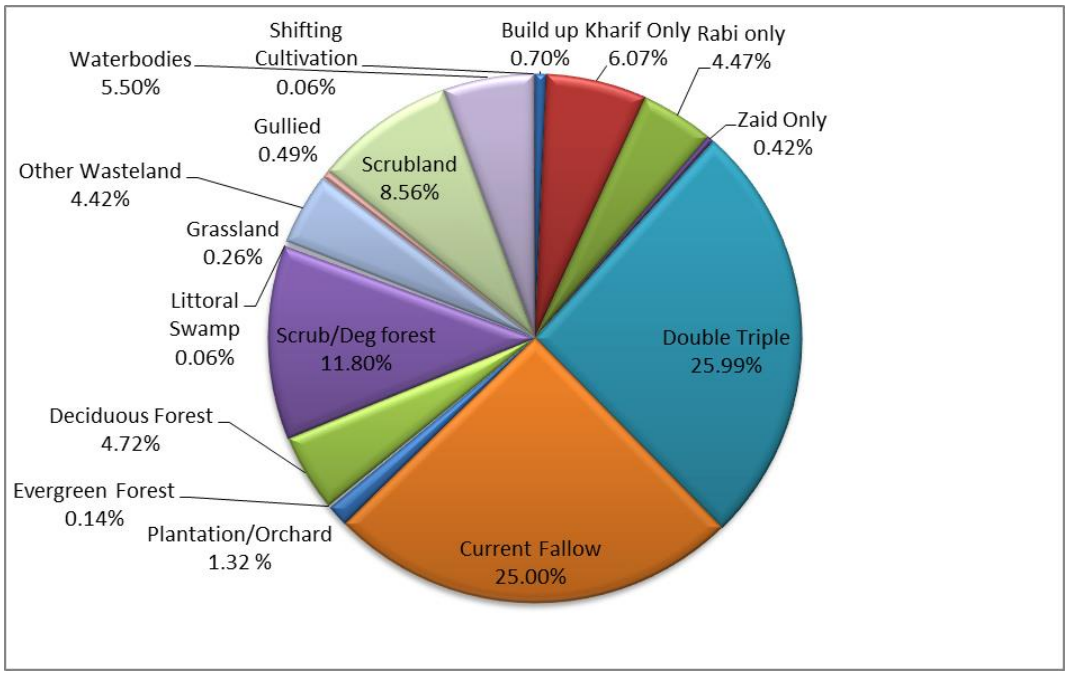


Figure 6.2 Distribution of LULC in Mahanadi basin (2004-05)

6.1.2 Soil texture

The main soil types found in the basin are sandy, clayey and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 6.3 shows various categories of soil in the basin. The soils are classified as sandy, loamy, clayey, clayey skeletal, loamy skeletal and rock outcrops based on the soil texture information.

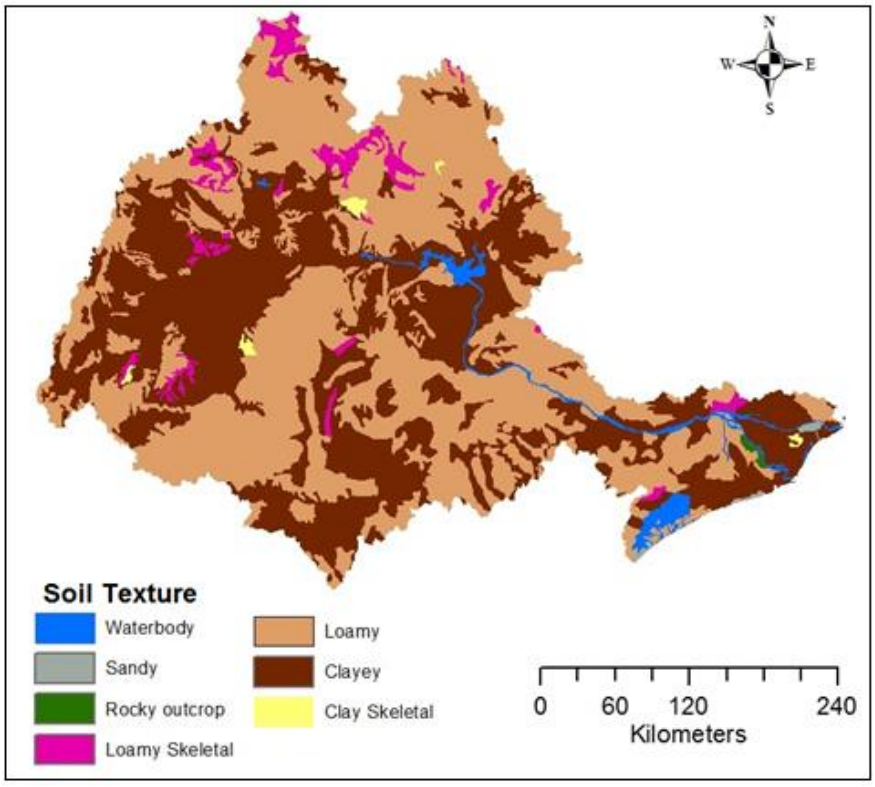


Figure 6.3 Soil texture map of Mahanadi basin

6.1.3 Topography

The topography of the basin consists of the Northern Plateau, the Eastern Ghats, the Coastal Plain and the erodible plains of Central Table Land. The first two are hilly regions. The Coastal plain is the fertile delta area. The central table land is the central interior region of the basin, traversed by the river and its tributaries. The elevation values ranges from a minimum of 0 m to a maximum of 1,321 m. The average elevation is about 321 m in the basin. Figure 6.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Mahanadi basin.

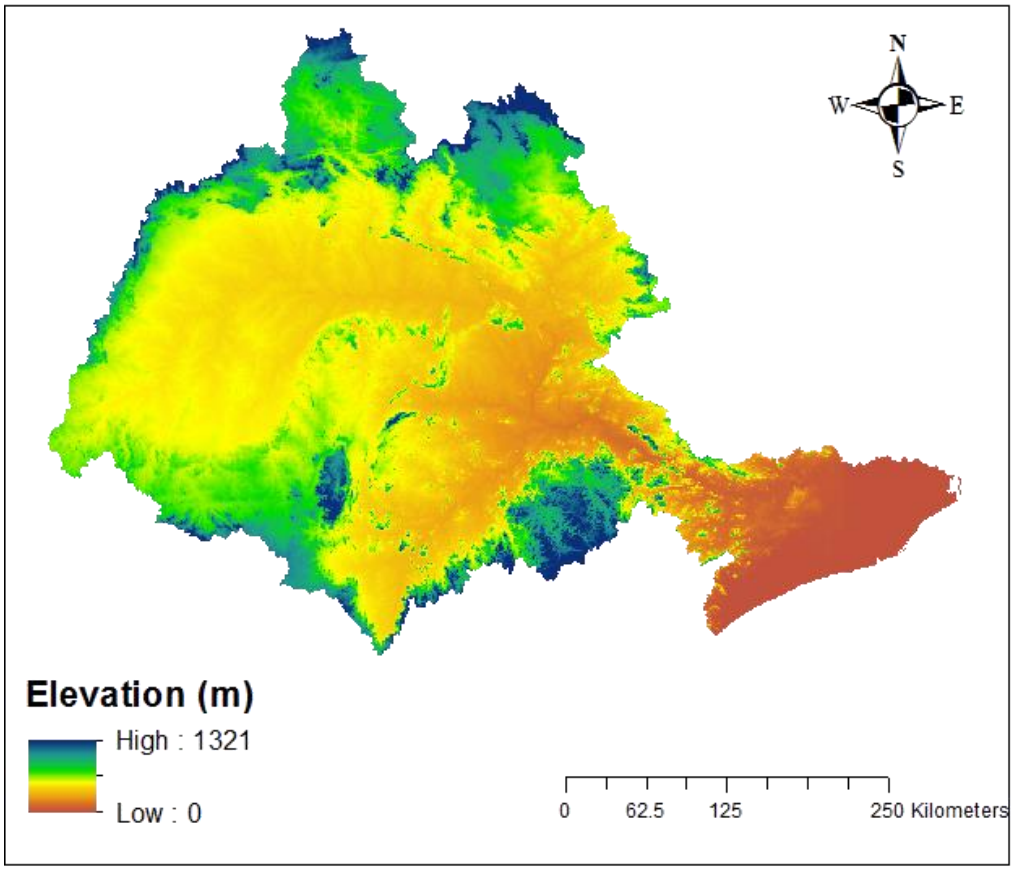


Figure 6.4 SRTM DEM map of Mahanadi basin

6.2 Hydro-Meteorological and other Input Data

6.2.1 Rainfall grids

Figure 6.5 shows gridded annual rainfall of Mahanadi Basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 6.6. Annual rainfall of the basin varies from 923 mm to 1,905 mm and mean rainfall of these 30 years is found to be 1,317 mm. Of the 30 years, for 15 years annual rainfall is higher than the mean rainfall and for remaining 15 years lower than the mean rainfall.

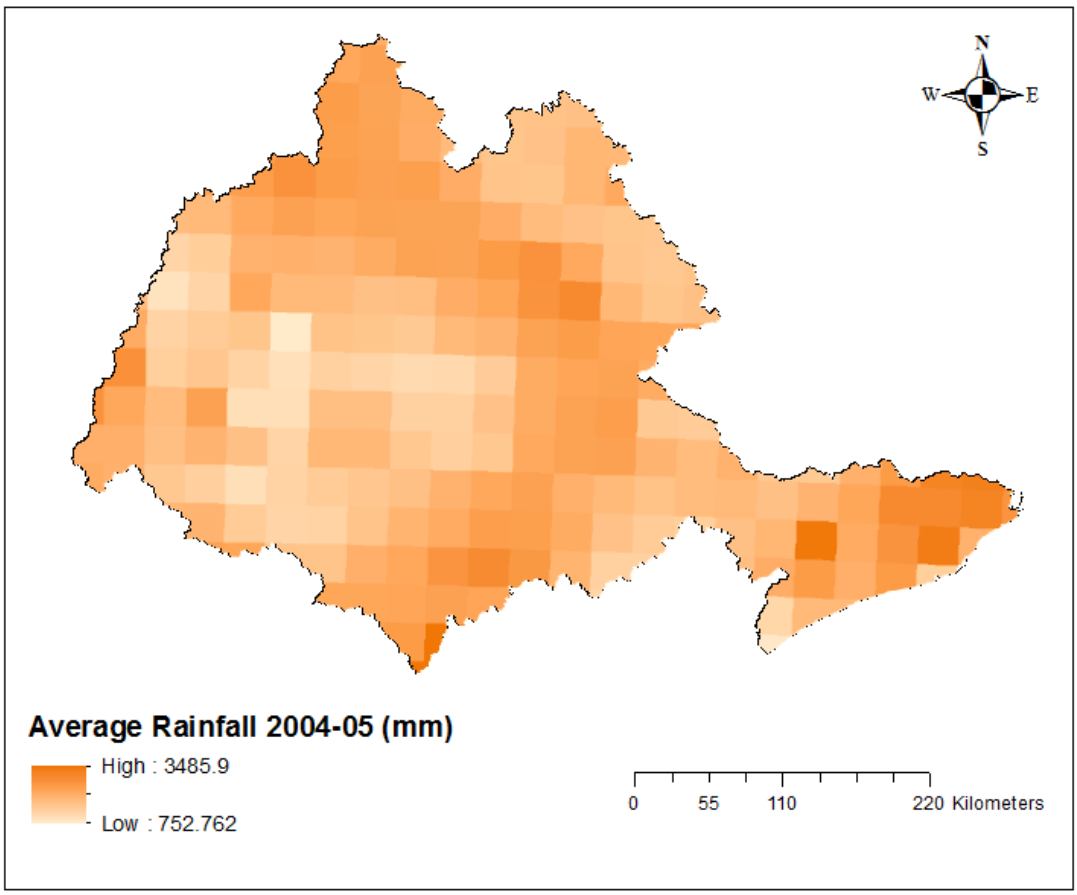


Figure 6.5 Gridded rainfall of Mahanadi basin (2004-05)

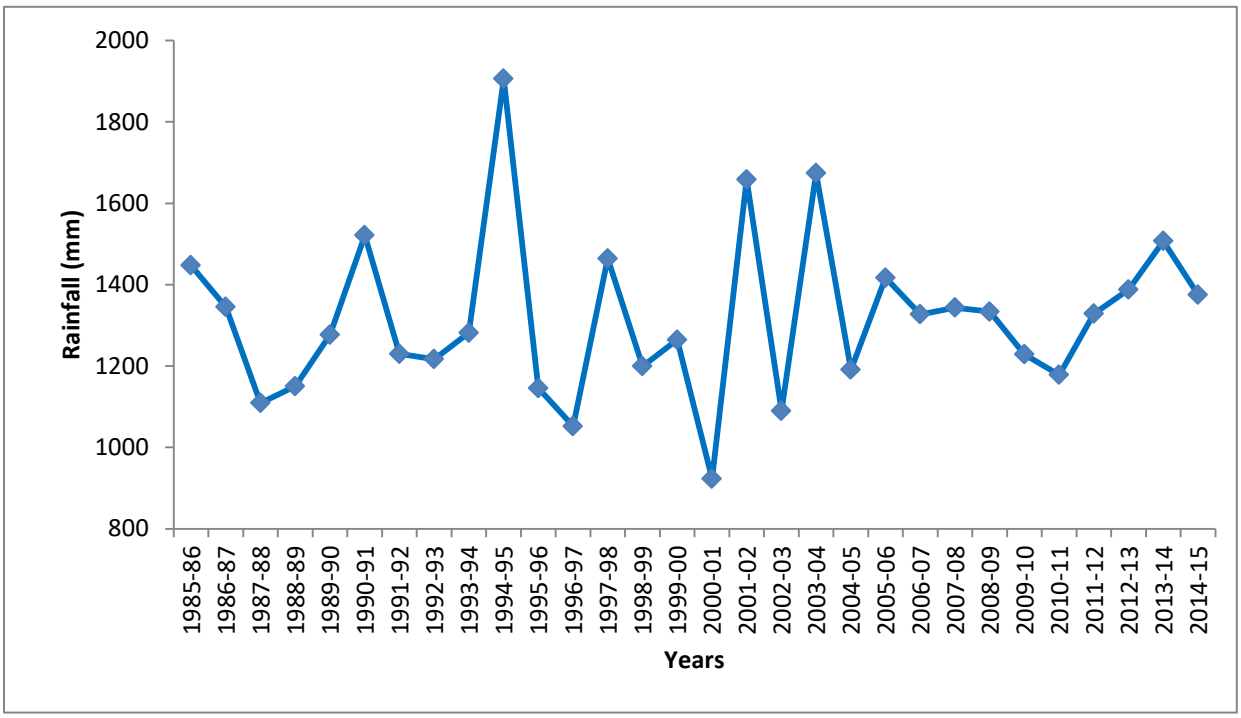


Figure 6.6 Annual rainfall of Mahanadi basin (1985-86 to 2014-15)

6.2.2 Temperature grids

Gridded mean annual temperature of Mahanadi basin in 2004-05 is shown in Figure 6.7. The mean annual maximum temperature during 2004-05 was about 27.75°C and mean annual minimum temperature about 26.22°C.

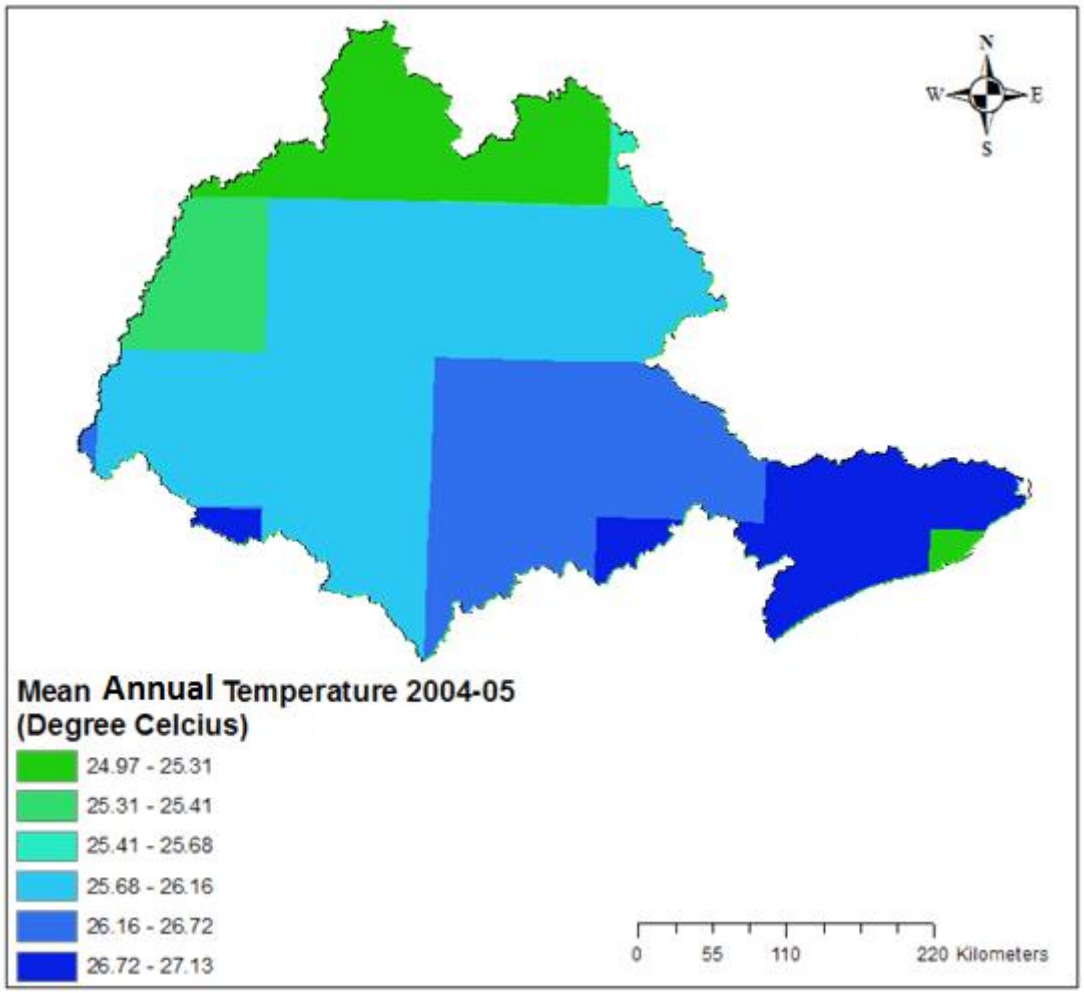


Figure 6.7 Gridded mean annual temperature of Mahanadi basin (2004-05)

6.2.3 Sub-basins of Mahanadi basin

The Mahanadi basin is divided into 6 sub-basins (Figure 6.8) viz. Bamnidih, Jondhra, Basantpur, Kantamal, Tikarpara and combined delta region as one sub-basin. Table - 6.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

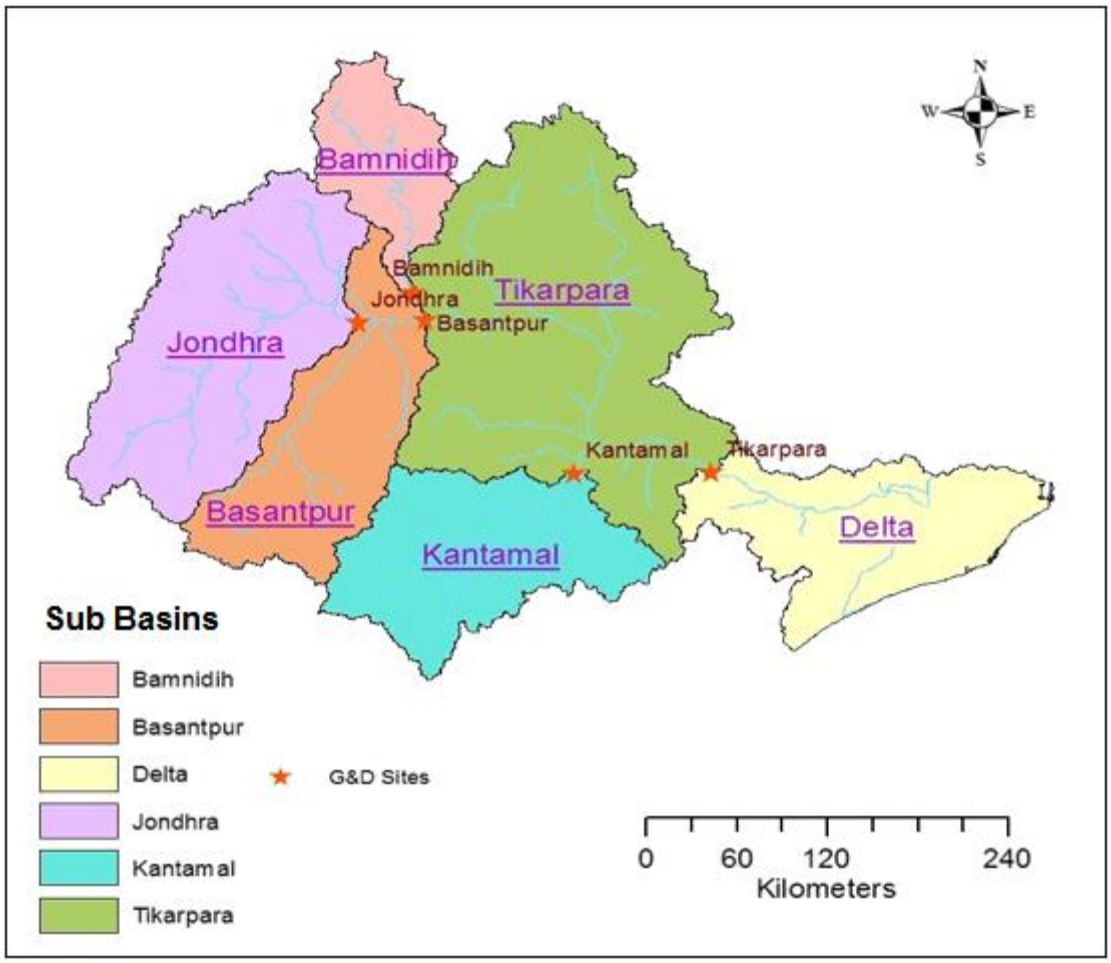


Figure 6.8 Sub-basins of Mahanadi basin

Table - 6.1 Sub-basin wise details of Mahanadi basin

S No	Sub-basin	River	Individual drainage area (sq.km)
1	Bamnidih	Hasdeo	9,761
2	Jondhra (including sigma)	Seonath	29,609
3	Basantpur	Mahanadi	19,404
4	Kantamal	Tel	20,216
5	Tikarpara	Mahanadi	46,376
6	Delta	Mahanadi	19,539
		Total basin area	1,44,905

6.2.4 River discharge

The river discharge data was available at all the 5 sites (Basantpur, Tikarpara located on main Mahanadi, Bamnidih and Jondhra located on left flank tributary Hasdeo and Seonath respectively and Kantamal on right flank tributary Tel) for the study period of 30 years. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level.

6.2.5 Reservoir flux

Figure 6.9 shows the location of some of major reservoirs in Mahanadi basin. The data of 3 Major reservoirs such as Hirakud Dam, Minimata Bango Dam and Ravishankar Dam maintained by CWC and 5 medium projects data received from State Governments were considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed discharge.

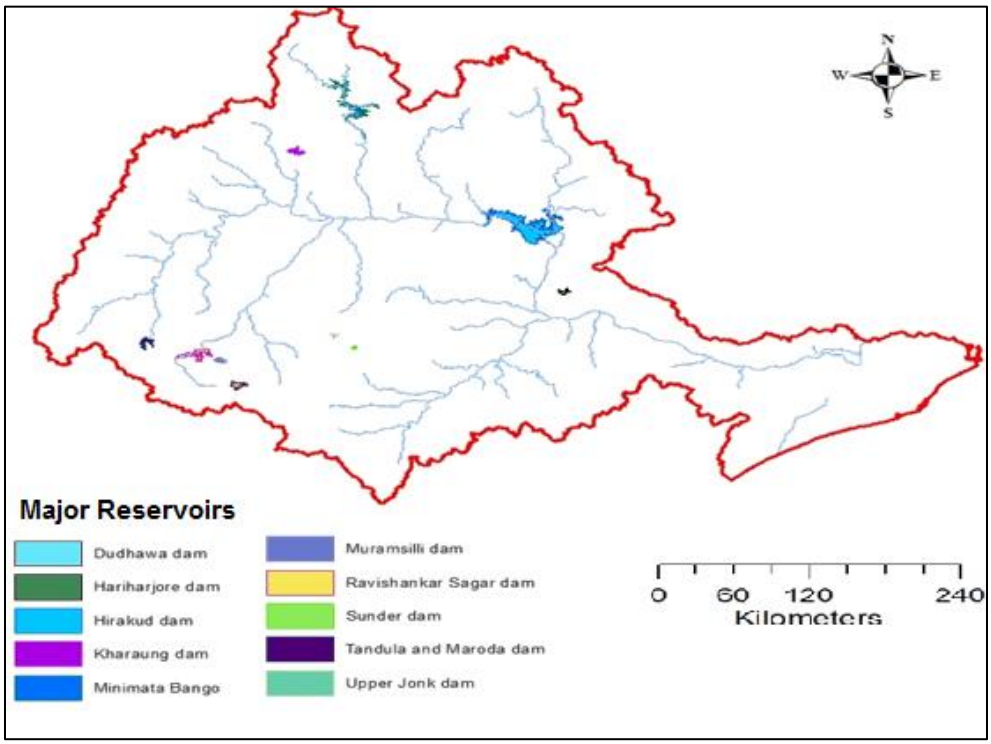


Figure 6.9 Major reservoirs in Mahanadi basin

6.2.6 Groundwater flux

The spatial variation of annual groundwater flux for year 2004-05 is shown in Figure 6.10 and annual groundwater flux variation for 1985-86 to 2014-15 is shown in Figure 6.11.

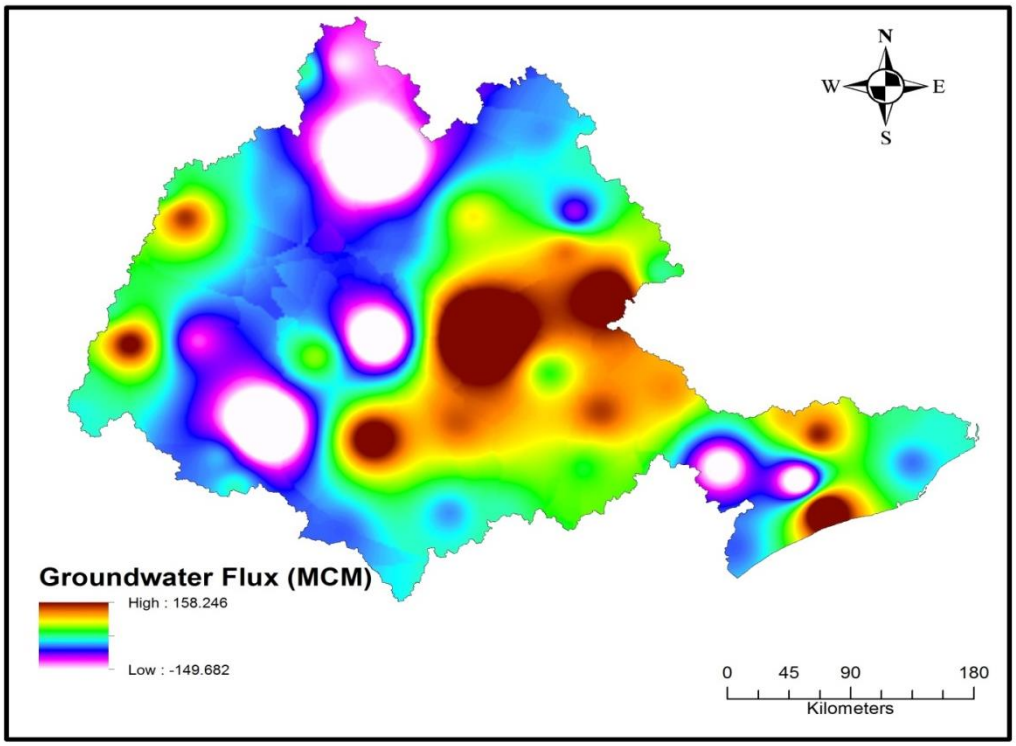


Figure 6.10 Groundwater flux (spatial data) estimated during 2004-05

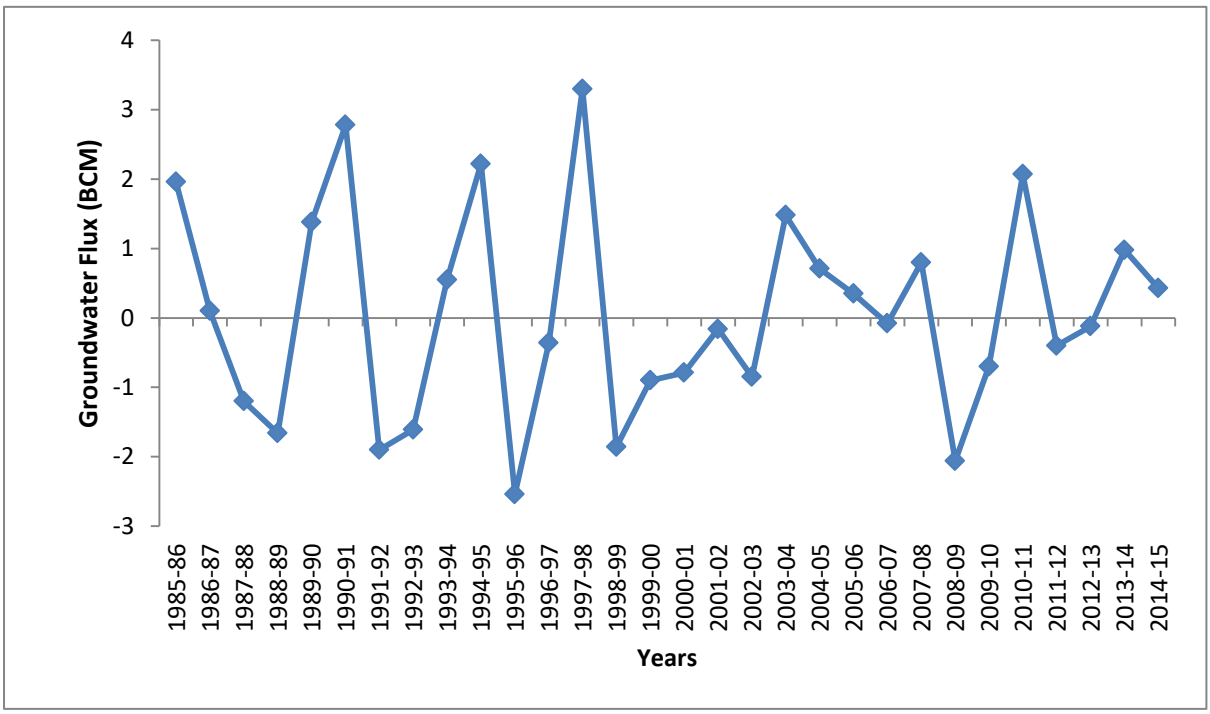


Figure 6.11 Annual groundwater flux of Mahanadi basin (1985-1986 to 2014-2015)

6.2.7 Major crops in the basin

Based on the district-wise crop area statistics district wise major crops for each crop season were identified. The Mahanadi basin was divided into 24 (varying year to year) regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/

dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Rabi only season in a district, if gram is a major crop, it may be wheat in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if wheat is a major crop in Rabi only season, it may be linseed during 2006-07. Different major crops for each season are emerged.

6.2.8 Irrigation command area

Figure 6.12 shows location of irrigation command boundaries inside and outside the Mahanadi basin considered for the year 2004-05. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence, the command area considered during the year 1985-86 was worked out to be around 13,82,500 hectare while it was 30,67,600 hectare in 2014-15.

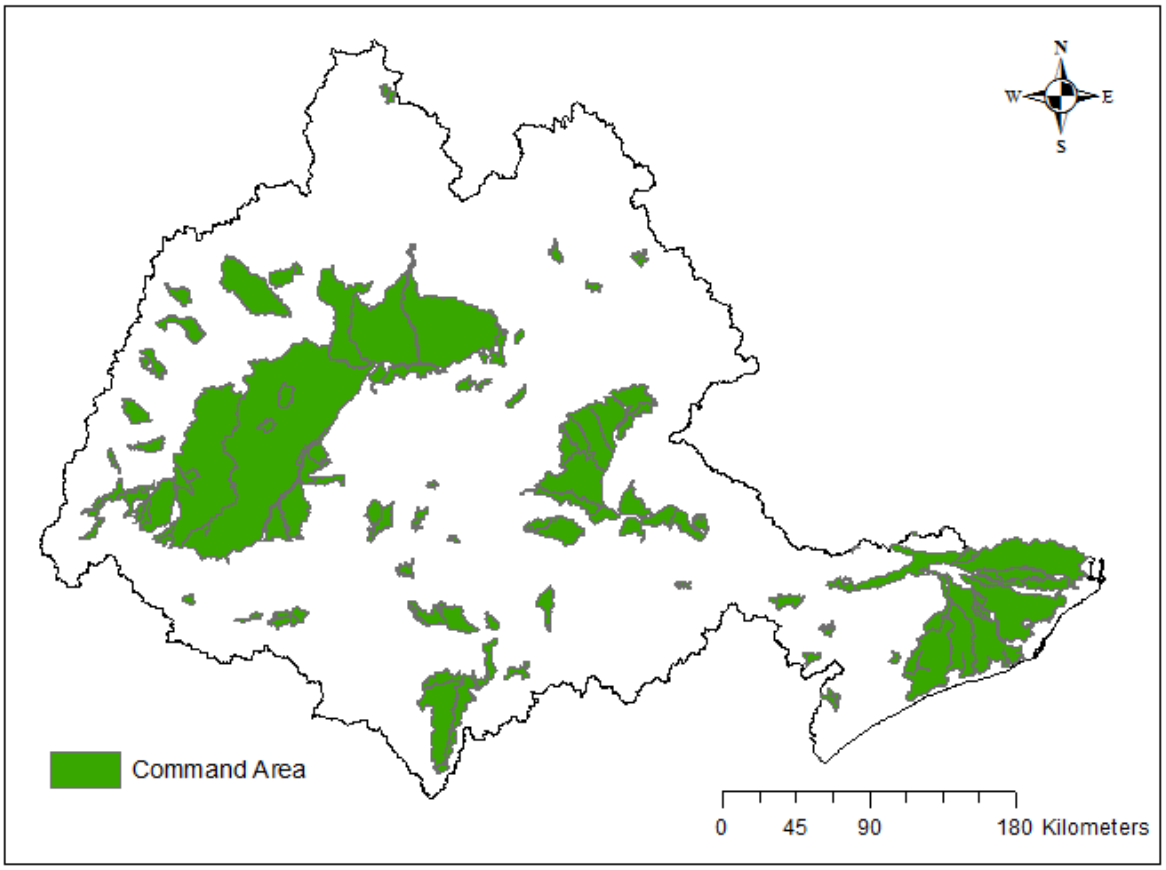


Figure 6.12 Irrigation command boundaries of Mahanadi basin

6.2.9 Domestic, industrial and livestock demand

Figure 6.13 shows district boundaries layer with district population for the year 2011 census. The mean annual domestic, industrial and livestock demands are estimated at 0.20 BCM in the basin.

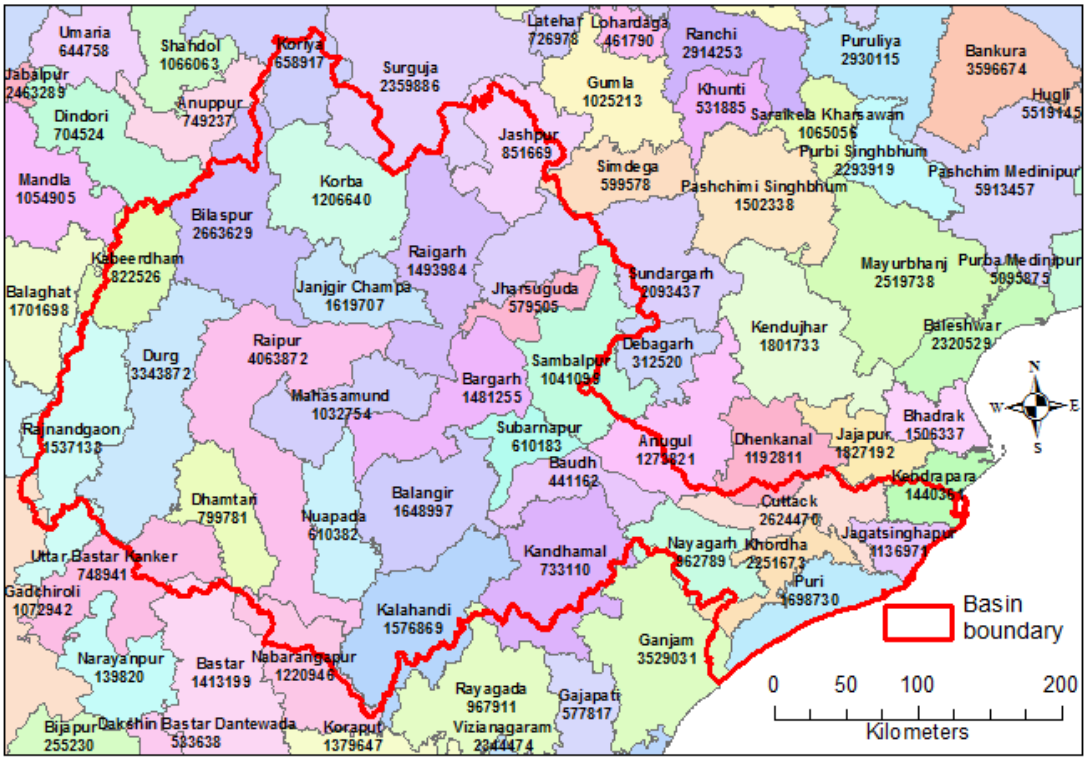


Figure 6.13 District boundaries in Mahanadi basin

6.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 6.2 provides annual evaporation values from each of sub-basins for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for the basin is worked out as 1.41 BCM. It has been observed that the major reservoir viz. Hirakud dam contributes more evaporation losses.

Table - 6.2 Evaporation in the reservoirs of Mahanadi basin

Year	Reservoir evaporation in each independent sub-basin (BCM)						
	Bamnidih	Jondhra	Basantpur	Kantamal	Tikarpara	Delta	Total
1985-1986	0.20	0.18	0.61	0.01	1.29	0.27	1.56
1986-1987	0.23	0.20	0.68	0.01	1.36	0.32	1.68
1987-1988	0.07	0.07	0.28	0.01	0.88	0.24	1.12
1988-1989	0.09	0.09	0.38	0.02	1.16	0.48	1.64
1989-1990	0.08	0.07	0.34	0.01	0.99	0.29	1.28
1990-1991	0.30	0.27	0.89	0.01	1.56	0.31	1.87
1991-1992	0.11	0.10	0.35	0.01	0.77	0.29	1.06
1992-1993	0.11	0.10	0.36	0.01	0.84	0.24	1.08
1993-1994	0.13	0.11	0.40	0.01	1.02	0.25	1.27
1994-1995	0.31	0.27	0.91	0.01	1.58	0.32	1.90
1995-1996	0.12	0.11	0.37	0.01	0.90	0.24	1.14
1996-1997	0.13	0.11	0.38	0.01	0.95	0.22	1.17

1997-1998	0.33	0.29	0.91	0.01	1.58	0.30	1.88
1998-1999	0.15	0.14	0.49	0.01	1.18	0.31	1.49
1999-2000	0.16	0.14	0.52	0.02	1.35	0.45	1.80
2000-2001	0.15	0.14	0.48	0.02	1.27	0.40	1.67
2001-2002	0.13	0.11	0.40	0.01	0.96	0.26	1.22
2002-2003	0.15	0.14	0.51	0.02	1.30	0.44	1.74
2003-2004	0.09	0.08	0.43	0.01	1.11	0.26	1.37
2004-2005	0.16	0.15	0.53	0.02	1.32	0.41	1.73
2005-2006	0.14	0.13	0.44	0.01	1.15	0.26	1.41
2006-2007	0.09	0.08	0.28	0.01	0.77	0.24	1.01
2007-2008	0.13	0.11	0.43	0.01	1.09	0.27	1.36
2008-2009	0.13	0.11	0.41	0.01	0.85	0.21	1.06
2009-2010	0.10	0.09	0.32	0.01	0.79	0.27	1.06
2010-2011	0.12	0.11	0.41	0.01	1.11	0.30	1.41
2011-2012	0.12	0.11	0.36	0.01	0.93	0.22	1.15
2012-2013	0.18	0.17	0.55	0.01	1.27	0.16	1.43
2013-2014	0.25	0.22	0.75	0.01	1.43	0.19	1.62
2014-2015	0.07	0.07	0.27	0.01	0.83	0.16	1.03
Avg.	0.15	0.14	0.48	0.01	1.12	0.29	1.41

6.3 Runoff Estimation

The observed discharges are available for the sites Basantpur and Tikarpara on Mahanadi river; Bamnidih on river Hasdeo; Jondhra on river Seonath and Kantamal on river Tel. The model estimated runoff is calibrated against the observed discharge at all these 5 locations. Computed runoff at Deltaic region is added to the whole basin without any calibration, since it does not have any observed discharges. Tables F.1 to F.5 at Annexure - F give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for these discharge stations. Figure 6.14 shows comparison between mean observed discharge and mean calibrated runoff at various gauge stations. Figures 6.15 to 6.19 show comparative graphs of calibrated runoff and observed discharge at these discharge stations.

Table - F.6 gives calibrated runoff of Mahanadi basin for years 1985-86 to 2014-15. The mean annual calibrated runoff is about 54.80 BCM. The maximum annual calibrated runoff is 117.74 BCM during 1994-95. The minimum annual calibrated runoff is 19.56 BCM during 2000-2001. The mean annual ECII is about 16.24 BCM. The maximum annual ECII is about 29.962 BCM during 2009-10. The minimum annual ECII is about 10.572 BCM during 2000-2001.

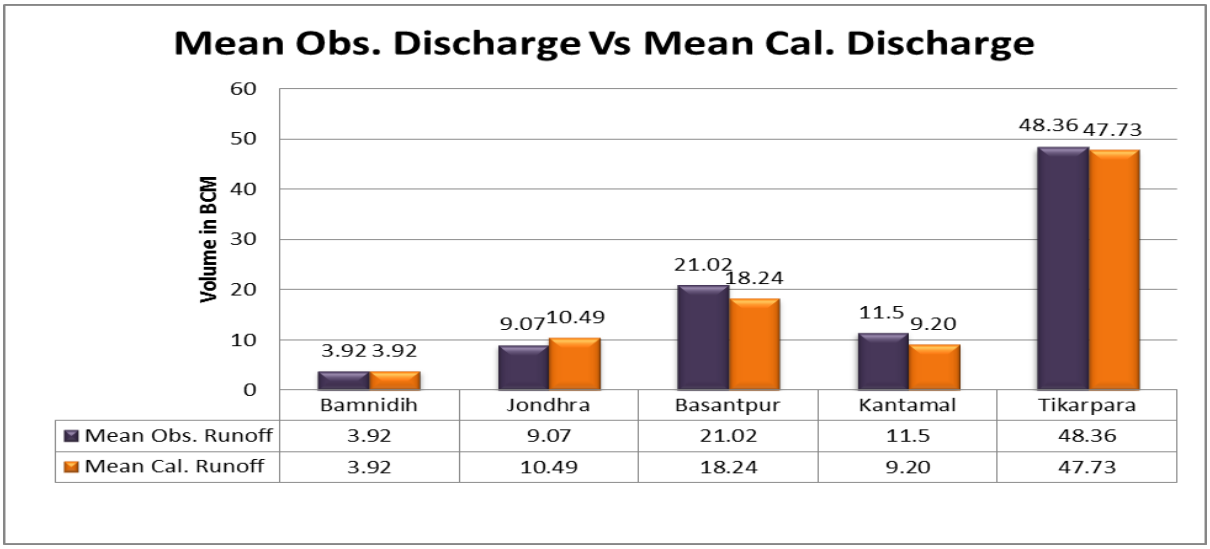


Figure 6.14 Calibrated runoff and observed at various gauge stations

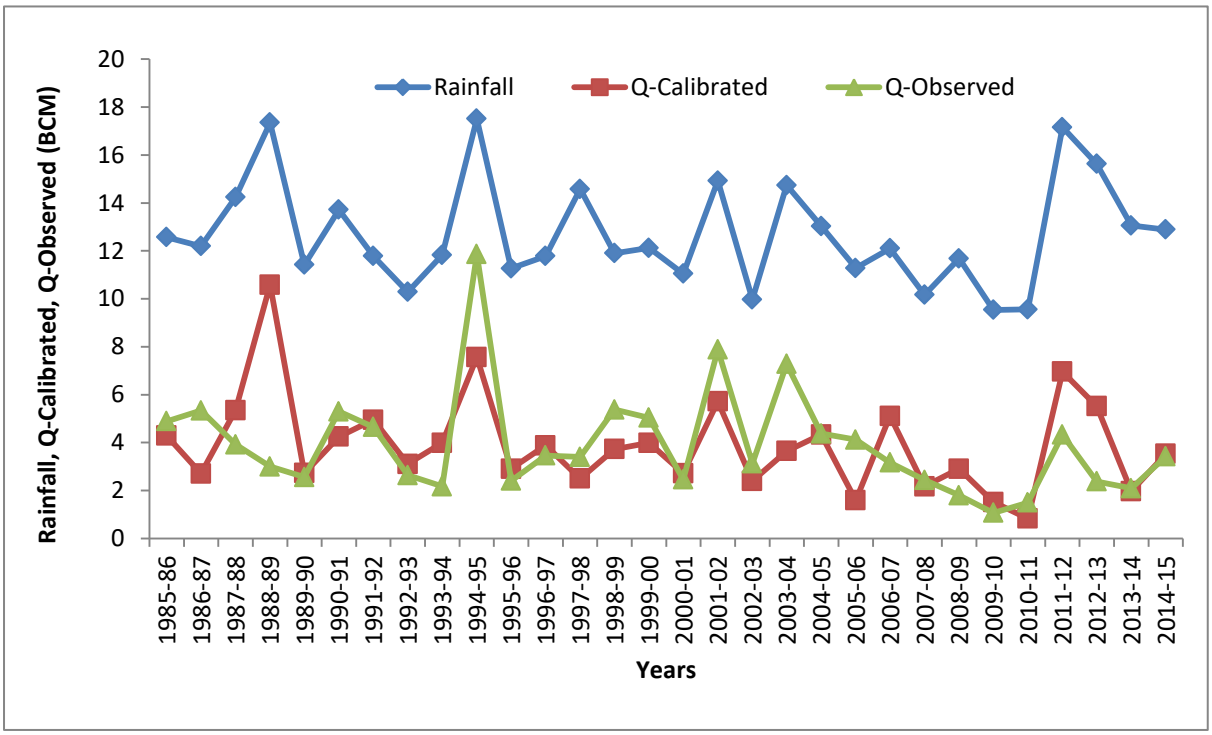


Figure 6.15 Calibrated runoff and observed discharge at Bamnidih

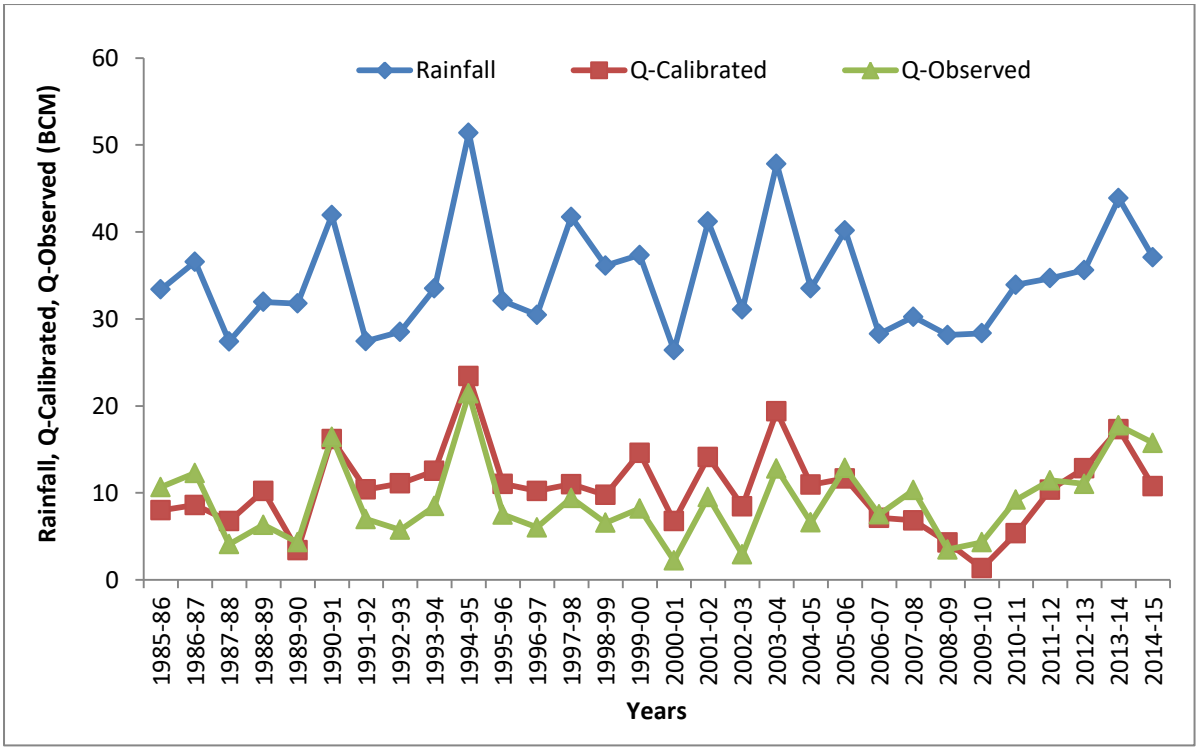


Figure 6.16 Calibrated runoff and observed discharge at Jondhra

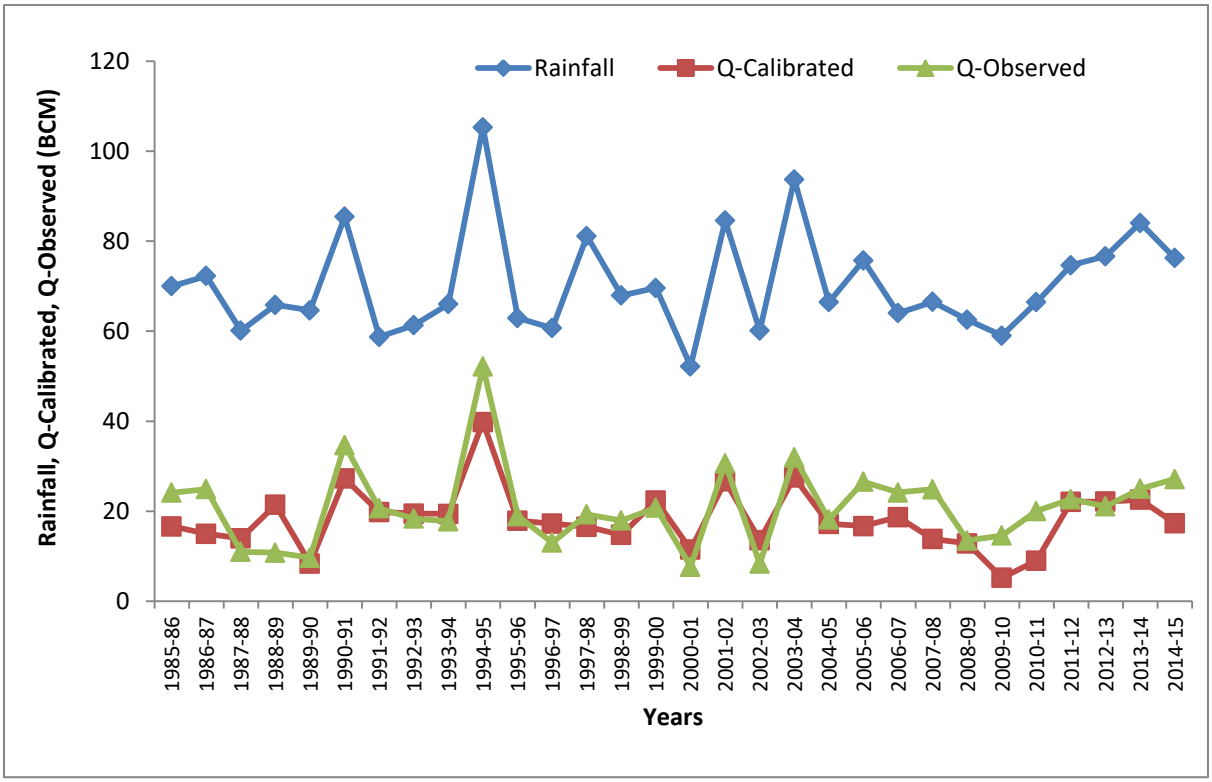


Figure 6.17 Calibrated runoff and observed discharge at Basantpur

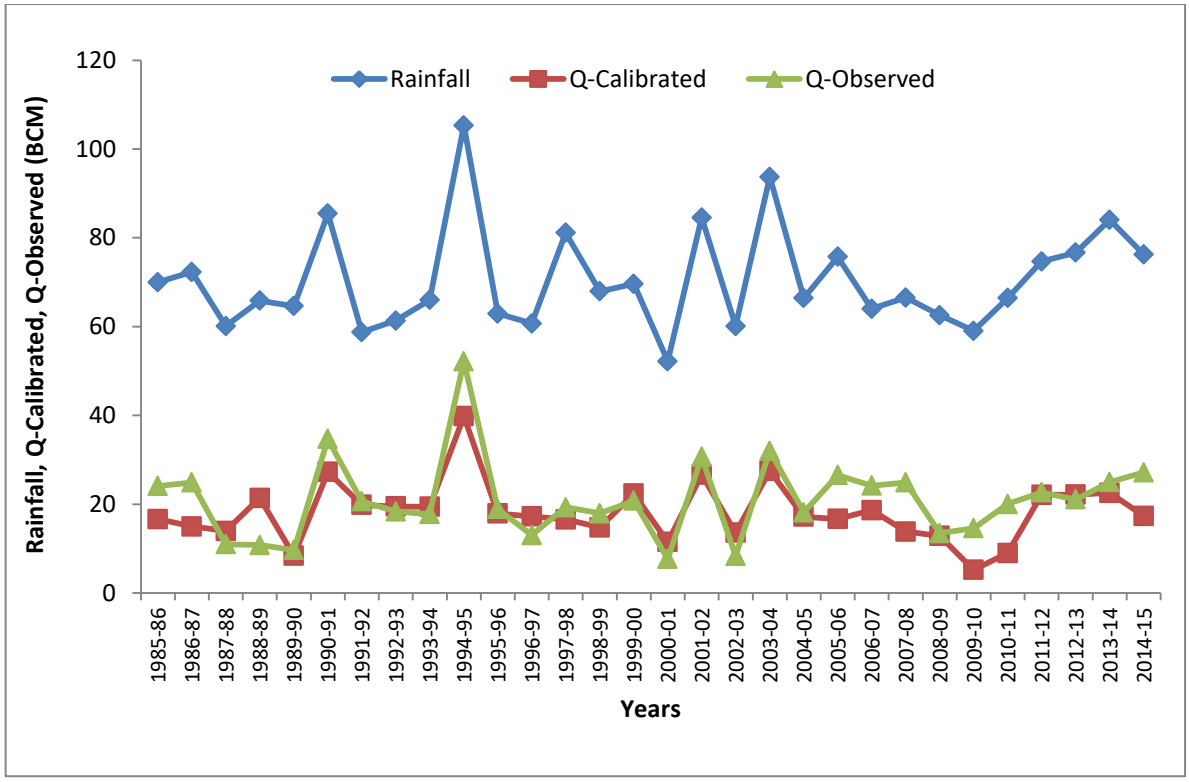


Figure 6.18 Calibrated runoff and observed discharge at Kantamal

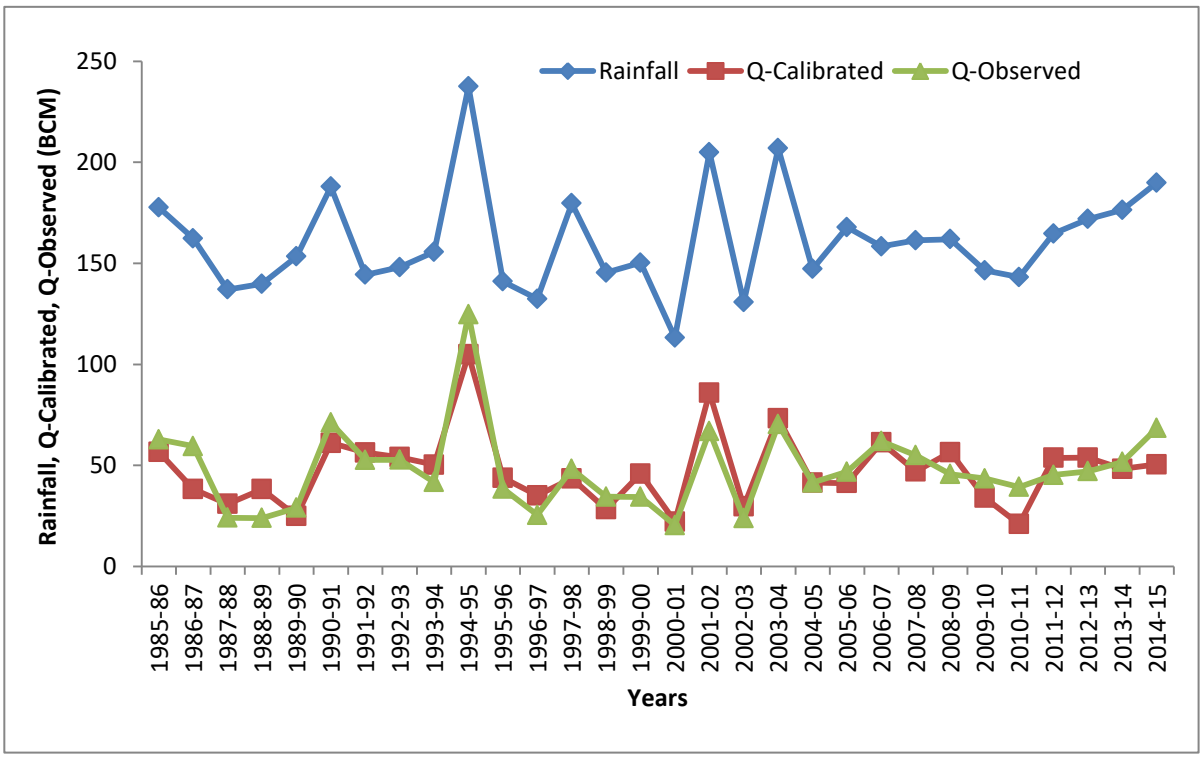


Figure 6.19 Calibrated runoff and observed discharge at Tikarpara

6.4 Annual Water Resources Availability of Mahanadi Basin

Table - F.6 at Annexure - F shows the different components required to estimate the basin level water resources of Mahanadi for 30 years. The maximum annual water resource is 142.61 BCM during 1994-95 in the 30 years. The minimum annual water resource is 31.77 BCM during 2000-01 which is the driest year in the 30 years. The mean available basin water resource is 73.00 BCM. The mean available water resource of Mahanadi basin accounts about 36.50 % of mean annual rainfall during 1985-86 to 2014-15.

6.4.1 Annual water resources of Mahanadi basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 1994-95 and 2000-01, extreme wet and dry rainfall conditions occurred in Mahanadi river basin. The annual water resources of Mahanadi Basin during these two extreme rainfall conditions are 142.61 BCM and 31.77 BCM, respectively as shown in Table - 6.3. The water balance components during these years are presented in Figures 6.20 and 6.21.

Table - 6.3 Water resources availability in Mahanadi basin during extreme rainfall conditions

Condition	Year of occurrence	Rainfall (BCM)	Water resources availability (BCM)
Maximum Rainfall	1994-1995	292.30	142.61
Minimum Rainfall	2000-2001	137.94	31.77

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.49 and 0.23 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years, potential evapotranspiration is less compared to the dry years which will have cumulative effect in runoff. It is found that the ECII during 2000-01 is less than the year 1994-95.

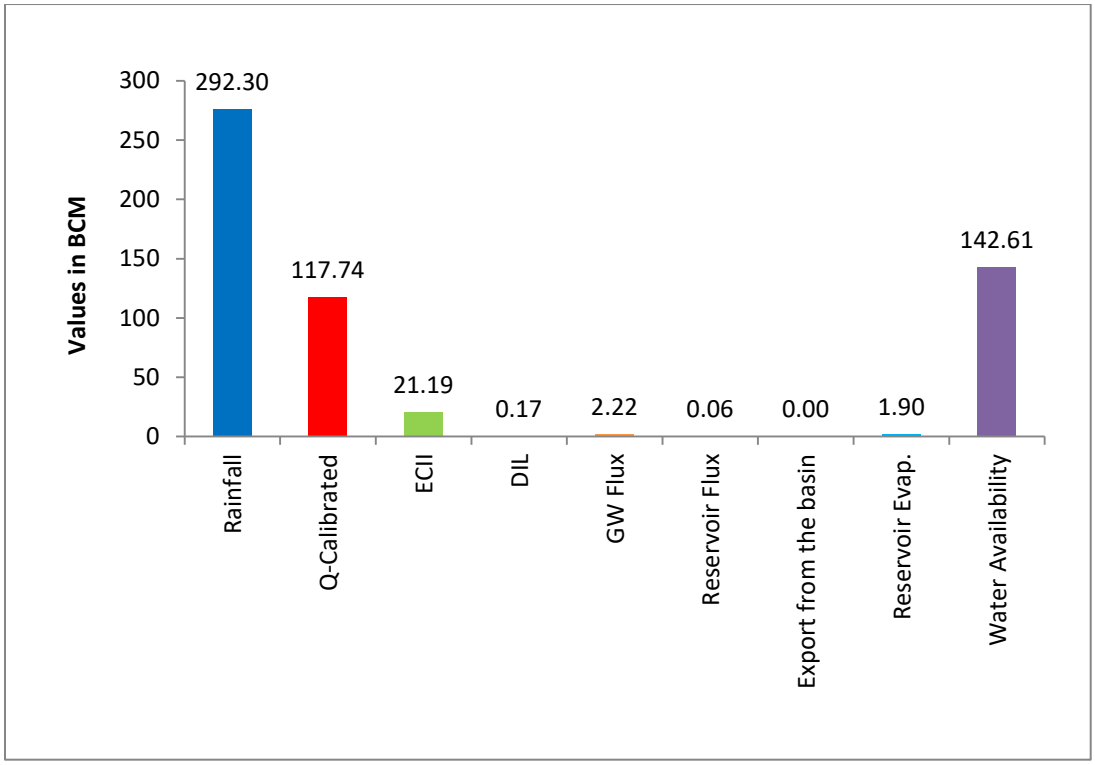


Figure 6.20 Water balance components of Mahanadi basin during extreme high rainfall (1994-95)

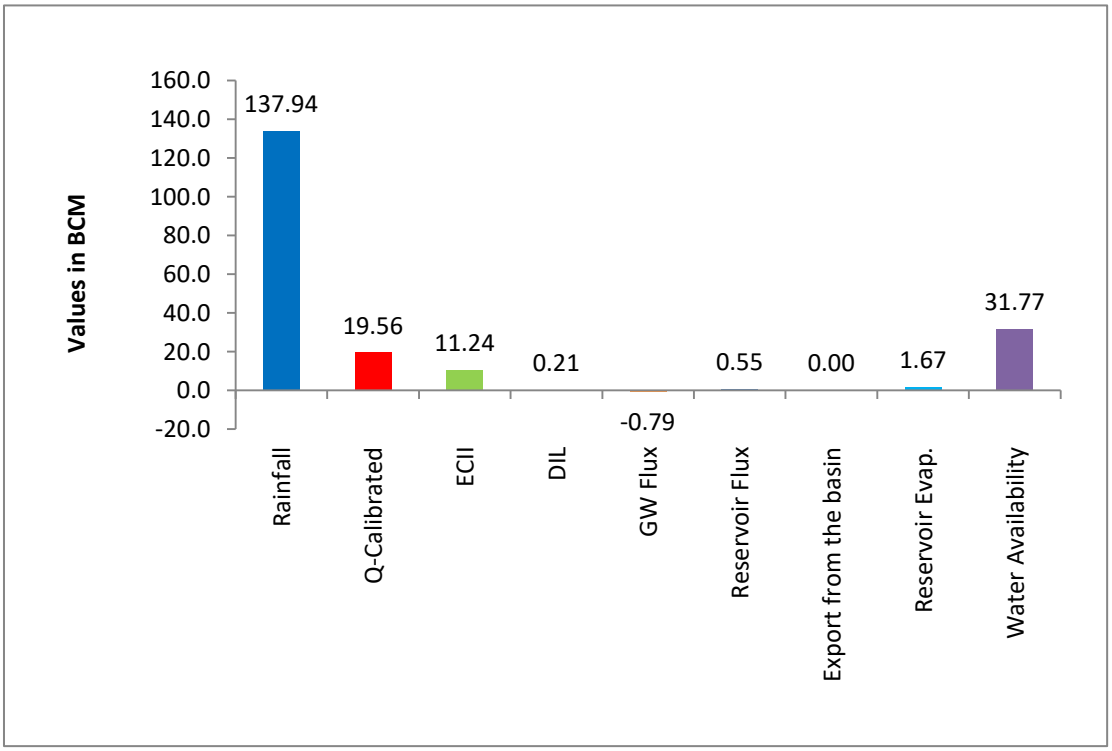


Figure 6.21 Water balance components of Mahanadi basin during extreme low rainfall (2000-01)

6.4.2 Mean water resources of Mahanadi basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs. Figure 6.22 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Export from basin+ Evaporation from Reservoirs)

= 54.80 + 16.24 + 0.20 + (0.06) + (0.29) + 0.00 + 1.41 = 73.00 BCM

The mean available annual water resource of the Mahanadi basin is 73.00 BCM and 75% dependable flow is 49.00 BCM.

It is observed that the computed runoff factors varies from 0.14 (1,178 mm rainfall) to 0.43 (1906 mm rainfall). The mean runoff factor for 30 year period is 0.28.

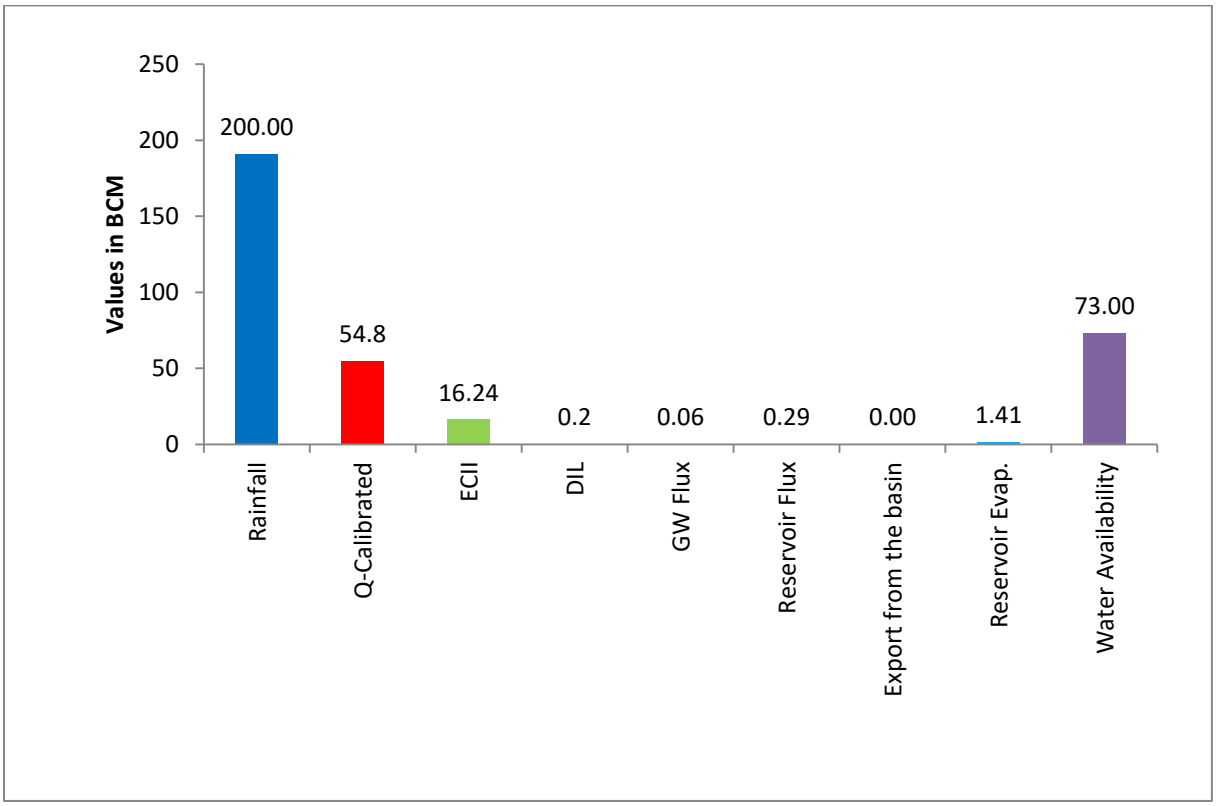


Figure 6.22 Mean water balance components of Mahanadi basin

6.5 Basin Outward Diversions/Imports

There is an import from Indravati river to Tel River in Kantamal sub-basin from 2007-08 to 2014-15. Table - 6.4 gives the details of water imported into the basin.

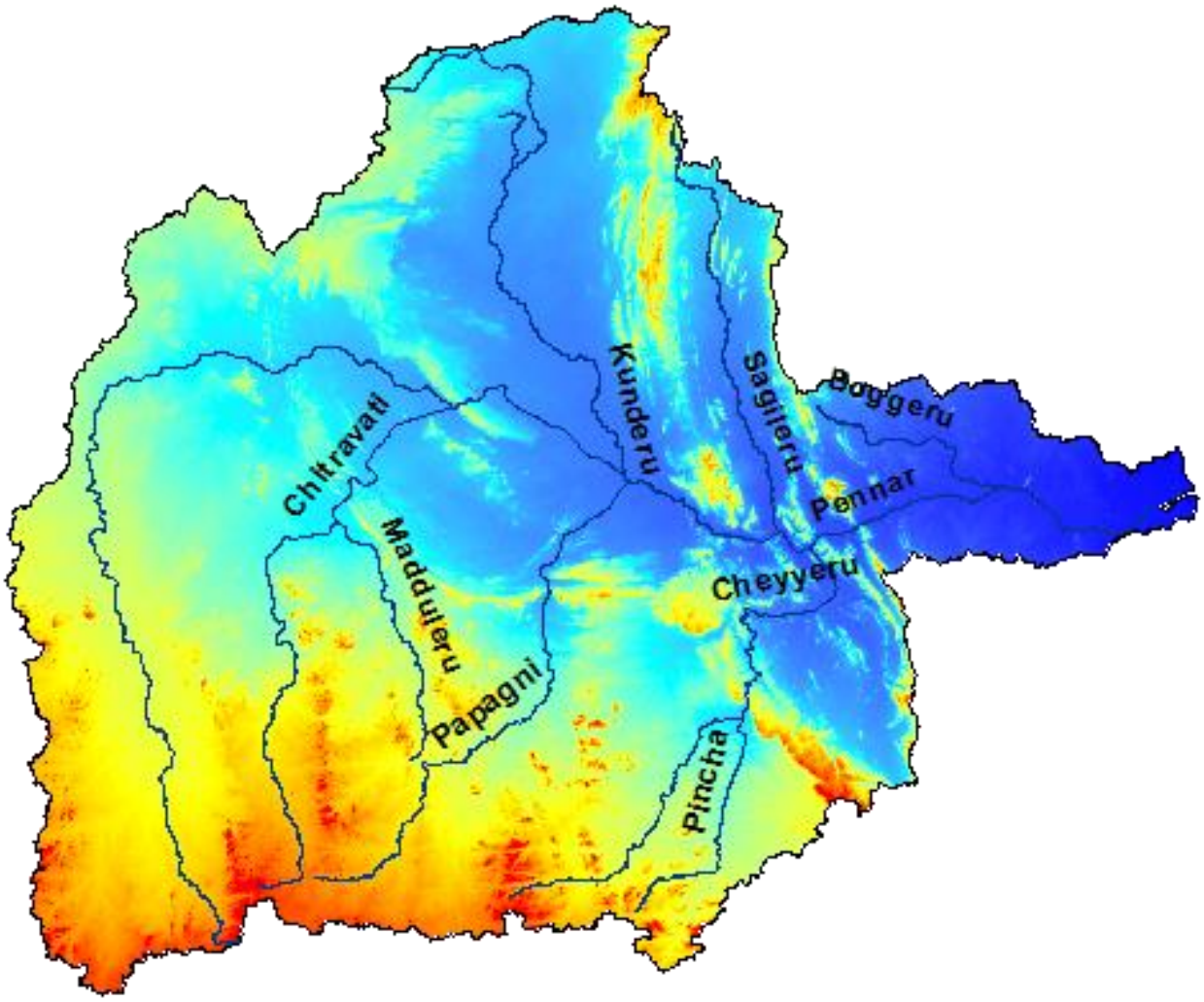
Table - 6.4 Details of diversions considered for Mahanadi basin study

S.No.	Name of Projects	Quantity of diversion water (BCM)	Remarks
1	Upper Indravati Hydro Electric Project	2.50 (Mean is calculated considering 8 years)	The import takes place after power generation (from 2007-08 to 2014-15)
	Total	2.50	

HIGHLIGHTS

- *Mean available water resource of Mahanadi basin is 73.00 BCM.*
- *Maximum annual water availability is 142.61 BCM during 1994-95.*
- *Minimum annual water availability is 31.77 BCM during 2000-01.*
- *Annual rainfall in the basin varies from 923 mm to 1,905 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1,317 mm.*
- *Mahanadi basin is divided into six sub-basins for the reassessment study viz. Bamnidih, Jondhra, Basantpur, Kantamal, Tikarpara and combined delta region as one sub-basin.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.20 BCM.*
- *Average annual evaporation from water bodies in the basin is 1.41 BCM.*

PENNAR BASIN



7.1 Geo-Spatial Datasets

7.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of Pennar basin is shown in Figure 7.1. The image corresponds to the 2004-05 year and consists of 15 different classes. The map indicates current Fallow (26.6%), Kharif only (23.67%), Scrubland (18.9%) and Deciduous Forest (12.16%) are the major classes in Pennar basin (Figure 7.2).

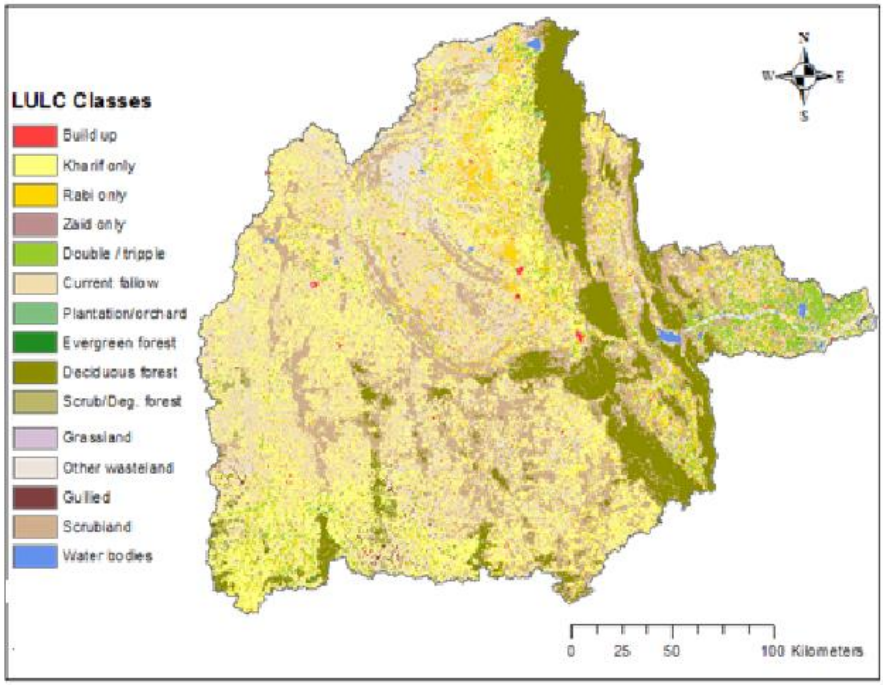


Figure 7.1 LULC Map of Pennar basin (2004-05)

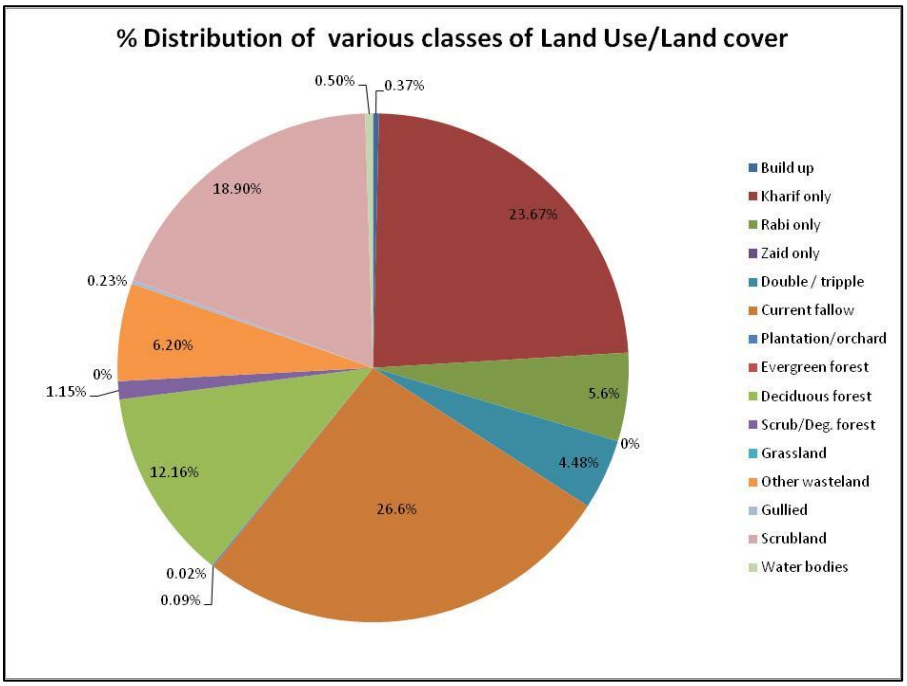


Figure 7.2 Distribution of LULC in Pennar basin (2004-05)

7.1.2 Soil texture

The main soil types found in the basin are clay, clayey skeletal and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 7.3 shows various categories of soil in the basin. The soils are classified as loamy, clayey and rock outcrop based on the soil texture information.

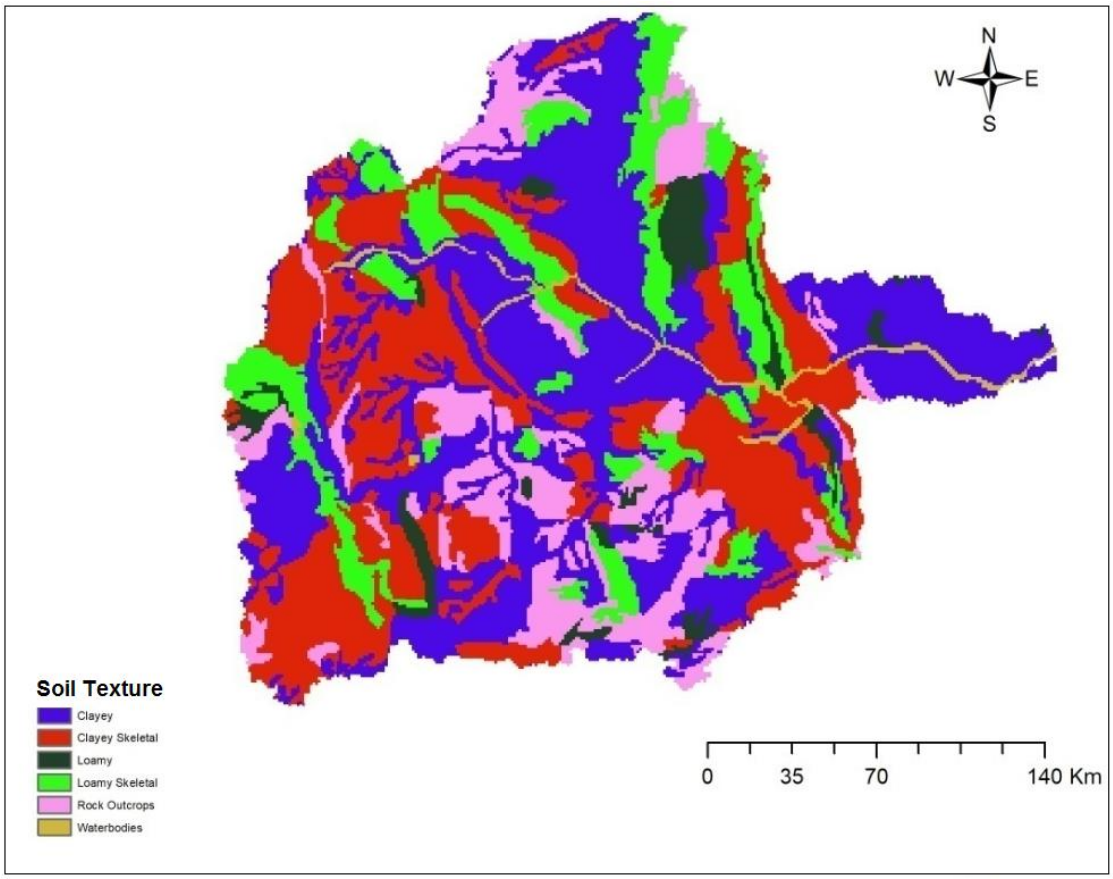


Figure 7.3 Soil texture map of Pennar basin

7.1.3 Topography

The topography of the basin consists of ghat areas, plateau and the coastal plains. The upper regions of the basin are mostly hilly and forested. The lower region of the basin is deltaic plains. The elevation values ranges from a minimum of 0 m to a maximum of 1,439 m. The average elevation is about 415 m of the basin. Figure 7.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of Pennar basin.

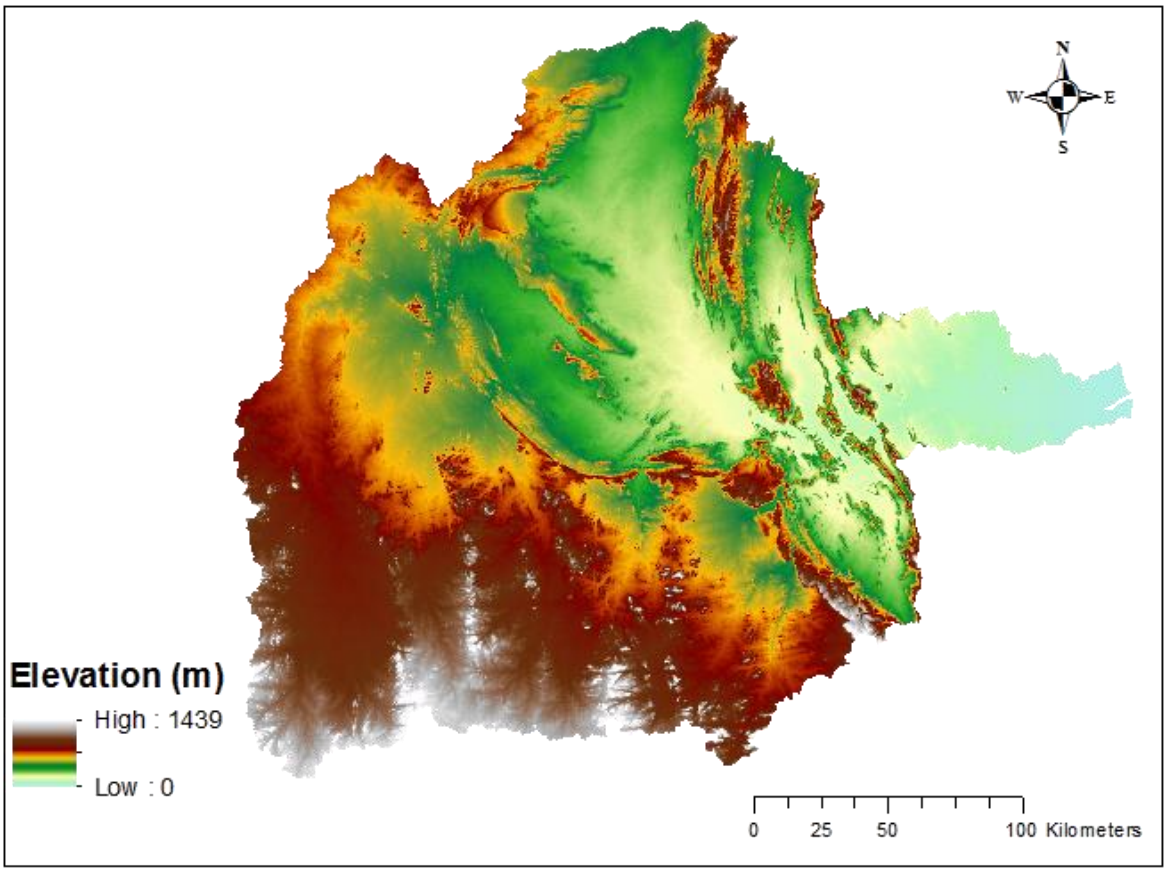


Figure 7.4 SRTM DEM map of Pennar basin

7.2 Hydro-Meteorological and other Input Data

7.2.1 Rainfall grids

Figure 7.5 shows gridded rainfall map of Pennar Basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 7.6. Annual rainfall of the basin varies from 426 mm in 2002-03 to 1,083 mm in 1996-97 and mean rainfall of these 30 years is found to be 716 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum rainfall of around 381.86 mm is observed in Chennur sub-basin, while maximum rainfall of 1,075.41 mm is observed in Nellore sub-basin. Of the 30 years, for 15 years annual rainfall is higher than the mean rainfall and for remaining 15 years lower than the mean rainfall.

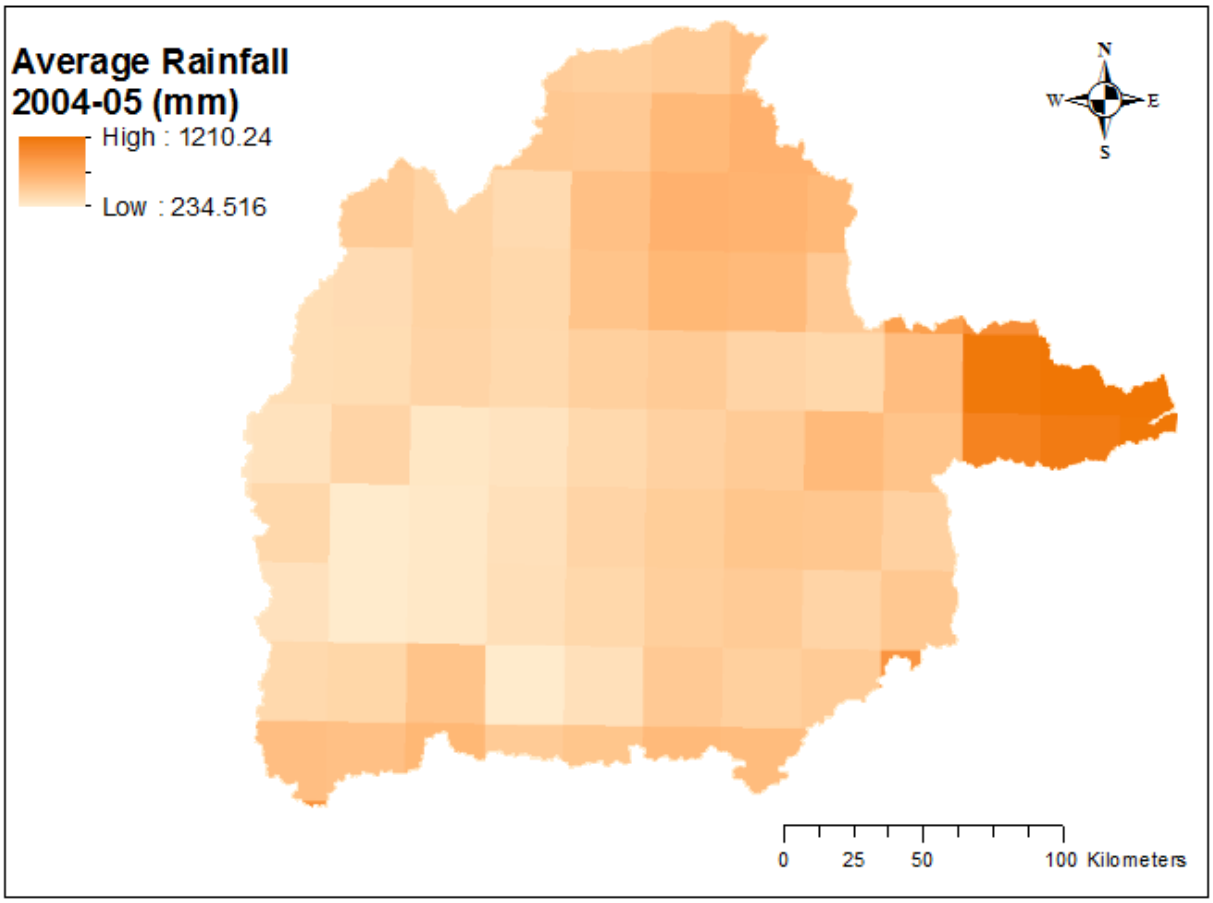


Figure 7.5 Gridded rainfall of Pennar basin (2004-05)

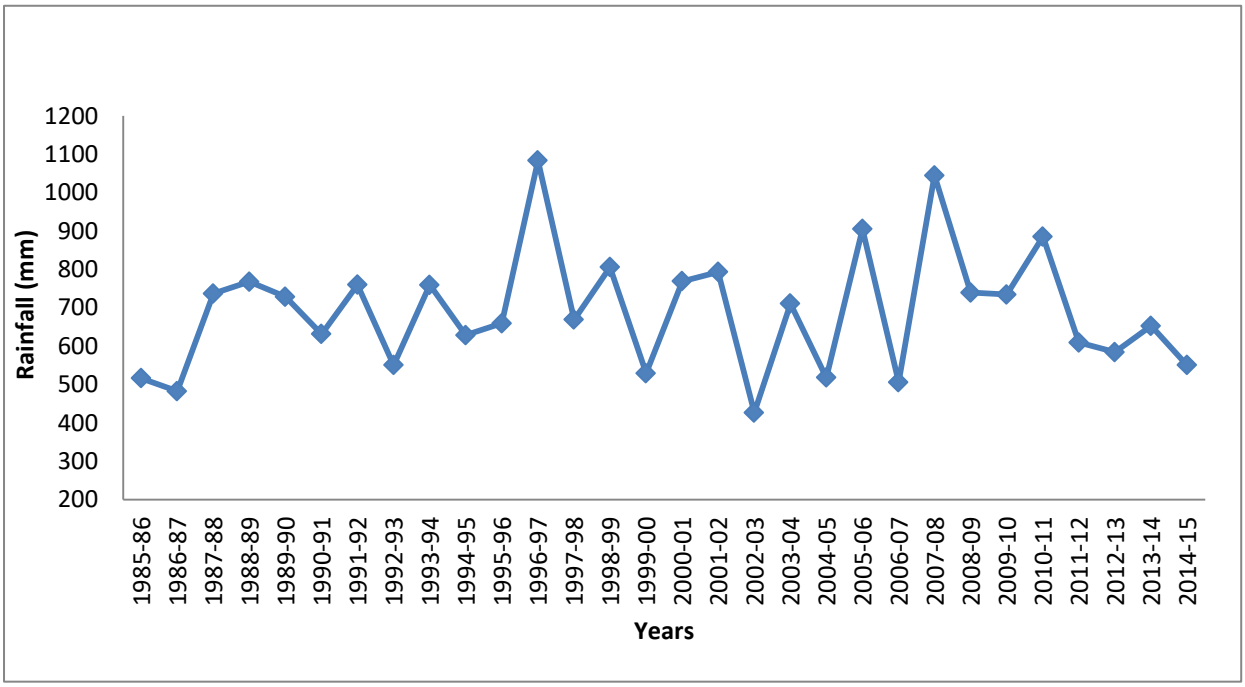


Figure 7.6 Annual rainfall in Pennar basin (1985-86 to 2014-15)

7.2.2 Temperature grids

Gridded mean annual temperature of Pennar basin in 2004-05 is shown in Figure 7.7. The mean annual temperature during 2004-05 was about 26.7^{0}C.

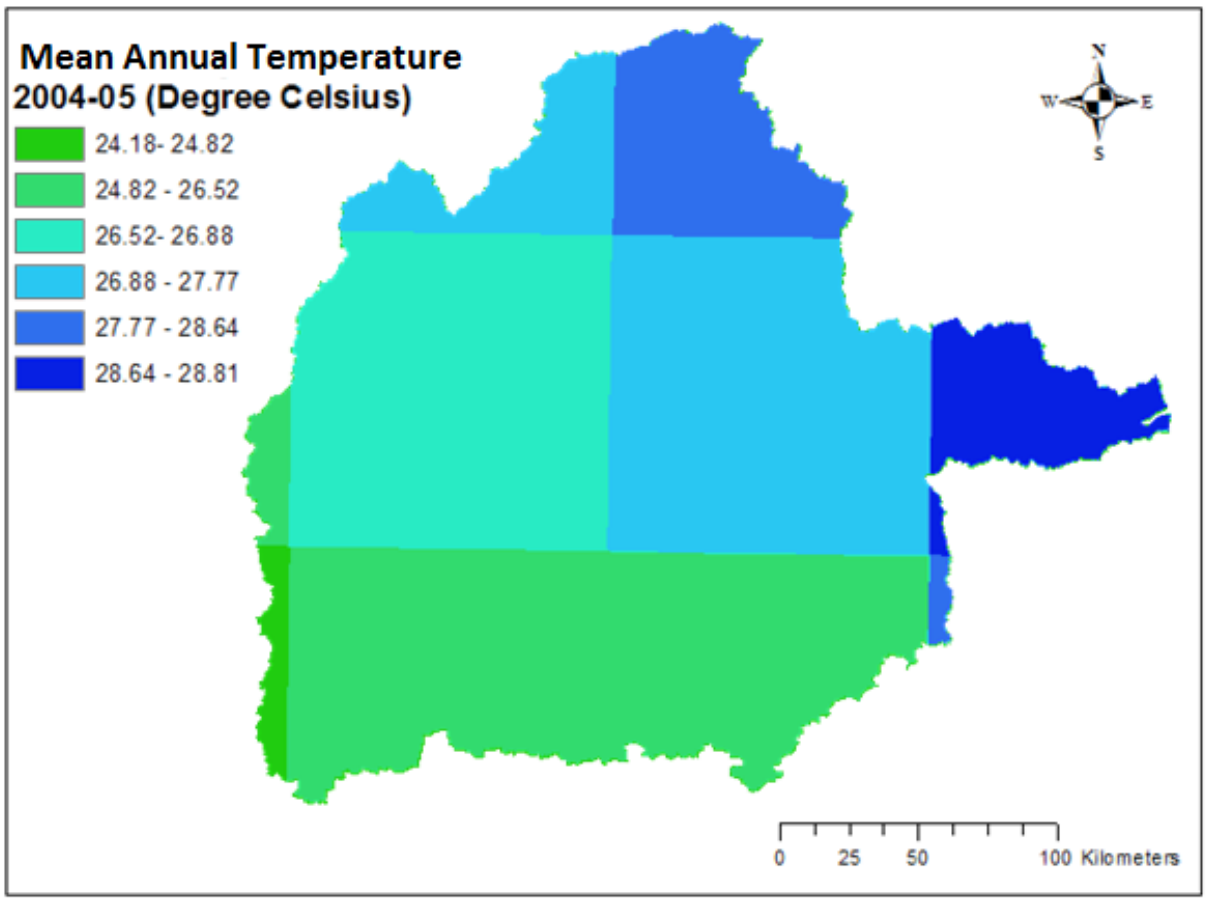


Figure 7.7 Gridded mean annual temperature of Pennar basin (2004-05)

7.2.3 Sub-basins of Pennar basin

The Pennar basin is divided in to 3 sub-basins (Figure 7.8) viz. Chennur, Nellore and Delta. Table - 7.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

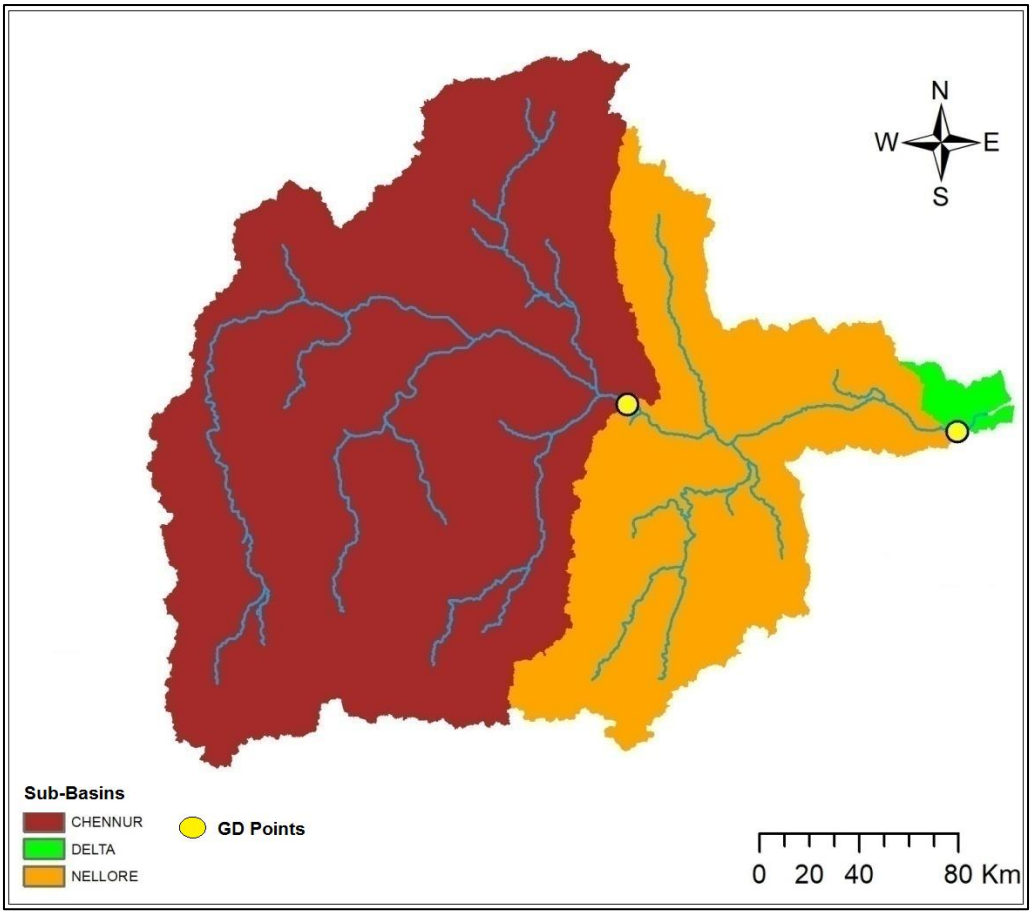


Figure 7.8 Sub-basins of Pennar basin

Table - 7.1 Sub-basin wise details of Pennar basin

Sl No.	Sub-basin	Individual drainage area (sq.km)
1	Chennur	37439.8
2	Nellore	16761.6
3	Delta	703.98
	Total basin area	54,905

7.2.4 River discharge

The river discharge data was available for 26 years (1989-90 to 2014-15) for site Chennur and for the whole study period (30 years) for site Nellore. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level.

7.2.5 Reservoir flux

Figure 7.9 shows the location of some of the reservoirs in Pennar basin. The reservoir, Somasila was considered for estimating storage fluxes changes for each water year wise for 30 year period. These surface storage fluxes were used for calibration and validation purpose of computed discharge.

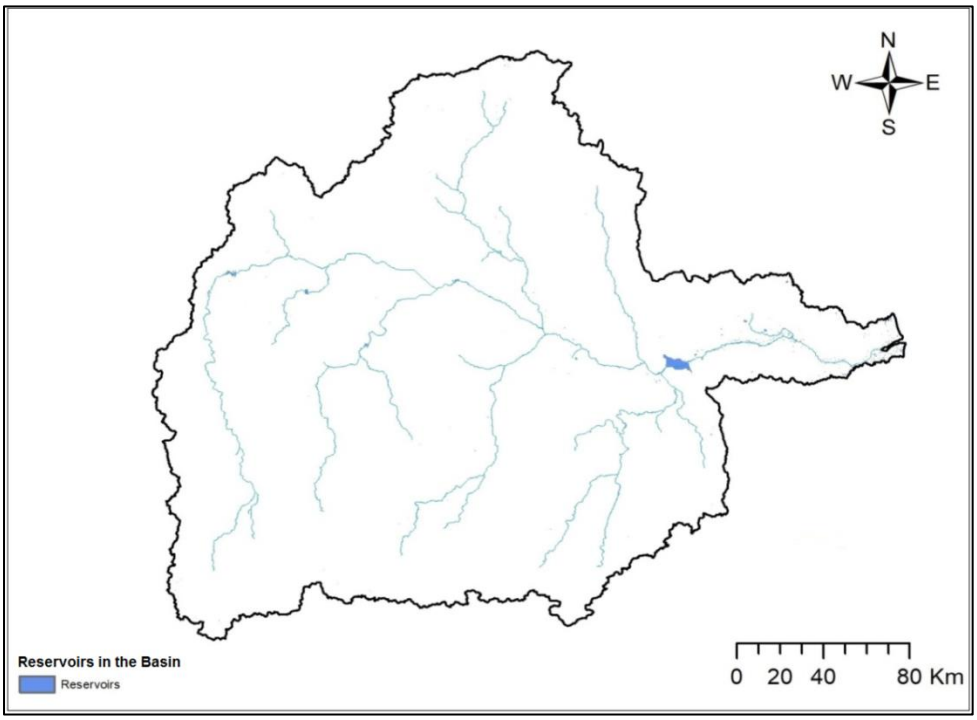


Figure 7.9 Major reservoirs in Pennar basin

7.2.6 Groundwater flux

Spatial variation of annual groundwater flux for year 2004-05 is shown in Figure 7.10. Annual variation of groundwater flux for 1985-86 to 2014-15 is shown in Figure 7.11

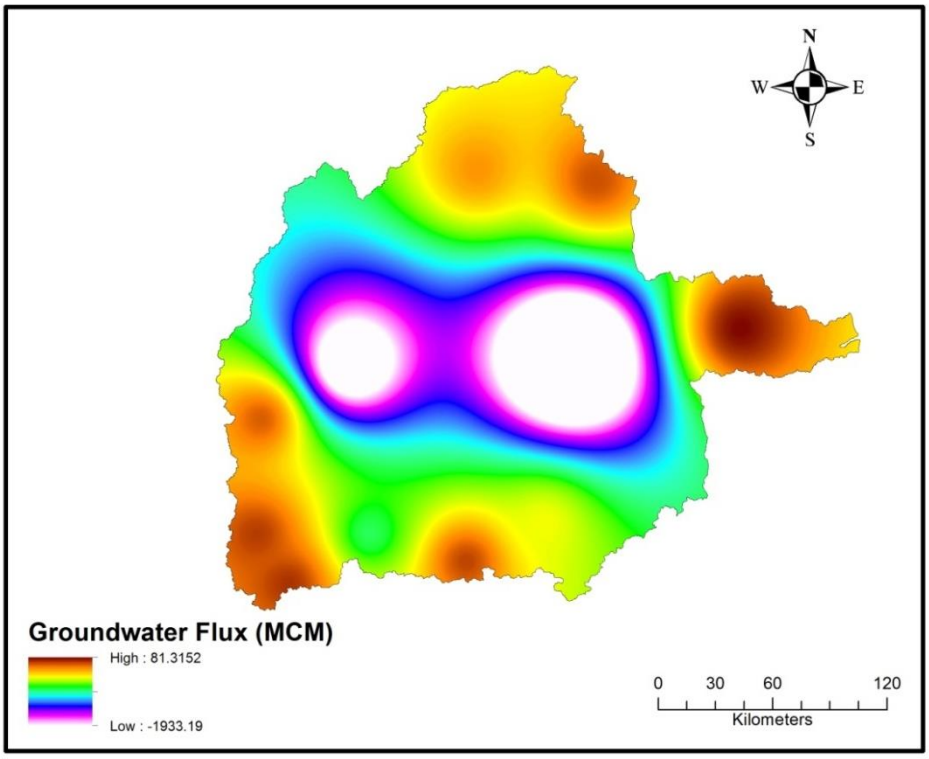


Figure 7.10 Groundwater flux (spatial data) estimated during 2004-05

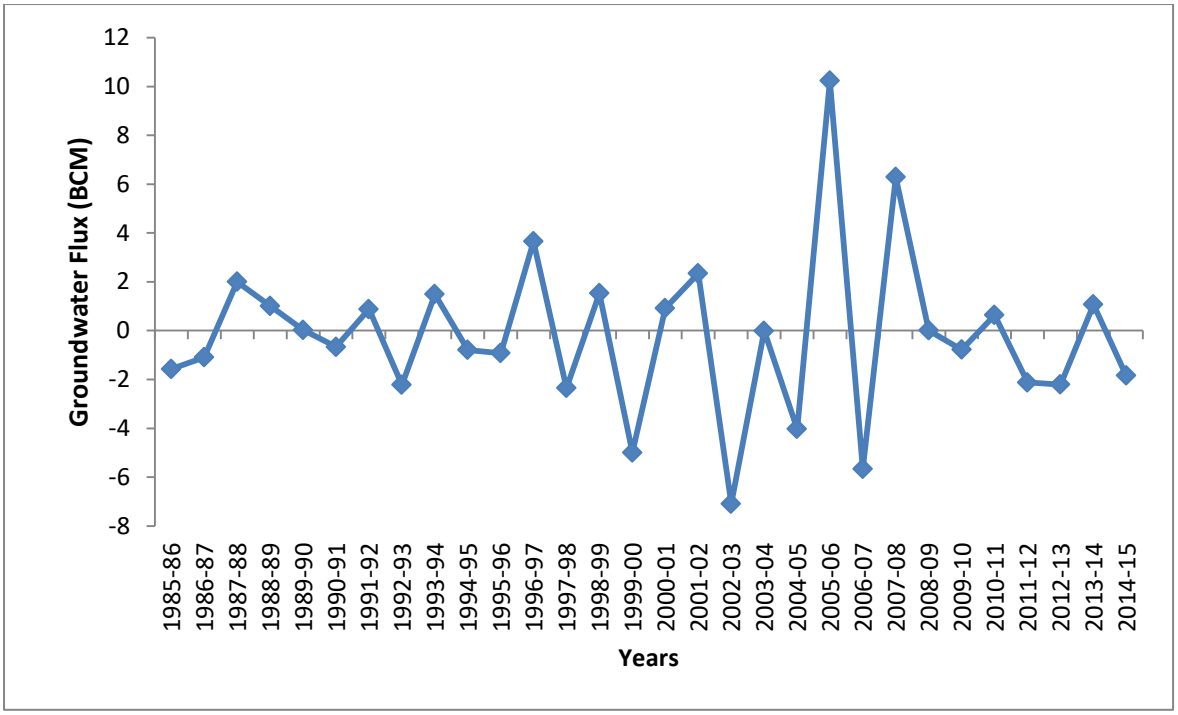


Figure 7.11 Annual groundwater flux of Pennar basin (1985-1986 to 2014-2015)

7.2.7 Major crops in the basin

Pennar basin was divided in 4 regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if groundnut is a major crop, it may be ragi or jowar in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if groundnut is a major crop in Kharif only season, it may be rice or bajra during 2005-06.

7.2.8 Irrigation command area

Figure 7.12 shows location of irrigation command boundaries inside and outside the basin considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence the command area considered during the year 1985-86 was worked out to be around 16, 59, 864 hectare while it was 16,71,919 hectare in 2014-15 (excluding the basin outside command). Basin outside command has been taken uniformly for all years while working out ECII from these areas.

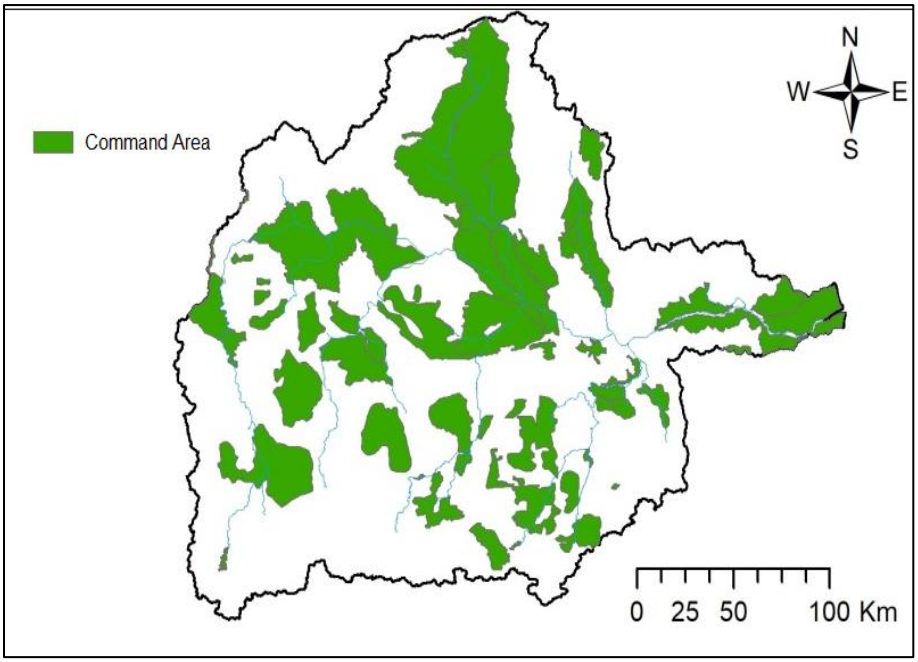


Figure 7.12 Irrigation command boundaries of Pennar basin

7.2.9 Domestic, industrial and livestock demand

Figure 7.13 shows district boundaries layer with district population for the year 2011 census. Population data of census year 1991, 2001, 2011 and livestock census of 1982, 1983, 1987, 1990, 1992, 1993, 1997, 1999, 2003, 2007 and 2012 of basin states were used in the study. Population statistics for the years in between and beyond 2011 was interpolated using geometric progression method. The mean annual domestic, industrial and livestock demands are estimated at 0.24 BCM in the basin.

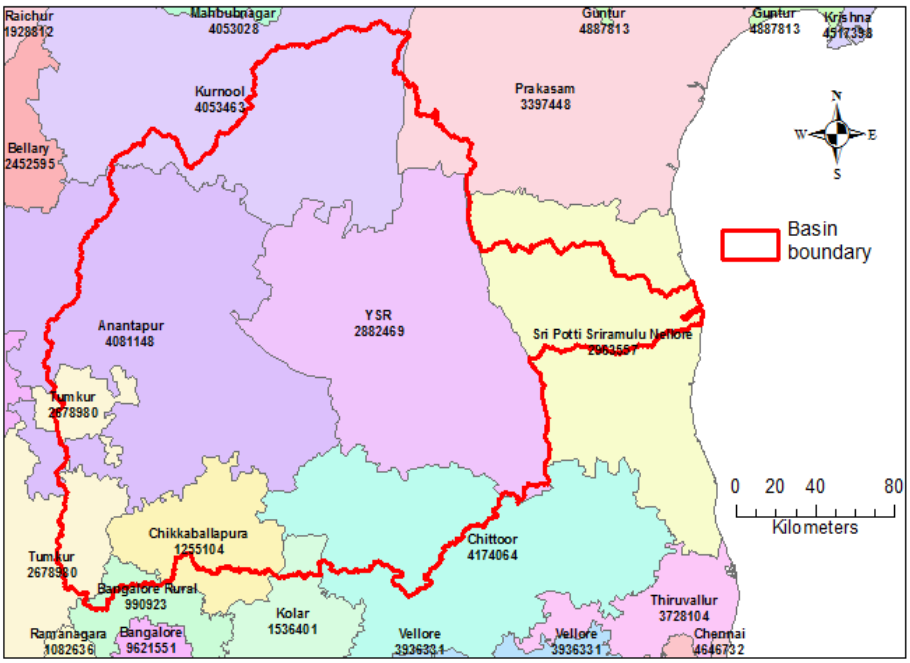


Figure 7.13 District boundaries in Pennar basin

7.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 7.2 provides annual evaporation values from the Pennar basin for the period from 1985-86 to 2014-15 (30 years). The average annual evaporation volume for the basin is worked out as 0.14 BCM.

Table - 7.2 Evaporation in the reservoirs of Pennar basin

Year	Evaporation (BCM)	Year	Evaporation (BCM)
1985-86	0.15	2000-01	0.15
1986-87	0.13	2001-02	0.14
1987-88	0.13	2002-03	0.11
1988-89	0.13	2003-04	0.16
1989-90	0.14	2004-05	0.17
1990-91	0.11	2005-06	0.14
1991-92	0.15	2006-07	0.12
1992-93	0.17	2007-08	0.18
1993-94	0.13	2008-09	0.13
1994-95	0.12	2009-10	0.13
1995-96	0.12	2010-11	0.15
1996-97	0.18	2011-12	0.12
1997-98	0.13	2012-13	0.11
1998-99	0.14	2013-14	0.12
1999-00	0.17	2014-15	0.04
		Avg.	0.14

7.3 Previous Estimates

In 1949 when the basin wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula, the annual runoff of Pennar river system was estimated as practically nil. In 1960, Central Water & Power Commission while conducting the irrigation potential studies, assessed the total annual runoff of Pennar river as 6.86 BCM which is also reported in CWC's Publication No 30/88 "Water Resources of India", April 1988.

In the 1993 study, observed discharges is taken into account for arriving the natural flow at Sangam Anicut (Catchment area =50,253 sq.km) and interpolated for the whole Pennar basin (Catchment Area = 55,213 sq.km) whereas in the present study, calibrated runoffs have been calculated up to Nellore (Catchment Area = 54,201.4 sq.km) and the remaining delta portion (703.98 sq. km) remains uncalibrated. Thus the whole basin (CA=54,905.38 sq.km) is taken into account. Mean annual rainfall during 1985-2015 (40 BCM) is more than that during 1944-45 to 1983-84.

7.4 Runoff Estimation

Chennur and Nellore discharge sites are located on Pennar river, and the model estimated runoff is calibrated against the observed discharge at both the locations. Computed discharge at Deltaic region is added to the whole basin without any calibration, since it does not have any observed discharges. Tables - G.1 to G.2 at Annexure - G give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for the two discharge stations. Figures 7.14 and 7.15 show comparative graphs of calibrated runoff and observed discharge at these discharge stations. From

the graphs, it may be observed that the model estimated runoff and observed discharge at both the sites (Chennur and Nellore) are matching very well. Table G.3 at Annexure-G gives calibrated runoff of Pennar basin for 30 years. The mean annual calibrated runoff is about 3.96 BCM. The maximum annual calibrated runoff is 20.87 BCM during 1996-97. The minimum annual calibrated runoff occurred on several occasion as 0 during 1985-86, 86-87, 87-88, 2003-04 and 2014-15. The mean annual ECII is about 8.20 BCM. The maximum annual ECII is about 10.36 BCM during 1997-98. The minimum annual ECII is about 5.83 BCM during 1996-67.

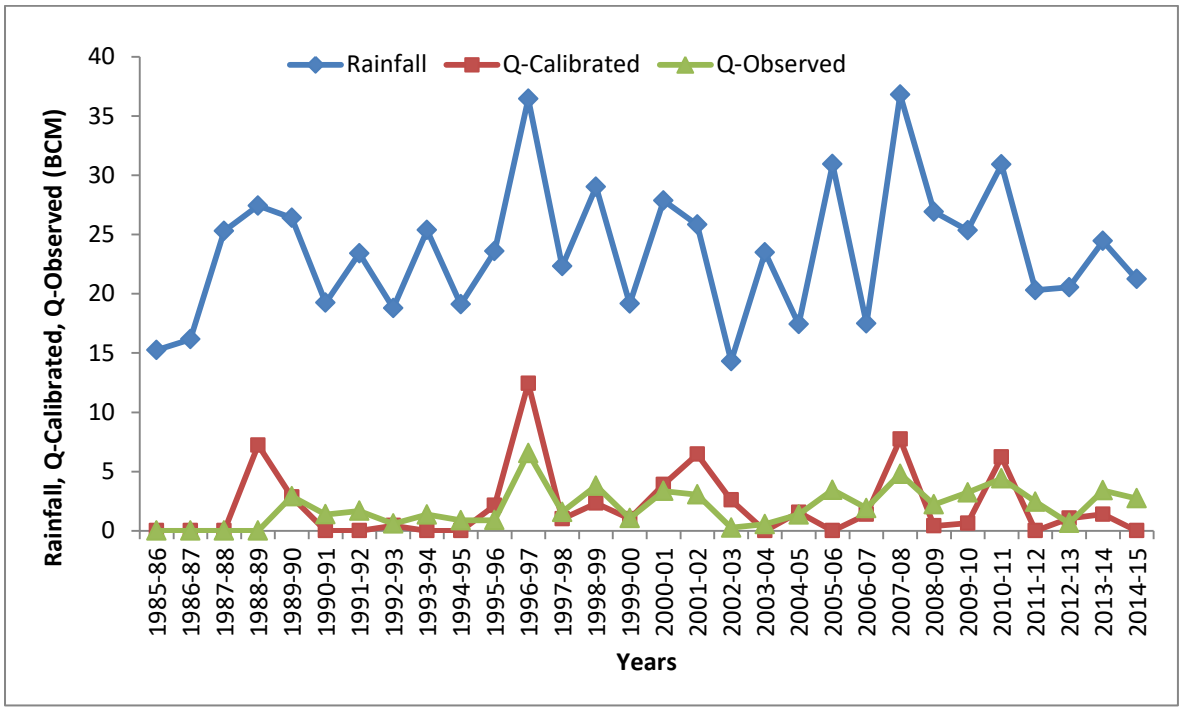


Figure 7.14 Calibrated runoff and observed discharge at Chennur

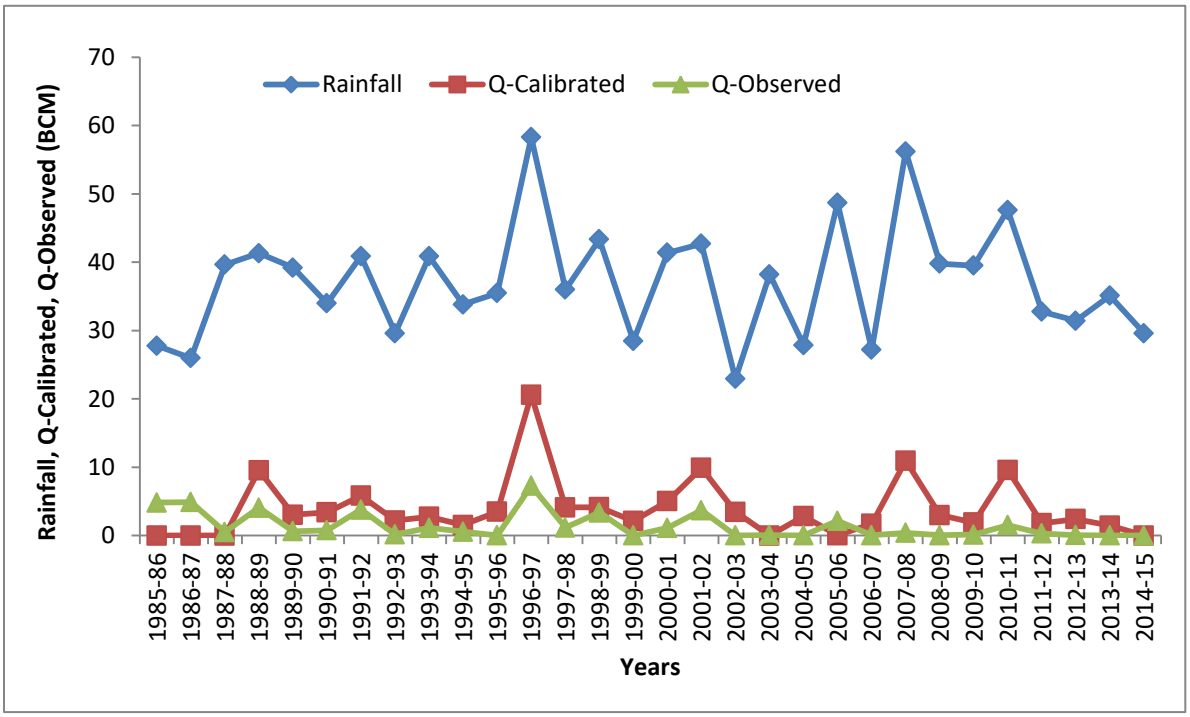


Figure 7.15 Calibrated runoff and observed discharge at Nellore

7.5 Annual Water Resources Availability of the Basin

Table - G.3 at Annexure - G shows the different components required to estimate the basin level water resources of Pennar for 30 years. The maximum annual water resource is 30.23 BCM during 1996-97 in the 30 years. The minimum annual water resource is 3.36 BCM during 2002-03 which is understandable since the basin has also received least rainfall during the same year. The mean available basin water resource is 11.02 BCM. The mean available water resource of Pennar basin accounts to about 27.55% of mean rainfall during 1985-86 to 2014-15.

7.5.1 Annual water resources of Pennar basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 1996-97 and 2002-03, extreme wet and dry rainfall conditions occurred in Pennar river basin respectively. The annual water resources of Pennar basin during these two extreme rainfall conditions are 30.23 BCM and 3.36 BCM, respectively as shown in Table - 7.3. The water balance components during these years are presented in Figures 7.15 and 7.16.

Table - 7.3 Water resources availability in Pennar basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources Availability (BCM)
Maximum Rainfall	1996-97	64.08	30.23
Minimum Rainfall	2002-03	24.41	3.36

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.47 and 0.13 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years, potential evapo-transpiration is less compared to the dry years. This will have cumulative effect in discharge. It is found that the ECII during 1996-97 is less than the year 2002-03.

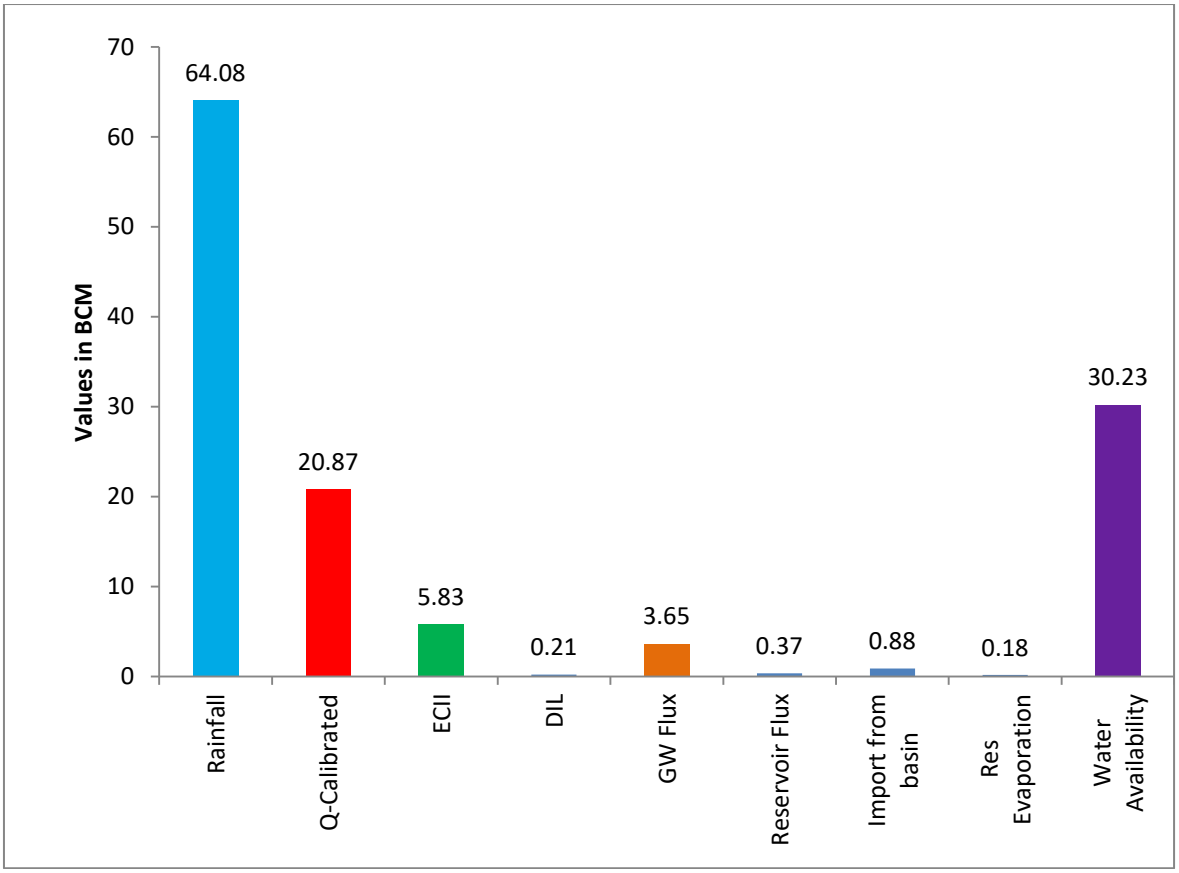


Figure 7.15 Water balance components of Pennar basin during extreme high rainfall (1996-97)

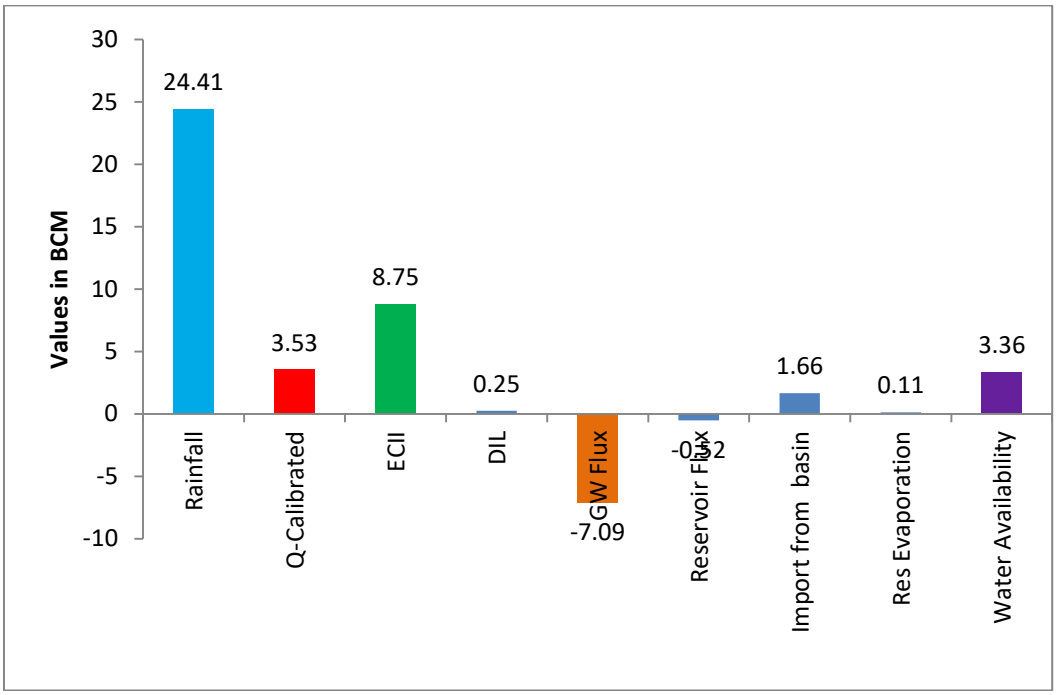


Figure 7.16 Water balance components of Pennar basin during extreme low rainfall (2002-03)

7.5.2 Mean water resources of Pennar basin

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs. Figure 7.17 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

Mean water resources = Mean of (Calibrated discharge + Estimated Consumptive Irrigation Input+ Domestic, Industries and Livestock consumption + Groundwater Flux + Reservoir Flux - Import to the basin+ Evaporation from Reservoirs)

= 3.96 + 8.20 + 0.24 + (-0.21) + 0.02 - 1.33 + 0.14 = 11.02 BCM

The mean available annual water resources of the Pennar are 11.02 BCM.

75% dependable flow of Pennar basin = 5.95 BCM

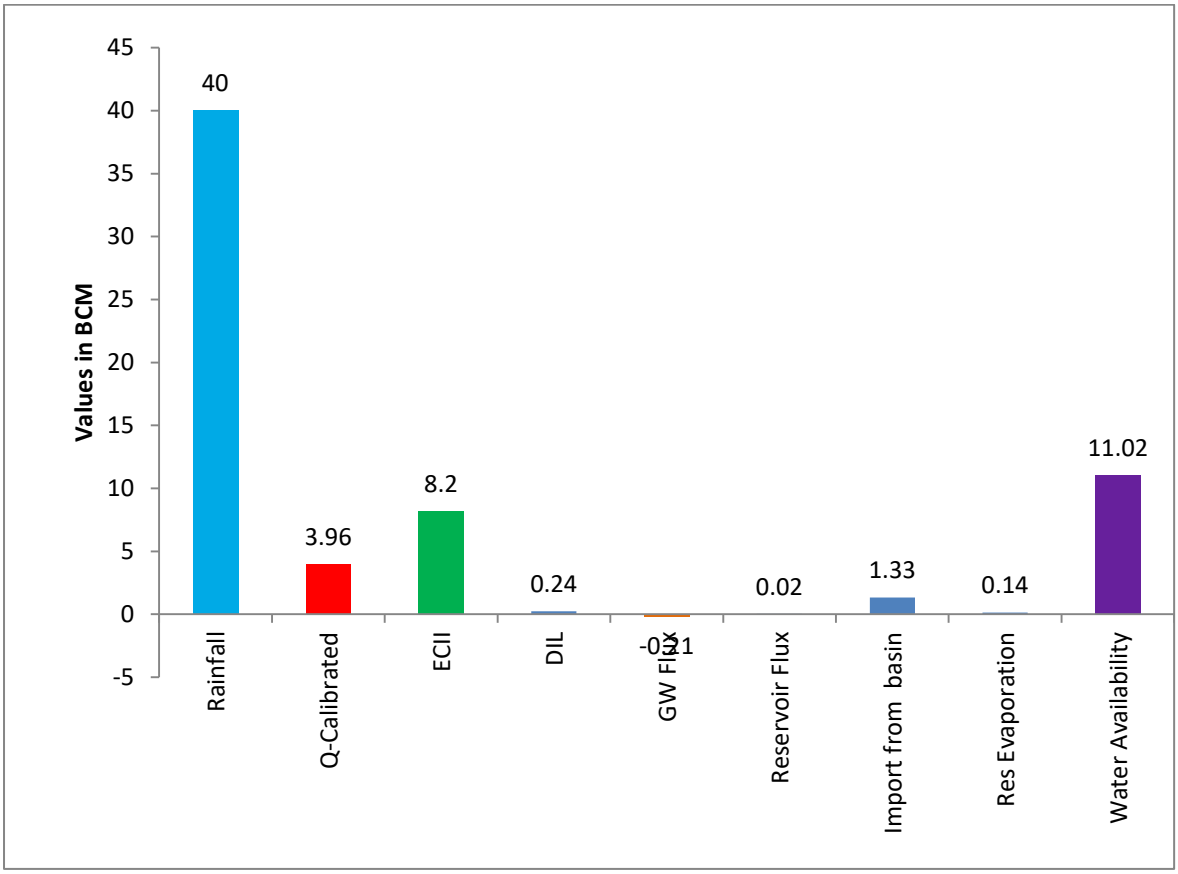
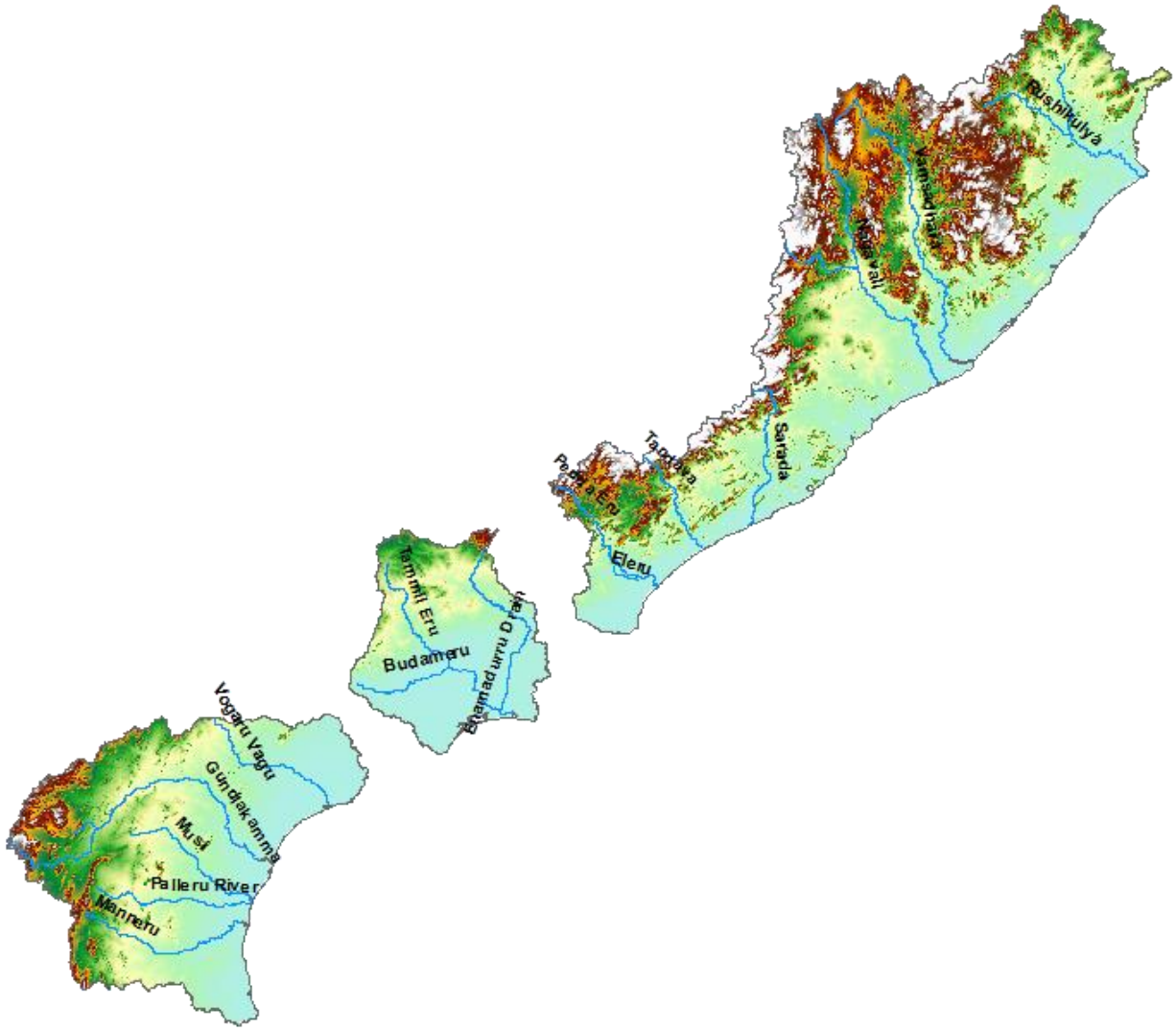


Figure 7.17 Mean water balance components of Pennar basin

HIGHLIGHTS

- *Mean available water resource of Pennar basin is 11.02 BCM.*
- *Maximum annual water availability is 30.23 BCM during 1996-97.*
- *Minimum annual water availability is 3.36 BCM during 2002-03.*
- *Annual rainfall in the basin varies from 426 mm to 1,083 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 716 mm.*
- *Pennar basin is divided into three sub-basins for the reassessment study viz. Chennur, Nellore and Delta.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.24 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.14 BCM.*

EAST FLOWING RIVERS (EFR) BETWEEN MAHANADI AND PENNAR



8.1 Geo-Spatial Datasets

8.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of EFR between Mahanadi and Pennar basin is shown in Figure 8.1. The image corresponds to the 2004-05 year and consists of 17 different classes. The land cover analysis of 2004-05 indicates Deciduous Forest (21%), Current fallow (17%) and Double/Triple crop (16%) are the major classes in the basin (Figure 8.2).

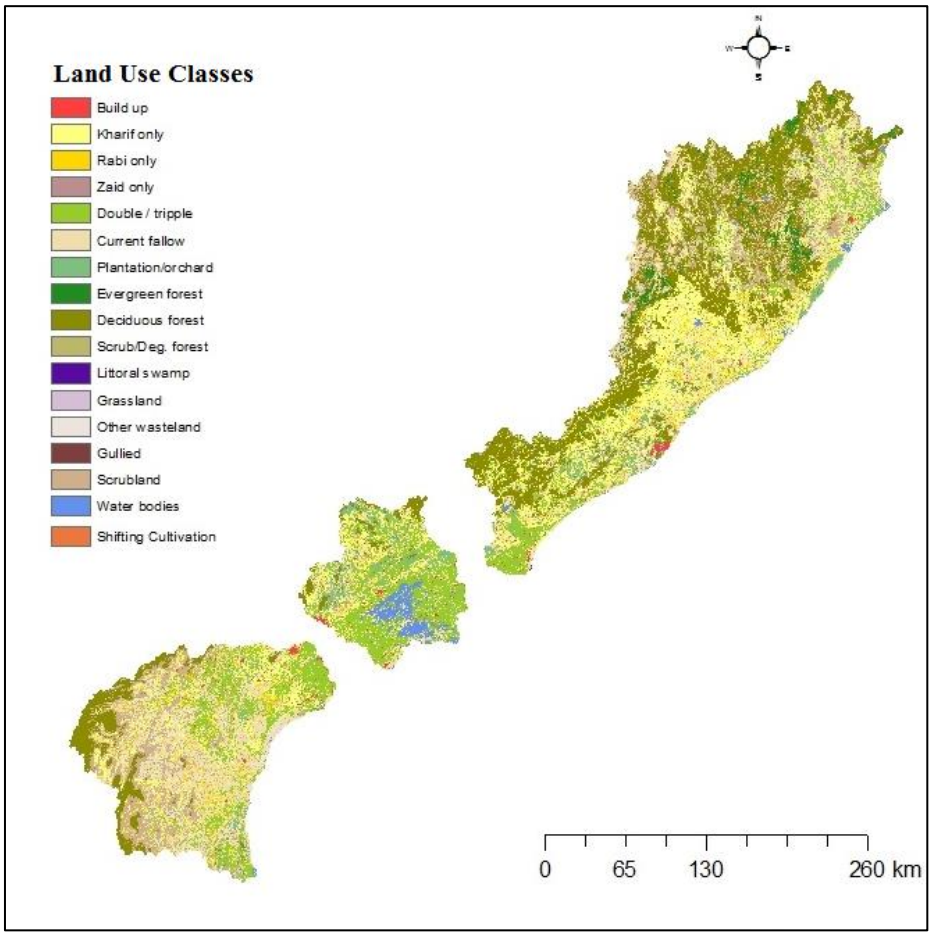


Figure 8.1 LULC map of EFR between Mahanadi and Pennar (2004-05)

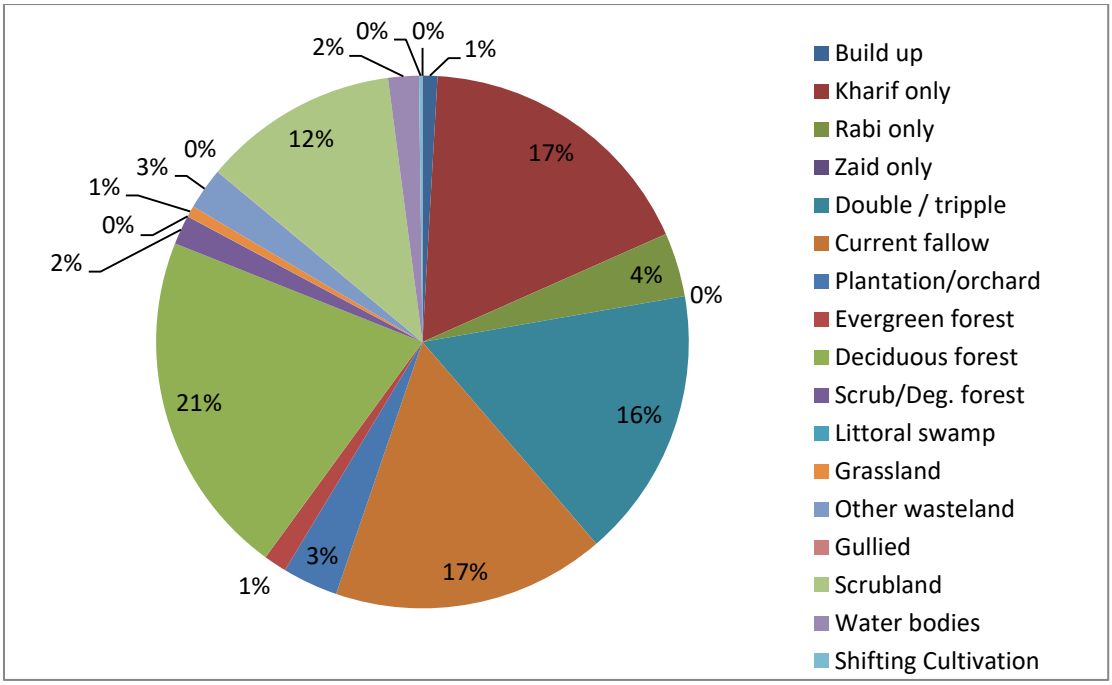


Figure 8.2 Distribution of LULC in EFR between Mahanadi and Pennar basin (2004-05)

8.1.2 Soil texture

Sandy, clayey, loamy, loamy skeletal, clayey skeletal, rocky outcrop are the main soil texture classes in the study basin. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 8.3 shows various categories of soil in the basin. Based on texture, the larger part of the basin (study area) falls under fine texture category i.e. clayey and loamy that accounts for low infiltration rate and more runoff in the basin.

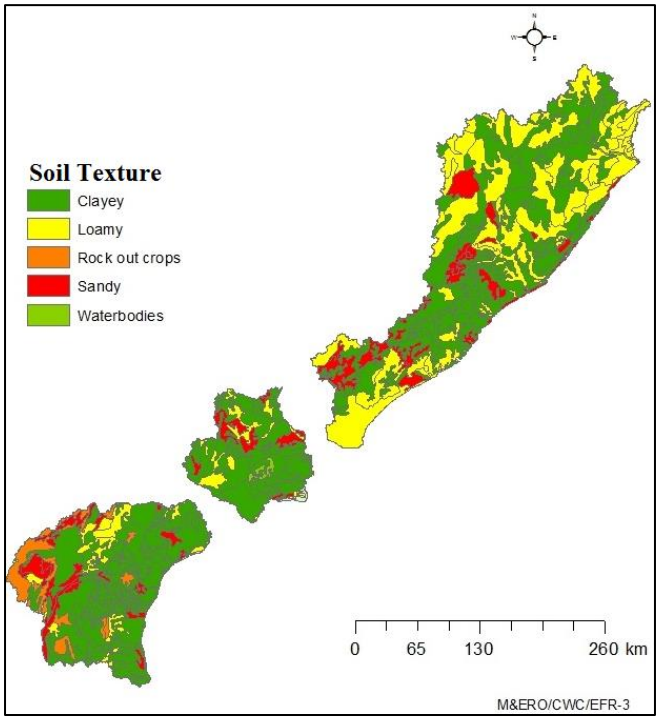


Figure 8.3 Soil texture map of EFR between Mahanadi and Pennar basin

8.1.3 Topography

The topography of the basin consists of Ghat areas, plateau and the coastal plains. The basin is bounded by the Eastern Ghats on the north and west, by Nallamala Range and Andhra plains on the south. The elevation values ranges from a minimum of 0 m to a maximum of 1,610 m. Larger part of the basin is plains, mountain parts lie in districts of Andhra Pradesh and Odisha. Figure 8.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of the basin.

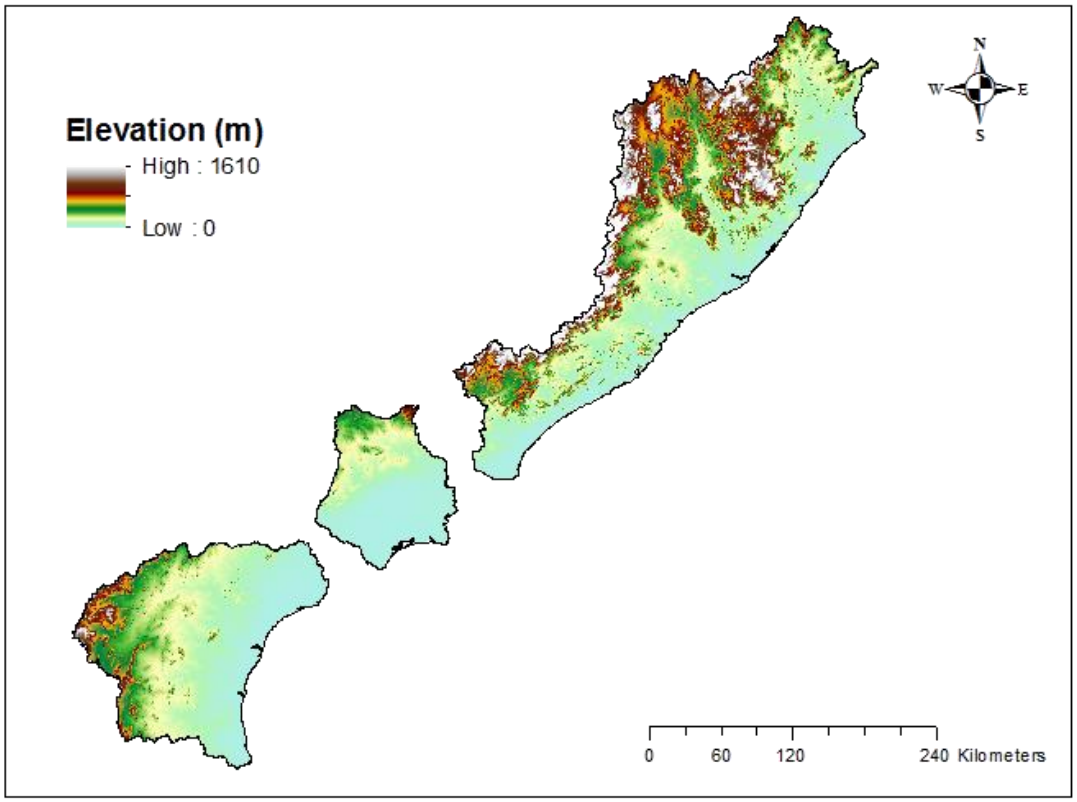


Figure 8.4 SRTM DEM map of EFR between Mahanadi and Pennar basin

8.2 Hydro-Meteorological and other Input Data

8.2.1 Rainfall grids

Figure 8.5 shows gridded rainfall map of EFR between Mahanadi and Pennar basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 8.6. Annual rainfall of the basin varies from 784 mm to 1,565 mm and mean rainfall of these 30 years is found to be 1,144 mm. Of the 30 years, for 12 years annual rainfall is higher than the mean rainfall and for remaining 17 years lower than the mean rainfall.

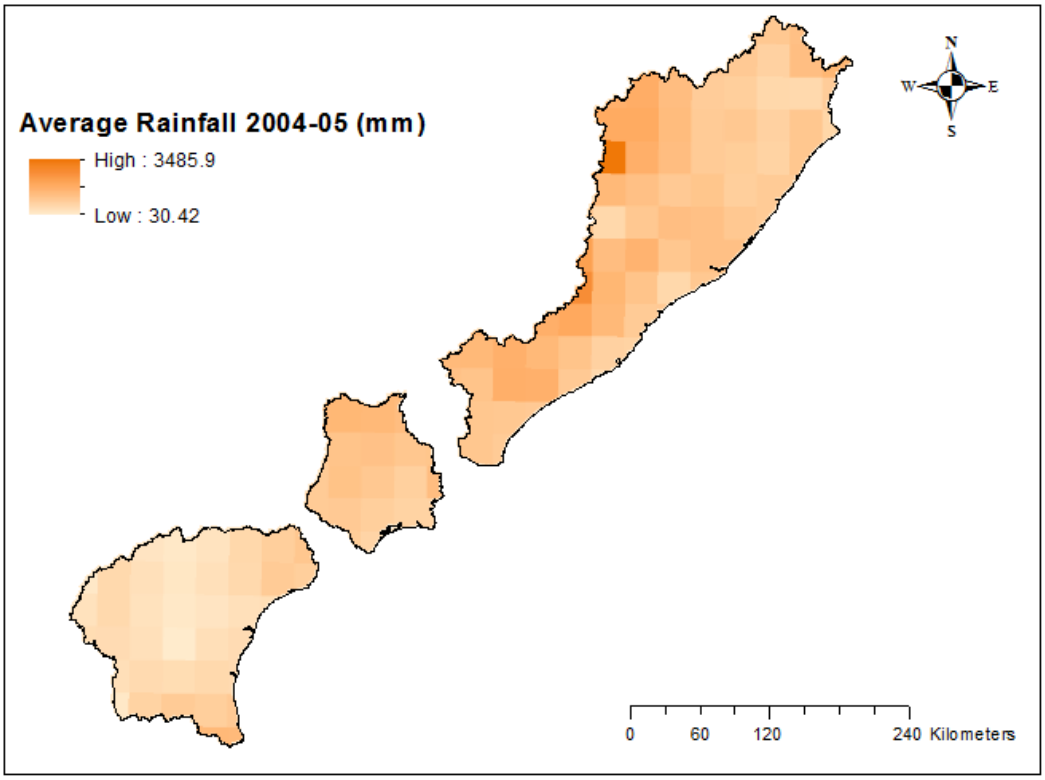


Figure 8.5 Gridded rainfall of EFR between Mahanadi and Pennar basin (2004-05)

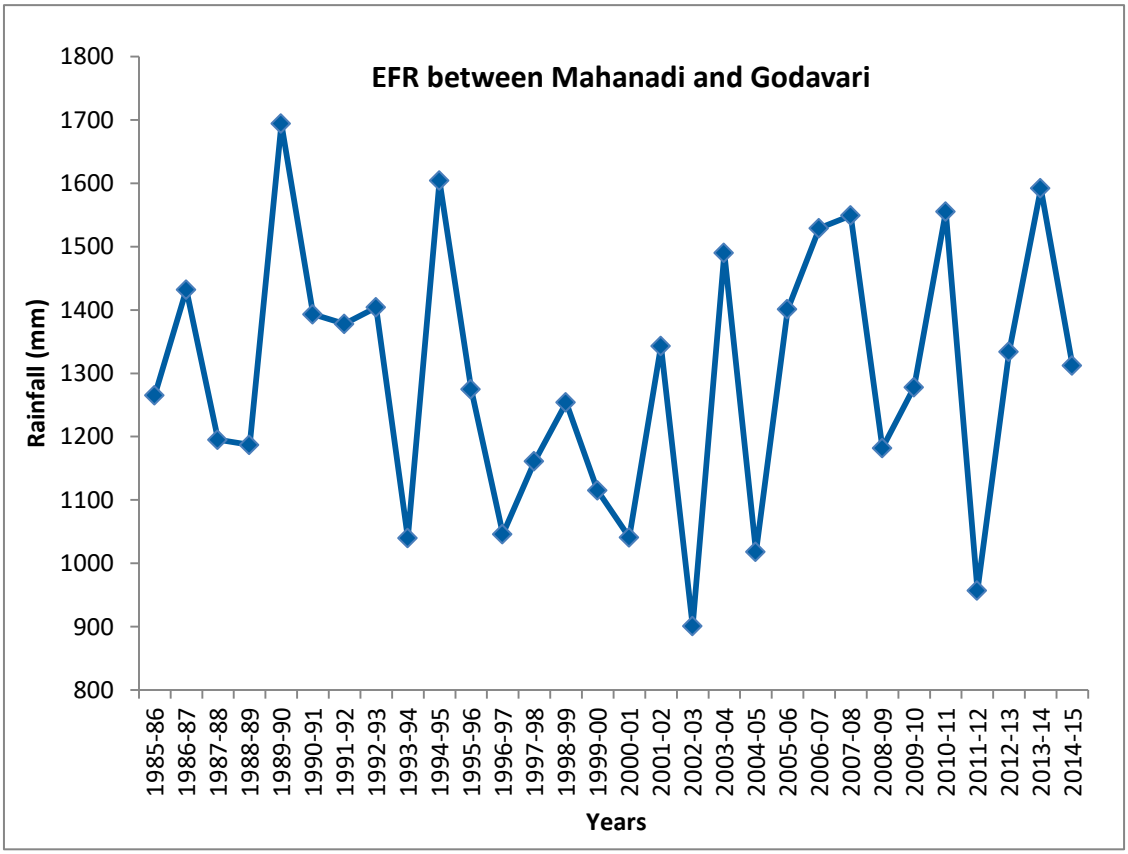


Figure 8.6(a) Annual rainfall of EFR between Mahanadi and Godvari basin (1985-2015)

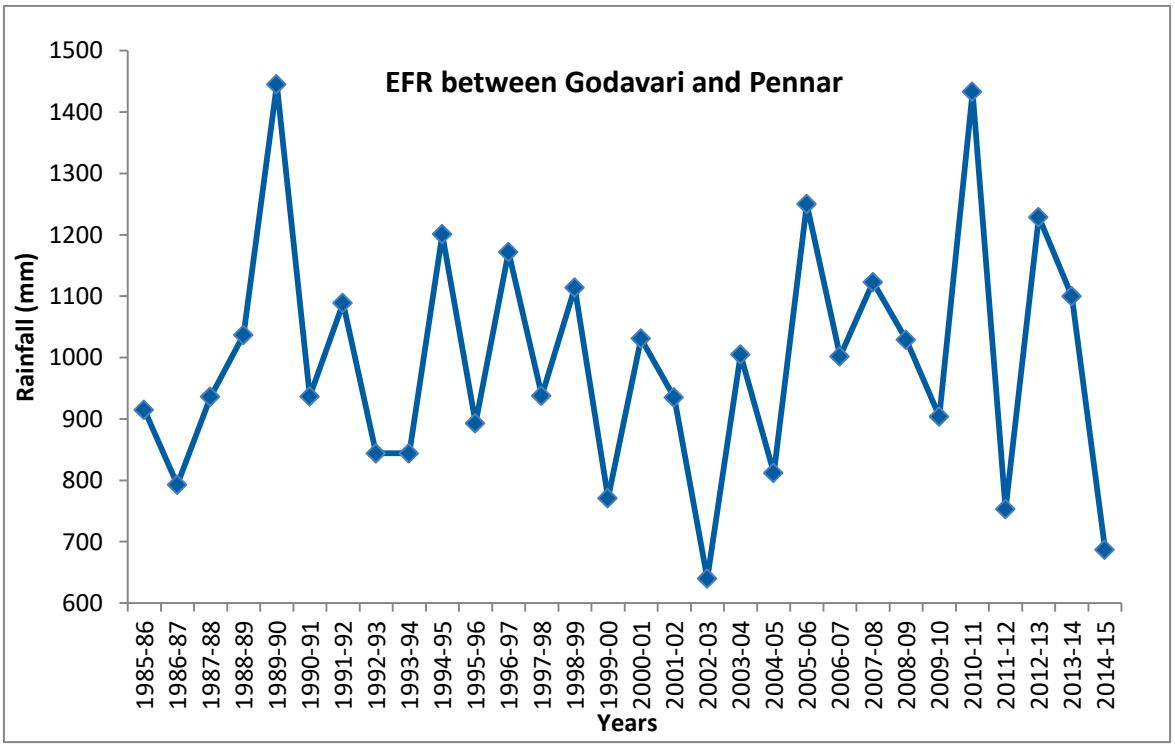


Figure 8.6(b) Annual rainfall of EFR between Godavari and Pennar basin (1985-2015)

8.2.2 Temperature grids

Gridded mean annual temperature of EFR between Mahanadi and Pennar basin is shown in Figure 8.7. The mean annual temperature during 2004-05 varied from 26.96^{o}C to 29.20^{o}C.

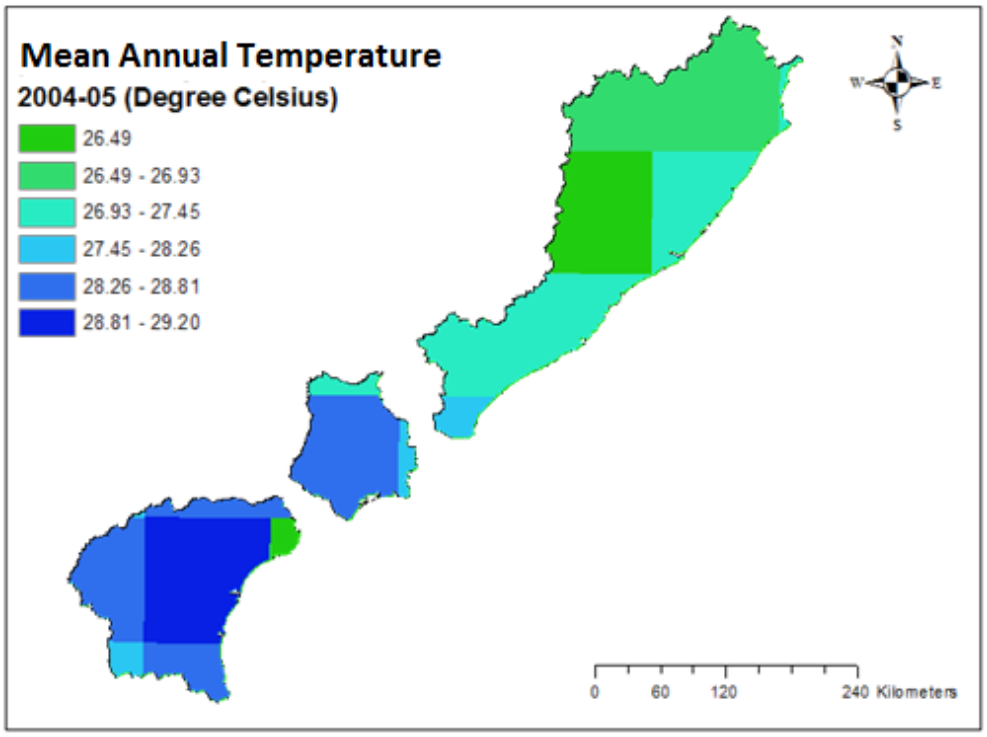


Figure 8.7 Gridded mean annual temperature of EFR between Mahanadi and Pennar basin (2004-05)

8.2.3 Sub-Basins of EFR between Mahanadi and Pennar

EFR between Mahanadi and Pennar basin is divided in to 6 sub-basins as shown in Figure 8.8 namely Purushottampur, Kashinagar, Srikakulam, Anakapally, Delta (Remaining area between Mahanadi and Godavari) and EFR between Godavari and Pennar. The sub-basins are divided in such way that the location of CWC discharge stations is taken as sub-basin outlet. The drainage area of each sub-basin is given at Table - 8.1.

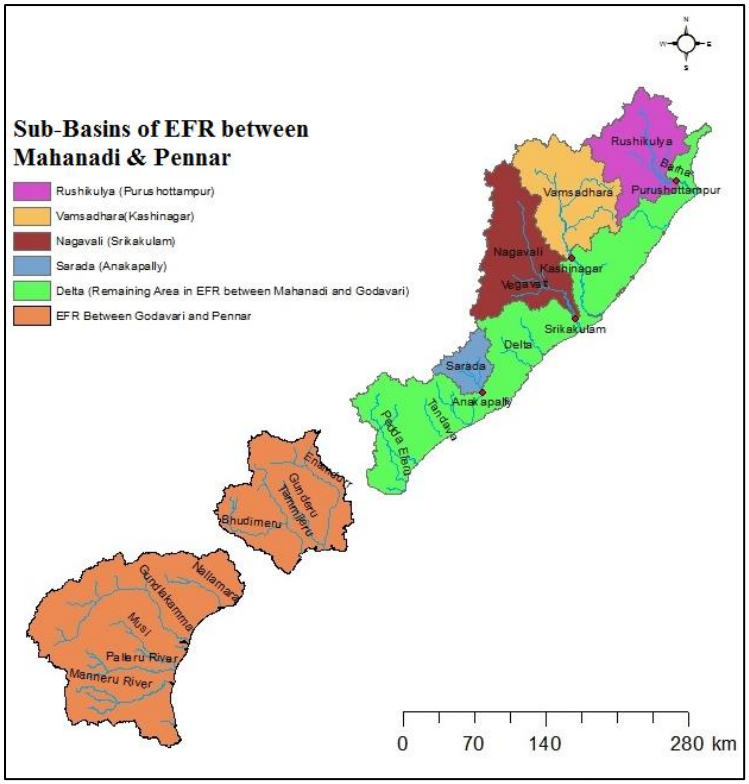


Figure 8.8 Sub-basins of EFR between Mahanadi and Pennar

Table - 8.1 Sub-basin wise details of EFR between Mahanadi and Pennar basin

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Purushottampur	Rushikulya	7,003
2	Kashinagar	Vamsadhara	7,919
3	Srikakulam	Nagavali	8,643
4	Anakapally	Sarada	2,017
5	Delta	Remaining Area between Mahanadi and Godavari	22,108
6	EFR between Godavari and Pennar	--	34,383
	Total basin area		82,073

8.2.4 River discharge

The river discharge data on main river are available at Kashinagar G&D site and at sites Anakapally, Srikakulam and Purushottampur for 30, 24, 24 and 22 years respectively. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level.

8.2.5 Reservoir flux

Reservoir flux data are not available for any major and medium reservoirs falling within the basin. However, Figure 8.9 shows the location of reservoirs in the basin.

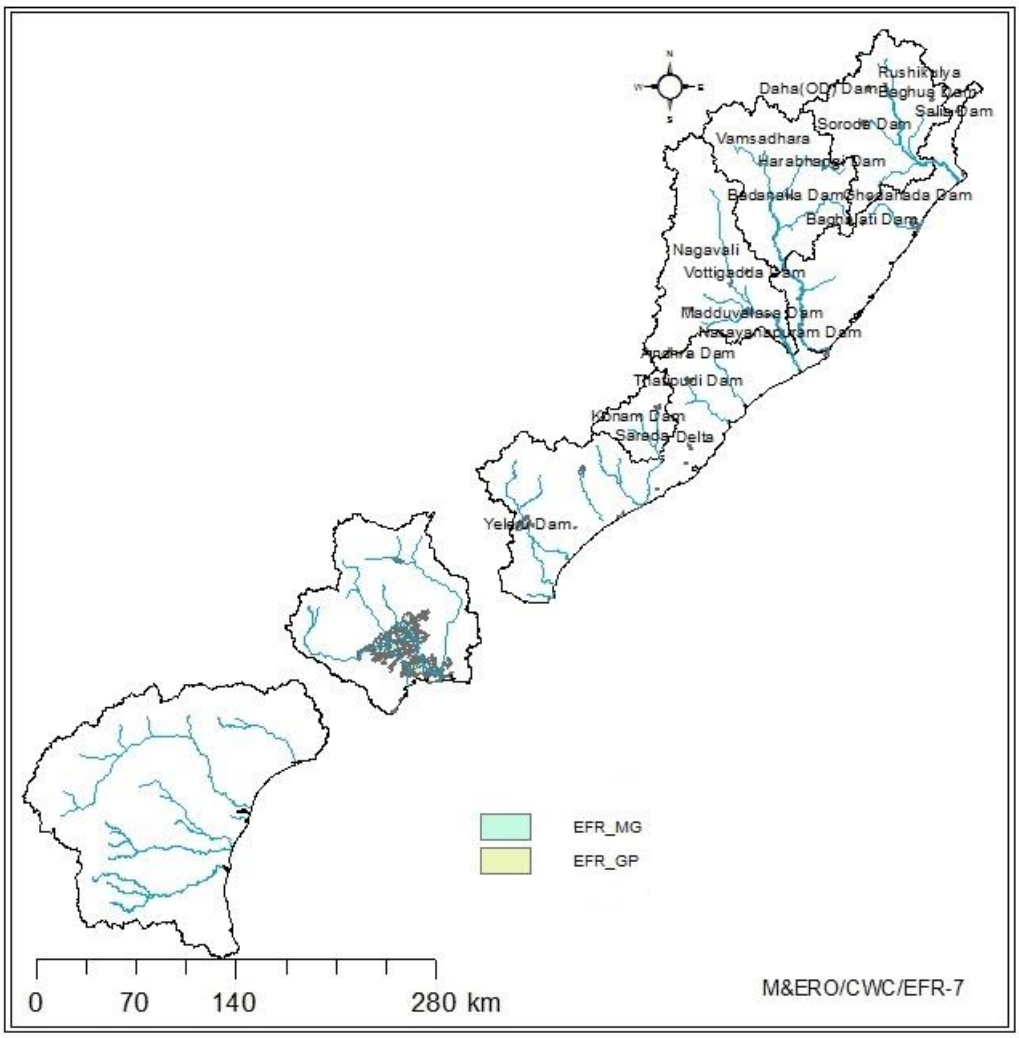


Figure 8.9 Major reservoirs in EFR between Mahanadi and Pennar basin

8.2.6 Groundwater flux

The spatial annual groundwater flux in the basin varies from 0.58 BCM to -0.42 BCM during year 2009-10 as shown Figure 8.10. The mean annual groundwater flux from 1984-85 to 2014-15 of the basin is estimated at -0.06 BCM (Figure 8.11).

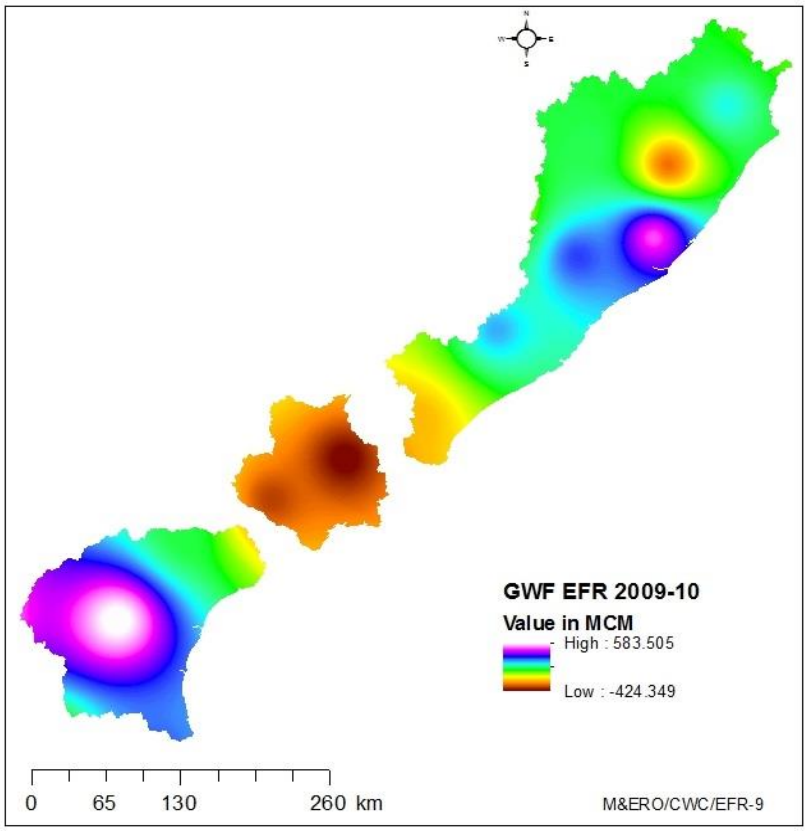


Figure 8.10 Groundwater Flux (spatial data) estimated during 2009-10

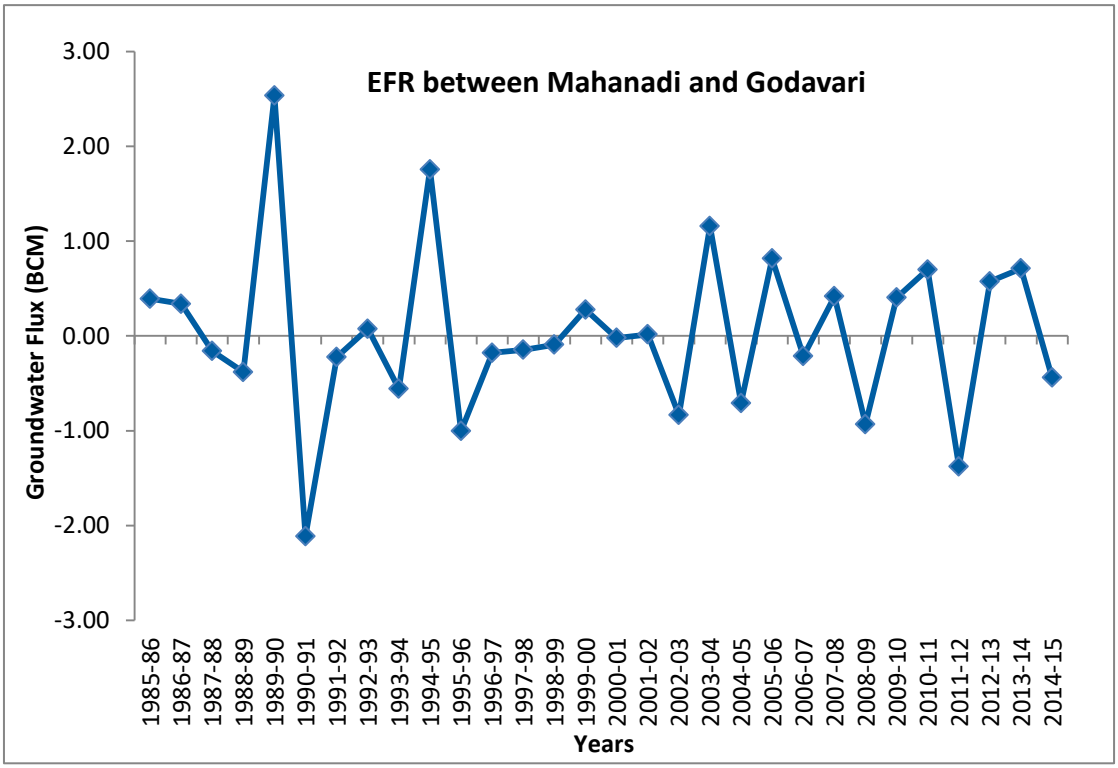


Figure 8.11(a) Annual groundwater flux of EFR between Mahanadi and Godavari basin (1985-1986 to 2014-15)

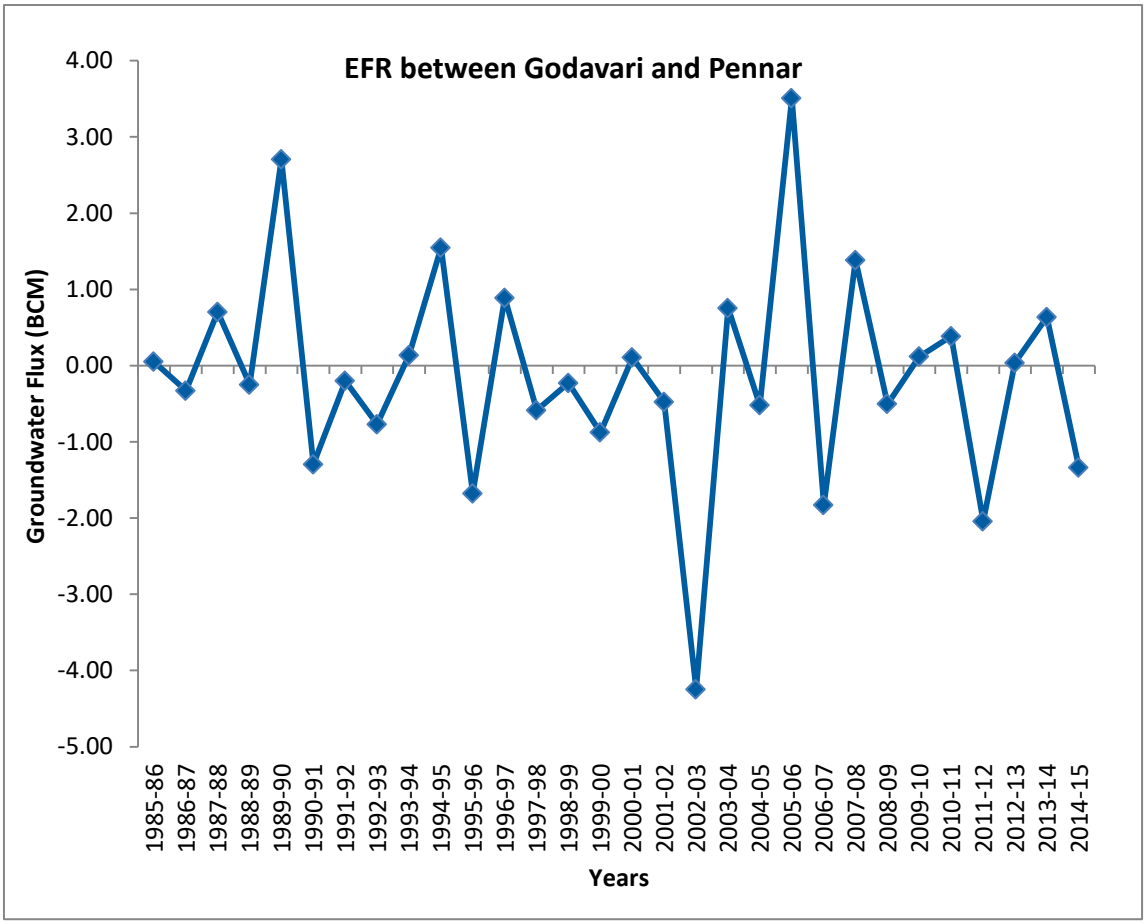


Figure 8.11(b) Annual groundwater flux of EFR between Godavari and Pennar basin (1985-1986 to 2014-15)

8.2.7 Major crops in the basin

EFR between Mahanadi and Pennar basin was divided in 12 (varying year to year) regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if maize is a major crop, it may be rice in the neighbouring district.

8.2.8 Irrigation command area

Figure 8.12 shows location of irrigation command boundaries of the EFR between Mahanadi and Pennar considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam.

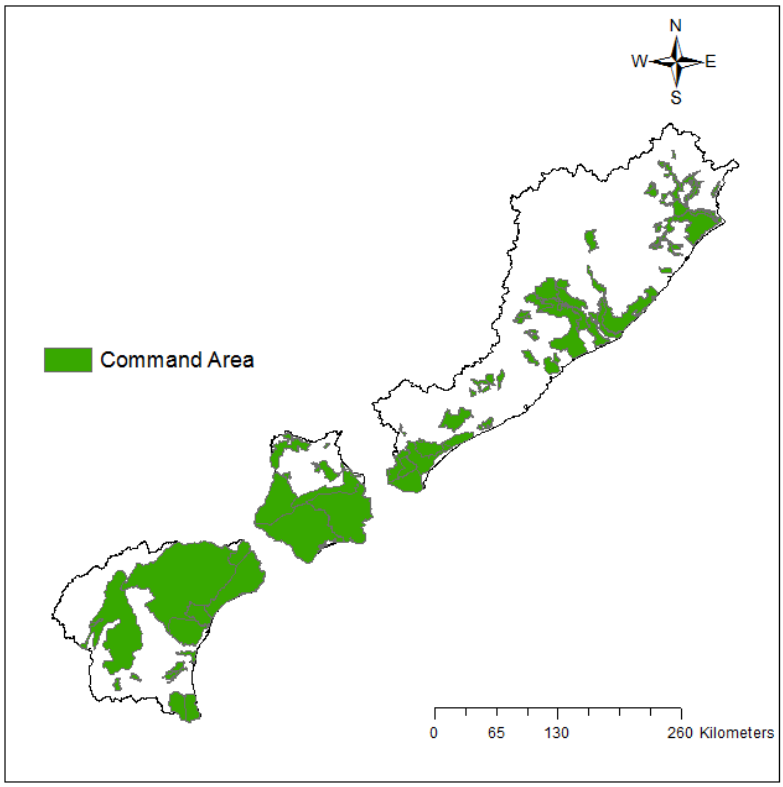


Figure 8.12 Irrigation command boundaries of EFR between Mahanadi and Pennar basin

8.2.9 Domestic, industrial and livestock demand

The mean annual domestic, industrial and livestock demands are estimated as 0.20 BCM during the period 1985-86 to 2014-15 in the basin. District boundaries with population of 2011 census are shown in Figure 8.13.

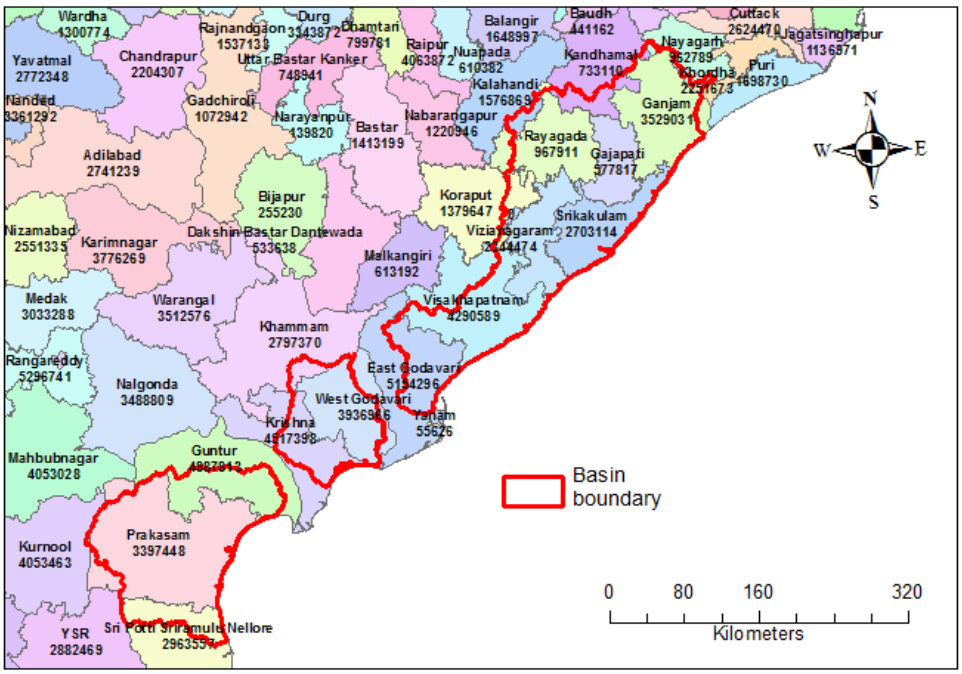


Figure 8.13 District boundaries in EFR between Mahanadi and Pennar basin

8.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 8.2 provides annual evaporation values from the basin for the period from 1985-86 to 2014-15. The average value of evaporation from the reservoirs is 1.26 BCM.

Table - 8.2 Evaporation in the reservoirs of EFR between Mahanadi and Pennar

Year	Reservoir Evaporation In Each Independent Sub-Basin (BCM)					
	Purusho-Ttampur	Kashinagar	Srikakulam	Anakapally	Delta	EFR Between Godavari and Pennar
1985-1986	0.03	0.03	0.05	0.01	0.42	1.18
1986-1987	0.03	0.02	0.03	0.01	0.22	0.80
1987-1988	0.02	0.02	0.03	0.01	0.24	1.06
1988-1989	0.02	0.02	0.02	0.01	0.23	1.43
1989-1990	0.03	0.02	0.03	0.01	0.32	1.39
1990-1991	0.03	0.01	0.03	0.01	0.20	1.03
1991-1992	0.02	0.01	0.03	0.01	0.22	1.35
1992-1993	0.03	0.01	0.03	0.01	0.23	0.98
1993-1994	0.02	0.02	0.02	0.00	0.00	0.88
1994-1995	0.02	0.01	0.03	0.01	0.29	1.33
1995-1996	0.03	0.02	0.05	0.01	0.43	1.10
1996-1997	0.02	0.02	0.02	0.01	0.11	2.02
1997-1998	0.02	0.02	0.03	0.01	0.28	1.14
1998-1999	0.03	0.03	0.05	0.01	0.51	1.72
1999-2000	0.02	0.02	0.03	0.01	0.28	1.04
2000-2001	0.02	0.02	0.02	0.00	0.11	1.51
2001-2002	0.03	0.02	0.03	0.01	0.26	1.03
2002-2003	0.02	0.02	0.02	0.00	0.09	0.82
2003-2004	0.03	0.02	0.02	0.01	0.10	1.61
2004-2005	0.05	0.02	0.03	0.01	0.13	0.89
2005-2006	0.04	0.03	0.06	0.01	0.26	1.45
2006-2007	0.03	0.02	0.05	0.01	0.32	1.40
2007-2008	0.03	0.02	0.08	0.02	0.41	1.82
2008-2009	0.02	0.02	0.03	0.00	0.27	1.57
2009-2010	0.03	0.03	0.06	0.01	0.49	1.08
2010-2011	0.04	0.03	0.05	0.01	0.43	1.41
2011-2012	0.01	0.03	0.04	0.01	0.26	0.89
2012-2013	0.07	0.04	0.04	0.01	0.31	1.32
2013-2014	0.05	0.03	0.05	0.01	0.35	1.22
2014-2015	0.03	0.02	0.02	0.00	0.12	1.31
Average	0.03	0.02	0.04	0.01	0.26	1.26
Average excluding 2014-15	0.03	0.02	0.04	0.01	0.27	1.26

8.3 Previous Estimates

When the basin wise assessment of the water resources of the country was made in 1949 on the basis of Khosla's formula, the annual runoff of the basin of the East Flowing Rivers between Mahanadi and the Godavari was estimated as 16.07 BCM. Similarly the annual runoff of the basin of the East Flowing Rivers between Krishna and Pennar has been estimated as 1.55 BCM. In 1960 the CW&PC, while conducting irrigation potential study, assessed the total annual runoff of the rivers between Mahanadi and the Godavari as 17.21 BCM based on the available observed data and Strange's Rainfall-Runoff Coefficients. In CWC Publication No.30/88, “Water Resources of India", April 1988, the average annual runoff in the east flowing rivers between Mahanadi and Pennar has been indicated as 16.95 BCM reportedly based on Khosla's formula.

8.4 Runoff Estimation

Discharge stations namely Purushottampur, Kashinagar, Srikakulam and Anakapally are selected on East Flowing Rivers between Mahanadi and Pennar and the model estimated runoff is calibrated against the observed discharge at all the four locations. Tables - H.1 to H.4 at Annexure - H give calibrated runoff along with observed discharge, rainfall, ECII, etc during 30 years for these discharge stations. Figure 8.14 shows comparison between mean observed discharge and mean calibrated runoff at various gauge stations. Figures 8.15 to 8.18 show comparative graphs of calibrated runoff and observed discharge at these discharge stations.

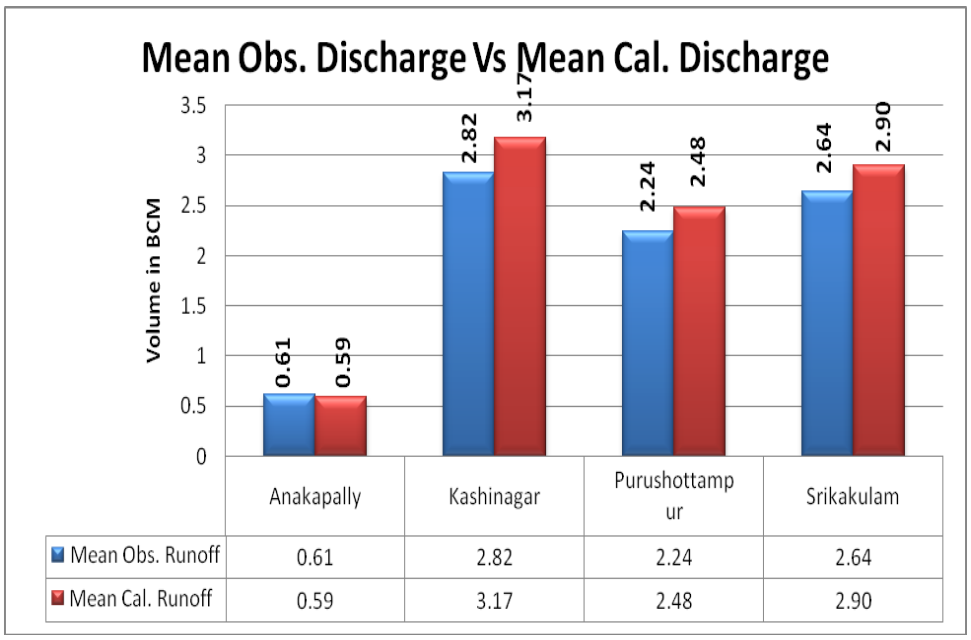


Figure 8.14 Calibrated runoff and Observed discharge at various gauge stations

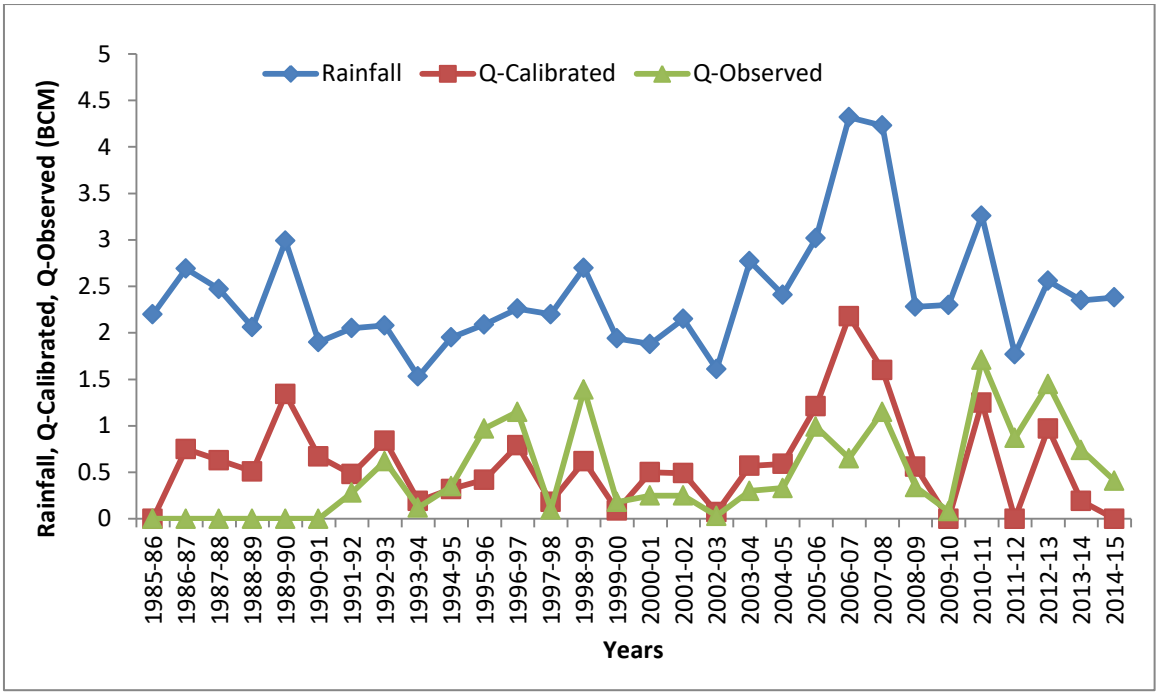


Figure 8.15 Calibrated runoff and observed discharge at Anakapalli

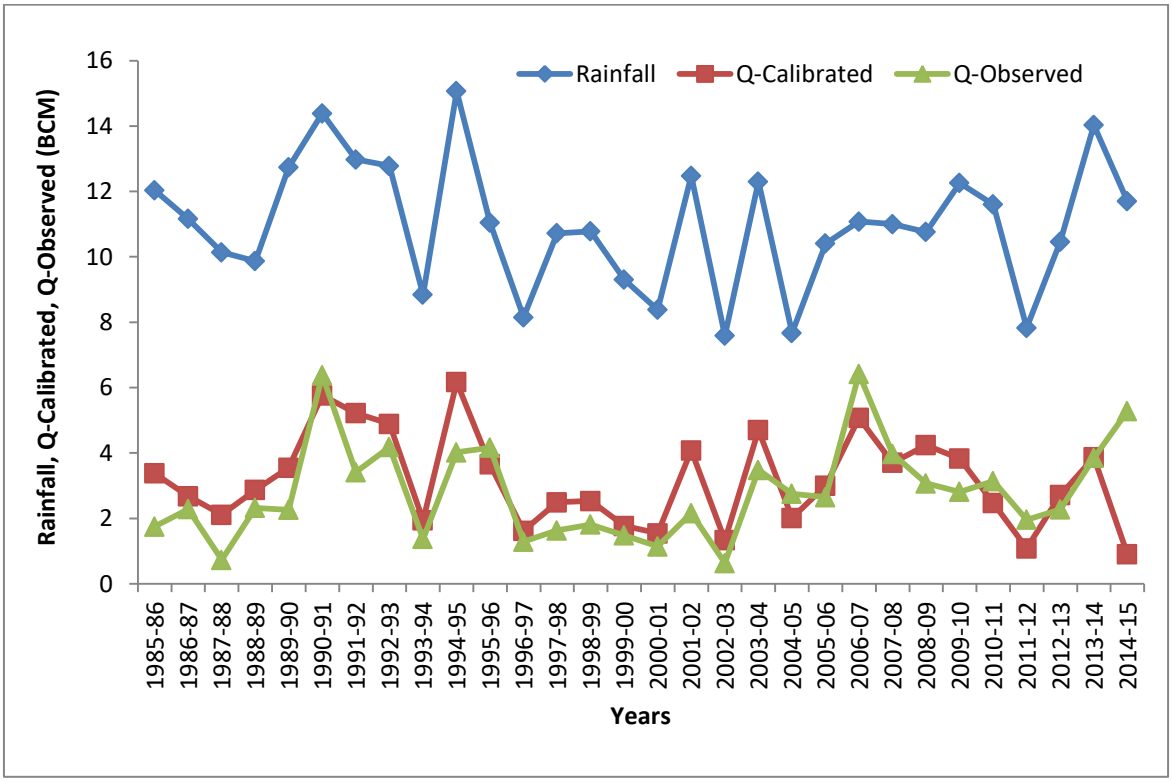


Figure 8.16 Calibrated runoff and observed discharge at Kashinagar

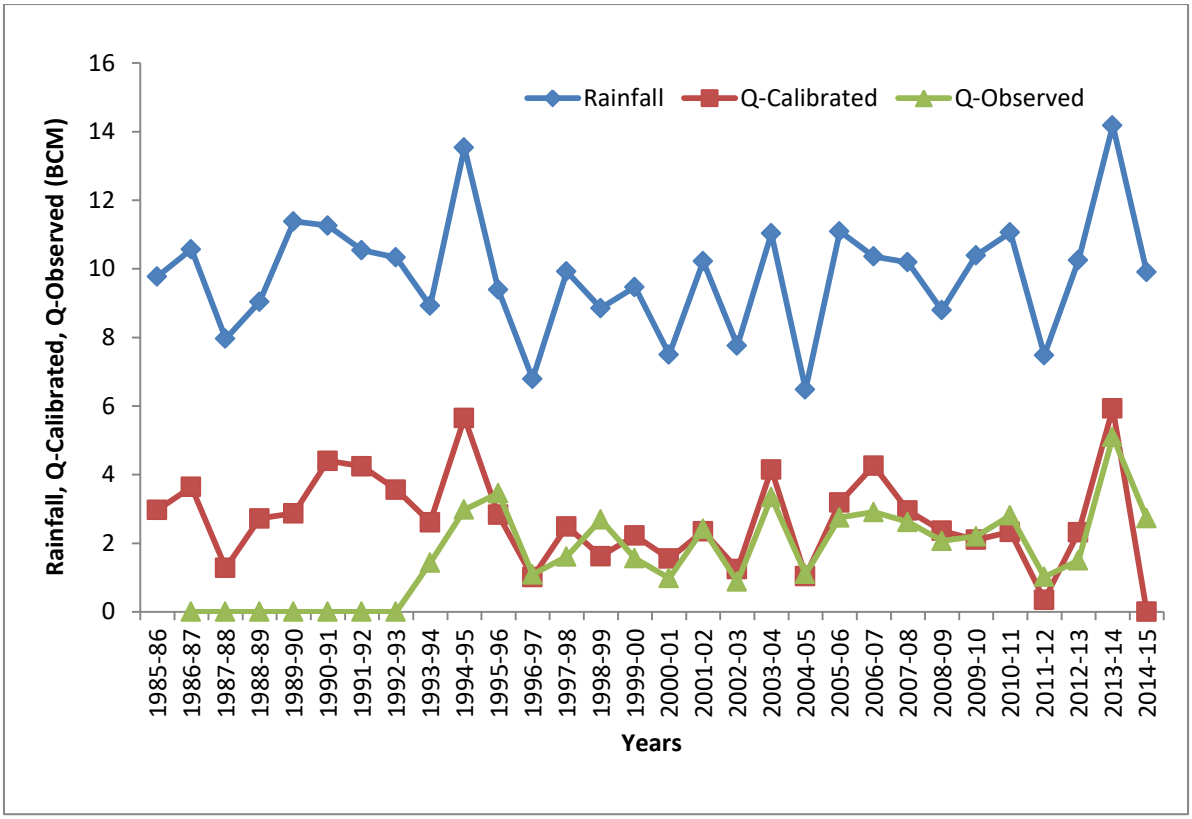


Figure 8.17 Calibrated runoff and observed discharge at Purushottampur

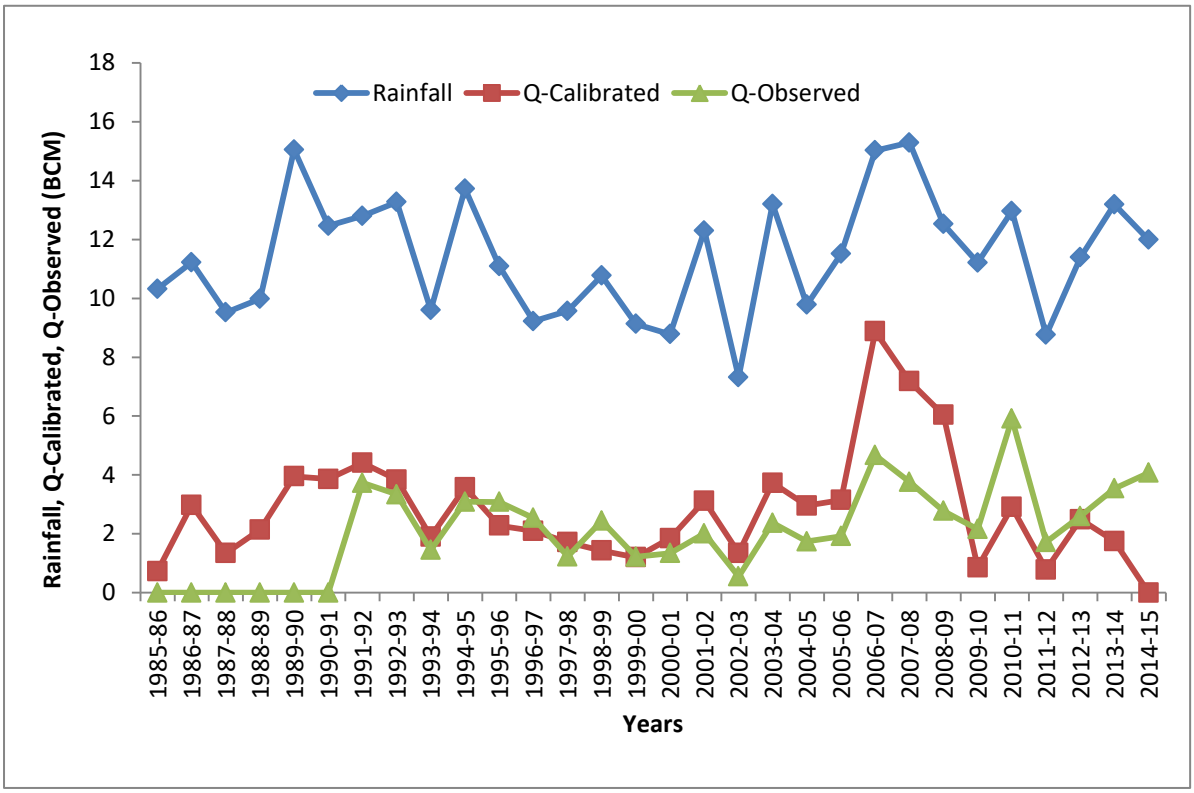


Figure 8.18 Calibrated runoff and observed discharge at Srikakulam

8.4 Annual Water Resources Availability of EFR between Mahanadi and Pennar Basin

Table - H.5 at Annexure - H shows the different components required to estimate the basin level water resources of EFR between Mahanadi and Pennar basin for 30 years. The mean annual calibrated runoff is about 25.55 BCM. The maximum annual calibrated runoff is 45.10 BCM during 2006-07. The minimum annual calibrated runoff is 9.05 BCM during 2011-12. The mean annual ECII is about 6.00 BCM. The maximum annual ECII is about 10.83 BCM during 2011-12. The minimum annual ECII is about 2.58 BCM during 1991-92.

The maximum annual water resource is 44.33 BCM during 2006-07 in the 30 years. The minimum annual water resource is 9.30 BCM during 2011-12 which is the driest year in the 30 years. The mean available basin water resource is 26.41 BCM. The mean available water resource of EFR between Mahanadi and Pennar basin accounts about 27.23 % of mean rainfall during 1985-86 to 2014-15.

8.4.1 Annual water resources of EFR between Mahanadi and Pennar basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 1989-90 and 2002-03, extreme wet and dry rainfall conditions occurred in the basin. The annual water resources of the basin during these two extreme rainfall conditions are 42.57 BCM and 10.69 BCM respectively as shown in Table - 8.3. The water balance components during these years are presented in Figures 8.19 and 8.20.

Table - 8.3 Water resources availability in EFR between Mahanadi and Pennar basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources availability (BCM)
Maximum Rainfall	1989-90	130.81	42.58
Minimum Rainfall	2002-03	63.53	10.70

Water resources availability- rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.32 and 0.17 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years PET is less compared to the dry years, this will have cumulative effect in runoff.

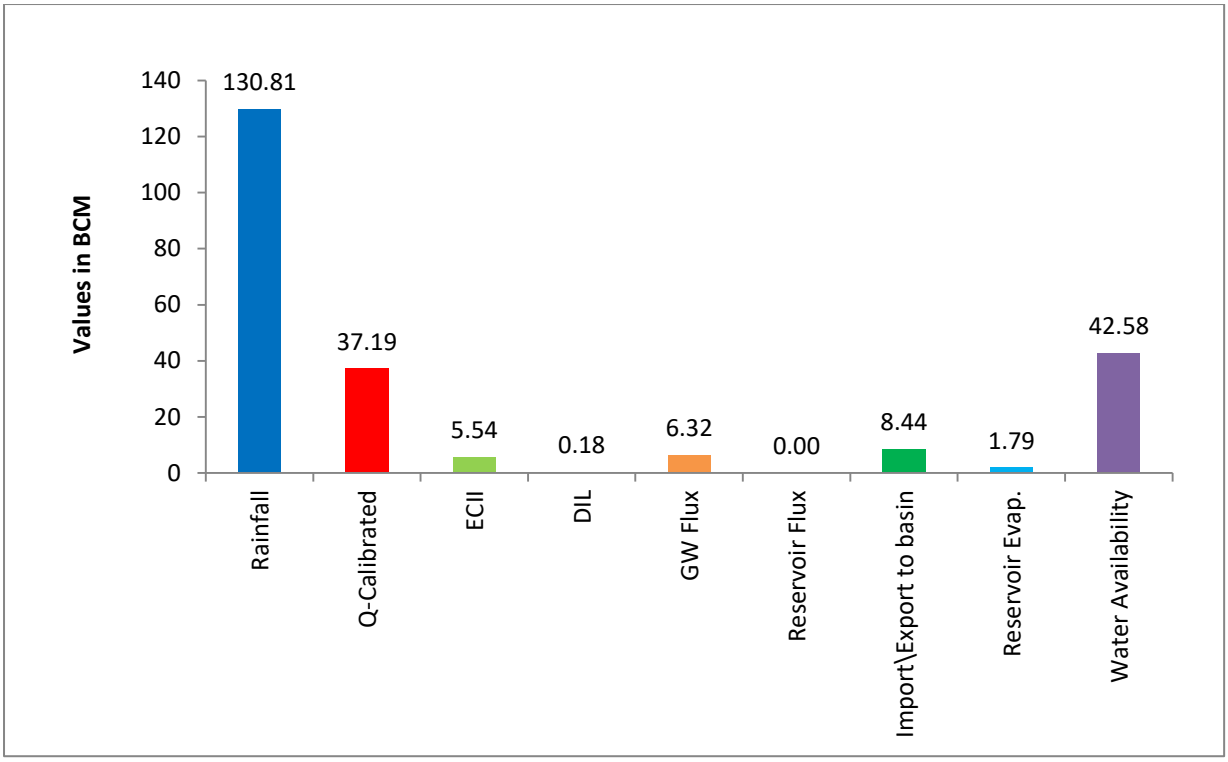


Figure 8.19 Water balance components of EFR between Mahanadi and Pennar basin during extreme high rainfall (1989-90)

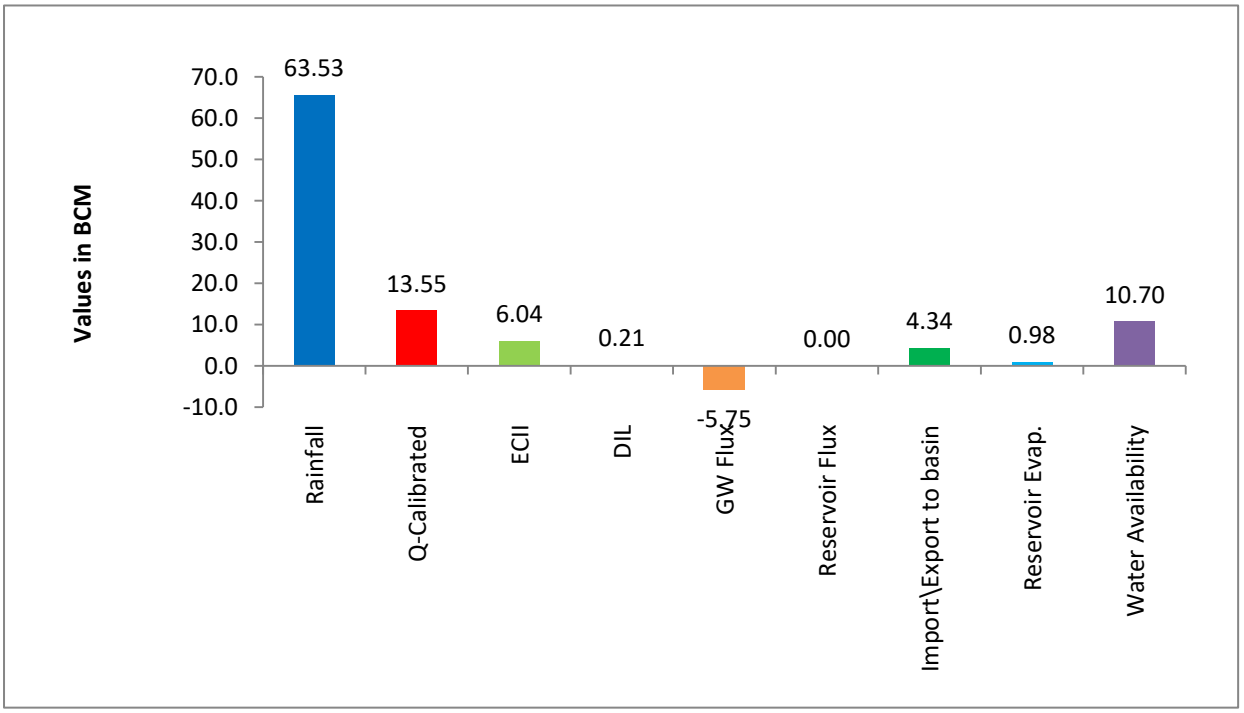


Figure 8.20 Water balance components of EFR between Mahanadi and Pennar basin during extreme low rainfall (2002-03)

8.4.2 Mean water resources of EFR between Mahanadi & Pennar

The mean water resources of the basin is computed by taking mean of the 30 years water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and Industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industries and Livestock consumption + Groundwater Flux + Reservoir Flux + Export / Import from basin+ Evaporation from Reservoirs)

= 25.50 + 6.00 + 0.20 + (-0.06) + 0.00 + (-6.85) + 1.62 = 26.41 BCM

75% dependable flow of EFR between Mahanadi and Pennar basin = 17.41 BCM

The mean available annual water resource of the EFR between Mahanadi and Pennar basin is 26.41 BCM. Figure 8.21 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

It is observed that the computed runoff factors varies from 0.02 (1,024 mm rainfall) to 0.41 (1,330 mm rainfall). The mean runoff factor for 30 year period is 0.26.

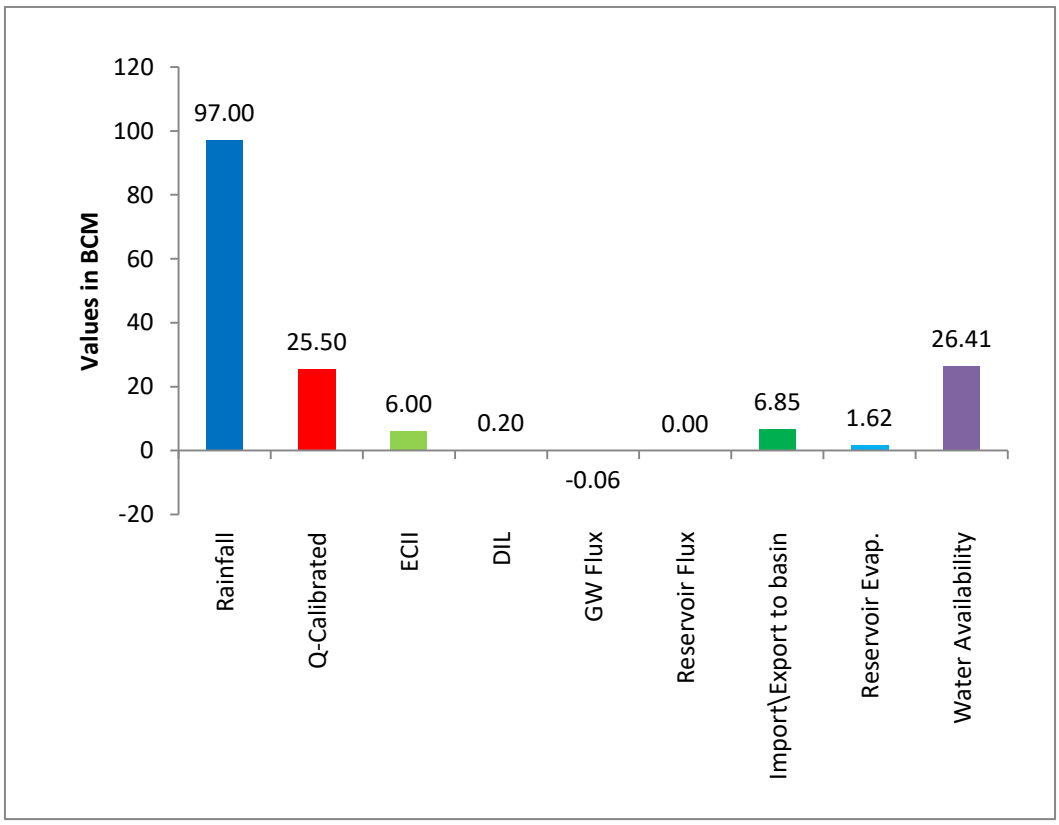


Figure 8.21 Mean water balance components of EFR between Mahanadi & Pennar basin

8.5 Basin Outward Diversions / Imports

The imports to the basin during the period 1985-86 to 2014-15 are depicted in Table - 8.4.

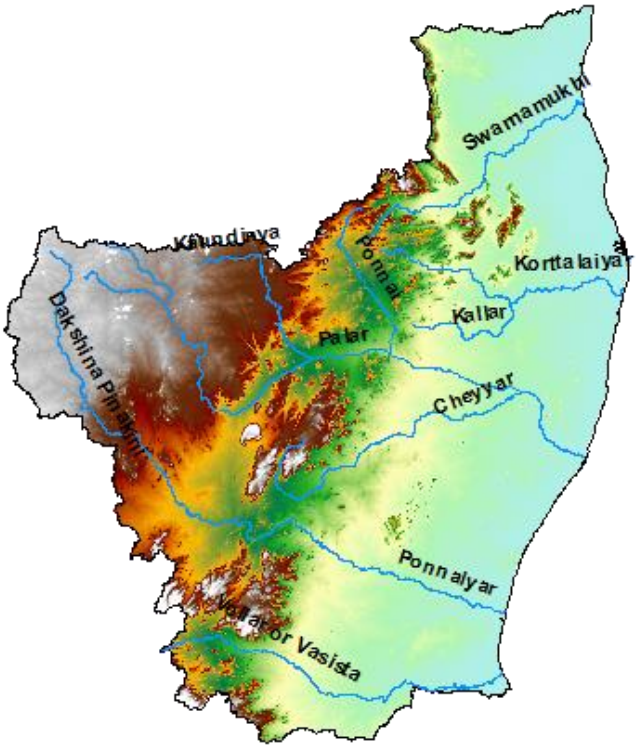
Table - 8.4 Details of Imports considered for Mahanadi and Pennar basin study

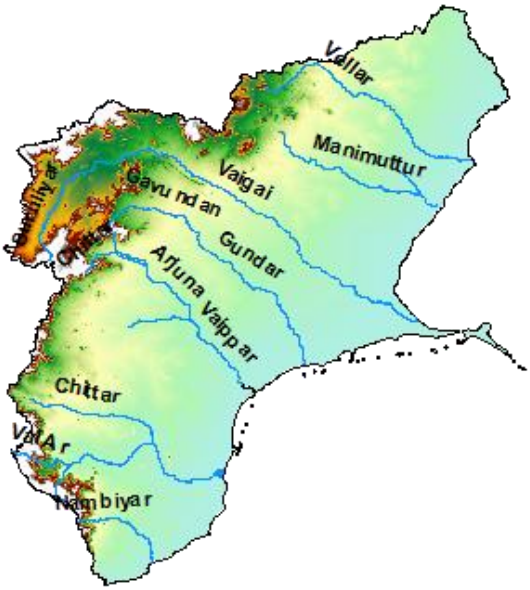
Sl. No.	Imports	Average Quantity (in BCM)	Remarks
A	**Between Godavari and Krishna**		#Figures represents the ECII component worked out for NSD Left Bank Canal and Right Bank Canal command area lying outside the basin * The values against KDS system are derived on pro rata basis (from the values available in KWDT -II award from the year 1985 to 2006 and later data downloaded from CADARSMS website) after accounting the return flows into delta area within the basin. The return-flows into the delta basin are taken as ECII generated from delta area.
1.	NSD LBC command area lying outside the basin#	0.6170	
2.	KDS command area (Left side) lying outside the basin*	2.0902	
	Total of A	**2.7072**	
B	**Between Krishna and Pennar**		
1.	NSD RBC command area lying outside the basin#	2.6960	
2.	KDS command area (Right side) lying outside the basin*	1.4481	
	Total of B	**4.1441**	
	Grand total of A and B	**6.8513**	

HIGHLIGHTS

- *Mean available water resource of EFR between Mahanadi and Pennar basin is 26.41 BCM.*
- *Maximum annual water availability is 44.33 BCM during 2006-07.*
- *Minimum annual water availability is 9.30 BCM during 2011-12.*
- *Annual rainfall in the basin varies from 784 mm to 1,565 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1,144 mm.*
- *EFR between Mahanadi and Pennar basin is divided into six sub-basins for the reassessment study viz. Purushottampur, Kashinagar, Srikakulam, Anakapally, Delta (Remaining area between Mahanadi and Godavari) and EFR between Godavari and Pennar.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.20 BCM.*
- *Average annual evaporation from water bodies in the basin is 1.62 BCM.*

EAST FLOWING RIVERS (EFR) BETWEEN PENNAR AND KANYAKUMARI





9.1 Geo-Spatial Data Sets

9.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of EFR between Pennar and Kanyakumari basin is shown in Figure 9.1.The map corresponds to year 2004-05 indicating Current Fallow (21.74%), Kharif only (23.97%), Double/triple (11.20%) and Deciduous Forest (9.54%) are the major classes in the basin (Figure 9.2).

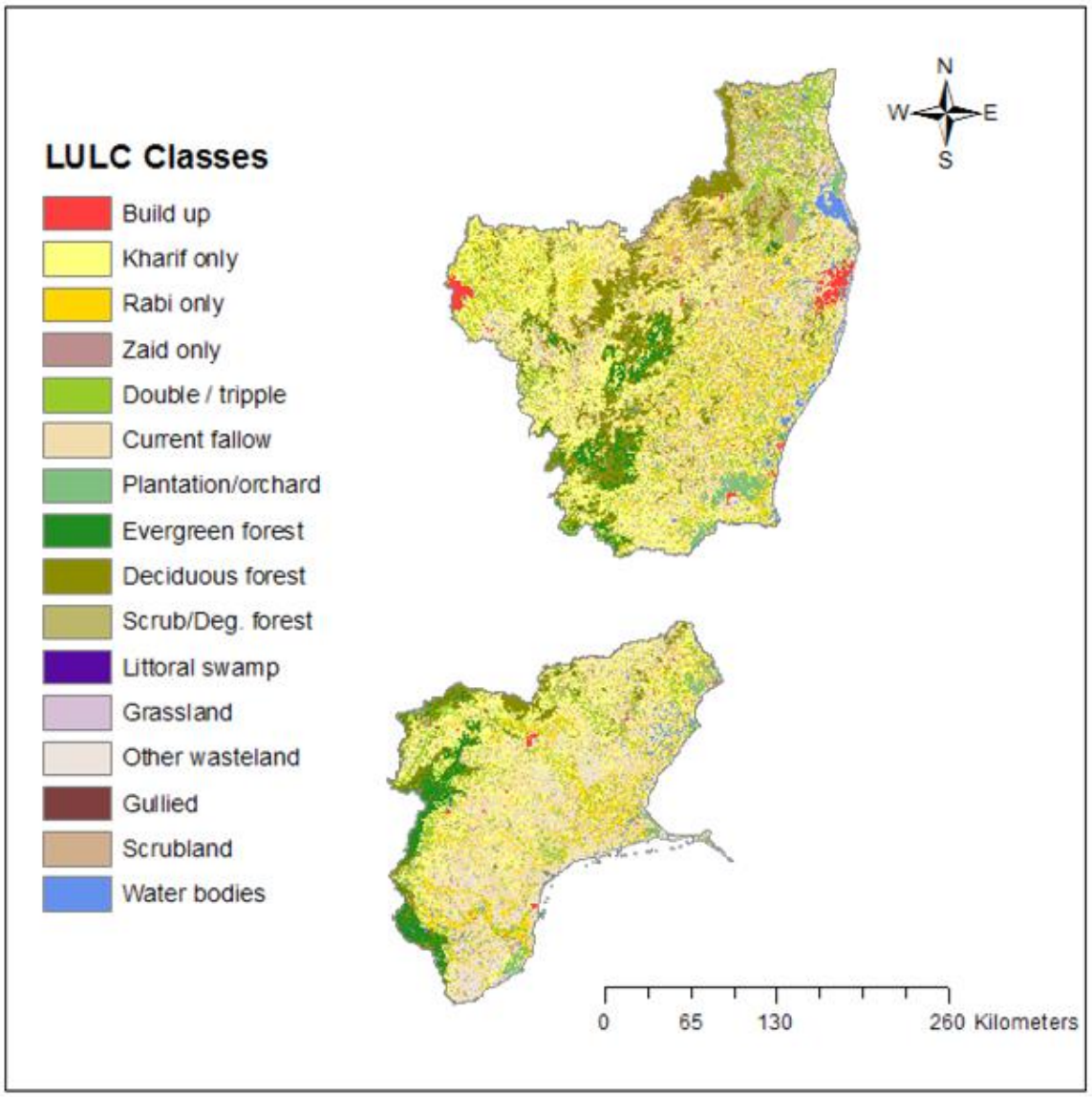


Figure 9.1 LULC map of EFR between Pennar and Kanyakumari (2004-05)

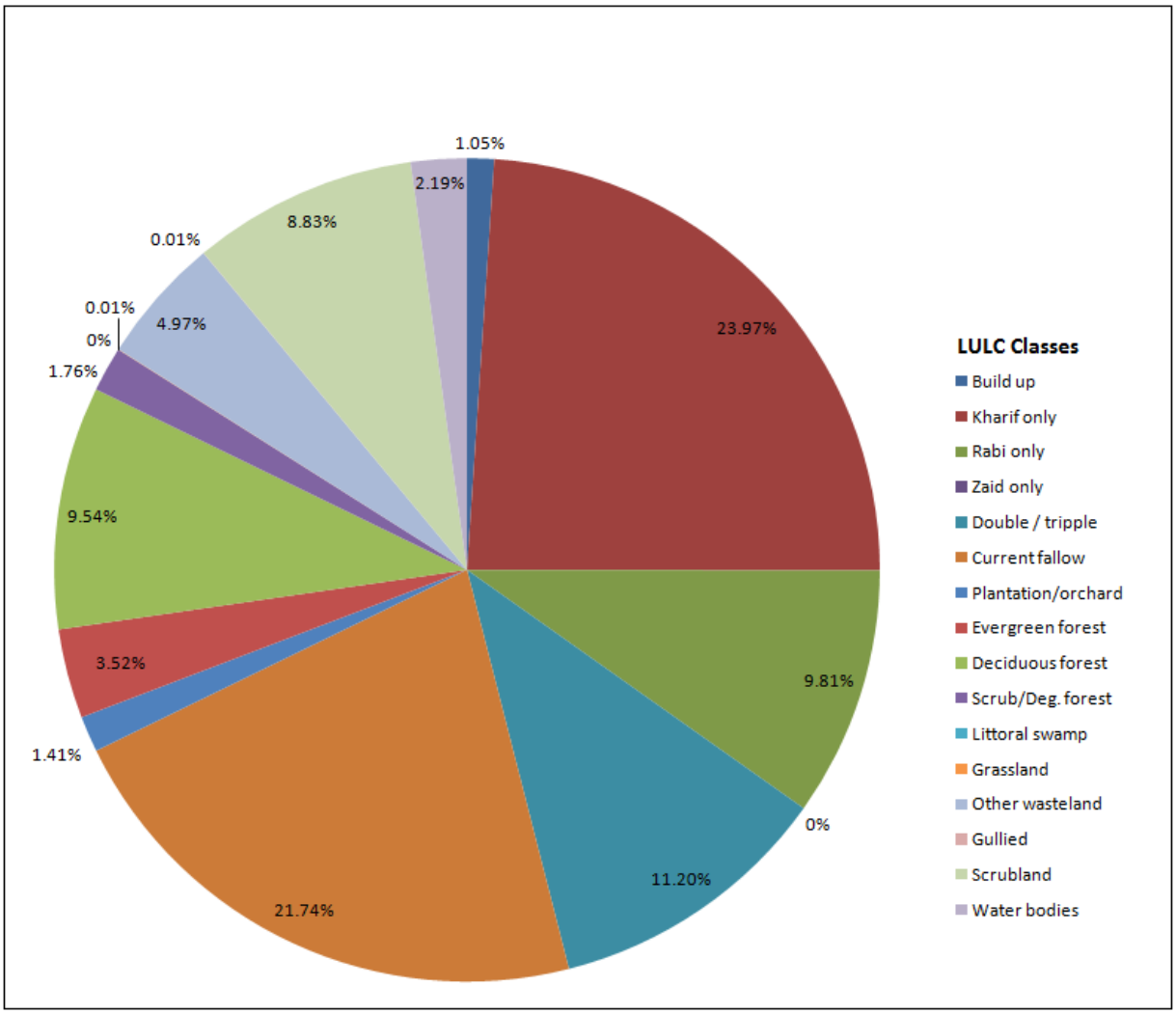


Figure 9.2 Distribution of LULC in EFR between Pennar and Kanyakumari basin (2004-05)

9.1.2 Soil texture

The main soil types found in the basin are clay, clayey skeletal and loamy soils. The coastal plains consist of fertile delta area highly suited for intensive cultivation. Figure 9.3 shows various categories of soil in the basin. The soils are classified as clay, loam, sand, clay skeletal, loamy skeletal, marshy and rock outcrops based on the soil texture information.

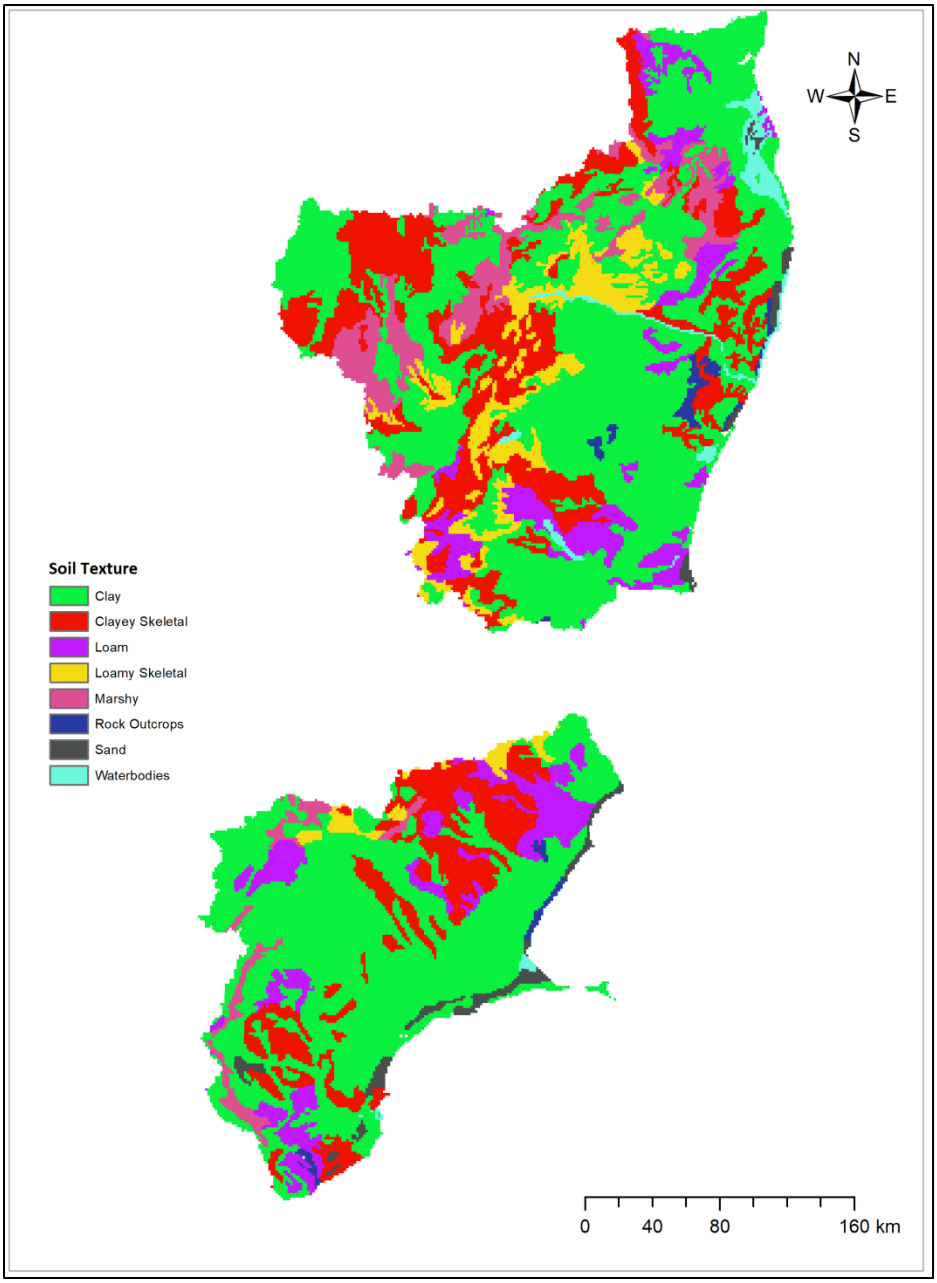


Figure 9.3 Soil texture map of EFR between Pennar and Kanyakumari basin

9.1.3 Topography

The topography of the basin consists of ghat areas, plateau and the coastal plains. The upper regions (western side) of the basin are mostly hilly and forested. The lower region of the basin is deltaic plains. The elevation value ranges from a minimum of 0 m to a maximum of 2,650 m. The average elevation is about 186 m in the basin. Figure 9.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating sub-basin boundaries of EFR between Pennar and Kanyakumari basin.

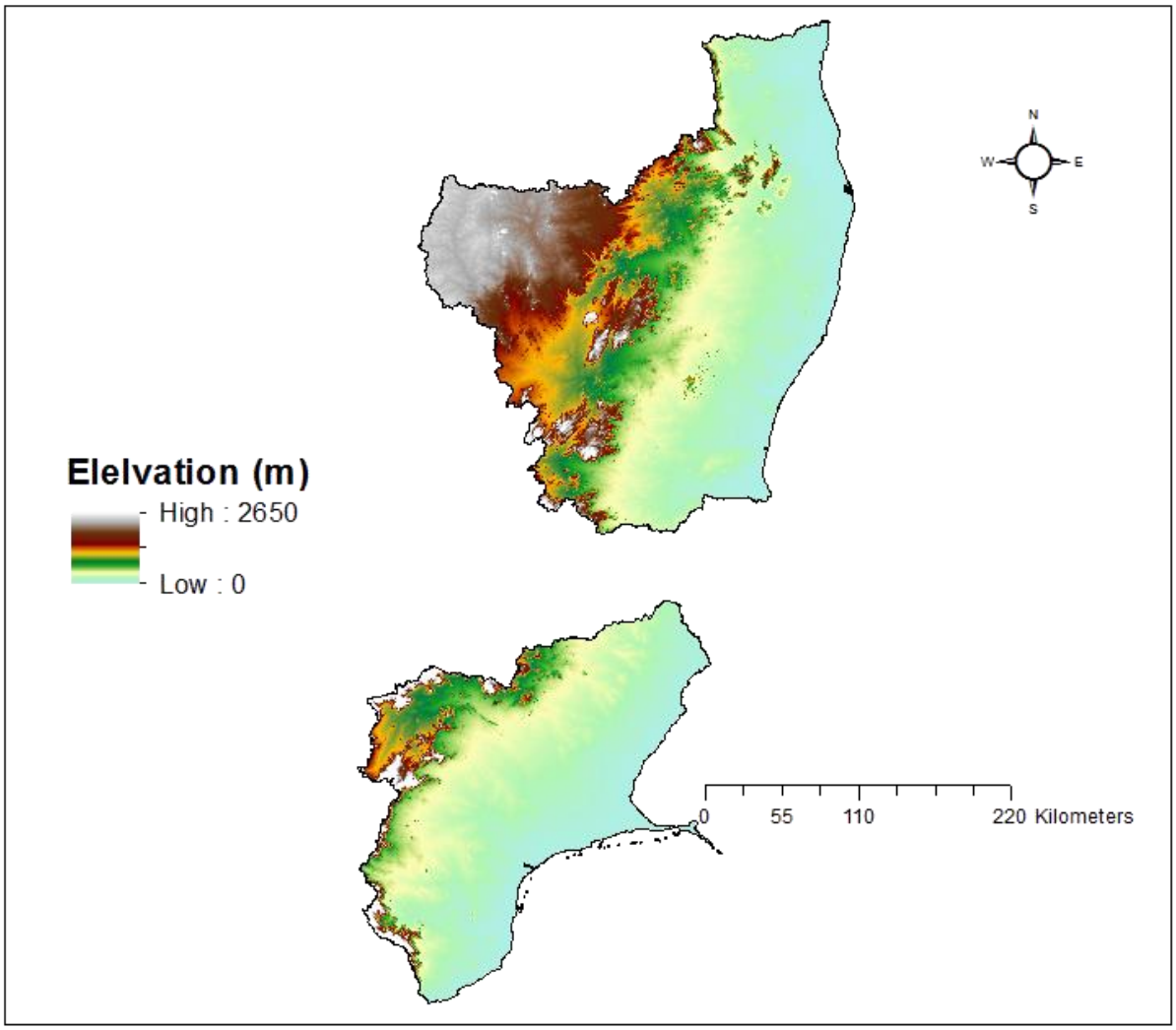


Figure 9.4 SRTM DEM map of EFR between Pennar and Kanyakumari basin

9.2 Hydro-Meteorological and other Input Data

9.2.1 Rainfall grids

Figure 9.5 shows gridded rainfall map of EFR between Pennar and Kanyakumari basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 9.6. Annual rainfall of the basin varies from 411 mm in 2002-03 to 1,424 mm in 2011-12 and mean rainfall of these 30 years is found to be 960 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum rainfall of around 330.58 mm is observed in Vilupuram sub-basin while maximum rainfall of 2,189 mm is observed in Paramakudi sub-basin. Of the 30 years, for 15 years annual rainfall is higher than the mean rainfall and for the remaining 15 years lower than the mean rainfall.

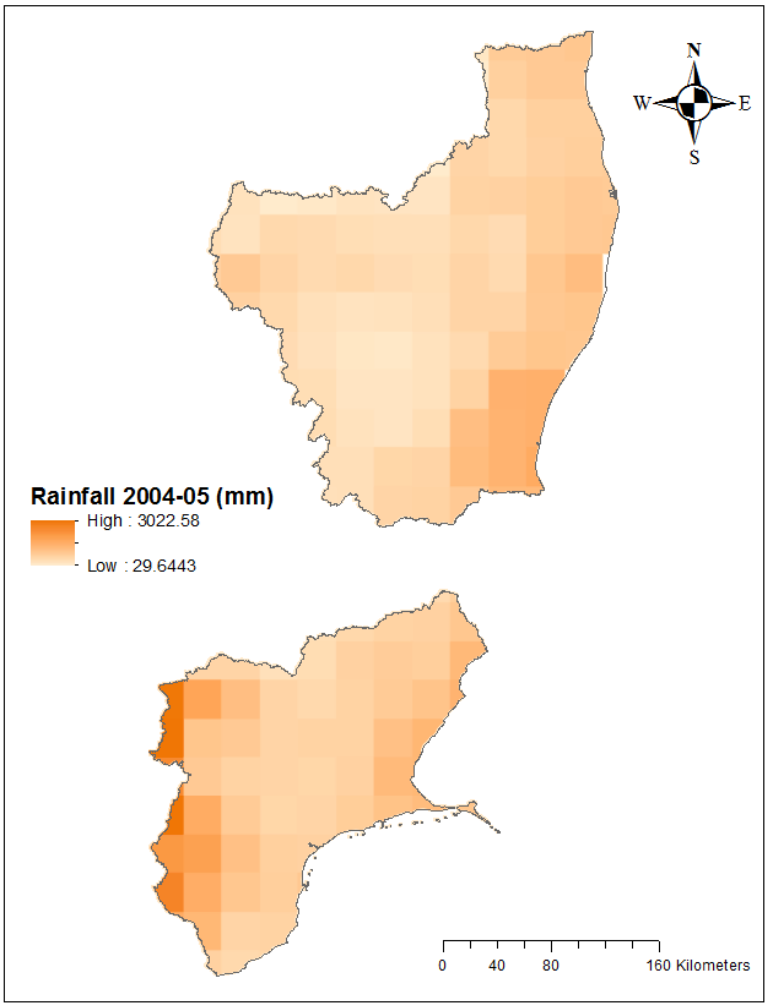


Figure 9.5 Gridded rainfall of EFR between Pennar and Kanyakumari basin (2004-05)

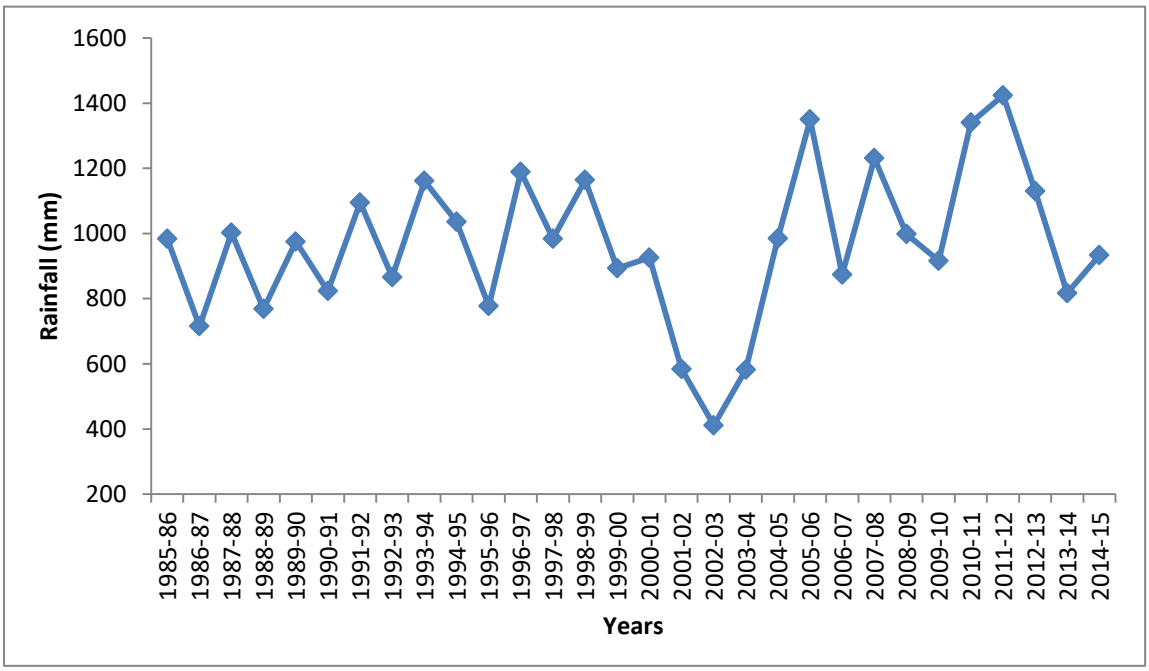


Figure 9.6 Annual rainfall in EFR between Pennar and Kanyakumari (1985-86 to 2014-15)

9.2.2 Temperature grids

The mean annual temperature during 2004-05 varies from 24.04^{0}C to 28.96^{0}C. Temperature grid is shown at Figure 9.7.

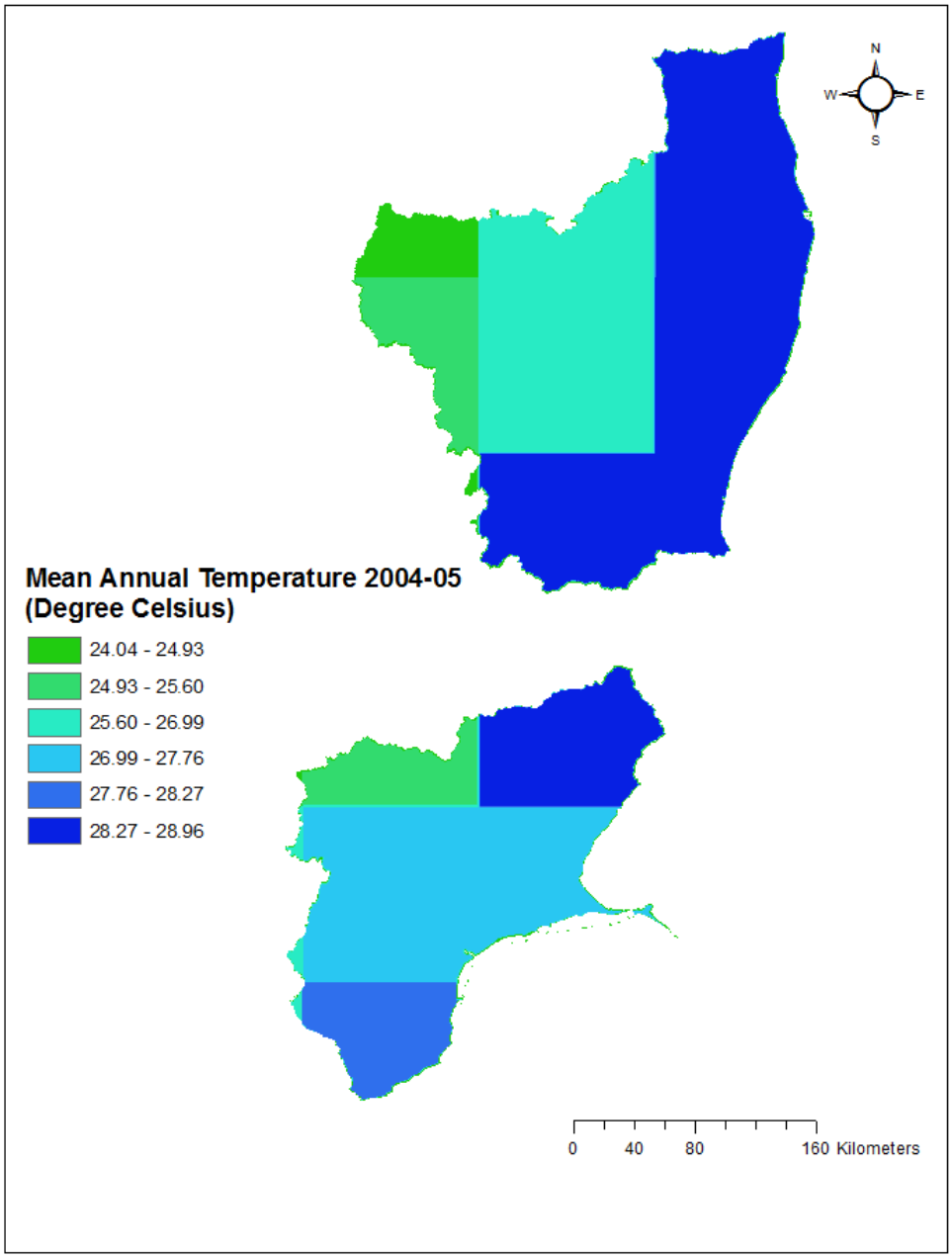


Figure 9.7 Gridded mean annual temperature of EFR between Pennar and Kanyakumari basin (2004-05)

9.2.3 Sub-basins of EFR between Pennar and Kanyakumari

The basin is divided in to 5 sub-basins (Figure 9.8) viz. Chengalpet, Vilupuram, Paramakudi and Murappanad and uncalibrated area. The remaining area is taken as uncalibrated area as no discharge site is available. Table - 9.1 gives details of each sub-basin. The sub-basins are divided in such a way that the location of CWC discharge sites is taken as sub-basin outlet.

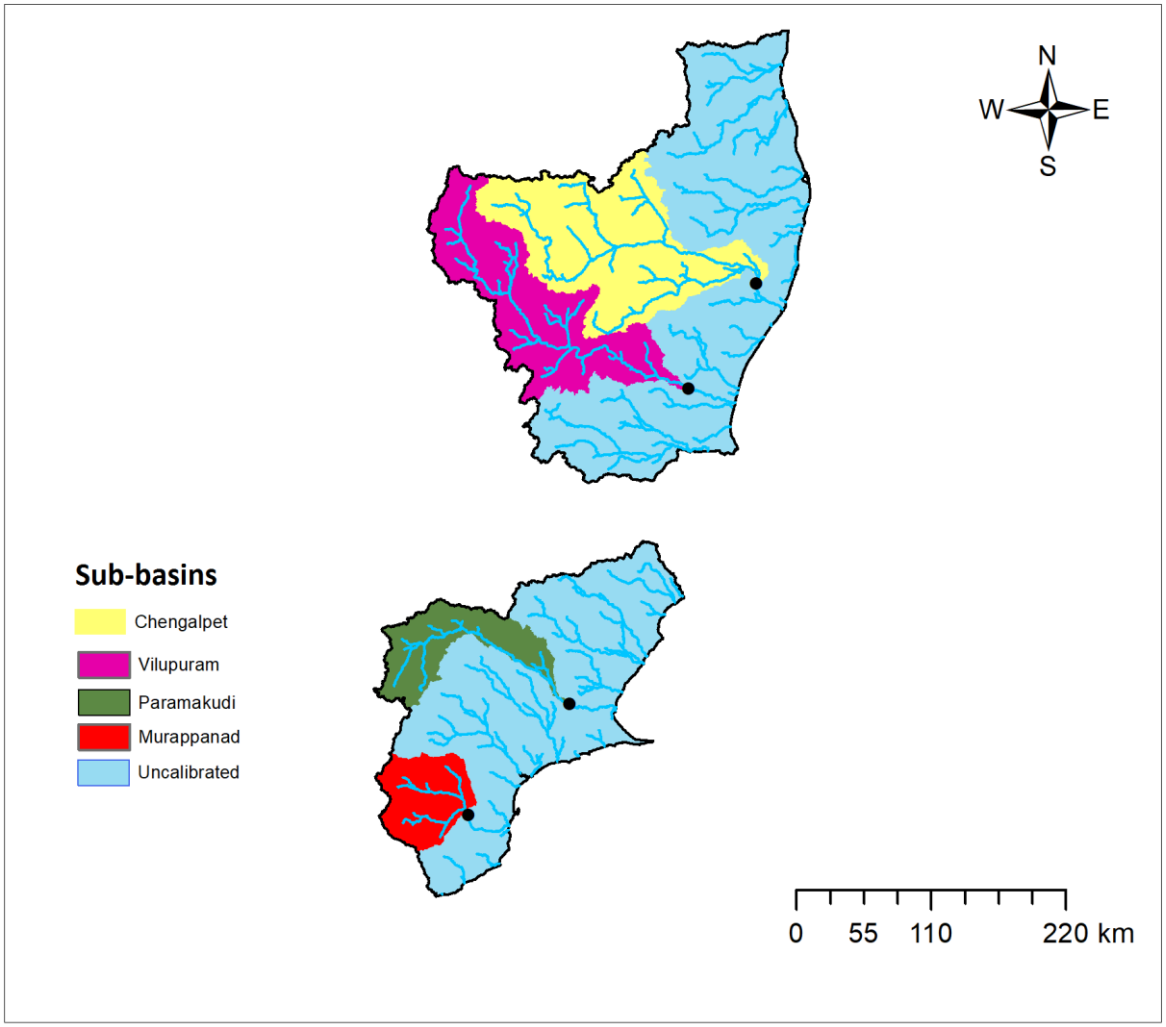


Figure 9.8 Sub-basins of EFR between Pennar and Kanyakumari basin

Table - 9.1 Sub-basin wise details of EFR between Pennar and Kanyakumari

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Chengalpet	Palar	16,250
2	Vilupuram	Pannaiyar	13,231
3	Paramakudi	Vaigai	5,684
4	Muruppanad	Tambraparani	4,585
5	Uncalibrated portion		61,907
	Total basin area		1,01,657

9.2.4 River discharge

The river discharge data was available for 30 years (1985-86 to 2014-15) for all the 4 sites Chengalpet, Vilupuram, Paramakudi and Murappanad. The daily discharge data was aggregated to annual scale and was used for calibration and validation of model computed discharge at sub-basin level. The area other than the 4 sub-basins are not calibrated but taken into account for calculating the water resources availability of the basin using the same calibrated input values and coefficients.

9.2.5 Reservoir flux

Figure 9.9 shows the location of some of the reservoirs in EFR between Pennar and Kanyakumari. There is no major/medium reservoir in the basin with significant storage whose annual fluxes contribute to the water resources assessment of the basin.

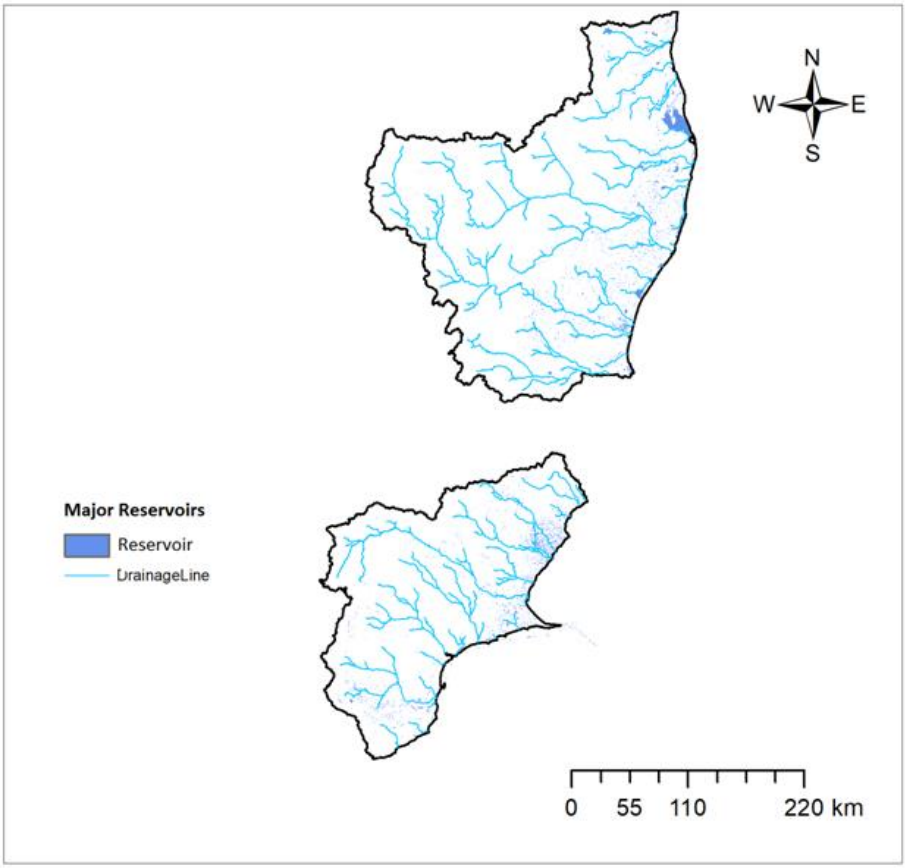


Figure 9.9 Major reservoirs in EFR between Pennar and Kanyakumari basin

9.2.6 Groundwater flux

The spatial annual groundwater flux in the basin varies from 644.716 MCM to -1,946.85 MCM during year 2004-05 as shown Figure 9.10. The yearly variation in groundwater flux (in BCM) from 1985-2015 is shown in Figure 9.11.

9.2.7 Major crops in the basin

EFR between Pennar and Kanyakumari basin was divided in 6 regions based on the historic district-wise crop statistics collected from various sources (http://lus.dacnet.nic.in/ dt_lus.aspx). Each region specifies a unique crop for each crop season both spatially and temporally within the basin. For example (spatial variation) in Kharif only season in a district, if groundnut is a major crop, it may be

ragi or jowar in the neighbouring district. Similarly, temporal variation indicates for example during 2004-05, if groundnut is a major crop in Kharif only season, it may be rice or bajra during 2005-06.

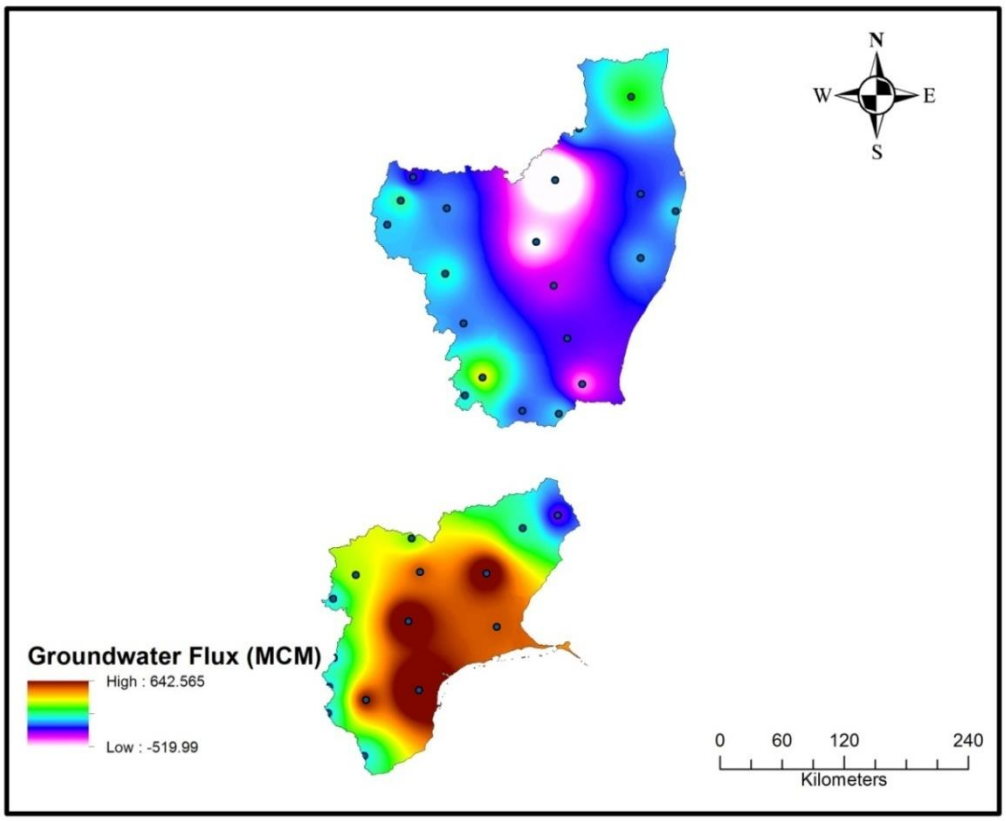


Figure 9.10 Groundwater flux (spatial data) estimated during 2004-05

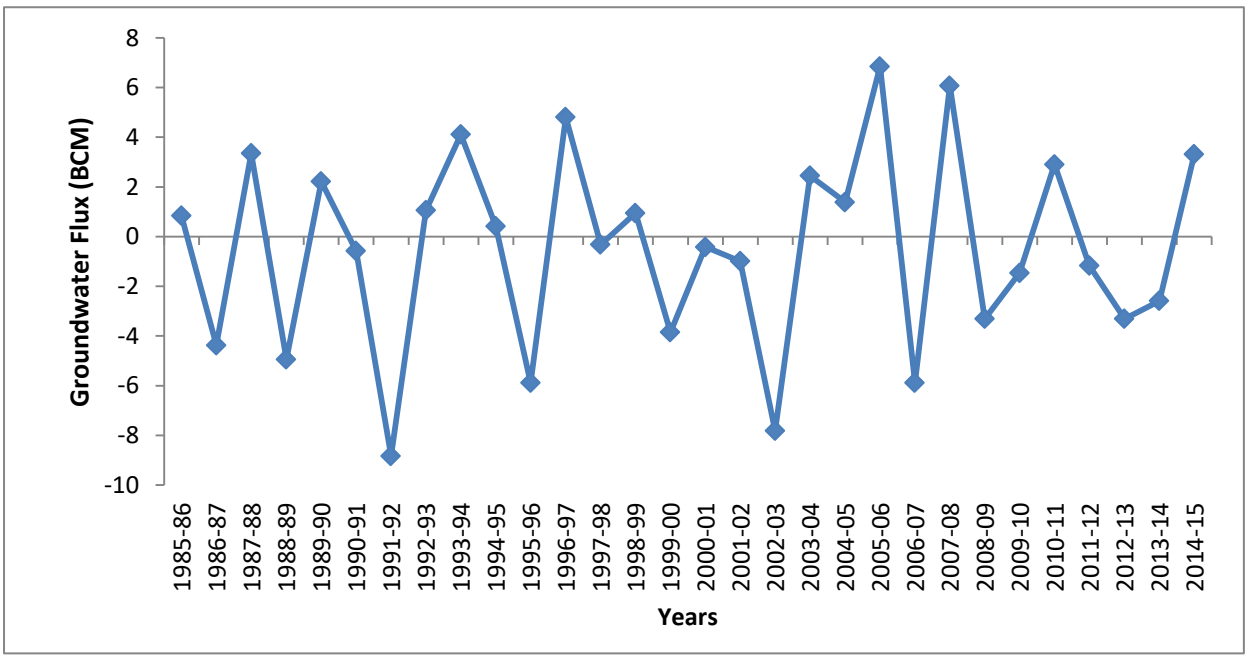


Figure 9.11 Annual groundwater flux of EFR between Pennar and Kanyakumari basin (1985-86 to 2014-15)

9.2.8 Irrigation command area

Figure 9.12 shows location of irrigation command boundaries inside and outside the EFR between Pennar and Kanyakumari considered for the year 2014-15. Since annual command boundary maps are not available, command area has been selected from the year 2014-15 based on the completion of the project/dam. Hence the command area considered during the year 1985-86 was worked out to be around 19,97,566 hectare while it was 20,03,344 hectare in 2014-15 (excluding the basin outside command). Basin outside command has been taken uniformly for all years while working out ECII from these areas.

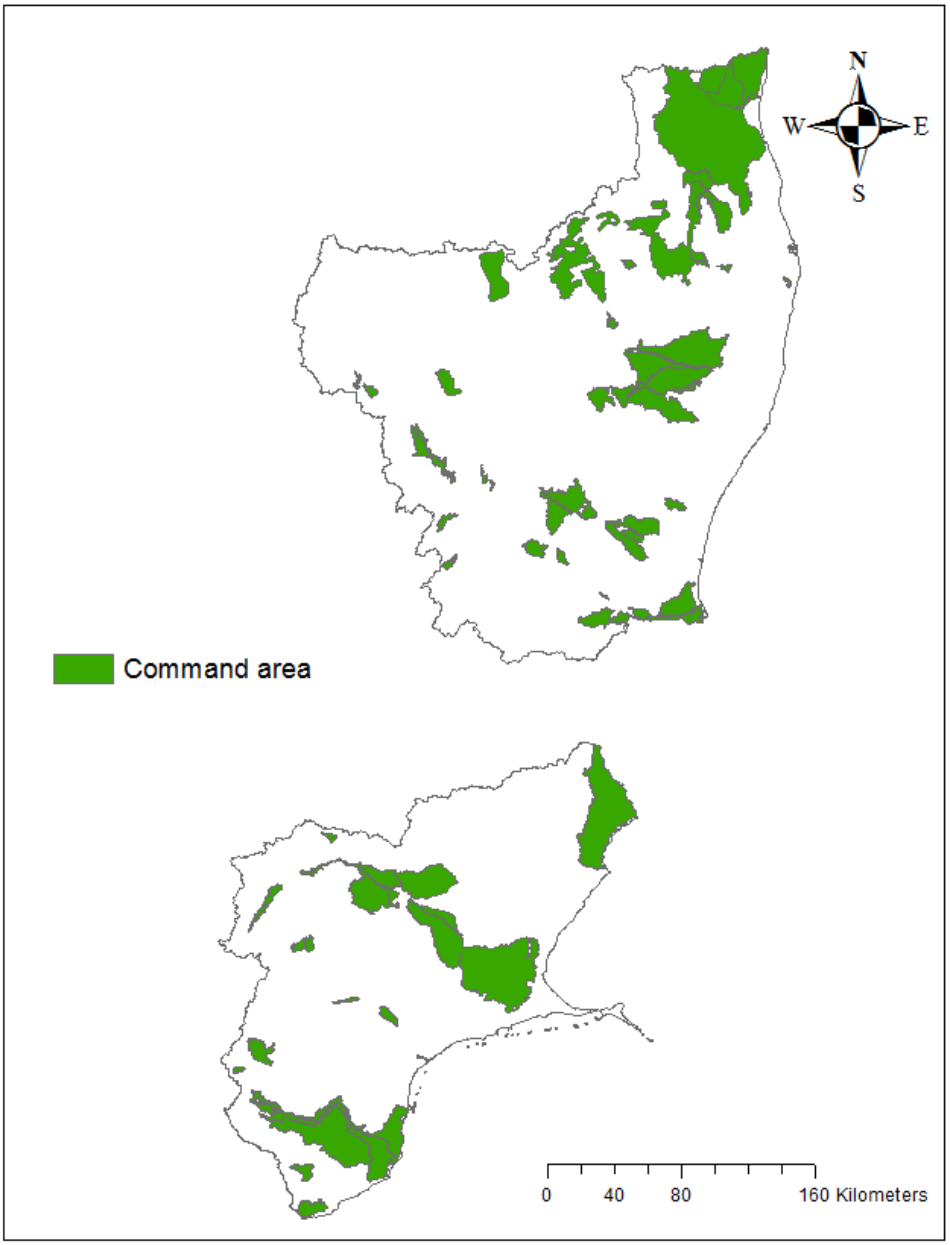


Figure 9.12 Irrigation command boundaries EFR between Pennar and Kanyakumari basin

9.2.9 Domestic, industrial and livestock demand

The mean annual domestic, industrial and livestock demand is estimated at 0.96 BCM in the basin during the period 1985-86 to 2014-15. The domestic demand is estimated as described in the calculation of groundwater flux taking into account the district boundaries of the year 2011 (Figure 9.13). Geometric progression method is used for calculation of population statistics for intervening period and for beyond census years. The mean annual domestic, industrial and livestock demands are estimated at 0.05 BCM in the basin.

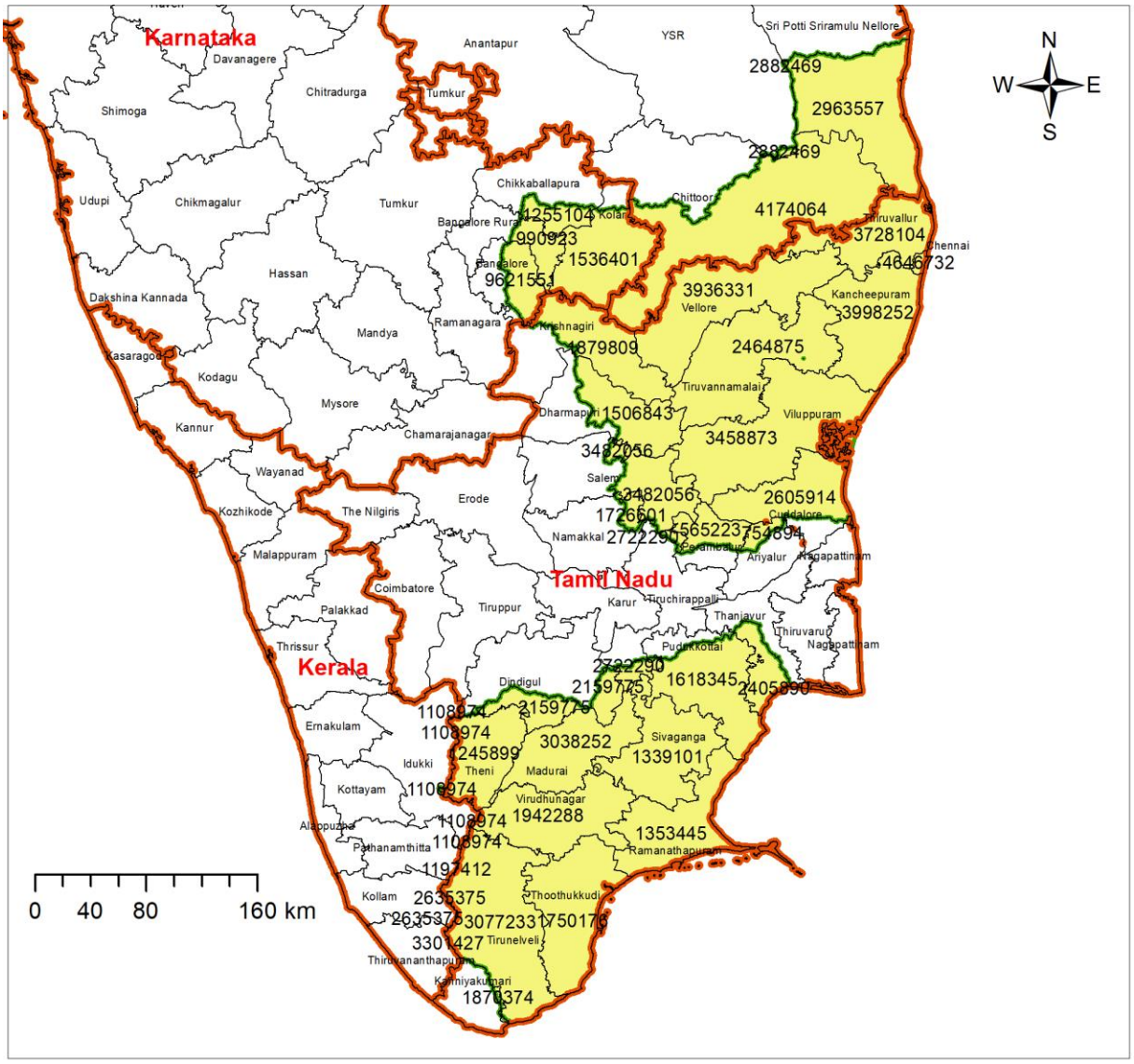


Figure 9.13 District boundaries in EFR between Pennar and Kanyakumari basin

9.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table - 9.2 provides annual evaporation values for the basin for period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 0.37 BCM.

Table - 9.2 Evaporation in reservoirs of EFR between Pennar and Kanyakumari basin

Year	Evaporation from reservoirs (BCM)	Year	Evaporation from reservoirs (BCM)
1985-86	0.48	2000-01	0.44
1986-87	0.32	2001-02	0.29
1987-88	0.46	2002-03	0.28
1988-89	0.34	2003-04	0.33
1989-90	0.45	2004-05	0.42
1990-91	0.33	2005-06	0.37
1991-92	0.46	2006-07	0.34
1992-93	0.31	2007-08	0.44
1993-94	0.35	2008-09	0.33
1994-95	0.46	2009-10	0.33
1995-96	0.35	2010-11	0.37
1996-97	0.39	2011-12	0.39
1997-98	0.4	2012-13	0.36
1998-99	0.37	2013-14	0.36
1999-00	0.33	2014-15	0.26
		Avg	0.37

9.3 Runoff Estimation

The discharge sites Chengalpet (on river Palar), Vilupuram (on river Ponnaiyar), Paramakudi (on river Vaigai) and Murappanad (on river Tambraparani) are located in the basin. The model estimated runoff is calibrated against the observed discharge at all the four locations. For the regions where the discharge is not calibrated, computed discharge is added to the whole basin without any calibration. Tables I.1 to I.4 at Annexure - I give calibrated runoff along with observed discharge, rainfall, ECII, etc. during 30 years for these discharge stations. Figures 9.14 to 9.17 show comparative graphs of calibrated runoff and observed discharge at these discharge stations. From the graphs, it may be seen that the model estimated runoff and observed discharge at almost all the sites (Chengalpet, Vilupuram, Paramakudi and Murappanad) are matching very well.

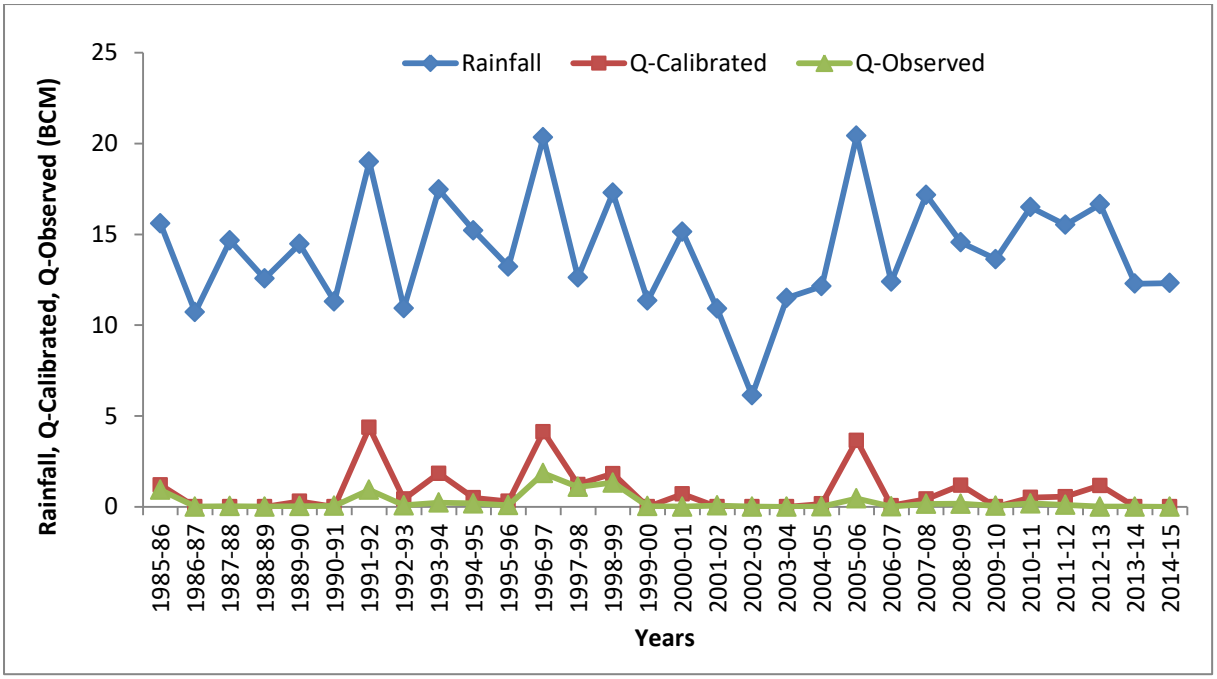


Figure 9.14 Calibrated runoff and observed discharge at Chengalpet

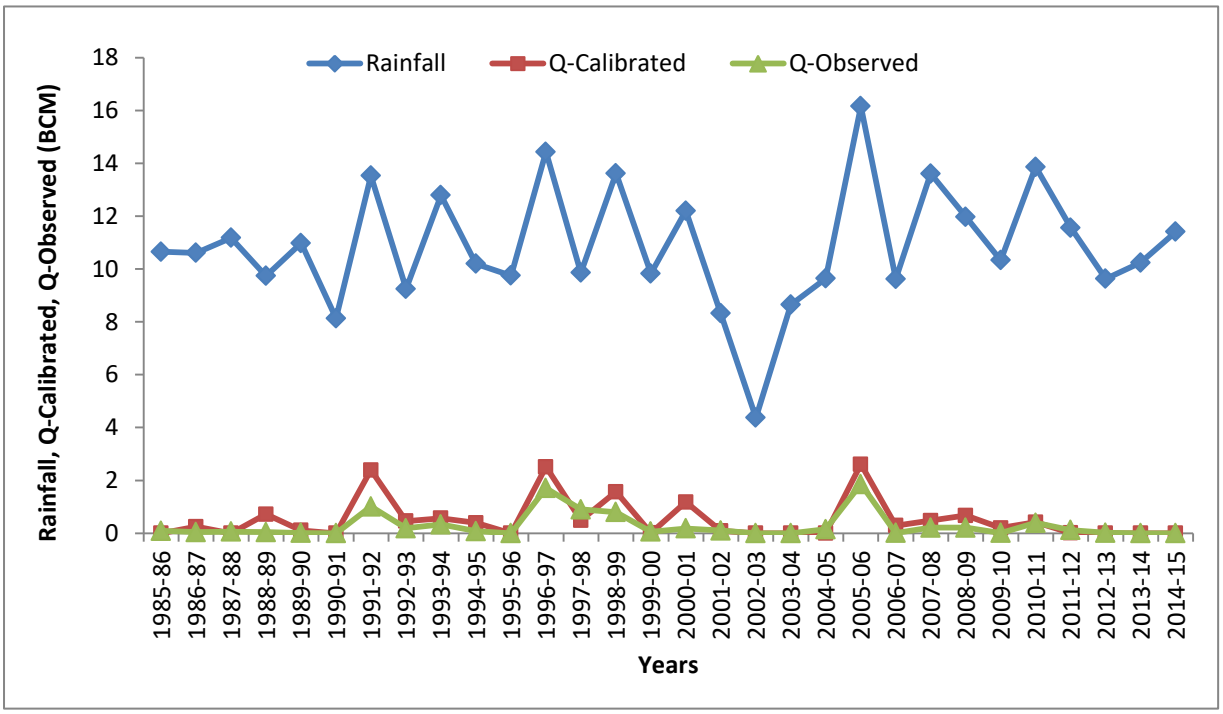


Figure 9.15 Calibrated runoff and observed discharge at Vilupuram

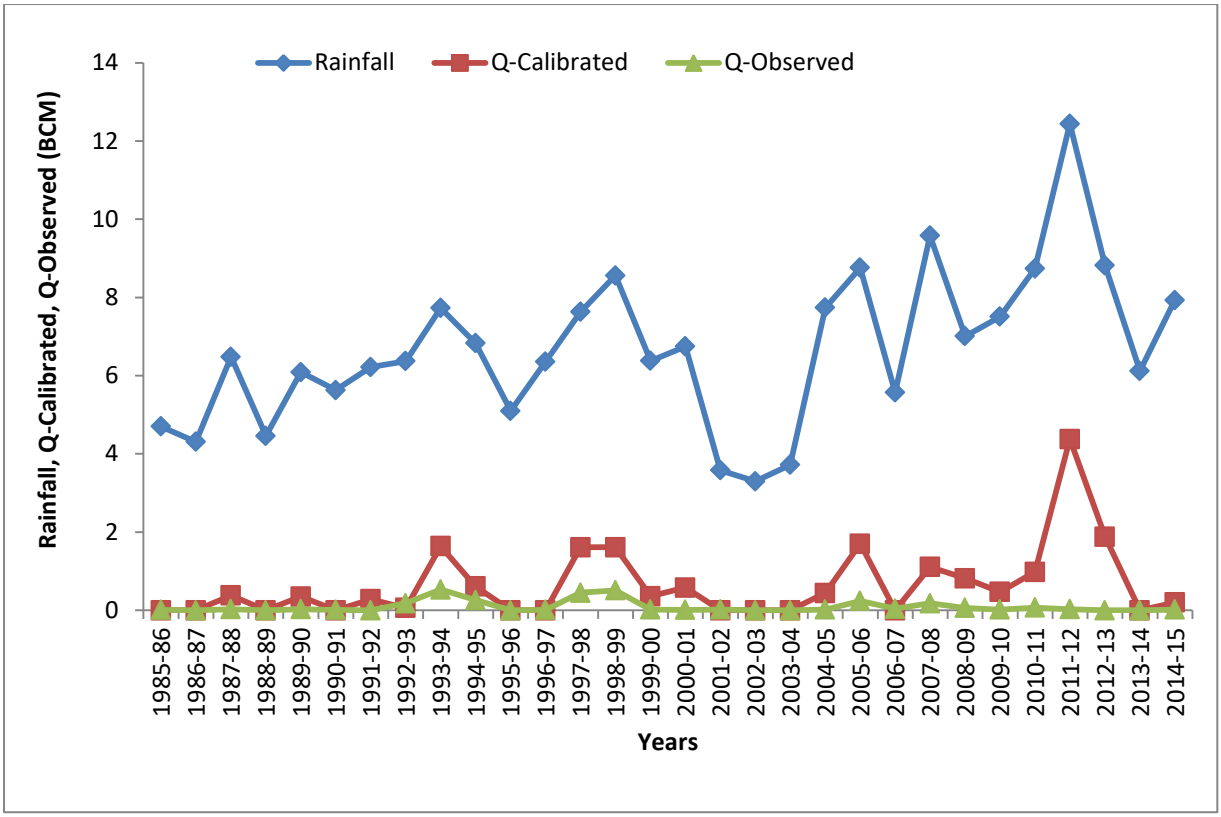


Figure 9.16 Calibrated runoff and observed discharge at Paramakudi

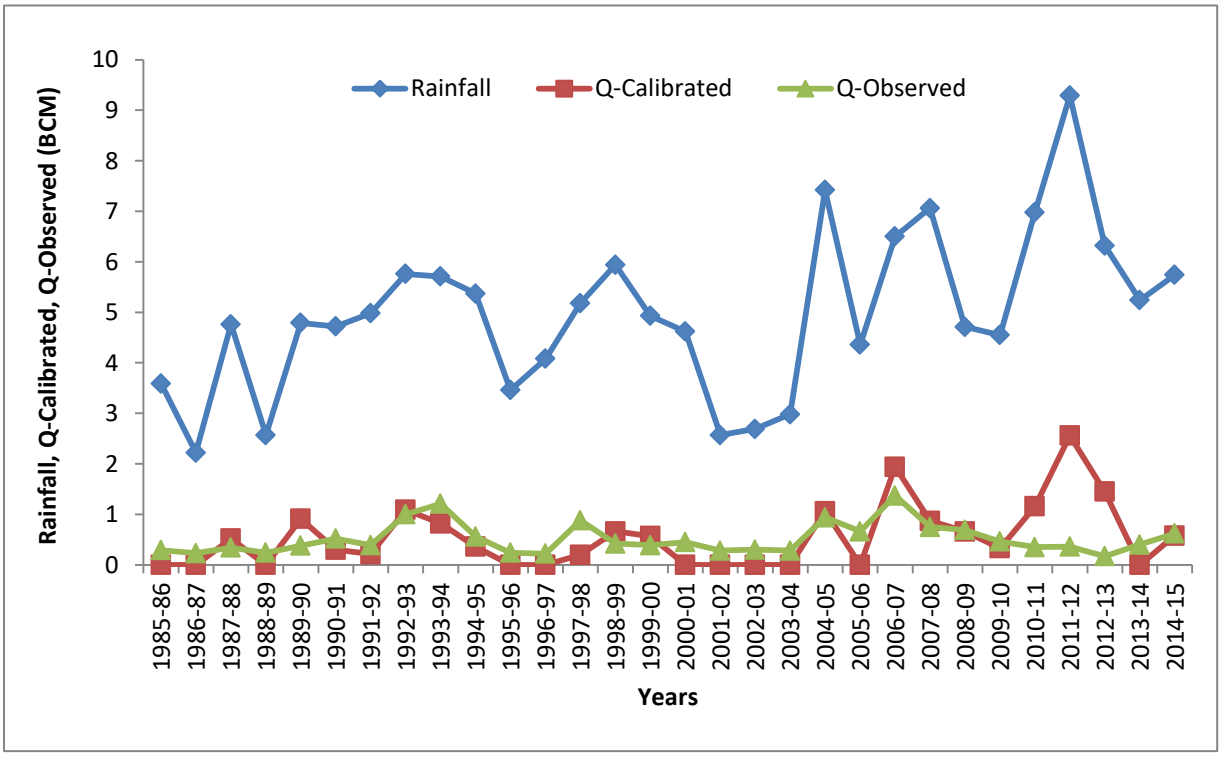


Figure 9.17 Calibrated runoff and observed discharge at Murappanad

9.4 Annual Water Resources Availability of EFR between Pennar and Kanyakumari Basin

Table - I.5 at Annexure - I shows the different components required to estimate the basin level water resources of EFR between Pennar and Kanyakumari basin for 30 years. The mean annual calibrated runoff is about 12.50 BCM. The maximum annual calibrated runoff is 36.04 BCM during 2005-06. The minimum annual calibrated runoff occurred on several occasion as 0 during 2002-03, 2003-04 and 2013-14. The mean annual ECII is about 13.41 BCM. The maximum annual ECII is about 22.18 BCM during 2002-03. The minimum annual ECII is about 7.50 BCM during 2014-15.

The maximum annual water resource is 56.99 BCM during 2005-06 in the 30 years. The minimum annual water resource is 15.63 BCM during 2002-03 which is understandable since the basin has also received least rainfall during the same year. The mean available basin water resource is 26.74 BCM. The mean available water resources of this basin accounts to about 27.28% of mean annual rainfall during 1985-86 to 2014-15.

9.4.1 Annual water resources of EFR between Pennar & Kanyakumari basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 2011-12 and 2002-03, extreme wet and dry rainfall conditions occurred in EFR between Pennar and Kanyakumari respectively. The annual water resources of this basin during these two extreme rainfall conditions are 43.46 BCM and 15.63 BCM, respectively as shown in Table - 9.3. The water balance components during these years are presented in Figures 9.18 and 9.19.

Table - 9.3 water resources availability in EFR between Pennar & Kanyakumari basin during extreme rainfall conditions

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources availability (BCM)
Maximum Rainfall	2011-12	145.29	43.46
Minimum Rainfall	2002-03	40.80	15.63

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.3 and 0.38 respectively. During higher rainfall years, potential evapo-transpiration is less compared to the dry years which will have cumulative effect in runoff. It is found that the ECII during 2011-12 is less than the year 2002-03.

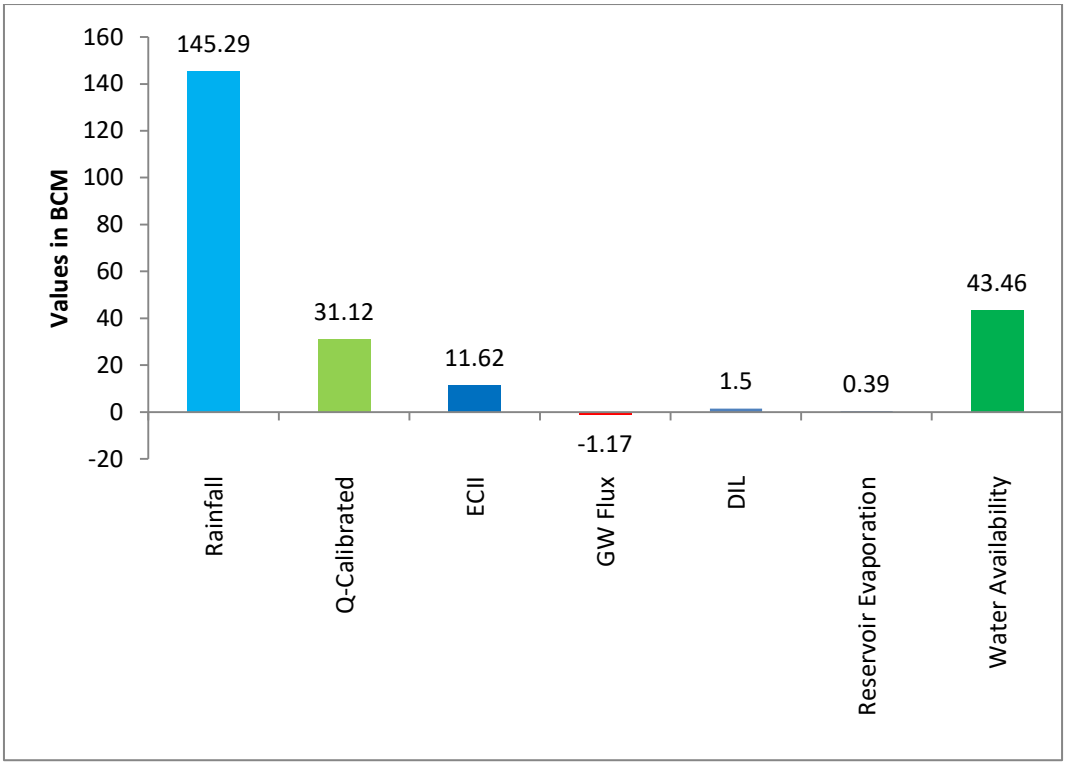


Figure 9.18 Water balance components of EFR between Pennar and Kanyakumari basin during extreme high rainfall (2011-12)

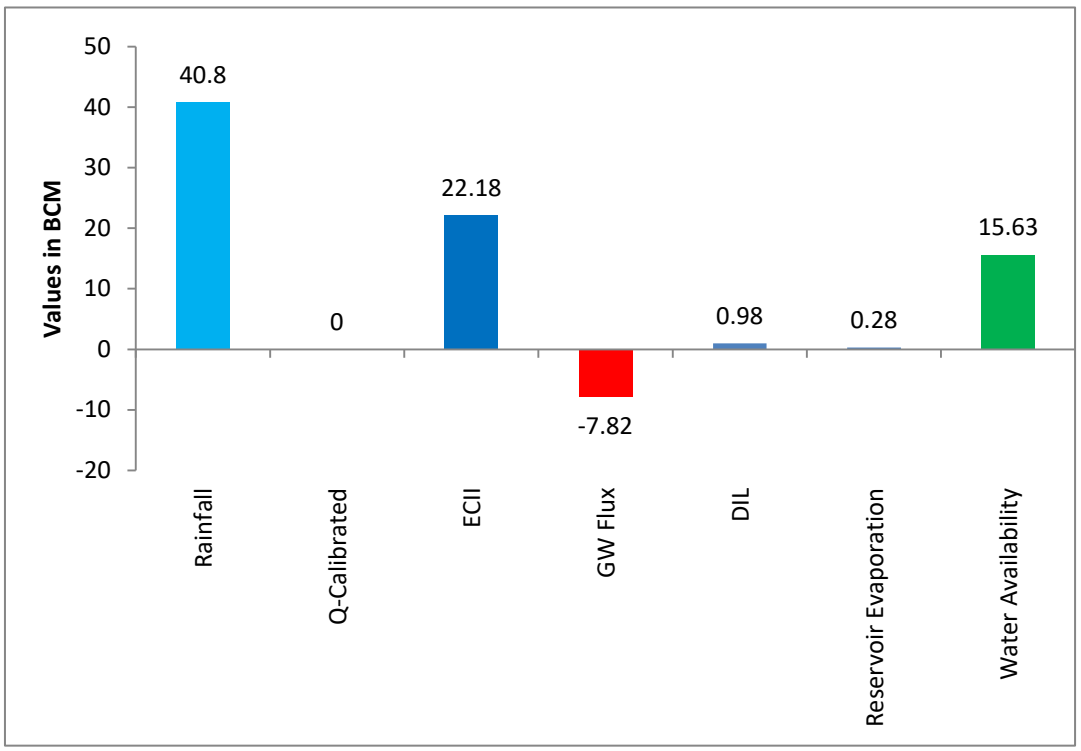


Figure 9.19 Water balance components of EFR between Pennar and Kanyakumari basin during extreme low rainfall (2002-03)

9.4.2 Mean water resources of EFR between Pennar and Kanyakumari basin

The mean water resource of the basin is computed by taking mean of the 30 years, water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and Industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industries and Livestock consumption + Groundwater Flux + Reservoir Flux + Evaporation from Reservoirs)

= 12.50 + 13.41 + 0.96 + (-0.50) + 0.00 + 0.37 = 26.74 BCM

75% dependable flow of EFR between Pennar and Kanyakumari Basin = 18.21 BCM

The mean available annual water resource of the EFR between Pennar and Kanyakumari basin is 26.74 BCM. Figure 9.20 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

It is observed that the computed runoff factors varies from 0.01 (587 mm rainfall) to 0.29 (1,087 mm rainfall). The mean runoff factor for 30 year period is 0.13.

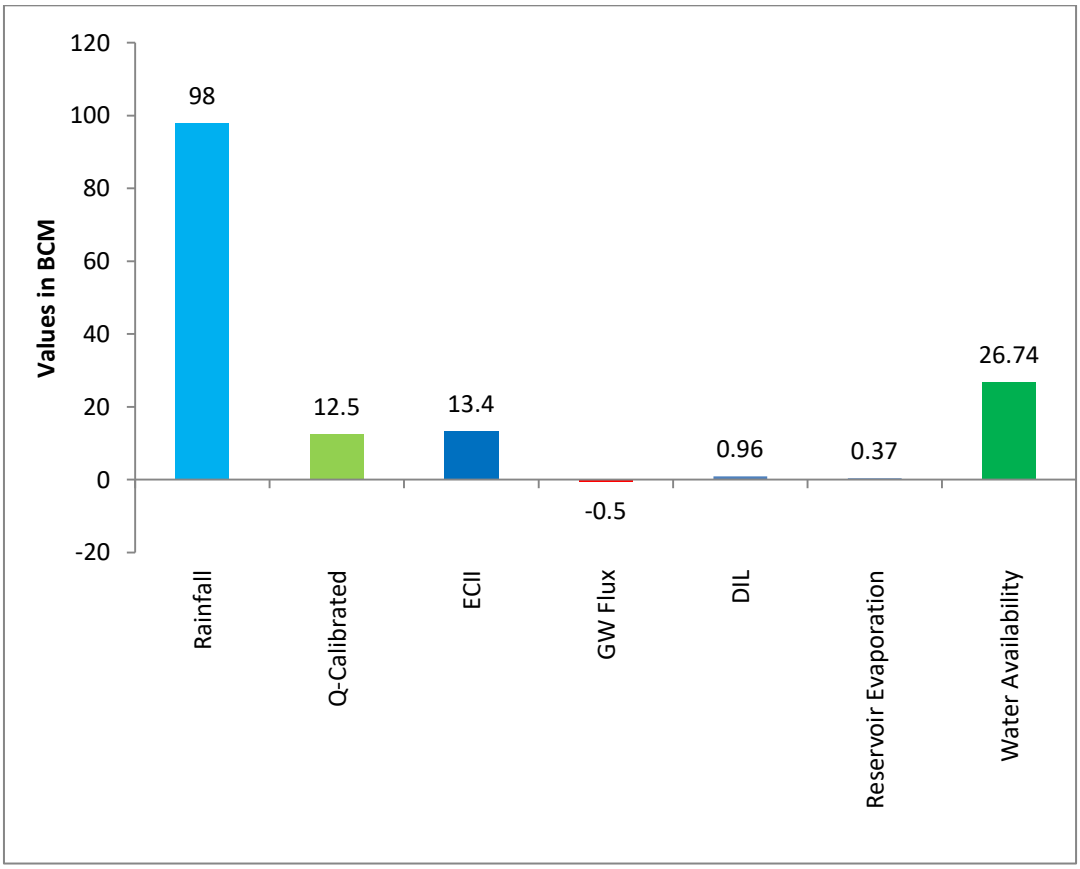
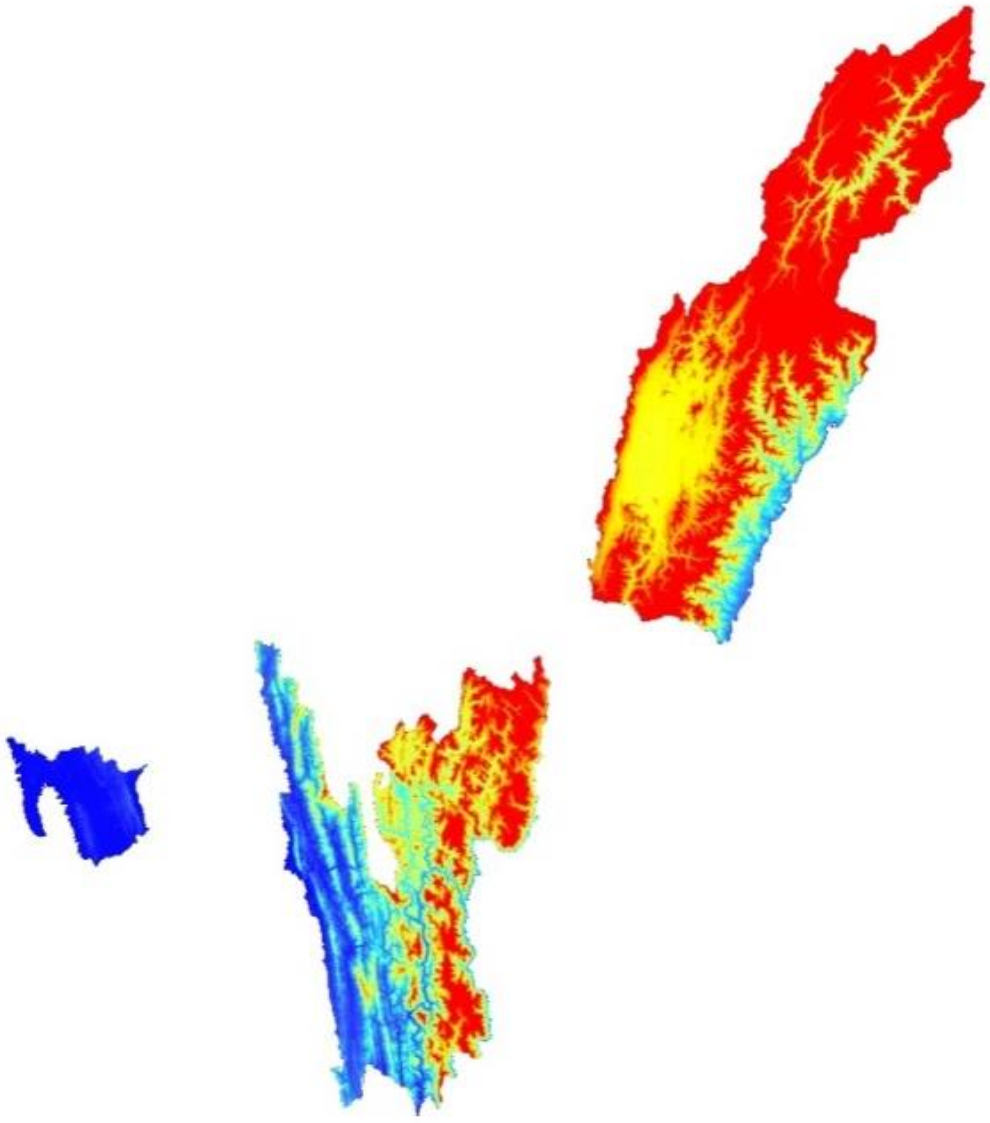


Figure 9.20 Mean water balance components of EFR between Pennar and Kanyakumari basin

HIGHLIGHTS

- *Mean available water resources of EFR between Pennar and Kanyakumari basin is 26.74 BCM.*
- *Maximum annual water availability is 56.99 BCM during 2005-06.*
- *Minimum annual water availability is 12.32 BCM during 1995-96.*
- *Annual rainfall in the basin varies from 411 mm to 1,424 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 960 mm.*
- *EFR between Mahanadi and Pennar basin is divided into five sub-basins for the reassessment study viz. Chengalpet, Vilupuram, Paramakudi and Murappanad and Uncalibrated portion.*
- *Average annual domestic, industrial and livestock demand in the basin is 0.96 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.37 BCM.*

MINOR RIVERS DRAINING INTO MYANMAR (BURMA) AND BANGLADESH



10.1 Geo-Spatial Datasets

10.1.1 Land Use and Land Cover

The Land Use and Land Cover (LULC) map of Minor rivers draining into Myanmar (Burma) and Bangladesh basin is shown in Figure 10.1. The image corresponds to the 2004-05 year and consists of 10 different classes. The map indicates Deciduous Forest (44.24%), Evergreen Forest (29.36%), Scrub/deg. Forest (11%), Kharif only (10.79%) and Shifting Cultivation (1.3%) are the major classes in the basin (Figure 10.2).

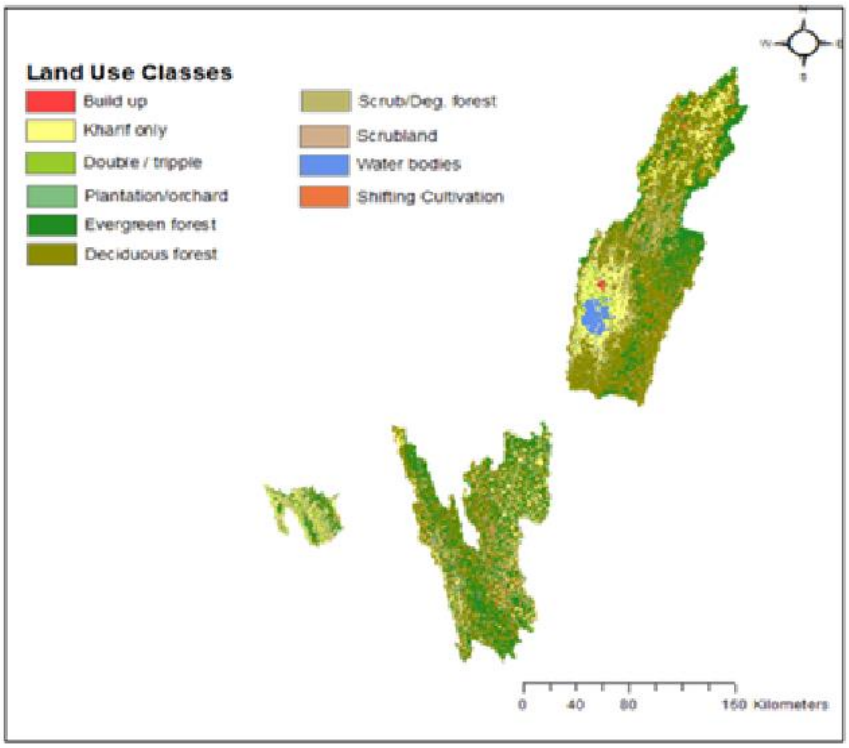


Figure 10.1 LULC map of Minor rivers draining into Myanmar (Burma) and Bangladesh basin (2004-05)

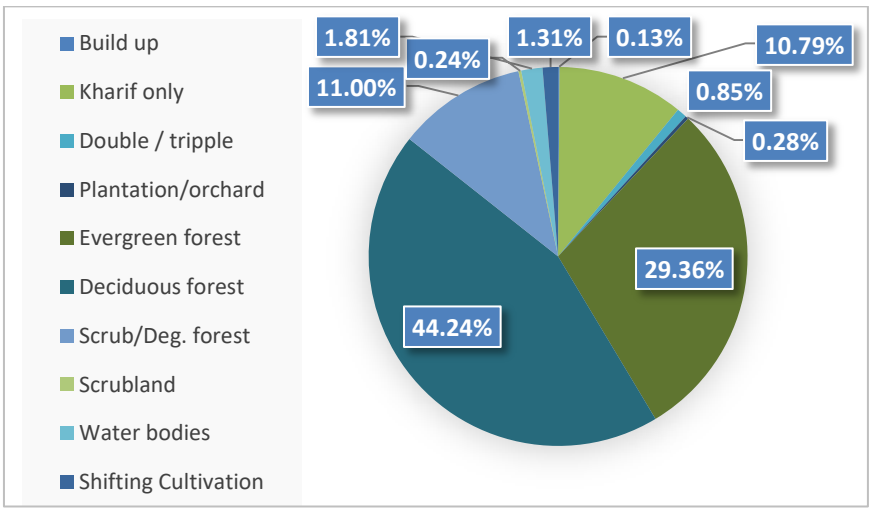


Figure 10.2 Distribution of LULC in Minor rivers draining into Myanmar (Burma) and Bangladesh basin (2004-05)

10.1.2 Soil texture

The main soil types found in the basin are clay and loamy soils. Figure 10.3 shows various categories of soils in the basin. The soils are classified as sandy, loamy, clayey based on the soil texture information.

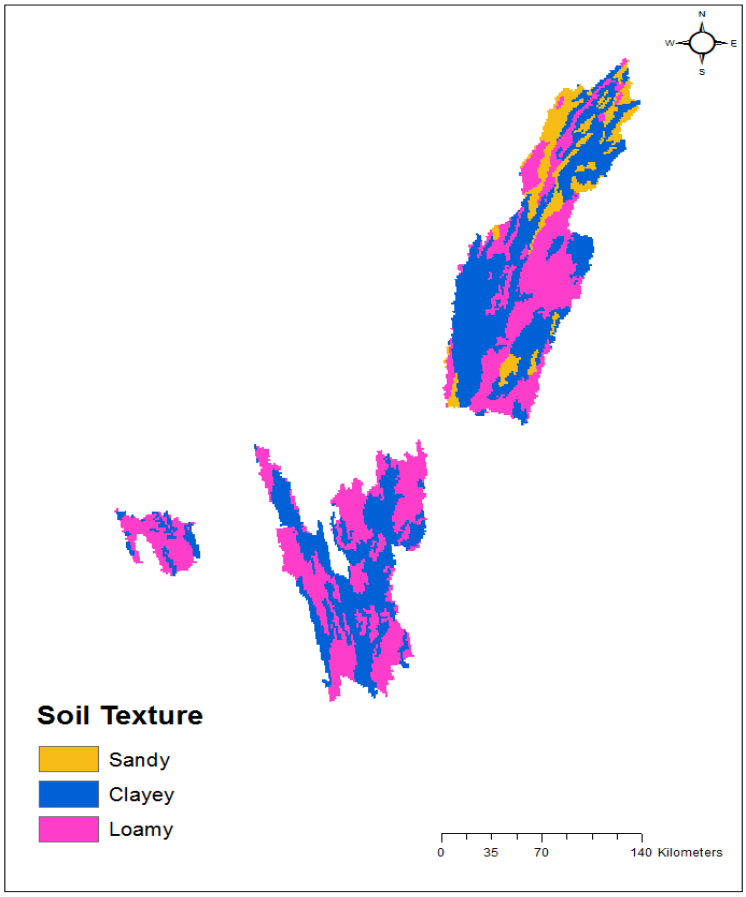


Figure 10.3 Soil texture map of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

10.1.3 Topography

The topography of the basin consists of mountainous areas, hills and the reverine plains. The major portions of the basin are mostly hilly and forested. The bordering area with Bangladesh of the basin is riverine plains. The elevation values ranges from a minimum of 3 m to a maximum of 3823 m. Figure 10.4 shows Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) map of the basin. The DEM was used for delineating the basin.

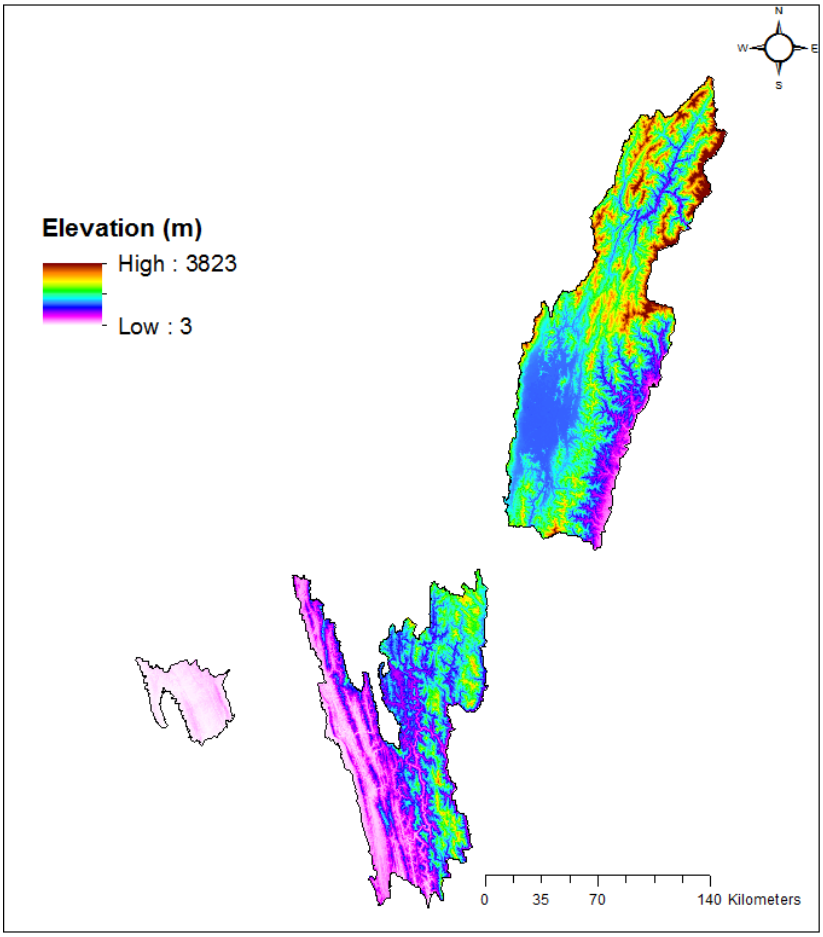


Figure 10.4 SRTM DEM map of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

10.2 Hydro-Meteorological and other Input Data

10.2.1 Rainfall grids

Figure 10.5 shows gridded rainfall map of Minor rivers draining into Myanmar (Burma) and Bangladesh basin for the year 2004-05. The annual variations in the rainfall during study period of 30 years (1985-86 to 2014-15) are shown in Figure 10.6. Annual rainfall of the basin varies from 1,397 mm to 2,847 mm and mean rainfall of these 30 years is found to be 1,812 mm. Rainfall analysis at sub-basin level during the study period reveals that minimum rainfall of around 1,635 mm is observed in Manipur sub-basin, while maximum rainfall of 2,559 mm is observed in Mizoram sub-basin. Of the 30 years, for 16 years annual rainfall is higher than the mean rainfall and for remaining 13 years lower than the mean rainfall. However, there is a decreasing trend of rainfall towards recent years.

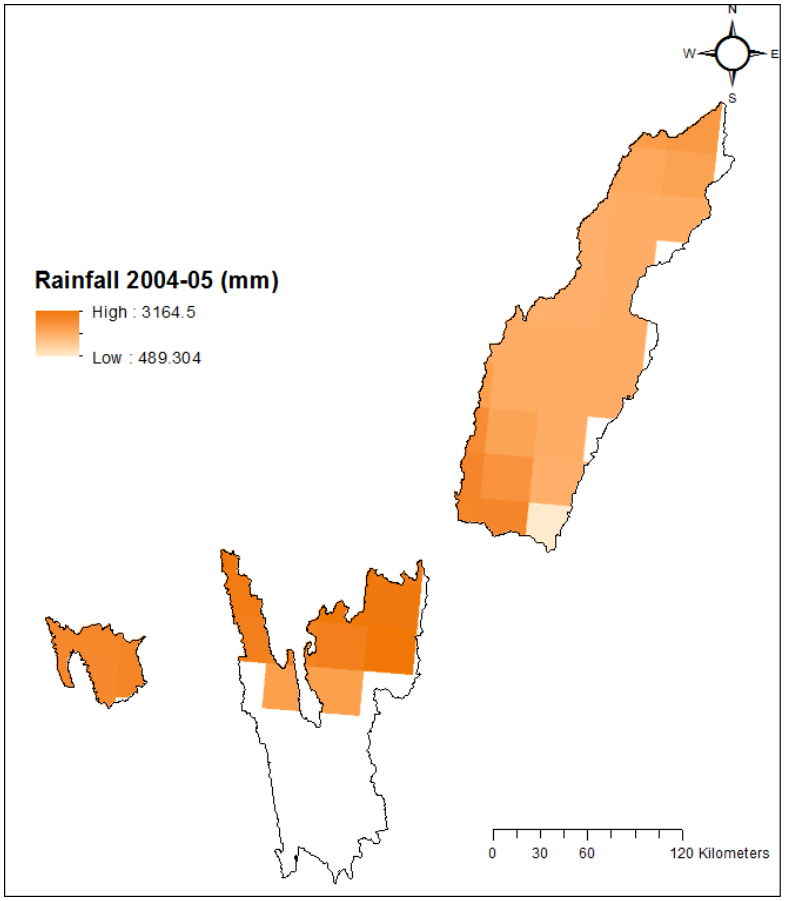


Figure 10.5 Gridded rainfall of Minor rivers draining into Myanmar (Burma) and Bangladesh basin (2004-05)

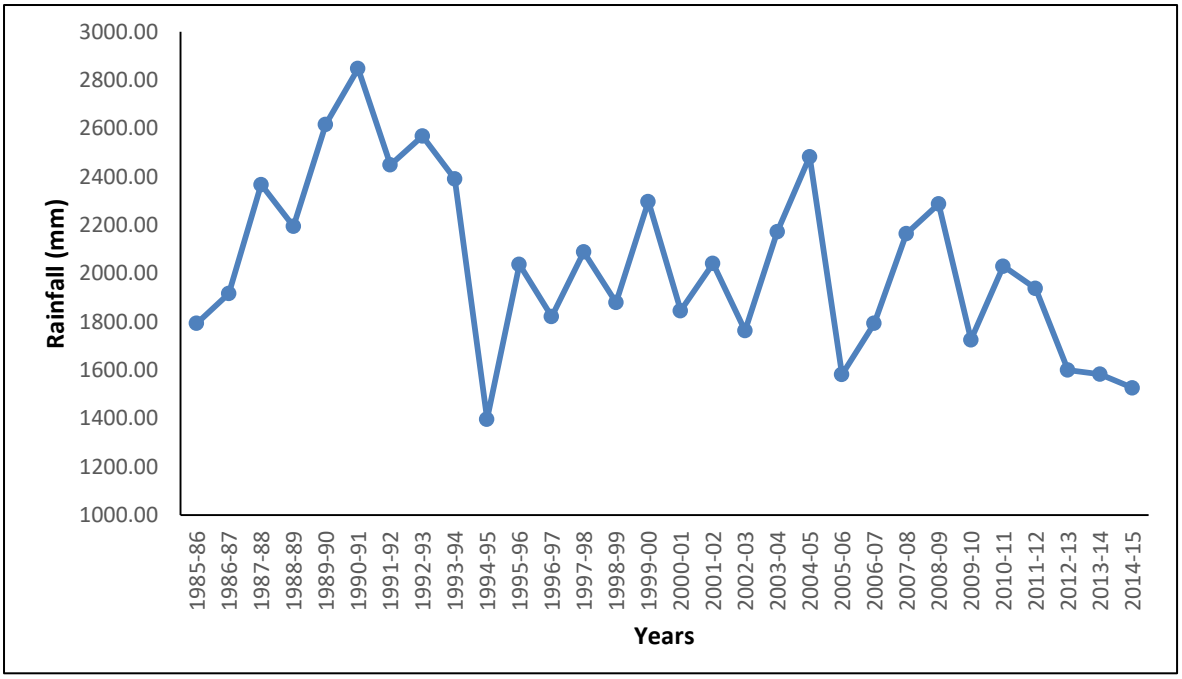


Figure 10.6 Annual rainfalls in Minor rivers draining into Myanmar (Burma) and Bangladesh basin (1985-86 to 2014-15)

10.2.2 Temperature grids

Gridded mean annual temperature of the basin in 2004-05 is shown in Figure 10.7. The mean annual temperature during 2004-05 varied from 14.52^{0}C to 23.30^{0}C.

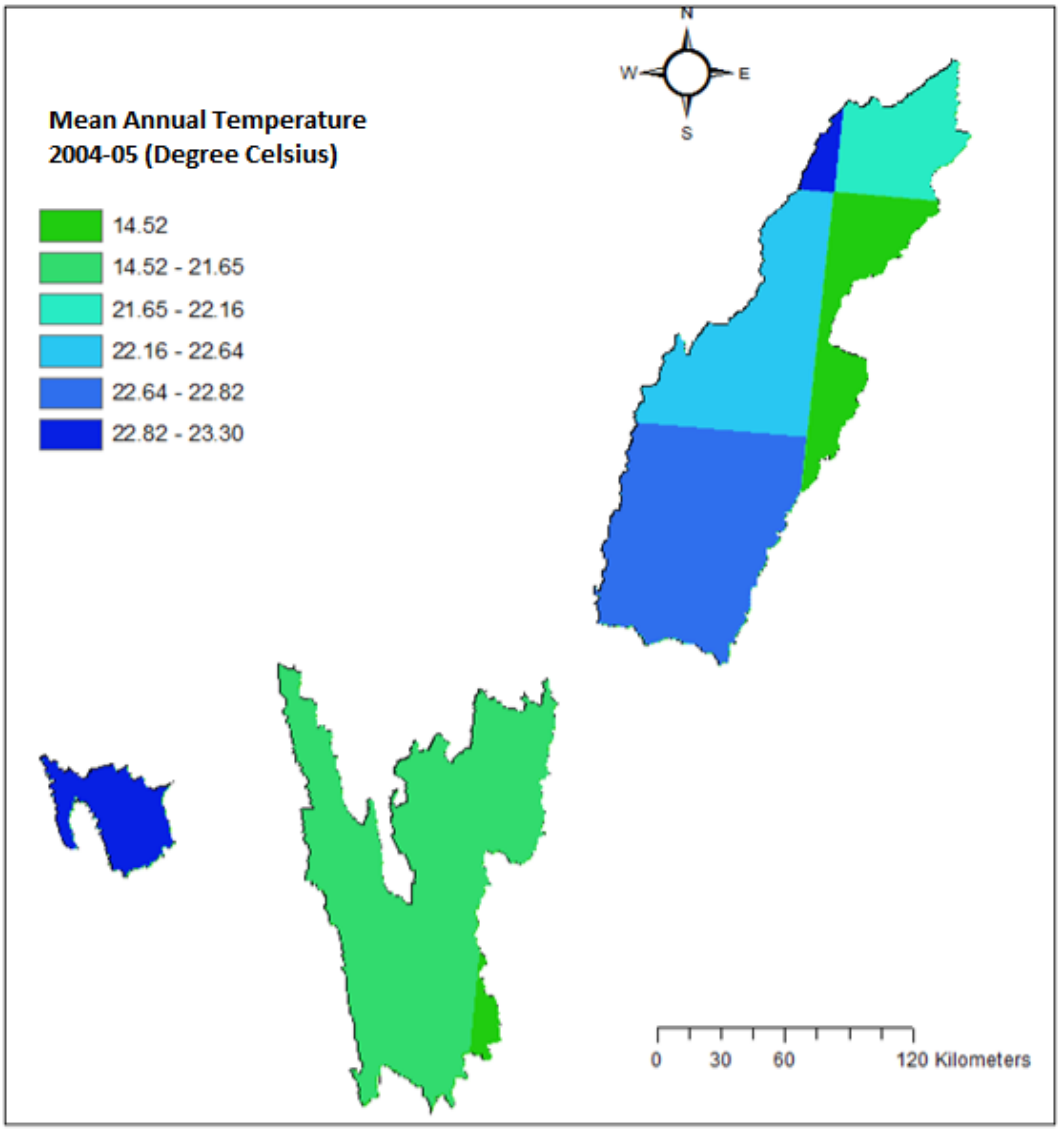


Figure 10.7 Gridded mean annual temperature of Minor rivers draining into Myanmar (Burma) and Bangladesh basin (2004-05)

10.2.3 Sub-Basins of Minor rivers draining into Myanmar (Burma) and Bangladesh

The basin is divided into three distinct discontinuous regions. These are taken as three sub-basins (Figure 10.8) viz. Meghalaya, Manipur and Tripura sub-basins. Table - 10.1 gives details of each sub-basin. There are very few discharge sites available in this region. All of the discharge sites are either too small or their data are insufficient to validate the model.

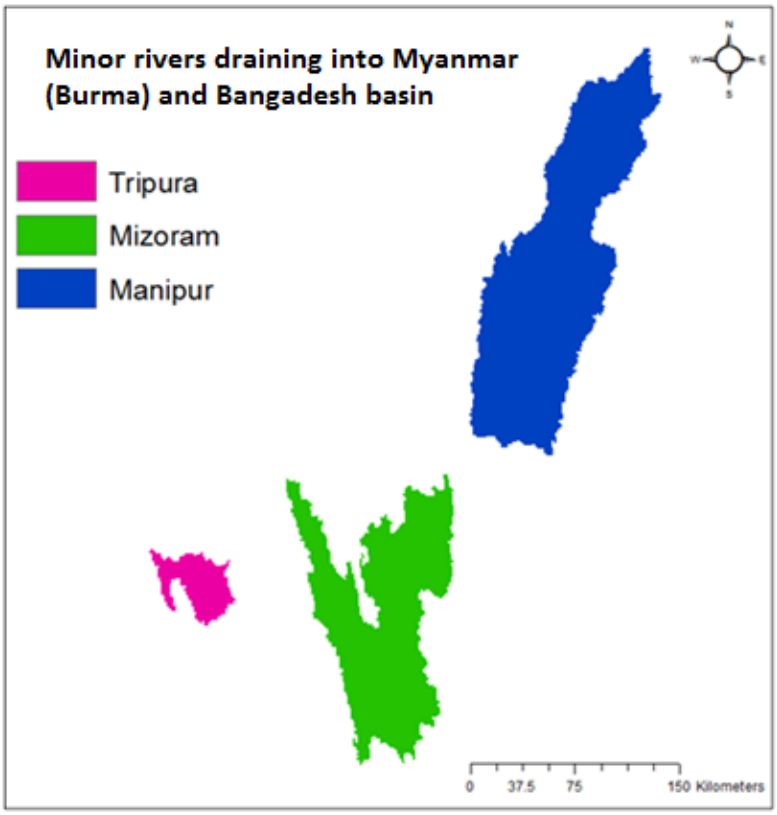


Figure 10.8 Sub-basins of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

Table - 10.1 Sub-basin wise details of Minor Rivers draining to Myanmar (Burma) and Bangladesh basin

S. No.	Sub-basin	River	Individual drainage area (sq.km)
1	Manipur	Imphal etal	16,142
2	Mizoram	Tlawng etal	12,217
3	Tripura	Belonia etal	3,023
	Total basin area		31,382

10.2.4 River discharge

The river discharge data was available only at the site Belonia on river Belonia in Tripura. Due to small catchment area of above site, discharge data were not considered for validation of the model.

10.2.5 Reservoir flux

There is no major reservoir in this basin except the Loktak Lake in Manipur,. State Government does not maintain any level data for this reservoir. Surface storage fluxes were not used for calibration

and validation purpose of computed runoff. However, reservoir storage flux value for this region is insignificant.

10.2.6 Groundwater flux

The spatial annual groundwater flux in the basin for year 2004-05 is shown in Figure 10.9. The yearly variation in groundwater flux (in MCM) from 1985-86 to 2014-2015 is shown in Figure 10.10.

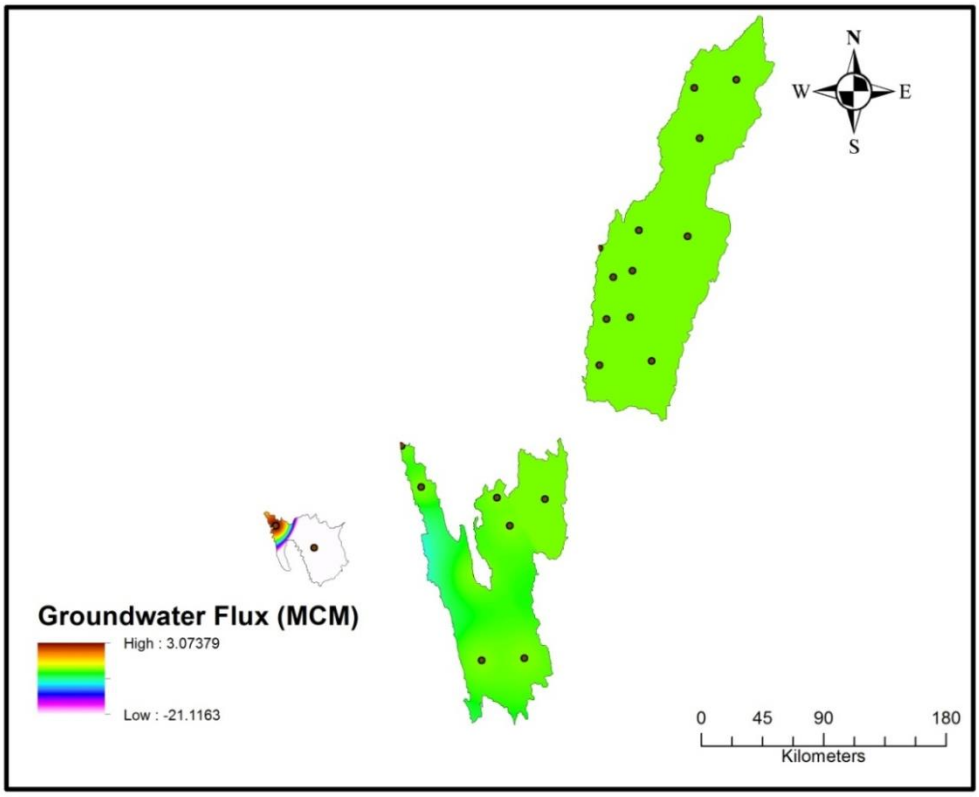


Figure 10.9 Groundwater flux (spatial data) estimated during 2004-05

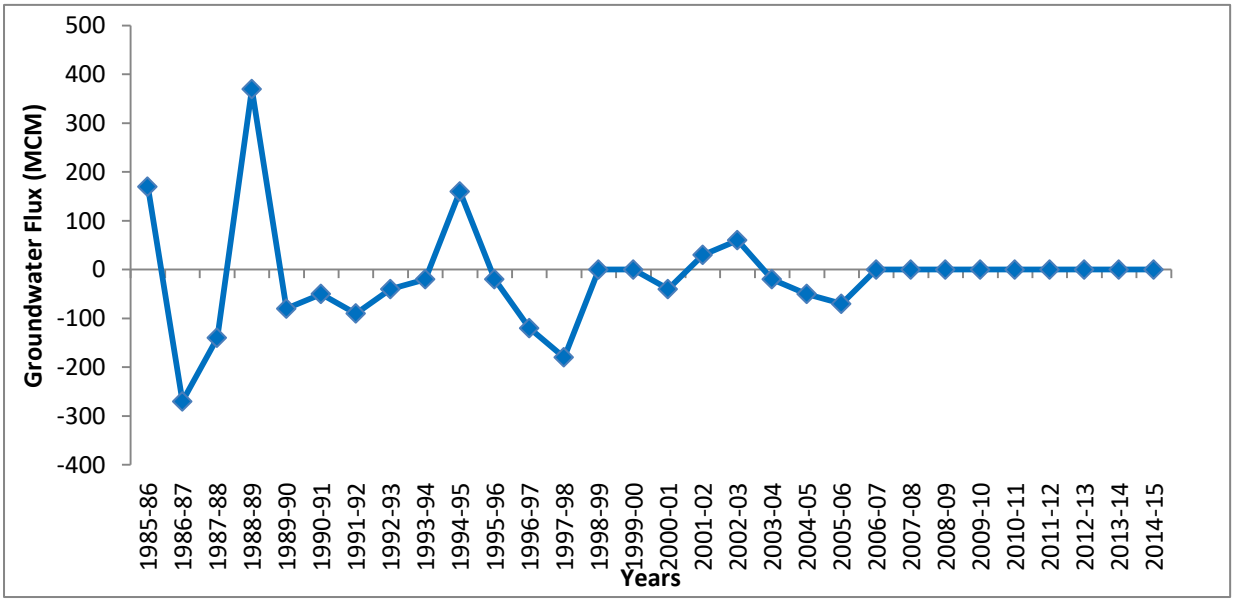


Figure 10.10 Annual groundwater flux of Minor rivers draining into Myanmar (Burma) and Bangladesh basin (1985-86 to 2014-15)

10.2.7 Major crops in the basin

River draining into Myanmar (Burma) and Bangladesh basin has more than 80% of forested area. Hence, major land-use is forest and principal crop is tree. The basin was divided in 5 regions based on the forest cover (Table - 10.2). Each region specifies based on canopy of forest cover. The land cover coefficients used in different land use categories are of two types.

Table - 10.2 Details of regions in Minor rivers draining into Myanmar (Burma) and Bangladesh basin

Sl No	Regions	District	Area	% area under basin	% area under dense and moderate dense forest	% area under forest
1	**Dense**	Phenk	2,026	80	46	83
		South Tripura	3,057	50	48	81
2	**Open + Dense Forest**	Saiha	1,400	100	40	90
		Tuensang	4,228	60	39	74
		Zunheboto	1,255	50	37	78
		Champai	3,185	70	36	86
3	**Open Forest**	Senapati	3,271	50	36	70
		Lunglei	4,536	80	35	94
		Lawngtali	2,258	100	28	92
4	**Open Forest bush type + Agriculture**	Aizwal	3,575	3	29	93
		Serchip	1,421	100	26	79
		Mamit	3,025	30	20	91
		Churachanpur	4,570	25	26	93
		Chandel	3,313	100	22	84
		Ukhrul	4,544	100	25.5	78
5	**Agriculture**	Thaoubal	514	100	1	11
		Bisnupur	496	100	0	4.23
		Imphal East	669	100	6	32

10.2.8 Irrigation command area

Figure 10.11 shows location of irrigation command boundaries inside and outside the basin considered for the year 2014-15.

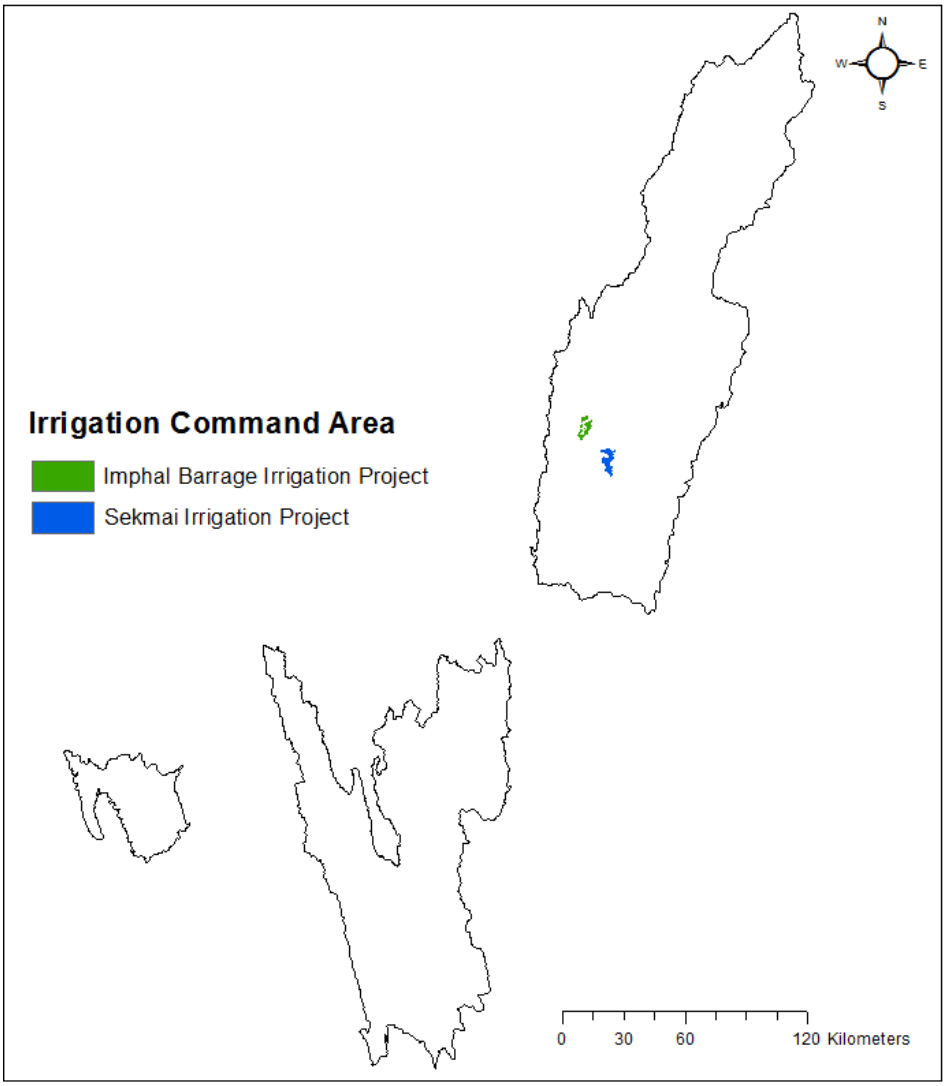


Figure 10.11 Irrigation command boundaries in Minor rivers draining into Myanmar (Burma) and Bangladesh basin

10.2.9 Domestic, industrial and livestock demand

Figure 10.12 shows district boundaries layer with district population for the year 2011 census. The mean annual domestic, industrial and livestock demands are estimated at 0.07 BCM in the basin.

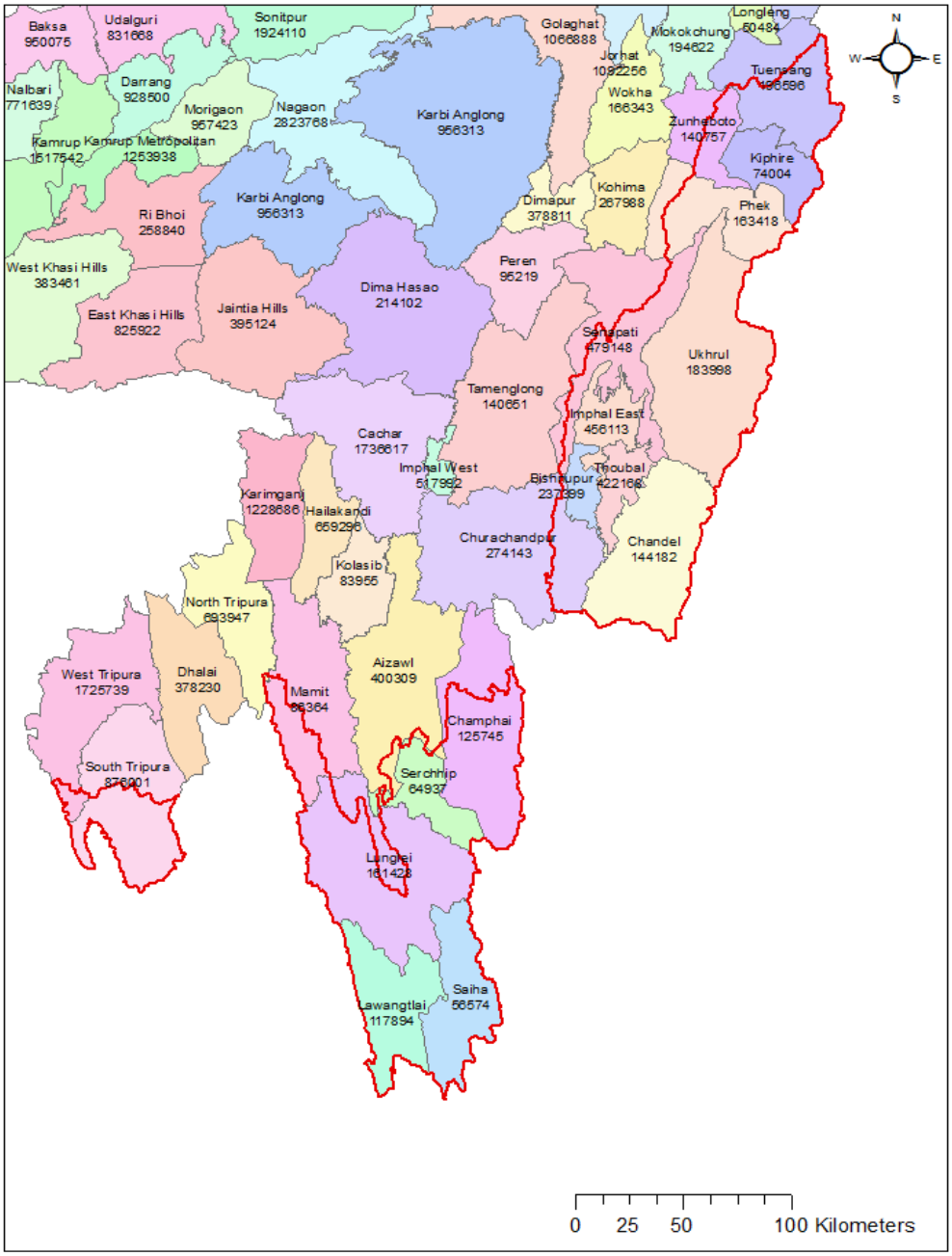


Figure 10.12 District boundaries of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

10.2.10 Evaporation from major/medium/minor reservoirs and other water bodies

Table 10.3 shows annual evaporation values from each of sub-basins for the period of 1985-86 to 2014-15 (30 years). The average annual evaporation volume for total basin is worked out as 0.40 BCM.

Table - 10.3 Evaporation in reservoirs of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

Year	Evaporation from reservoirs (BCM)	Year	Evaporation from reservoirs (BCM)
1985-86	0.31	2000-01	0.49
1986-87	0.48	2001-02	0.38
1987-88	0.32	2002-03	0.53
1988-89	0.46	2003-04	0.51
1989-90	0.51	2004-05	0.50
1990-91	0.37	2005-06	0.46
1991-92	0.39	2006-07	0.30
1992-93	0.37	2007-08	0.40
1993-94	0.29	2008-09	0.20
1994-95	0.36	2009-10	0.42
1995-96	0.54	2010-11	0.39
1996-97	0.39	2011-12	0.33
1997-98	0.38	2012-13	0.26
1998-99	0.26	2013-14	0.35
1999-00	0.54	2014-15	0.39
		Avg	0.40

10.3 Runoff Estimation

The runoff that is estimated from each pixel at monthly time step and aggregated within each sub-basin. The monthly surface runoff is further aggregated to annual time step for all the sub-basins. The estimated runoff for each sub-basin could not be calibrated with observed discharge at annual scale due unavailability of suitable discharge sites (Figures 10.13 to 10.15). Water availability at Manipur, Mizoram and Tripura sub-basin is given in Tables - J.1 to J.3 at Annexure - J respectively.

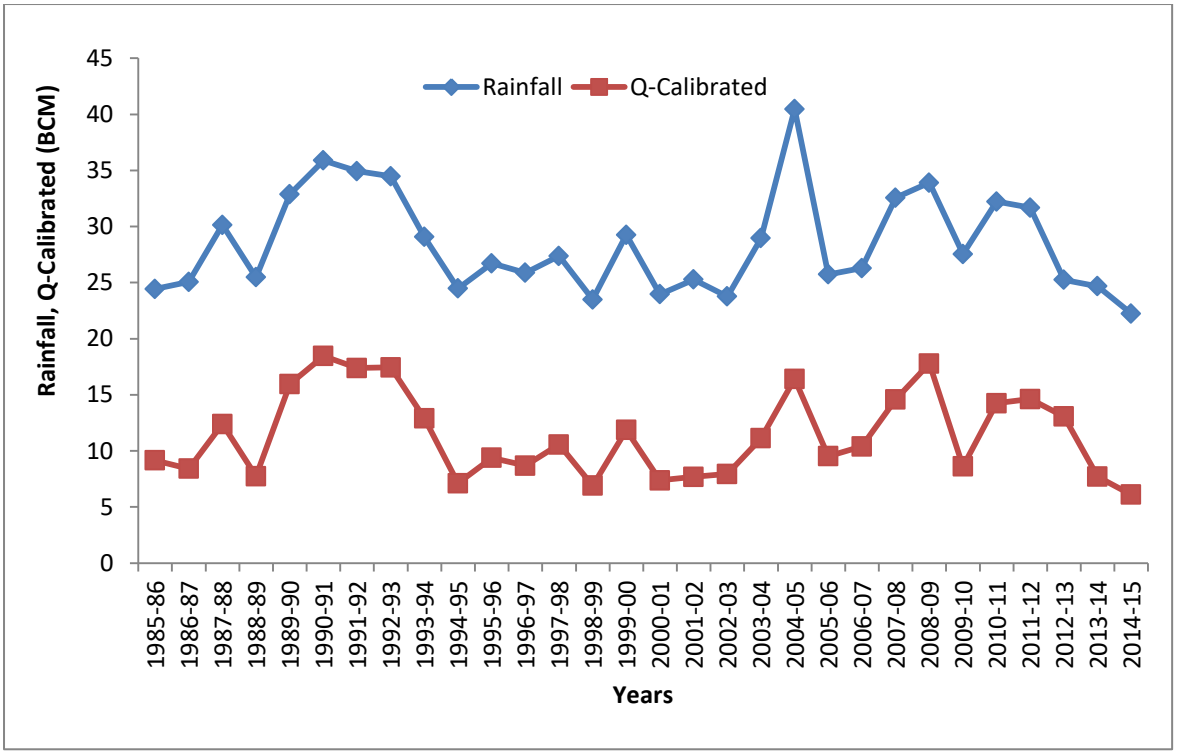


Figure 10.13 Calibrated runoff and rainfall in Manipur Sub-Basin

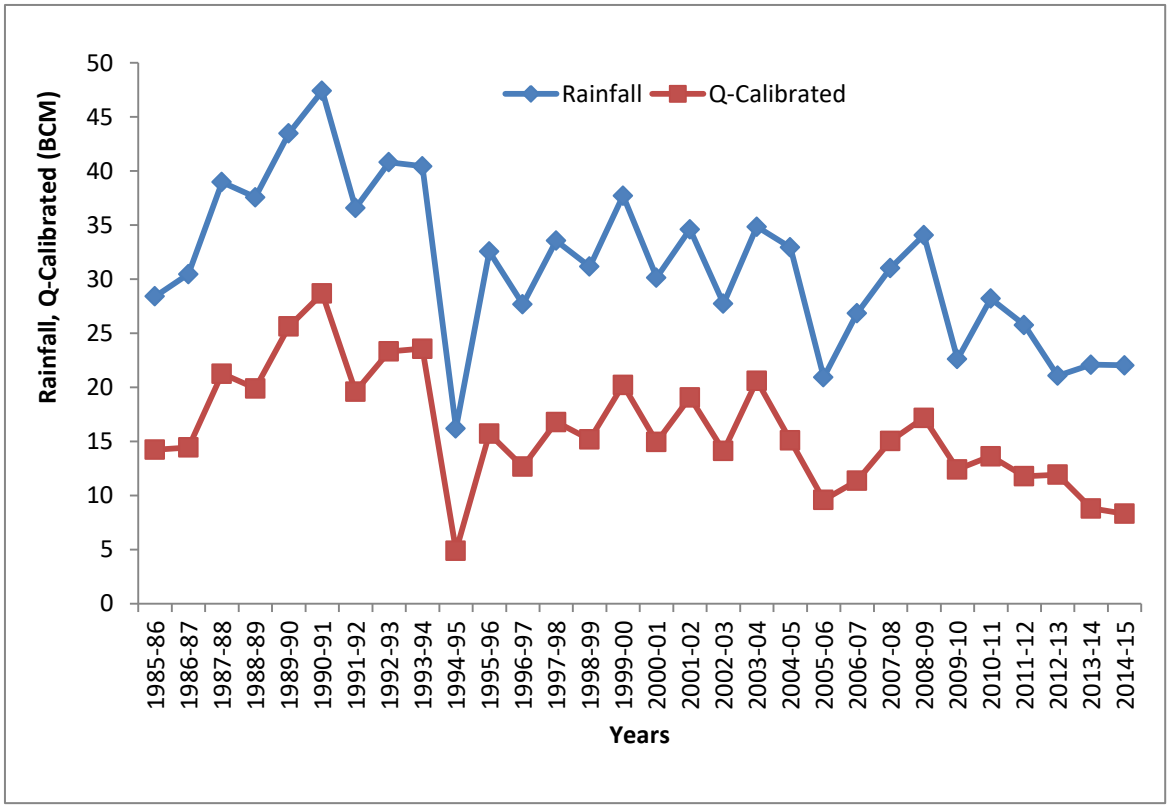


Figure 10.14 Calibrated runoff and rainfall in Mizoram sub-basin

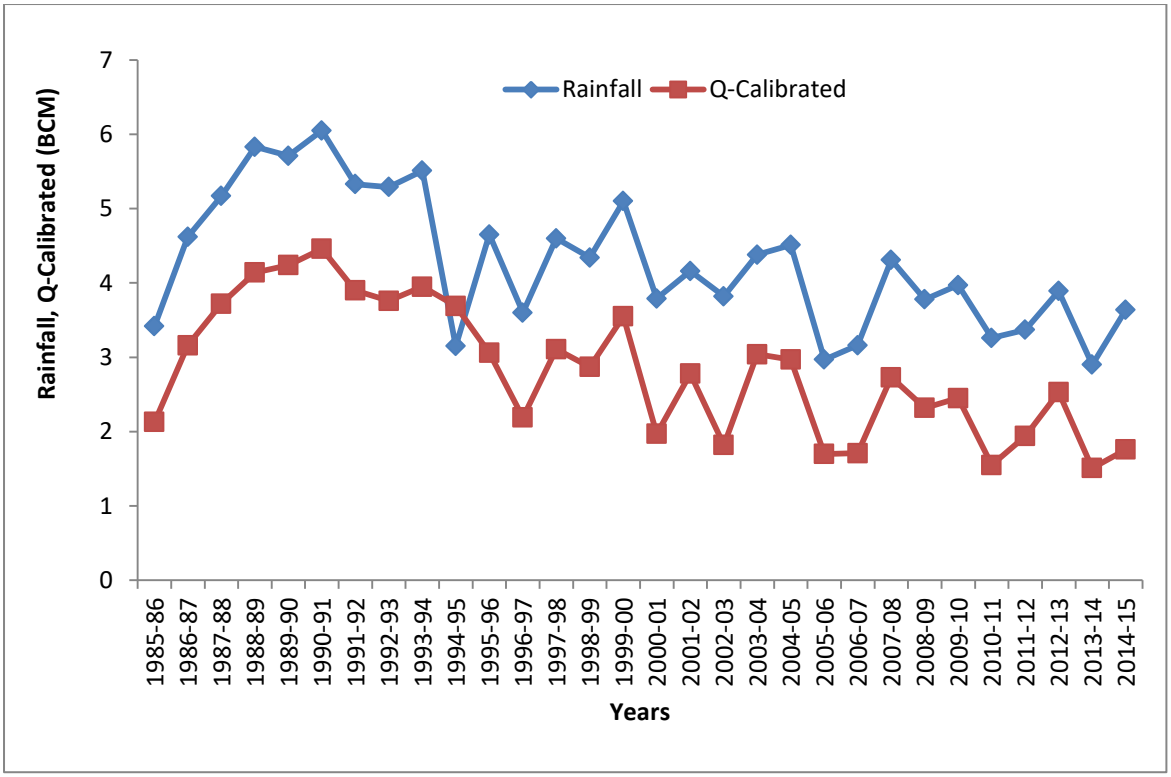


Figure 10.15 Calibrated runoff and rainfall in Tripura sub-basin

10.4 Annual Water Resources Availability of Minor rivers draining into Myanmar (Burma) and Bangladesh Basin

Table - J.4 at Annexure - J shows the different components that are required to estimate the basin level water resources of Minor rivers draining into Myanmar (Burma) and Bangladesh for 30 years. The mean annual calibrated runoff is about 30.21 BCM. The maximum annual calibrated runoff is 51.59 BCM during 1990-91. The minimum annual calibrated runoff is 15.70 BCM during 1994-95. The observed discharge of Tripura sub-basin is not available.

The maximum annual water resource is 52.15 BCM during 1990-91 in the 30 years. The minimum annual water resource is 17.39 BCM during 1994-95 which is the driest year in the 30 years. The mean available basin water resource is 31.17 BCM. The mean available water resource of the basin is about 51.10% of mean annual rainfall during 1985-86 to 2014-15.

10.4.1 Annual water resources of Minor Rivers draining to Myanmar (Burma) and Bangladesh basin during extreme rainfall conditions

Out of the total 30 years of meteorological data base of study period, during the years 1990-91 and 1994-95, extreme wet and dry rainfall conditions occurred in Minor Rivers draining into Myanmar (Burma) and Bangladesh basin. The annual water resources of the basin during these two extreme rainfall conditions are shown in Table - 10.4. The water balance components during these years are presented in Figures 10.16 and 10.17.

Table - 10.4 Water resources availability in Minor rivers draining into Myanmar (Burma) and Bangladesh basin during extreme rainfall condition

Condition	Year of Occurrence	Rainfall (BCM)	Water Resources availability (BCM)
Maximum Rainfall	1990-91	84.82	52.15
Minimum Rainfall	1994-95	42.95	17.39

Water resources availability - rainfall ratio during the extreme maximum and minimum rainfall years is found to be 0.61 and 0.40 respectively, this shows that the higher the rainfall, the higher percentage of runoff. During higher rainfall years, potential evapo-transpiration is less compared to the dry years which will have cumulative effect in runoff.

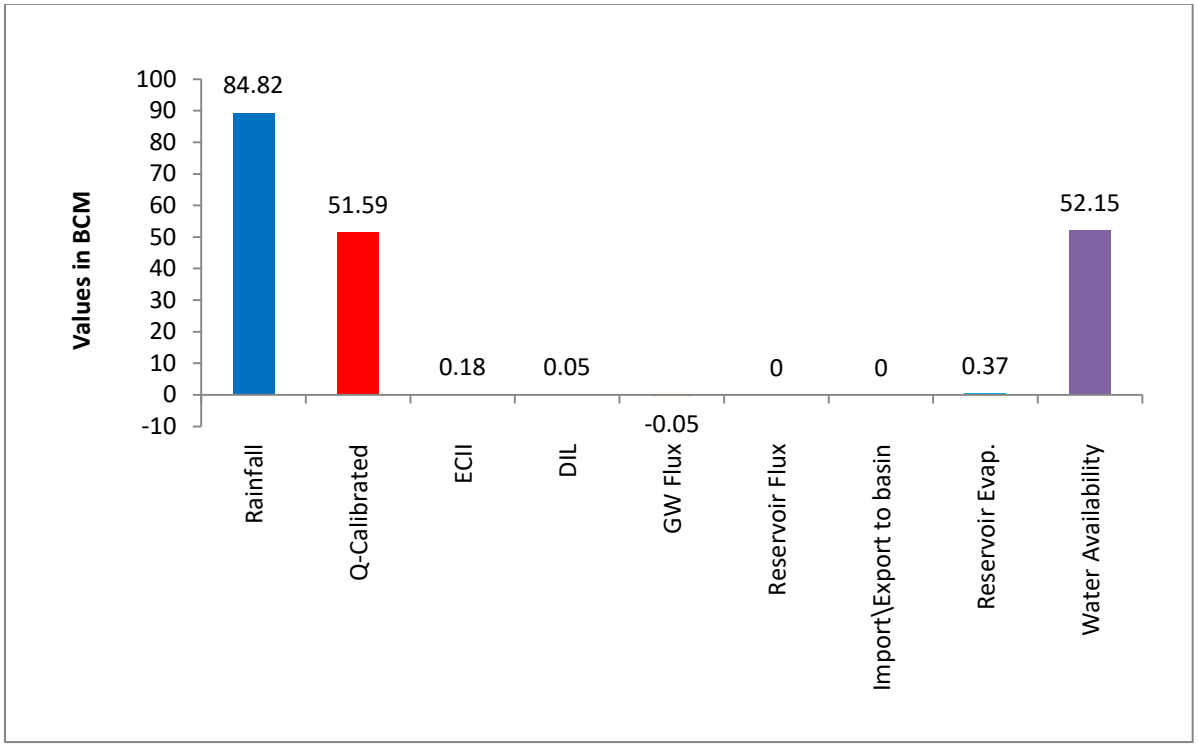


Figure 10.16 Water balance components of Minor rivers draining into Myanmar (Burma) and Bangladesh basin during extreme high rainfall (1990-91)

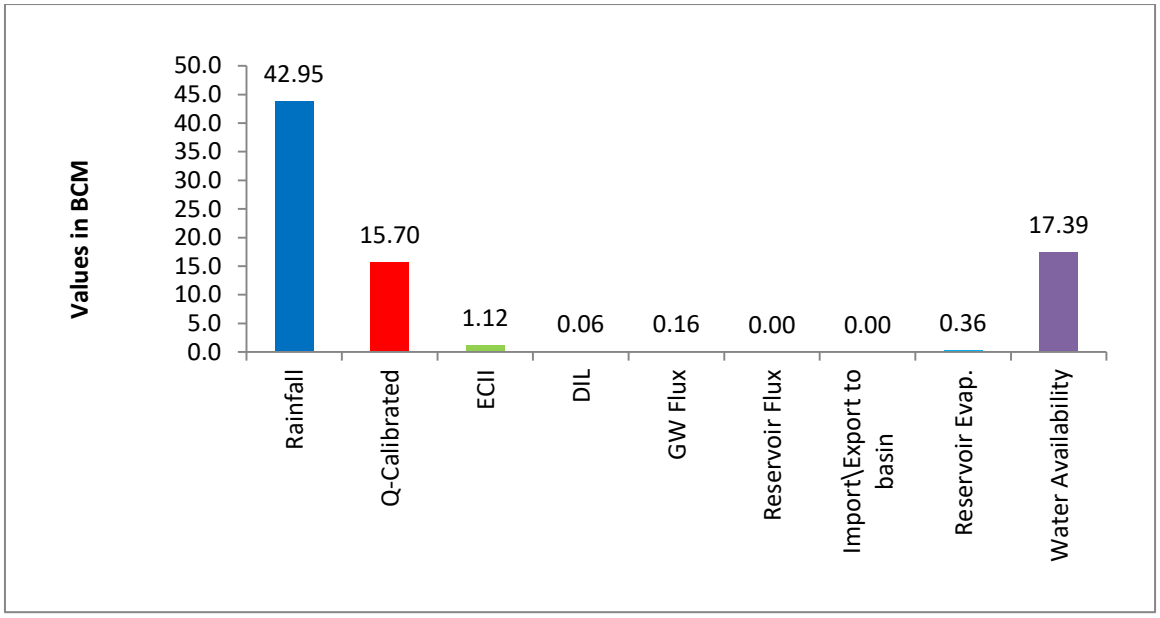


Figure 10.17 Water balance components of Minor rivers draining into Myanmar (Burma) and Bangladesh basin during extreme low rainfall (1994-95)

10.4.2 Mean water resources of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

The mean water resource of the basin is computed by taking mean of the 30 years, water balance components such as flow in the river at final outlet, upstream effective utilisations for irrigation, domestic and Industrial, change in storage of groundwater, change in storage of reservoirs and evaporation from reservoirs.

Mean water resources = Mean of (Calibrated Runoff + Estimated Consumptive Irrigation Input + Domestic, Industrial and Livestock consumption + Groundwater Flux + Reservoir Flux + Export from basin + Evaporation from Reservoirs)

= 30.21 + 0.50 + 0.07 + (-0.01) + 0.00 + 0.00 + 0.40 = 31.17 BCM

75% dependable flow of Minor rivers draining into Myanmar (Burma) and Bangladesh basin = 26.56 BCM

The mean available annual water resource of the Minor rivers draining into Myanmar (Burma) and Bangladesh is 31.17 BCM. Figure 10.18 shows the various water balance components averaged over a period of 30 years during 1985-86 to 2014-15.

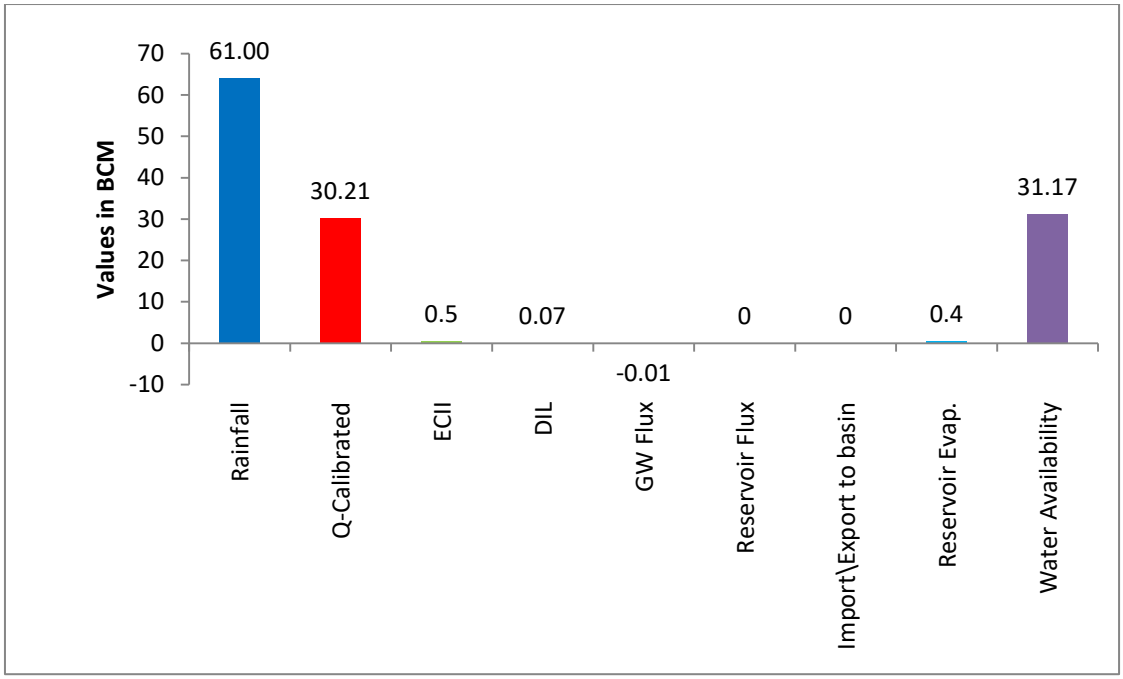


Figure 10.18 Mean water balance components of Minor rivers draining into Myanmar (Burma) and Bangladesh basin

HIGHLIGHTS

- *Mean available water resource of Minor rivers draining into Myanmar (Burma) and Bangladesh basin is 31.17 BCM.*
- *Maximum annual water availability is 52.15 BCM during 1990-91.*
- *Minimum annual water availability is 17.39 BCM during 1994-95.*
- *Annual rainfall in the basin varies from 1,397 mm to 2,847 mm during 1985-86 to 2014-15 and mean rainfall of these 30 years is 1,812 mm.*
- *Minor rivers draining into Myanmar (Burma) and Bangladesh basin is divided into three distinct discontinuous region, the same are taken as three sub-basins for the reassessment study viz. the same are taken as three sub-basins*
- *Average annual domestic, industrial and livestock demand in the basin is 0.07 BCM.*
- *Average annual evaporation from water bodies in the basin is 0.40 BCM.*

ANNEXURES

GODAVARI BASIN

Table - A.1 Water availability at Wardha (up to Bamini)

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9=3+4+5+6+8
1985-86	860.85	39.76	3.05	0.13	0.02	6.33	6.05	0.96	10.49
1986-87	959.25	44.31	4.26	0.13	0.73	12.36	17.15	1.25	18.73
1987-88	727.29	33.59	6.01	0.14	-0.90	3.15	2.68	0.82	9.22
1988-89	1260.24	58.21	4.54	0.14	1.47	22.17	28.46	0.86	29.17
1989-90	1078.69	49.82	1.99	0.15	0.02	15.38	10.17	0.84	18.38
1990-91	1323.81	61.14	1.18	0.15	-0.02	31.63	24.86	0.67	33.60
1991-92	666.93	30.80	5.00	0.16	-2.15	6.16	6.14	0.84	10.01
1992-93	1026.54	47.41	5.19	0.16	1.48	12.89	14.02	1.11	20.83
1993-94	884.86	40.87	6.14	0.17	-0.31	7.19	5.70	0.88	14.05
1994-95	1258.66	58.13	0.68	0.18	1.78	23.65	23.13	0.84	27.13
1995-96	963.40	44.50	4.38	0.18	-0.96	10.24	12.81	1.07	14.92
1996-97	849.51	39.24	5.36	0.19	-0.38	9.40	5.14	0.97	15.55
1997-98	961.44	44.41	5.45	0.20	0.61	8.52	3.25	1.16	15.92
1998-99	981.97	45.35	4.53	0.21	0.13	10.01	8.65	0.90	15.79
1999-00	1064.16	49.15	0.51	0.21	0.32	18.11	12.96	1.10	20.26
2000-01	849.70	39.25	3.94	0.22	-1.20	11.54	9.88	0.83	15.33
2001-02	941.98	43.51	2.08	0.23	0.09	13.74	9.93	1.07	17.21
2002-03	949.70	43.86	1.90	0.23	-0.34	14.04	13.04	0.85	16.70
2003-04	962.62	44.46	5.59	0.24	0.18	12.23	8.91	0.85	19.09
2004-05	727.10	33.58	5.59	0.24	-1.25	1.96	1.28	0.84	7.37
2005-06	1150.23	53.13	4.24	0.24	1.54	16.65	11.93	0.78	23.45
2006-07	1051.04	48.54	3.34	0.25	0.16	19.18	16.14	0.69	23.61
2007-08	1034.16	47.76	2.09	0.25	-0.13	16.68	11.44	0.73	19.62
2008-09	770.97	35.61	7.54	0.25	-0.98	5.79	3.17	0.68	13.28
2009-10	774.16	35.76	6.97	0.26	-0.94	3.61	1.03	0.74	10.64
2010-11	1243.39	57.43	5.06	0.26	2.28	18.61	17.18	0.73	26.94
2011-12	825.17	38.11	3.99	0.26	-1.14	11.93	7.88	1.39	16.44
2012-13	1007.80	46.55	4.40	0.27	0.85	12.57	10.71	1.47	19.55
2013-14	1480.02	68.36	0.89	0.27	1.15	30.22	28.94	1.28	33.81
2014-15	866.46	40.02	4.97	0.27	-1.14	9.91	6.07	1.42	15.42
Avg	983.40	45.42	4.03	0.21	0.03	13.19	11.29	0.95	18.42

Table - A.2 Water availability at Pranhita (up to Tekra)

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9= 3+4+5+6+8
1985-86	1011.11	109.17	7.28	0.29	0.29	21.90	24.77	1.48	30.86
1986-87	1240.07	133.89	7.54	0.30	1.26	38.61	48.10	1.92	49.26
1987-88	850.72	91.85	8.80	0.31	-2.14	12.17	10.96	1.32	20.08
1988-89	1334.70	144.10	7.23	0.32	2.31	46.70	53.41	1.38	57.56
1989-90	1136.79	122.73	6.64	0.33	0.81	27.77	27.59	1.38	36.56
1990-91	1451.74	156.74	3.26	0.34	-1.93	72.08	62.73	1.15	74.54
1991-92	854.00	92.20	9.89	0.35	-1.95	20.29	20.23	1.21	29.42
1992-93	1153.70	124.56	9.07	0.36	1.92	35.24	38.46	1.67	47.89
1993-94	1084.49	117.09	8.47	0.37	0.43	27.04	22.82	1.41	37.35
1994-95	1648.38	177.97	2.41	0.38	2.88	77.35	78.81	1.38	84.04
1995-96	1117.06	120.60	7.60	0.40	-1.99	28.99	31.39	1.71	36.34
1996-97	910.67	98.32	7.95	0.41	-1.04	20.02	15.16	1.43	28.41
1997-98	1220.99	131.83	6.77	0.43	2.42	22.01	22.77	1.91	33.17
1998-99	1173.23	126.67	6.56	0.44	-0.51	31.99	32.08	1.47	39.59
1999-00	1215.37	131.22	2.05	0.46	0.40	47.73	42.28	1.76	52.02
2000-01	1012.45	109.31	9.09	0.47	-2.66	34.05	31.89	1.26	41.83
2001-02	1162.22	125.48	4.97	0.49	-0.14	39.49	26.85	1.66	46.10
2002-03	1020.60	110.19	6.01	0.50	-0.51	31.17	25.24	1.33	38.13
2003-04	1215.62	131.25	9.80	0.50	1.01	39.81	31.49	1.30	52.06
2004-05	905.88	97.80	9.21	0.51	-2.30	12.75	12.11	1.34	21.15
2005-06	1321.28	142.65	7.60	0.52	3.13	44.43	39.89	1.03	56.34
2006-07	1110.41	119.89	8.08	0.53	-0.63	39.43	46.47	0.86	47.89
2007-08	1101.29	118.90	6.18	0.53	-0.25	33.13	37.97	0.99	40.22
2008-09	937.92	101.26	11.41	0.54	-2.17	21.40	19.23	0.91	31.72
2009-10	941.02	101.60	10.09	0.55	-0.83	18.30	12.85	0.93	28.67
2010-11	1378.48	148.83	12.17	0.56	4.31	47.71	45.56	1.42	65.79
2011-12	997.33	107.68	8.24	0.56	-1.98	31.28	28.73	2.05	39.79
2012-13	1155.45	124.75	7.57	0.57	1.10	35.53	37.49	2.19	46.60
2013-14	1697.91	183.32	2.14	0.58	2.39	78.88	85.19	2.26	85.88
2014-15	1016.68	109.77	8.33	0.59	-2.34	23.42	20.83	2.77	32.40
Avg	1145.92	123.72	7.42	0.45	0.04	35.73	34.44	1.50	44.76

Table - A.3 Water availability at Godavari (up to Yelli)

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10= 3+4+5+6+7+9
1985-86	509.76	27.3	7.3	0.18	-0.92	-0.71	0.99	1.09	0.65	7.5
1986-87	531.52	28.47	8.8	0.19	0.8	-0.08	0	0.86	0.74	10.45
1987-88	719.53	38.53	4.3	0.2	0.83	0.29	5.42	2.19	0.84	11.87
1988-89	1033.98	55.37	6.2	0.2	1.52	0.58	20.36	13.67	0.8	29.66
1989-90	986.35	52.82	6.22	0.21	0.11	-0.2	17.33	9.32	0.89	24.55
1990-91	933.5	49.99	1.3	0.22	0.38	0.47	24.05	13.57	0.78	27.2
1991-92	587.22	31.45	9.57	0.22	-5.16	-0.95	11.91	4.81	0.6	16.2
1992-93	683.8	36.62	3.94	0.23	3.95	0.15	2.71	3.61	0.82	11.79
1993-94	769.72	41.22	1.41	0.24	0.53	-0.05	9.17	1.39	0.9	12.21
1994-95	680.19	36.43	5.42	0.25	-0.73	0.13	7.94	2.43	0.75	13.76
1995-96	601.92	32.24	4.14	0.26	-1.11	-0.45	5.48	1.63	0.77	9.09
1996-97	804.95	43.11	0.66	0.27	1.08	0.42	12.91	2.94	0.79	16.14
1997-98	741.07	39.69	1.93	0.28	0.61	-0.06	8.34	0.81	0.88	11.99
1998-99	1002.51	53.69	0.44	0.29	1.61	1.04	17.56	10.9	0.95	21.89
1999-00	824.09	44.13	1.00	0.29	-1.22	-0.3	16.62	3.74	0.88	17.27
2000-01	612.29	32.79	7.88	0.3	-1.25	-0.85	6.22	4.82	0.66	12.96
2001-02	734.65	39.34	2.81	0.31	-0.07	-0.05	11.25	2.87	0.81	15.07
2002-03	735.54	39.39	6.75	0.32	-0.84	0	10.26	2.75	0.75	17.24
2003-04	639.69	34.26	6.21	0.32	0	-0.15	6.38	1.27	0.67	13.43
2004-05	719.33	38.52	5.19	0.33	0.17	0.71	7.41	0.19	0.79	14.6
2005-06	1219.78	65.32	5.27	0.34	1.25	0.11	32.34	9.03	0.48	39.79
2006-07	917.28	49.12	4.45	0.34	0.73	0.23	20.85	12.97	0.52	27.13
2007-08	701.02	37.54	7.94	0.35	-1.47	-0.3	8.98	1.78	0.56	16.05
2008-09	679.36	36.38	5.3	0.36	-0.6	-0.33	10.86	1.71	0.44	16.01
2009-10	736.32	39.43	2.13	0.36	-2.47	-0.36	11.63	0.51	0.35	11.65
2010-11	988.26	52.93	6.27	0.37	3.24	0.78	13.68	4.99	0.62	24.95
2011-12	579.24	31.02	5.36	0.37	-1.4	-0.71	8.12	1.38	0.47	12.21
2012-13	537.09	28.76	4.55	0.38	-1.06	-0.2	2.82	0.15	0.48	6.97
2013-14	936.29	50.14	1.19	0.39	2.21	0.66	14.81	2.62	0.7	19.96
2014-15	604.04	32.35	7.36	0.39	-2.02	-0.39	7.21	0.08	0.27	12.82
Avg	758.34	40.61	4.71	0.29	-0.04	-0.02	11.07	4.00	0.69	16.70

Table - A.4 Water availability at Godavari (up to Mancherial)

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10= 3+4+5+6+7+9
1985-86	656.26	66.47	9.79	0.35	-1.68	-0.97	5.51	2.08	1.02	14.03
1986-87	650.78	65.91	13.18	0.36	0.77	-0.08	3.02	4.66	1.72	18.97
1987-88	788.55	79.86	5.94	0.37	1.06	0.02	11.71	1.88	1.23	20.34
1988-89	1281.04	129.74	8.59	0.38	2.79	1.61	54.59	35.59	1.66	69.63
1989-90	1170.16	118.51	8.92	0.40	1.03	-0.26	39.62	22.40	1.79	51.51
1990-91	1116.60	113.09	3.75	0.41	-0.18	1.26	53.58	28.76	1.57	60.39
1991-92	628.96	63.70	12.52	0.42	-7.98	-2.87	21.19	7.29	0.88	24.16
1992-93	744.00	75.35	8.13	0.44	5.63	0.29	3.94	4.83	1.99	20.43
1993-94	803.06	81.33	3.04	0.45	-0.38	-0.12	16.34	2.87	1.28	20.61
1994-95	784.93	79.50	9.10	0.47	0.21	0.66	12.08	4.11	1.63	24.15
1995-96	851.90	86.28	6.04	0.49	-0.64	-0.04	19.48	9.44	2.00	27.32
1996-97	902.43	91.40	1.99	0.50	1.46	0.32	24.79	6.45	1.17	30.24
1997-98	796.57	80.68	4.88	0.52	0.04	-0.70	12.52	1.54	2.20	19.46
1998-99	1095.67	110.97	3.13	0.54	2.71	1.64	31.67	15.81	2.16	41.84
1999-00	853.77	86.47	3.85	0.55	-1.93	-0.74	24.92	6.28	1.95	28.61
2000-01	777.76	78.77	10.54	0.58	-1.38	-0.91	19.69	11.31	0.98	29.50
2001-02	807.98	81.83	6.26	0.59	-0.48	-0.15	18.91	3.93	1.95	27.09
2002-03	728.25	73.76	9.59	0.60	-1.92	-0.03	15.19	2.57	1.08	24.51
2003-04	766.32	77.61	10.28	0.62	1.10	-0.17	10.98	3.32	1.51	24.32
2004-05	749.32	75.89	7.08	0.63	-1.08	0.68	12.59	0.29	1.18	21.07
2005-06	1248.20	126.42	9.95	0.63	3.29	0.38	51.17	11.14	1.05	66.48
2006-07	894.87	90.63	7.28	0.64	0.36	0.43	28.92	15.12	1.08	38.71
2007-08	755.53	76.52	11.16	0.66	-1.54	-0.71	13.31	1.11	1.18	24.06
2008-09	731.61	74.10	8.10	0.67	-0.84	-0.52	16.52	2.34	0.82	24.76
2009-10	711.35	72.04	6.21	0.68	-4.29	-0.37	12.08	0.46	0.67	14.99
2010-11	1081.83	109.57	10.18	0.69	5.67	2.03	28.83	9.77	1.31	48.71
2011-12	631.77	63.98	9.49	0.70	-3.37	-0.94	14.07	2.65	0.90	20.86
2012-13	695.15	70.40	6.46	0.71	-0.62	-0.17	5.93	2.22	1.16	13.47
2013-14	1094.42	110.84	3.57	0.73	3.82	3.83	26.07	7.49	1.50	39.52
2014-15	645.03	65.33	10.20	0.74	-4.54	-3.51	13.06	1.02	0.66	16.60
Avg	848.14	85.90	7.64	0.55	-0.10	0.00	20.74	7.62	1.38	30.21

Table - A.5 Water availability at Indravathi (up to Pathagudem)

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10= 3+4+5+6+7+9
1985-86	1337.90	53.26	2.06	0.10	0.10	0.00	20.84	16.10	0.32	23.42
1986-87	1434.58	57.11	2.52	0.10	-0.14	0.00	24.31	24.24	0.28	27.06
1987-88	1211.18	48.21	3.75	0.10	-0.15	0.00	17.22	12.61	0.34	21.26
1988-89	1307.52	52.05	2.67	0.10	0.07	0.00	19.00	20.09	0.35	22.18
1989-90	1595.22	63.50	3.08	0.09	1.36	0.00	21.76	20.00	0.39	26.69
1990-91	1834.45	73.02	0.35	0.09	-1.18	0.00	43.68	47.98	0.36	43.31
1991-92	1338.99	53.30	4.18	0.09	0.25	0.00	24.16	18.76	0.31	29.00
1992-93	1527.08	60.79	2.63	0.09	-0.23	0.00	32.40	24.40	0.29	35.20
1993-94	1276.20	50.80	3.34	0.09	0.12	0.00	20.70	15.35	0.34	24.59
1994-95	2016.67	80.28	2.37	0.09	0.97	0.00	41.71	41.53	0.39	45.53
1995-96	1393.14	55.46	1.81	0.09	-0.65	0.00	28.21	21.38	0.31	29.78
1996-97	1333.54	53.08	3.13	0.09	-0.04	0.00	22.09	16.90	0.27	25.56
1997-98	1260.54	50.18	3.14	0.09	-0.03	0.00	21.04	15.12	0.28	24.52
1998-99	1194.95	47.57	2.92	0.09	0.18	0.00	15.23	16.64	0.41	18.83
1999-00	1363.98	54.30	2.21	0.09	-0.05	0.86	19.94	26.77	0.27	23.32
2000-01	1195.89	47.60	4.40	0.09	-0.43	-0.64	16.28	18.27	0.31	20.00
2001-02	1822.88	72.56	2.86	0.09	0.16	-0.19	40.15	34.65	0.27	43.34
2002-03	962.09	38.30	4.18	0.09	-0.56	0.12	10.08	11.19	0.30	14.21
2003-04	1867.78	74.35	1.16	0.10	1.15	0.11	40.93	31.49	0.39	43.83
2004-05	1414.78	56.32	2.95	0.10	-0.34	-0.15	22.94	19.27	0.31	25.81
2005-06	1414.65	56.31	1.44	0.10	0.42	0.12	23.83	21.72	0.17	26.08
2006-07	1796.81	71.53	3.47	0.10	-0.03	0.04	46.11	37.07	0.11	49.80
2007-08	1789.08	71.22	1.47	0.10	-0.31	-0.18	36.79	24.95	0.13	38.00
2008-09	1295.31	51.56	3.69	0.10	-0.46	-0.07	19.33	18.47	0.11	22.70
2009-10	1096.04	43.63	7.67	0.10	-0.19	0.18	9.60	11.27	0.11	17.46
2010-11	1604.92	63.89	3.06	0.10	0.80	0.13	30.26	31.17	0.16	34.51
2011-12	1242.71	49.47	4.98	0.10	-0.54	-0.20	19.85	13.66	0.09	24.27
2012-13	1630.80	64.92	4.98	0.10	0.19	0.10	33.15	26.33	0.14	38.67
2013-14	1667.56	66.38	1.20	0.10	0.37	0.17	30.36	39.99	0.15	32.36
2014-15	1414.87	56.32	3.63	0.10	0.39	0.09	25.27	24.33	0.02	29.51
Avg	1454.74	57.91	3.04	0.09	0.04	0.02	25.91	23.39	0.26	29.36

Table - A.6 Water availability at Maner (up to Somanapally)

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	7	8	9	10= 3+4+5+6+7+9
1985-86	768.87	9.93	2.48	0.05	-0.18	0.06	0.34	0.03	2.45
1986-87	1032.4	13.33	1.50	0.06	-0.01	3.05	1.45	0.22	4.81
1987-88	922.58	11.91	2.18	0.06	0.04	1.37	0.94	0.03	3.68
1988-89	1367.1	17.65	1.33	0.06	0.27	6.61	5.15	0.15	8.42
1989-90	1408.4	18.19	1.53	0.06	0.19	5.98	3.70	0.19	7.95
1990-91	1147.6	14.82	1.26	0.06	-0.12	5.11	2.67	0.18	6.50
1991-92	721.34	9.31	2.91	0.06	-0.49	0.17	1.05	0.03	2.67
1992-93	828.47	10.70	1.21	0.06	-0.04	0.52	0.66	0.23	1.99
1993-94	907.17	11.71	1.99	0.07	-0.09	1.52	0.79	0.03	3.51
1994-95	1086.1	14.02	1.58	0.07	0.27	2.87	0.74	0.16	4.95
1995-96	1159.8	14.97	0.52	0.07	0.11	4.00	1.61	0.26	4.96
1996-97	1146.0	14.80	1.60	0.07	0.10	3.41	1.94	0.03	5.22
1997-98	757.44	9.78	1.21	0.07	-0.39	0.35	0.28	0.25	1.49
1998-99	980.97	12.67	0.92	0.08	0.24	2.08	1.85	0.24	3.56
1999-00	962.88	12.43	0.93	0.08	-0.17	1.94	1.28	0.24	3.01
2000-01	1101.9	14.23	2.70	0.08	0.08	4.28	1.95	0.03	7.17
2001-02	770.02	9.94	1.05	0.08	-0.23	0.53	0.57	0.23	1.66
2002-03	739.79	9.55	2.76	0.09	-0.36	0.51	0.46	0.02	3.02
2003-04	915.14	11.82	1.47	0.09	0.19	0.57	0.28	0.17	2.50
2004-05	669.72	8.65	2.46	0.09	-0.50	0.00	0.01	0.02	2.08
2005-06	1120.7	14.47	1.52	0.09	0.71	2.28	0.78	0.10	4.70
2006-07	1145.7	14.79	0.92	0.10	0.01	4.35	2.08	0.09	5.47
2007-08	948.13	12.24	1.03	0.10	0.05	0.84	0.70	0.11	2.13
2008-09	1046.8	13.52	1.27	0.10	-0.20	3.16	1.12	0.09	4.41
2009-10	699.17	9.03	1.71	0.10	-0.46	0.00	0.12	0.04	1.39
2010-11	1254.8	16.20	1.37	0.10	0.53	4.68	2.02	0.11	6.79
2011-12	630.95	8.15	2.32	0.10	-0.59	0.13	0.31	0.07	2.03
2012-13	998.54	12.89	1.16	0.10	0.11	1.31	1.09	0.12	2.81
2013-14	1453.2	18.76	0.59	0.10	0.59	5.95	2.59	0.13	7.36
2014-15	720.99	9.31	1.59	0.10	-0.84	1.55	0.30	0.06	2.47
Avg	980.44	12.66	1.57	0.08	-0.04	2.27	1.29	0.12	4.00

Table - A.7 Water availability at Sabari (up to Konta)

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	7	8	9	10= 3+4+5+6+7+9
1985-86	1238.00	23.84	0.72	0.05	-0.05	9.02	12.54	0.43	10.17
1986-87	1414.03	27.23	0.84	0.05	0.02	12.57	20.70	0.39	13.88
1987-88	1287.47	24.79	0.86	0.05	0.02	9.37	7.49	0.45	10.76
1988-89	1310.94	25.25	0.97	0.06	0.01	12.21	12.80	0.33	13.56
1989-90	1844.06	35.51	0.91	0.06	2.12	16.90	14.24	0.42	20.41
1990-91	1684.61	32.44	0.66	0.06	-1.61	21.71	24.32	0.36	21.17
1991-92	1392.86	26.82	0.98	0.06	-0.44	14.05	15.34	0.37	15.03
1992-93	1553.63	29.92	0.96	0.06	-0.28	15.95	14.37	0.38	17.07
1993-94	1272.11	24.50	0.83	0.06	-0.02	10.91	10.21	0.40	12.17
1994-95	1835.16	35.34	0.60	0.06	1.32	18.63	22.31	0.43	21.03
1995-96	1407.35	27.10	0.82	0.06	-0.61	13.93	17.39	0.37	14.57
1996-97	1295.14	24.94	1.33	0.06	0.28	9.95	14.27	0.36	11.98
1997-98	1123.00	21.63	1.04	0.07	-0.33	7.01	10.90	0.37	8.16
1998-99	1351.87	26.03	0.75	0.07	0.08	10.59	13.31	0.36	11.85
1999-00	1297.31	24.98	1.10	0.07	0.23	10.49	16.65	0.38	12.27
2000-01	1391.81	26.80	1.33	0.07	-0.32	12.06	14.98	0.41	13.55
2001-02	1489.13	28.68	0.97	0.07	-0.06	13.36	13.08	0.38	14.73
2002-03	1026.77	19.77	1.43	0.07	-0.74	6.51	6.77	0.37	7.65
2003-04	1829.52	35.23	0.58	0.08	1.23	18.07	18.04	0.40	20.36
2004-05	1345.54	25.91	0.95	0.08	-0.62	10.95	14.48	0.42	11.79
2005-06	1704.39	32.82	0.39	0.08	1.13	15.59	13.74	0.37	17.55
2006-07	2512.95	48.39	1.01	0.08	-0.38	35.65	23.10	0.30	36.66
2007-08	1916.32	36.90	0.57	0.08	0.17	20.33	19.53	0.35	21.49
2008-09	1446.98	27.87	1.61	0.08	-0.49	13.42	13.03	0.21	14.83
2009-10	1106.47	21.31	2.38	0.08	-0.28	5.99	7.57	0.25	8.42
2010-11	1780.41	34.29	1.23	0.08	0.84	17.34	19.47	0.38	19.88
2011-12	1224.23	23.58	2.64	0.08	-1.17	9.30	9.72	0.22	11.07
2012-13	1673.19	32.22	2.42	0.08	0.77	15.64	17.68	0.33	19.24
2013-14	1702.52	32.79	0.59	0.08	0.25	17.65	21.56	0.30	18.86
2014-15	1632.07	31.43	2.31	0.08	-0.05	15.54	19.52	0.03	17.91
Avg	1502.99	28.94	1.13	0.07	0.03	14.02	15.30	0.35	15.60

Table - A.8 Water availability at Godavari catchment (up to Polavaram)

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10= 3+4+5+6+7+9
1985-86	952.66	292.05	17.64	0.92	-1.72	-0.97	46.10	64.61	3.51	65.48
1986-87	1078.36	330.59	21.74	0.94	1.77	-0.08	71.92	127.18	5.08	101.37
1987-88	931.62	285.60	16.83	0.96	-1.11	0.02	39.8	45.98	3.58	60.08
1988-89	1352.02	414.49	16.17	0.99	5.70	1.61	138.73	158.56	4.36	167.56
1989-90	1326.25	406.59	16.48	1.01	6.60	-0.26	107.14	112.13	4.77	135.74
1990-91	1405.64	430.92	4.46	1.04	-5.98	1.26	195.34	216.15	4.15	200.27
1991-92	903.39	276.95	25.57	1.07	-10.87	-2.87	69.13	82.10	3.01	85.04
1992-93	1091.04	334.48	18.05	1.10	6.72	0.29	76.86	100.70	5.18	108.20
1993-94	1038.38	318.33	12.77	1.13	0.05	-0.12	66.62	65.89	3.67	84.12
1994-95	1413.05	433.19	11.48	1.17	6.30	0.66	150.31	171.40	4.55	174.47
1995-96	1104.24	338.52	12.2	1.20	-4.05	-0.04	84.12	96.87	5.26	98.69
1996-97	1041.65	319.34	11.03	1.24	0.85	0.32	71.13	67.68	3.52	88.09
1997-98	1051.07	322.22	13.24	1.28	1.55	-0.70	60.46	53.50	5.63	81.46
1998-99	1167.60	357.95	9.89	1.31	2.71	1.64	79.68	86.27	5.28	100.51
1999-00	1121.90	343.94	6.04	1.35	-1.38	0.12	96.03	106.19	5.17	107.33
2000-01	1038.80	318.46	23.73	1.40	-4.83	-1.55	85.33	90.77	3.04	107.12
2001-02	1138.12	348.91	11.83	1.44	-1.10	-0.34	100.65	95.94	4.53	117.01
2002-03	900.48	276.06	19.76	1.46	-4.42	0.09	51.52	63.86	3.16	71.57
2003-04	1210.90	371.22	19.39	1.50	5.09	-0.06	101.44	104.53	3.82	131.18
2004-05	952.53	292.01	21.37	1.52	-5.16	0.54	42.92	58.53	3.32	64.51
2005-06	1330.24	407.81	16.57	1.54	9.53	0.51	127.83	125.33	2.77	158.75
2006-07	1265.10	387.84	16.49	1.57	-0.88	0.47	152.51	155.13	2.48	172.64
2007-08	1132.59	347.22	16.2	1.59	-1.68	-0.89	91.96	109.21	2.80	109.98
2008-09	992.37	304.23	22.17	1.61	-4.42	-0.58	63.79	67.55	2.18	84.75
2009-10	877.24	268.93	26.77	1.62	-6.39	-0.19	27.64	33.91	2.04	51.49
2010-11	1364.27	418.24	24.33	1.64	12.77	2.16	126.9	136.05	3.45	171.25
2011-12	896.94	274.97	23.92	1.66	-8.38	-1.14	60.05	64.40	3.39	79.50
2012-13	1130.59	346.60	18.77	1.69	1.93	-0.07	82.1	106.88	4.02	108.44
2013-14	1493.18	457.76	3.27	1.71	7.70	4.00	154.45	176.87	4.43	175.56
2014-15	978.04	299.83	22.94	1.73	-7.95	-3.42	65.9	67.89	3.56	82.76
Avg	1122.68	344.18	16.70	1.35	-0.03	0.01	89.61	100.40	3.86	111.50

Table - A.9 Water resources availability in Godavari basin

Year	Rainfall	Q-Calibrated	Irrigation Support (ECII)	DIL	GW Flux	Reservoir Flux	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9
1985-86	311.42	66.32	17.07	0.95	-1.72	-0.97	3.92	85.57
1986-87	350.21	92.98	21.17	0.98	1.79	-0.08	5.80	122.64
1987-88	302.68	60.86	16.26	1.00	-1.03	0.02	3.97	81.08
1988-89	431.71	122.85	15.60	0.81	0.02	2.23	4.87	146.38
1989-90	428.09	115.17	15.91	0.81	0.02	0.43	5.57	137.91
1990-91	453.11	194.05	3.89	0.84	-2.18	0.42	4.72	201.74
1991-92	296.56	67.28	25.00	0.84	-8.43	-3.78	3.49	84.4
1992-93	355.84	79.08	17.48	0.87	-0.58	1.11	5.91	103.87
1993-94	338.68	71.78	12.20	0.90	0.80	0.33	4.06	90.07
1994-95	463.3	156.47	10.91	0.90	4.71	2.25	5.28	180.52
1995-96	356.99	79.51	11.63	0.93	-3.06	-0.59	6.01	94.43
1996-97	340.22	77.90	10.46	0.93	0.21	0.74	4.43	94.67
1997-98	346.64	60.69	12.67	0.96	-1.73	-0.66	6.35	78.28
1998-99	381.17	88.94	9.32	0.99	-1.73	2.35	6.04	105.91
1999-00	365.46	110.75	5.47	0.99	0.29	-0.68	5.84	122.66
2000-01	333.79	79.14	23.16	1.02	-3.89	-1.66	3.48	101.25
2001-02	368.22	89.39	11.26	1.02	-1.73	-0.11	5.30	105.13
2002-03	294.19	51.19	19.19	1.05	-2.71	0.15	3.46	72.33
2003-04	392.34	85.95	18.82	1.05	4.82	0.13	4.50	115.27
2004-05	310.22	35.17	20.80	1.08	-3.90	0.12	3.71	56.98
2005-06	431.95	123.31	16.00	1.11	8.07	0.93	3.28	152.7
2006-07	411.94	139.51	15.92	1.11	-0.73	0.44	3.03	159.28
2007-08	366.99	114.59	15.63	1.14	-0.22	-1.28	3.37	133.23
2008-09	321.98	85.61	21.60	1.67	-4.63	-0.58	2.56	106.23
2009-10	288.33	49.68	26.20	1.68	-6.55	-0.19	2.47	73.29
2010-11	444.07	150.23	23.76	1.70	13.03	2.16	4.09	194.97
2011-12	293.79	81.89	23.35	1.72	-8.79	-1.14	3.74	100.77
2012-13	367.96	104.47	18.20	1.75	2.14	-0.07	4.53	131.02
2013-14	482.94	175.25	2.70	1.77	7.84	4.00	4.91	196.47
2014-15	319.3	87.17	22.37	1.79	-8.03	-3.42	3.69	103.57
Avg	365.00	96.57	16.13	1.15	-0.60	0.09	4.41	117.74

KRISHNA BASIN

Table - B.1 Water availability at Kurundwad

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11= 3+4+5+6+7+8+10
1985-86	1391	21.36	1.30	0.08	-0.11	0.26	2.46	6.62	8.37	0.11	10.72
1986-87	1327	20.37	1.08	0.08	0.19	-0.40	2.46	5.90	7.68	0.13	9.44
1987-88	1386	21.27	1.14	0.08	0.04	0.16	1.85	6.72	5.25	0.15	10.14
1988-89	1343	20.62	1.38	0.09	0.18	0.14	2.46	9.01	11.70	0.11	13.37
1989-90	1517	23.28	4.21	0.09	0.14	-0.19	2.21	5.76	7.83	0.13	12.34
1990-91	1889	29.00	3.96	0.09	0.04	0.21	2.21	9.43	14.47	0.13	16.07
1991-92	1719	26.39	4.47	0.09	-0.06	-0.30	2.21	9.90	15.35	0.11	16.43
1992-93	1251	19.20	1.75	0.09	-0.18	0.07	2.21	6.76	8.97	0.12	10.81
1993-94	1992	30.57	3.55	0.09	0.56	0.03	2.34	10.70	12.53	0.15	17.43
1994-95	2021	31.03	3.63	0.09	-0.14	-0.26	2.50	12.78	18.79	0.14	18.74
1995-96	1394	21.39	1.70	0.10	-0.14	0.08	1.91	7.93	5.92	0.12	11.69
1996-97	1518	23.30	1.20	0.10	0.23	0.62	1.91	10.38	8.61	0.17	14.60
1997-98	1805	27.72	5.16	0.10	-0.18	-0.27	1.91	8.76	15.38	0.16	15.64
1998-99	1583	24.30	4.28	0.10	0.35	0.33	1.91	5.93	8.27	0.19	13.09
1999-00	1608	24.68	4.10	0.10	-0.23	-0.17	1.91	8.28	10.62	0.16	14.17
2000-01	1015	15.58	1.70	0.10	-0.19	-0.13	1.92	5.15	5.35	0.16	8.72
2001-02	1129	17.34	4.96	0.11	0.08	-0.02	1.91	2.44	6.03	0.16	9.64
2002-03	1027	15.77	1.96	0.11	-0.29	0.06	1.91	4.81	5.89	0.14	8.70
2003-04	1001	15.37	2.00	0.11	-0.26	-0.10	1.98	3.47	4.71	0.15	7.36
2004-05	1568	24.07	3.82	0.11	0.32	0.14	2.13	7.76	10.80	0.16	14.44
2005-06	3473	53.31	3.38	0.11	0.17	0.06	2.56	29.53	23.67	0.18	36.00
2006-07	2041	31.33	4.08	0.12	0.20	0.07	2.40	14.40	24.68	0.15	21.41
2007-08	1777	27.28	4.65	0.12	-0.27	0.20	2.17	11.11	16.76	0.15	18.13
2008-09	1420	21.80	2.75	0.12	0.36	0.05	1.93	7.46	11.81	0.17	12.84
2009-10	1603	24.61	4.32	0.13	-0.03	-0.17	2.29	8.45	8.35	0.19	15.19
2010-11	1510	23.18	2.82	0.13	0.05	-0.06	2.12	9.13	9.83	0.19	14.38
2011-12	1470	22.56	4.87	0.14	-0.15	0.01	2.02	6.90	11.58	0.18	13.97
2012-13	1152	17.69	2.80	0.14	-0.24	-0.19	1.98	4.66	8.57	0.20	9.36
2013-14	1429	21.94	4.15	0.15	0.31	-0.47	2.53	7.94	12.35	0.23	14.83
2014-15	1508	23.16	4.59	0.16	-0.08	0.44	2.03	6.39	10.15	0.27	13.79
Avg	1562	23.98	3.19	0.11	0.02	0.01	2.14	8.48	11.01	0.16	14.11
Avg excluding 2005-06	1496	22.97	3.18	0.11	0.02	0.00	2.13	7.76	10.57	0.16	13.36

Table - B.2 Water Availability at Huvinhedgi

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	860	46.68	10.13	0.26	0.26	0.25	2.46	6.73	11.37	0.19	20.29
1986-87	897	48.69	8.89	0.27	0.27	-0.38	2.46	9.79	10.44	0.24	21.54
1987-88	995	54.05	12.17	0.27	0.27	0.15	1.85	9.56	9.54	0.30	24.57
1988-89	974	52.88	11.78	0.28	0.28	0.14	2.46	15.98	20.70	0.23	31.14
1989-90	1052	57.12	15.53	0.28	0.28	-0.11	2.21	9.99	13.99	0.27	28.46
1990-91	1108	60.16	14.28	0.29	0.29	0.10	2.21	11.56	19.18	0.27	28.98
1991-92	1112	60.36	14.42	0.29	0.29	-0.29	2.21	15.48	24.40	0.24	32.65
1992-93	876	47.58	11.24	0.30	0.30	-0.34	2.21	10.51	13.36	0.25	24.47
1993-94	1251	67.92	13.60	0.30	0.30	0.54	2.34	16.95	20.17	0.30	34.32
1994-95	1213	65.84	13.11	0.31	0.31	-0.64	2.50	17.24	32.08	0.26	33.09
1995-96	908	49.31	11.24	0.31	0.31	0.04	1.91	9.24	9.86	0.25	23.31
1996-97	1061	57.61	9.98	0.32	0.32	1.14	1.91	16.69	14.17	0.43	30.80
1997-98	1214	65.92	16.20	0.33	0.33	-0.40	1.91	15.10	22.06	0.38	33.85
1998-99	1207	65.55	14.42	0.33	0.33	0.29	1.91	15.23	16.60	0.49	33.01
1999-00	1037	56.31	12.18	0.34	0.34	-0.27	1.91	14.83	17.13	0.35	29.69
2000-01	801	43.51	11.71	0.35	0.35	0.09	1.92	8.00	8.06	0.38	22.80
2001-02	829	45.00	14.04	0.35	0.35	-0.24	1.91	6.80	7.96	0.35	23.57
2002-03	724	39.34	8.35	0.36	0.36	0.73	1.91	5.75	4.69	0.32	17.77
2003-04	707	38.39	8.74	0.36	0.36	-0.72	1.98	4.62	3.53	0.16	15.51
2004-05	992	53.88	14.59	0.37	0.37	0.26	2.13	13.02	10.28	0.38	31.12
2005-06	1993	108.22	14.45	0.38	0.38	0.44	2.56	63.49	26.58	0.85	82.54
2006-07	1144	62.11	16.09	0.39	0.39	-0.25	2.40	16.76	26.79	0.57	36.33
2007-08	1217	66.07	13.30	0.40	0.40	0.64	2.17	20.80	21.69	0.76	38.47
2008-09	917	49.82	12.46	0.41	0.41	-0.50	1.93	10.13	11.56	0.61	25.43
2009-10	1197	65.03	18.04	0.42	0.42	0.90	2.29	17.97	12.51	0.82	40.85
2010-11	1101	59.77	14.92	0.43	0.43	-0.42	2.12	13.50	10.53	0.83	31.81
2011-12	1006	54.63	17.94	0.44	0.44	-0.62	2.02	12.49	14.13	0.67	33.38
2012-13	880	47.80	13.74	0.45	0.45	0.55	1.98	6.60	5.15	0.71	24.50
2013-14	1014	55.07	15.93	0.47	0.47	-0.34	2.53	11.18	12.17	0.79	31.02
2014-15	1031	55.97	16.19	0.49	0.49	-0.27	2.03	8.33	10.88	0.64	27.90
Avg	1044	56.69	13.32	0.35	0.35	0.02	2.15	13.81	14.72	0.44	30.44
Avg excluding 2005-06	1011	54.91	13.28	0.35	0.35	0.00	2.13	12.10	14.31	0.43	28.64

Table - B.3 Water availability at Takli

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reserv Evap	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	567	18.94	9.41	0.19	-1.25	-0.46	1.03	0.00	2.82	0.28	9.21
1986-87	633	21.15	8.50	0.20	0.71	0.04	1.02	0.00	2.85	0.30	10.77
1987-88	755	25.23	7.67	0.20	0.67	0.14	0.71	0.00	1.12	0.36	9.74
1988-89	909	30.37	8.41	0.21	0.33	-0.03	1.09	5.76	7.19	0.31	16.09
1989-90	896	29.91	6.56	0.21	0.30	-0.01	0.98	4.62	5.10	0.37	13.05
1990-91	888	29.67	7.36	0.22	0.06	0.41	1.33	4.16	8.81	0.35	13.89
1991-92	1039	34.68	9.28	0.23	-0.67	-0.66	1.28	9.79	8.13	0.28	19.52
1992-93	688	22.99	9.30	0.23	-0.15	-0.08	1.00	0.00	2.06	0.33	10.63
1993-94	963	32.18	8.91	0.24	0.77	0.31	1.27	2.60	3.29	0.40	14.50
1994-95	834	27.84	8.60	0.24	-0.37	-0.43	1.14	1.72	11.42	0.30	11.20
1995-96	674	22.52	8.56	0.25	-0.57	-0.41	1.01	0.00	0.22	0.32	9.16
1996-97	972	32.46	8.01	0.26	1.06	0.60	1.04	4.34	4.18	0.39	15.70
1997-98	987	32.96	9.12	0.26	-0.23	-0.04	1.28	3.72	4.91	0.40	14.51
1998-99	1130	37.73	8.21	0.27	1.10	0.10	1.19	7.70	9.13	0.49	19.06
1999-00	841	28.08	7.48	0.28	-0.49	-0.47	1.27	3.64	2.32	0.40	12.10
2000-01	592	19.77	6.35	0.29	-0.80	-0.38	0.95	0.00	0.28	0.37	6.78
2001-02	724	24.18	10.07	0.29	-0.39	0.13	1.07	0.00	0.73	0.42	11.60
2002-03	606	20.23	9.61	0.30	0.01	-0.19	1.07	0.00	0.05	0.34	11.13
2003-04	584	19.49	10.06	0.30	-0.17	-0.07	1.13	0.00	0.01	0.33	11.58
2004-05	1205	40.23	9.86	0.31	0.33	0.62	1.25	9.59	1.48	0.43	22.39
2005-06	4022	134.31	8.69	0.31	0.61	0.22	1.70	98.64	9.28	0.50	110.67
2006-07	1424	47.56	11.91	0.32	0.32	0.13	1.70	15.52	11.67	0.44	30.35
2007-08	1167	38.98	11.32	0.33	0.04	-0.34	1.21	11.87	5.35	0.41	24.83
2008-09	1111	37.11	11.12	0.33	-0.05	0.10	0.94	9.57	2.09	0.41	22.43
2009-10	1074	35.86	8.60	0.34	-0.70	0.28	1.18	7.28	3.49	0.59	17.57
2010-11	983	32.84	8.27	0.35	0.67	-0.09	1.05	3.14	1.47	0.58	13.97
2011-12	1009	33.69	13.22	0.36	-0.53	-0.59	1.23	5.36	2.06	0.45	19.50
2012-13	841	28.09	10.79	0.37	-0.92	-0.34	1.18	3.03	0.00	0.44	14.55
2013-14	932	31.13	9.45	0.38	0.82	0.65	1.30	4.41	2.02	0.57	17.58
2014-15	859	28.70	11.52	0.39	0.04	-0.24	1.13	1.21	1.73	0.33	14.38
Avg	997	33.30	9.21	0.28	0.02	-0.04	1.16	7.26	3.84	0.40	18.28
Avg excluding 2005-06	893	29.81	9.23	0.28	0.00	-0.04	1.14	4.11	3.65	0.39	15.10

Table - B.4 Water availability at Yadgir

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	546	37.95	17.07	0.33	-2.18	-0.46	1.03	0.00	3.95	0.35	16.15
1986-87	582	40.48	16.57	0.33	-0.08	0.04	1.02	0.00	3.73	0.38	18.26
1987-88	758	52.70	12.74	0.34	2.18	0.14	0.71	0.00	3.59	0.45	16.56
1988-89	936	65.11	14.08	0.35	1.06	-0.03	1.09	15.45	14.06	0.40	32.39
1989-90	871	60.57	11.36	0.36	1.20	-0.01	0.98	9.77	10.55	0.46	24.13
1990-91	873	60.67	9.94	0.37	-0.78	0.41	1.33	15.18	15.09	0.44	26.89
1991-92	760	52.85	17.70	0.38	-1.52	-0.33	1.28	6.95	9.27	0.34	24.80
1992-93	625	43.47	20.38	0.38	-0.84	-0.10	1.00	0.00	2.71	0.41	21.25
1993-94	806	56.04	12.57	0.39	0.76	0.19	1.27	5.14	5.20	0.50	20.82
1994-95	650	45.22	16.06	0.40	-0.29	-0.62	1.14	0.00	10.58	0.38	17.07
1995-96	646	44.89	13.71	0.41	-0.01	-0.10	1.01	0.00	2.86	0.41	15.43
1996-97	899	62.53	11.19	0.42	1.68	0.13	1.04	10.60	8.36	0.49	25.55
1997-98	750	52.18	18.61	0.43	-1.41	0.32	1.28	0.00	5.20	0.50	19.73
1998-99	1106	76.93	11.10	0.44	2.85	0.47	1.19	18.10	21.07	0.62	34.78
1999-00	742	51.57	12.56	0.45	-2.82	-0.70	1.27	9.28	3.50	0.50	20.55
2000-01	665	46.27	9.73	0.47	-0.16	-0.21	0.95	3.12	3.86	0.47	14.36
2001-02	670	46.58	16.46	0.47	-0.15	-0.13	1.07	0.00	2.48	0.52	18.24
2002-03	568	39.48	15.82	0.48	-2.58	-0.21	1.07	0.00	0.77	0.44	15.02
2003-04	564	39.18	16.15	0.49	0.78	-0.25	1.13	0.00	1.62	0.43	18.72
2004-05	909	63.20	14.13	0.50	-0.77	0.69	1.25	10.26	2.56	0.55	26.61
2005-06	2610	181.47	18.52	0.51	5.58	0.32	1.70	108.15	13.54	0.68	135.46
2006-07	991	68.88	21.74	0.52	-1.67	0.24	1.70	12.62	14.19	0.58	35.73
2007-08	968	67.29	21.63	0.53	1.50	-0.37	1.21	11.11	7.63	0.60	36.22
2008-09	882	61.36	21.45	0.55	-1.08	0.23	0.94	7.88	4.74	0.58	30.54
2009-10	916	63.73	17.03	0.56	0.24	-0.03	1.18	6.01	7.55	0.80	25.79
2010-11	973	67.67	13.42	0.58	0.77	0.66	1.05	11.01	8.05	0.85	28.35
2011-12	788	54.80	20.37	0.60	-3.92	-0.93	1.23	9.49	3.96	0.64	27.48
2012-13	700	48.65	15.84	0.62	-0.44	-0.05	1.18	1.02	1.04	0.64	18.82
2013-14	890	61.88	15.57	0.64	3.75	1.12	1.30	4.33	4.33	0.83	27.54
2014-15	745	51.83	16.94	0.66	-3.20	-0.19	1.13	4.39	2.20	0.50	20.23
Avg	846	58.85	15.68	0.47	-0.05	0.01	1.16	9.33	6.61	0.52	27.12
Avg. excluding 2005-06	786	54.62	15.58	0.46	-0.24	0.00	1.14	5.92	6.37	0.52	23.38

Table - B.5 Water availability at Bawapuram

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	629	41.94	14.85	0.25	-2.14	-0.15	0.40	0.00	1.28	0.15	13.36
1986-87	784	52.26	10.13	0.26	0.30	0.09	0.43	4.21	2.16	0.17	15.59
1987-88	906	60.37	12.89	0.26	1.17	-0.12	0.39	3.73	2.47	0.20	18.51
1988-89	752	50.12	12.18	0.26	0.30	-0.07	0.17	9.26	4.45	0.15	22.26
1989-90	804	53.59	11.99	0.27	-0.05	0.50	0.17	4.81	2.81	0.16	17.85
1990-91	813	54.19	12.23	0.27	-0.64	0.30	0.17	4.68	4.49	0.18	17.19
1991-92	829	55.23	11.35	0.27	0.50	0.29	0.35	7.07	6.28	0.18	20.01
1992-93	899	59.91	12.52	0.28	0.64	-0.20	0.26	12.20	9.83	0.18	25.87
1993-94	858	57.17	12.66	0.28	0.19	-0.22	0.23	6.80	5.93	0.18	20.13
1994-95	814	54.24	13.31	0.29	-1.41	-0.04	0.38	10.37	10.20	0.14	23.04
1995-96	683	45.52	12.75	0.29	-0.72	-0.46	0.31	0.80	1.83	0.16	13.14
1996-97	798	53.16	10.08	0.30	1.27	-0.08	0.14	9.87	5.52	0.18	21.75
1997-98	813	54.18	14.95	0.30	0.46	0.46	0.34	2.58	4.74	0.19	19.27
1998-99	951	63.39	11.60	0.30	1.00	0.19	0.26	8.11	8.28	0.20	21.66
1999-00	846	56.38	13.42	0.31	-0.90	-0.36	0.28	10.52	5.26	0.15	23.42
2000-01	845	56.34	11.38	0.32	1.22	-0.16	0.25	10.81	5.58	0.18	23.98
2001-02	687	45.80	12.95	0.32	-0.73	-0.19	0.24	4.52	3.41	0.15	17.25
2002-03	535	35.67	12.57	0.32	-2.98	-0.04	0.41	0.00	0.84	0.13	10.42
2003-04	654	43.57	11.95	0.33	0.01	0.05	0.36	0.00	0.67	0.14	12.85
2004-05	721	48.06	10.52	0.34	-0.30	0.04	0.36	7.67	1.70	0.16	18.80
2005-06	1288	85.86	9.90	0.34	3.54	0.39	0.21	30.63	6.13	0.69	45.72
2006-07	725	48.35	14.68	0.35	-2.53	-0.15	0.17	8.71	4.56	0.49	21.72
2007-08	1101	73.37	10.23	0.36	3.90	0.54	0.15	18.06	11.53	0.72	33.96
2008-09	770	51.33	14.75	0.36	-1.09	-0.45	0.27	5.13	5.50	0.54	19.52
2009-10	1096	73.04	10.03	0.37	2.17	0.43	0.38	17.43	10.41	0.74	31.54
2010-11	1023	68.20	11.45	0.38	0.39	0.16	0.21	16.63	5.71	0.72	29.94
2011-12	993	66.21	15.50	0.39	-2.50	-0.33	0.47	21.61	3.62	0.62	35.76
2012-13	1032	68.79	15.87	0.40	-2.60	-0.48	0.37	21.07	1.35	0.56	35.19
2013-14	943	62.87	11.89	0.41	1.59	0.37	0.21	11.86	7.88	0.71	27.03
2014-15	963	64.19	16.78	0.42	0.51	1.39	0.22	5.37	7.21	0.60	25.28
Avg	852	56.78	12.58	0.32	0.02	0.06	0.29	9.15	5.05	0.32	22.73
Avg. excluding 2005-06	837	55.77	12.67	0.32	-0.10	0.05	0.29	8.41	5.02	0.31	21.94

Table - B.6 Water availability at Wadinepalli

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	657	159.81	46.79	1.15	-4.13	-0.14	8.29	0.00	10.78	0.98	52.94
1986-87	703	170.92	41.27	1.17	0.48	-1.51	8.77	0.00	10.79	1.06	51.25
1987-88	863	209.91	44.60	1.19	3.67	0.89	8.19	10.07	9.33	1.26	69.86
1988-89	905	220.15	45.21	1.21	1.82	-0.68	9.00	48.63	35.36	1.13	106.32
1989-90	911	221.62	46.46	1.23	2.15	0.50	8.34	27.11	22.28	1.29	87.07
1990-91	896	217.87	44.37	1.25	-1.71	0.52	8.47	31.76	38.06	1.24	85.90
1991-92	868	211.17	50.73	1.28	-1.01	-0.53	7.43	29.82	35.59	1.14	88.86
1992-93	760	184.73	51.03	1.30	0.01	0.00	8.04	5.72	16.54	1.17	67.28
1993-94	889	216.07	45.45	1.33	1.25	-1.08	8.45	24.66	26.73	1.31	81.37
1994-95	834	202.79	48.66	1.35	-0.97	-1.12	8.52	22.60	45.52	1.09	80.13
1995-96	757	184.03	46.68	1.38	-0.58	-0.18	7.45	6.01	8.78	1.23	61.99
1996-97	903	219.63	39.11	1.41	3.35	2.85	6.61	34.89	20.79	1.54	89.77
1997-98	837	203.60	55.82	1.44	-0.78	0.46	8.85	7.88	21.62	1.38	75.05
1998-99	1046	254.43	45.10	1.47	4.26	1.20	8.39	41.85	35.44	1.72	103.99
1999-00	796	193.57	43.85	1.50	-3.37	-2.43	8.22	28.38	14.65	1.28	77.42
2000-01	777	188.96	38.66	1.53	1.45	0.04	7.67	24.16	9.51	1.40	74.91
2001-02	730	177.57	49.09	1.56	-0.85	-0.83	7.01	8.35	7.14	1.38	65.70
2002-03	596	144.92	42.55	1.58	-5.87	-0.59	9.04	0.00	4.18	1.19	47.90
2003-04	670	162.94	42.39	1.61	1.54	-1.16	8.16	0.00	2.43	1.12	53.65
2004-05	803	195.29	44.64	1.64	-0.91	1.96	8.56	23.32	4.26	1.40	80.60
2005-06	1785	433.94	53.46	1.67	10.56	4.37	8.91	204.69	37.86	3.03	286.69
2006-07	883	214.62	65.24	1.70	-4.07	-1.94	9.96	28.53	35.88	2.23	101.64
2007-08	1046	254.38	58.70	1.74	6.09	2.70	7.03	42.43	38.23	3.00	121.68
2008-09	842	204.81	60.89	1.78	-1.82	-3.77	8.82	19.76	15.76	2.40	88.05
2009-10	992	241.21	57.54	1.82	2.57	2.26	9.73	29.28	24.85	3.01	106.22
2010-11	1013	246.42	56.87	1.87	1.93	2.82	7.28	32.79	17.12	3.27	106.83
2011-12	847	205.90	69.26	1.92	-6.66	-4.94	10.14	31.44	13.59	2.53	103.69
2012-13	843	205.10	60.45	1.98	-2.42	-0.82	7.97	15.70	2.79	2.78	85.63
2013-14	968	235.25	55.30	2.04	6.08	-1.07	8.55	29.00	15.84	3.35	103.26
2014-15	857	208.34	70.20	2.12	-2.71	-0.47	9.16	0.00	7.72	2.34	80.64
Avg	876	213.00	50.68	1.54	0.31	-0.09	8.37	26.96	19.65	1.78	89.54
Avg. excluding 2005-06	845	205.38	50.58	1.54	-0.04	-0.25	8.35	20.83	19.02	1.73	82.74

Table - B.7 Water availability at Vijayawada

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Export	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10	11=3+4+5+6+7+8+10
1985-86	671	172.15	50.82	1.22	-5.56	-0.14	14.42	0.00	5.47	1.03	61.78
1986-87	714	183.03	45.75	1.24	1.18	-1.51	15.76	0.00	4.99	1.11	63.52
1987-88	868	222.44	49.07	1.26	3.87	0.89	14.21	2.60	4.31	1.31	73.20
1988-89	926	237.50	49.92	1.28	2.45	-0.68	15.25	45.55	33.51	1.18	114.95
1989-90	950	243.66	50.69	1.30	2.20	0.50	14.68	25.85	21.30	1.35	96.57
1990-91	904	231.78	49.57	1.32	-2.05	0.52	14.49	25.52	29.04	1.30	90.68
1991-92	876	224.50	55.41	1.35	-2.45	-0.53	12.82	24.70	32.67	1.20	92.49
1992-93	767	196.70	55.05	1.38	-0.11	0.00	13.17	0.00	9.61	1.23	70.71
1993-94	886	227.15	49.62	1.40	1.80	-1.08	15.07	15.48	19.49	1.36	83.65
1994-95	851	218.08	53.56	1.43	-1.70	-1.12	15.23	17.60	39.13	1.14	86.14
1995-96	767	196.62	50.84	1.46	0.08	-0.18	12.77	0.00	6.33	1.28	66.24
1996-97	910	233.36	44.12	1.49	3.76	2.85	12.06	27.95	19.09	1.60	93.81
1997-98	831	212.96	63.23	1.52	-1.02	0.46	15.49	0.00	16.68	1.40	81.06
1998-99	1045	268.02	50.11	1.55	6.08	1.20	14.72	31.74	33.69	1.78	107.17
1999-00	806	206.64	48.88	1.58	-4.33	-2.43	14.82	21.14	10.36	1.33	81.00
2000-01	795	203.71	41.84	1.61	1.33	0.04	13.91	20.86	7.19	1.45	81.04
2001-02	738	189.20	51.70	1.64	-1.63	-0.83	12.38	2.76	3.20	1.43	67.45
2002-03	604	154.87	46.23	1.66	-5.82	-0.59	12.37	0.00	0.37	1.24	55.10
2003-04	696	178.41	44.34	1.69	1.59	-1.16	10.53	0.00	0.33	1.16	58.14
2004-05	806	206.70	47.30	1.72	-1.08	1.96	12.42	18.52	0.66	1.46	82.30
2005-06	1762	451.75	58.45	1.75	11.85	4.37	14.21	199.65	36.03	3.08	293.37
2006-07	893	228.92	72.39	1.79	-4.82	-1.94	17.16	19.42	26.74	2.53	106.52
2007-08	1040	266.57	65.85	1.83	6.83	2.70	13.69	31.03	26.26	3.12	125.04
2008-09	864	221.58	67.10	1.87	-2.55	-3.77	14.36	14.43	9.76	2.69	94.13
2009-10	982	251.86	64.63	1.91	2.49	2.26	16.62	15.96	14.51	3.22	107.10
2010-11	1036	265.67	62.18	1.96	2.74	2.82	11.45	30.42	13.82	3.57	115.12
2011-12	845	216.53	75.59	2.01	-7.59	-4.94	16.03	22.80	7.31	2.69	106.60
2012-13	866	222.11	65.00	2.07	-3.12	-0.82	10.65	14.60	1.71	3.03	91.41
2013-14	984	252.36	59.17	2.14	6.57	-1.07	14.42	23.67	11.26	3.58	108.48
2014-15	852	218.32	76.82	2.21	-2.55	-0.47	14.51	0.00	2.37	2.48	93.00
Avg	884	226.77	55.51	1.62	0.28	-0.09	13.99	21.74	14.91	1.88	94.93
Avg. excluding 2005-06	854	219.01	55.41	1.62	-0.12	-0.25	13.98	15.61	14.18	1.84	88.08

Table - B.8 Water resources availability in Krishna basin

Year	Rainfall	Q-Calibrated	ECII	DIL	GW Flux	Reservoir Flux	Export	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9	10=3+4+5+6+7+8+9
1985-86	165.90	0.00	52.55	1.24	-5.52	-0.14	12.69	1.14	61.95
1986-87	177.63	0.00	47.85	1.26	1.19	-1.51	13.66	1.14	63.60
1987-88	220.93	3.41	51.33	1.28	3.90	0.89	11.95	1.41	74.17
1988-89	239.94	46.79	51.77	1.31	2.51	-0.68	13.40	1.28	116.37
1989-90	245.56	26.63	52.05	1.33	2.51	0.50	13.32	1.49	97.82
1990-91	222.61	26.34	51.41	1.35	-2.29	0.52	12.65	1.39	91.37
1991-92	217.80	25.74	57.14	1.38	-2.54	-0.53	11.09	1.31	93.59
1992-93	198.56	0.00	56.91	1.40	-0.09	0.00	11.31	1.32	70.86
1993-94	219.77	16.02	51.99	1.43	1.80	-1.08	12.70	1.39	84.26
1994-95	210.43	19.04	55.16	1.46	-1.54	-1.12	13.63	1.25	87.88
1995-96	193.50	0.45	53.04	1.49	0.01	-0.18	10.57	1.38	66.75
1996-97	238.94	29.44	45.48	1.52	3.78	2.85	10.70	1.74	95.49
1997-98	204.34	0.00	65.41	1.54	-1.09	0.46	13.31	1.52	81.15
1998-99	265.75	32.33	51.86	1.58	6.12	1.20	12.97	1.90	107.96
1999-00	200.33	21.78	50.84	1.61	-4.34	-2.43	12.86	1.44	81.76
2000-01	208.44	21.82	43.95	1.64	1.37	0.04	11.81	1.57	82.19
2001-02	194.33	3.59	53.82	1.67	-1.72	-0.83	10.25	1.55	68.34
2002-03	154.59	0.00	49.20	1.69	-6.23	-0.59	9.41	1.31	54.79
2003-04	182.41	0.00	46.52	1.72	1.71	-1.16	8.35	1.27	58.41
2004-05	207.25	18.89	49.72	1.75	-1.12	1.96	10.00	1.55	82.76
2005-06	454.48	200.66	60.67	1.79	12.29	4.37	11.98	3.62	295.38
2006-07	227.14	20.95	74.92	1.82	-4.96	-1.94	14.62	2.96	108.37
2007-08	270.74	31.49	67.73	1.86	6.92	2.70	11.81	3.90	126.41
2008-09	223.62	15.15	69.37	1.90	-2.50	-3.77	12.09	3.30	95.54
2009-10	258.25	16.30	67.49	1.94	2.43	2.26	13.77	3.70	107.89
2010-11	272.10	32.66	63.75	1.99	2.81	2.82	9.87	4.05	117.95
2011-12	217.29	23.78	78.40	2.05	-7.84	-4.94	13.22	3.06	107.73
2012-13	227.96	16.11	67.01	2.11	-3.09	-0.82	8.64	3.55	93.50
2013-14	262.93	24.90	60.94	2.17	6.63	-1.07	12.66	4.00	110.23
2014-15	219.34	0.00	79.47	2.25	-2.67	-0.47	11.85	2.67	93.11
Avg	226.76	22.48	57.59	1.65	0.28	-0.09	11.90	2.11	95.92
Avg. excluding 2005-06	226.75	16.33	57.49	1.65	-0.13	-0.25	11.90	2.05	89.04

ANNEXURE - C

CAUVERY BASIN

Table - C.1 Water availability at Biligundulu

Year	Rainfall		ECII	DIL	GW flux	Reservoir flux	Q-Calibrated	Q-observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8	9	10=3+4+5+6+7+9
1985-86	798.34	29.91	7.14	0.22	-0.29	0.05	0.38	4.98	0.3	7.81
1986-87	977.86	36.64	5.09	0.22	0.15	-0.07	6.55	5.51	0.25	12.19
1987-88	1,020.25	38.23	3.8	0.22	0.54	-0.45	4.68	3.03	0.28	9.07
1988-89	853.09	31.96	6.13	0.23	-0.44	0.57	5.99	5.42	0.15	12.63
1989-90	884.31	33.13	5.24	0.23	-0.18	-0.01	4.98	5.29	0.29	10.55
1990-91	800.58	30	5.88	0.23	-0.36	0.57	2.19	4.47	0.16	8.68
1991-92	1,124.76	42.14	3.93	0.23	0.86	-0.56	12.3	9.62	0.26	17.02
1992-93	1,114.05	41.74	4.21	0.23	0.1	0.21	9.38	10.15	0.24	14.37
1993-94	994.52	37.26	3.76	0.24	0.17	-0.3	6.06	6.52	0.28	10.21
1994-95	1,038.73	38.92	4.68	0.24	-0.4	-0.07	10.17	11.16	0.24	14.86
1995-96	894.87	33.53	8.67	0.24	-0.47	0.41	2.91	5.52	0.18	11.95
1996-97	1,031.08	38.63	5.43	0.25	0.31	0.06	7.09	6.99	0.2	13.34
1997-98	1,173.35	43.96	5.02	0.25	1.02	0.21	10.32	7.85	0.27	17.08
1998-99	1,121.46	42.02	5.15	0.26	0.31	0.25	7.51	7.34	0.2	13.68
1999-00	1,045.80	39.18	4.55	0.26	-0.44	-0.27	10.38	7.73	0.18	14.66
2000-01	1,123.51	42.1	4.16	0.27	0.46	0.05	11.69	9.04	0.28	16.91
2001-02	838.6	31.42	7.56	0.27	-0.61	-0.07	4.4	5.43	0.13	11.68
2002-03	686.05	25.7	9.02	0.28	-0.78	0.01	0	3.11	0.1	8.64
2003-04	943.66	35.36	5.22	0.29	0.61	0.05	1.84	2.13	0.15	8.16
2004-05	1,038.10	38.9	4.4	0.3	0.38	-0.06	4.91	5.21	0.29	10.22
2005-06	1,286.57	48.21	3.22	0.31	1.33	0.48	13.46	10.87	0.24	19.03
2006-07	874.27	32.76	5.94	0.32	-1.93	-0.45	8.45	7.32	0.15	12.47
2007-08	1,213.77	45.48	4.3	0.33	1.17	0.57	9.81	9.99	0.23	16.41
2008-09	980.14	36.72	7.23	0.34	-0.09	-0.56	4.82	5.95	0.21	11.95
2009-10	1,048.51	39.29	11.85	0.35	0.07	0.14	2.33	6.3	0.16	14.89
2010-11	1,229.87	46.08	3.76	0.37	0.56	0.21	9.74	6	0.26	14.89
2011-12	1,114.03	41.74	11.02	0.38	-1.03	-0.3	6.76	6.79	0.29	17.12
2012-13	1,072.75	40.19	8.18	0.4	-1.93	-0.07	9.54	2.84	0.27	16.39
2013-14	1,060.37	39.73	7.37	0.42	0.74	0.41	5.07	7.35	0.2	14.22
2014-15	1,152.73	43.19	4.2	0.44	1.18	0.06	7.18	6.39	0.09	13.16
Average	1017.87	38.14	5.87	0.29	0.03	0.04	6.7	6.54	0.22	13.14

Table - C.2 Water availability at Musiri

Year	Rainfall		ECII	DIL	GW flux	Reservoir flux	Q-Calibrated	Q-observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8	9	10=3+4+5+6+7+9
1985-86	904.48	62.88	9.63	0.44	-0.67	-2.37	8.48	4.83	0.61	16.12
1986-87	928.51	64.55	7.58	0.44	-0.26	0.76	10.28	4.89	0.49	19.29
1987-88	1,052.85	73.20	5.90	0.45	2.51	-0.13	7.68	2.43	0.56	16.97
1988-89	868.47	60.38	10.76	0.45	-2.20	0.09	10.69	5.17	0.31	20.1
1989-90	963.42	66.98	7.41	0.46	0.23	-1.22	12.53	4.55	0.59	20
1990-91	735.07	51.11	10.95	0.46	-1.55	0.71	2.00	3.77	0.33	12.9
1991-92	1,034.33	71.91	6.31	0.47	1.59	0.09	16.38	7.75	0.52	25.36
1992-93	1,033.99	71.89	6.45	0.48	0.74	0.75	13.55	10.45	0.47	22.44
1993-94	1,014.73	70.55	5.82	0.49	1.44	-0.13	12.21	7.62	0.57	20.4
1994-95	1,005.63	69.92	6.77	0.50	-0.47	0.09	16.77	12.67	0.47	24.13
1995-96	850.30	59.12	13.55	0.51	-1.76	1.74	2.72	6.56	0.37	17.13
1996-97	946.18	65.78	9.38	0.52	1.45	-2.37	10.74	6.59	0.39	20.11
1997-98	1,038.82	72.22	7.76	0.53	1.46	0.76	14.11	9.75	0.53	25.15
1998-99	1,107.61	77.01	8.36	0.54	0.20	0.25	14.40	8.54	0.40	24.15
1999-00	1,015.07	70.57	9.03	0.55	-0.34	-0.27	16.58	7.52	0.35	25.9
2000-01	1,050.75	73.05	6.25	0.57	-0.04	-0.18	16.77	9.72	0.55	23.92
2001-02	626.01	43.52	14.31	0.58	-2.12	-1.58	2.05	5.90	0.26	13.5
2002-03	509.48	35.42	16.25	0.60	-2.25	-0.13	0.00	2.06	0.19	14.66
2003-04	710.83	49.42	11.96	0.62	0.37	0.09	0.00	1.59	0.29	13.33
2004-05	977.01	67.93	6.65	0.64	2.25	0.75	4.94	4.86	0.59	15.82
2005-06	1,202.72	83.62	7.75	0.66	4.04	2.39	15.19	12.56	0.47	30.5
2006-07	812.28	56.47	10.34	0.68	-3.75	-2.06	12.93	9.01	0.29	18.43
2007-08	1,128.77	78.48	7.39	0.70	2.61	1.74	11.74	12.21	0.45	24.63
2008-09	913.53	63.51	13.21	0.73	-1.29	-2.37	7.43	9.37	0.42	18.13
2009-10	933.05	64.87	18.85	0.76	-1.11	0.76	1.32	6.95	0.31	20.89
2010-11	1,209.20	84.07	7.65	0.79	3.19	1.58	12.47	5.75	0.51	26.19
2011-12	1,057.60	73.53	17.06	0.82	-2.10	-1.73	15.31	8.30	0.58	29.94
2012-13	1,019.57	70.89	15.16	0.86	-4.12	-1.22	15.56	2.91	0.55	26.79
2013-14	888.02	61.74	13.64	0.90	0.80	0.71	1.44	5.88	0.41	17.9
2014-15	1,085.05	75.44	7.05	0.94	4.13	0.82	7.00	4.88	0.17	20.11
Average	954.11	66.33	9.97	0.60	0.10	-0.06	9.78	6.84	0.43	20.82

Table - C.3 Water resources availability in Cauvery basin

Year	Rainfall	Q-Calibrated	ECII	GW flux	DIL	Reservoir flux	Reservoir Evaporation	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9=3+4+5+6+7+8
1985-86	78.65	11.32	12.28	-0.58	0.56	-2.37	0.91	22.12
1986-87	76.59	10.89	10.31	-0.86	0.57	0.76	0.74	22.40
1987-88	87.62	8.78	8.78	2.93	0.58	-0.13	0.84	21.77
1988-89	70.94	8.22	16.95	-3.31	0.58	0.09	0.46	23.00
1989-90	81.03	13.14	10.30	0.31	0.59	-1.22	0.88	23.99
1990-91	61.37	0.00	17.04	-1.65	0.60	0.71	0.49	17.19
1991-92	86.16	19.15	9.07	1.07	0.61	0.09	0.78	30.78
1992-93	86.00	15.15	9.08	1.21	0.62	0.75	0.71	27.52
1993-94	91.79	19.14	8.27	2.20	0.64	-0.13	0.85	30.95
1994-95	82.35	17.89	9.77	-0.70	0.65	0.09	0.71	28.40
1995-96	69.90	0.00	22.35	-2.76	0.66	1.74	0.55	22.53
1996-97	83.12	14.04	13.29	1.98	0.68	-2.37	0.59	28.22
1997-98	88.44	18.92	11.00	1.41	0.69	0.76	0.80	33.59
1998-99	95.30	16.99	12.12	0.58	0.71	0.25	0.60	31.25
1999-00	87.41	17.80	14.70	-0.60	0.72	-0.27	0.53	32.89
2000-01	88.79	18.22	8.83	-0.09	0.74	-0.18	0.83	28.36
2001-02	50.07	0.00	25.26	-2.08	0.76	-1.58	0.39	22.74
2002-03	38.93	0.00	29.15	-3.53	0.78	-0.13	0.29	26.56
2003-04	55.68	0.00	23.67	1.20	0.80	0.09	0.44	26.20
2004-05	84.44	8.90	9.16	1.81	0.83	0.75	0.88	22.32
2005-06	106.07	20.16	13.32	4.87	0.85	2.39	0.71	42.31
2006-07	69.55	11.82	16.46	-4.52	0.88	-2.06	0.44	23.03
2007-08	97.32	14.65	10.74	3.20	0.91	1.74	0.68	31.91
2008-09	80.94	9.64	19.67	-1.49	0.94	-2.37	0.63	27.04
2009-10	79.14	3.69	24.03	-1.38	0.97	0.76	0.47	28.54
2010-11	107.81	15.78	12.44	3.36	1.01	1.58	0.77	34.93
2011-12	99.86	18.10	21.27	-2.04	1.05	-1.73	0.87	37.52
2012-13	89.03	12.71	22.30	-5.22	1.09	-1.22	0.82	30.48
2013-14	74.79	0.00	23.79	1.04	1.13	0.71	0.61	27.28
2014-15	89.94	7.26	10.23	4.51	1.18	0.82	0.26	24.26
Average	81.30	11.08	15.19	0.03	0.78	-0.06	0.65	27.67

SUBERNAREKHA BASIN

Table - D.1 Water availability at Muri

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1990-91	1372.05	1.84	0.04	0.01	-0.01	0.64	1.17	0.68
1991-92	1363.05	1.83	0.03	0.01	-0.03	0.71	1.00	0.73
1992-93	1071.53	1.44	0.05	0.01	0.01	0.39	0.50	0.45
1993-94	1275.89	1.71	0.05	0.01	0.00	0.68	0.82	0.74
1994-95	1726.65	2.32	0.04	0.01	0.00	1.15	1.15	1.20
1995-96	1438.55	1.93	0.01	0.01	0.01	1.06	0.91	1.09
1996-97	1313.16	1.76	0.04	0.01	-0.01	0.82	0.81	0.86
1997-98	1520.13	2.04	0.01	0.01	0.02	0.73	0.98	0.77
1998-99	1229.89	1.65	0.02	0.01	-0.04	0.65	0.74	0.64
1999-00	1405.33	1.89	0.02	0.01	0.03	0.63	0.94	0.69
2000-01	976.56	1.31	0.09	0.01	-0.03	0.39	0.39	0.46
2001-02	1274.31	1.71	0.05	0.01	0.00	0.39	0.39	0.45
2002-03	1103.76	1.48	0.02	0.01	0.00	0.46	0.45	0.49
2003-04	1272.10	1.71	0.01	0.01	0.02	0.52	0.52	0.57
2004-05	957.18	1.29	0.04	0.01	-0.02	0.51	0.50	0.54
2005-06	836.84	1.12	0.11	0.01	0.03	0.25	0.23	0.40
2006-07	1212.08	1.63	0.06	0.01	-0.01	0.73	0.73	0.79
2007-08	1265.41	1.70	0.07	0.01	-0.01	0.68	0.71	0.75
2008-09	1731.02	2.33	0.09	0.00	0.02	0.75	0.74	0.86
2009-10	1025.91	1.38	0.08	0.00	-0.03	0.31	0.29	0.35
2010-11	790.64	1.06	0.12	0.01	-0.01	0.08	0.07	0.19
2011-12	1051.59	1.41	0.10	0.02	0.02	0.56	0.69	0.70
2012-13	1099.67	1.48	0.06	0.02	0.02	0.40	0.38	0.50
2013-14	1204.79	1.62	0.10	0.02	0.01	0.39	0.39	0.51
2014-15	933.92	1.25	0.23	0.02	-0.01	0.29	0.28	0.53
Average	1218.08	1.64	0.06	0.01	0.00	0.57	0.63	0.64

Table - D.2 Water availability at Adityapur

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1985-86	1502.11	9.37	0.03	0.02	0.10	4.05	3.99	4.20
1986-87	1197.76	7.47	0.14	0.02	-0.08	2.05	1.94	2.13
1987-88	1193.71	7.44	0.28	0.02	-0.02	2.39	2.11	2.66
1988-89	1227.60	7.65	0.34	0.02	-0.14	2.12	2.12	2.34
1989-90	1451.67	9.05	0.32	0.02	0.16	2.99	2.74	3.48
1990-91	1333.62	8.32	0.04	0.02	0.03	3.99	4.80	4.08
1991-92	1201.31	7.49	0.28	0.02	-0.17	2.17	2.11	2.29
1992-93	1152.05	7.18	0.25	0.02	0.23	1.37	1.35	1.87
1993-94	1307.65	8.15	0.28	0.02	-0.14	2.83	2.75	2.99
1994-95	1668.49	10.40	0.24	0.02	0.01	5.58	6.25	5.85
1995-96	1432.76	8.93	0.07	0.02	0.01	3.73	3.72	3.82
1996-97	1161.83	7.24	0.35	0.02	0.09	3.04	2.97	3.49
1997-98	1698.08	10.59	0.09	0.02	0.10	4.88	4.86	5.10
1998-99	1073.23	6.69	0.17	0.02	-0.13	1.62	1.59	1.68
1999-00	1497.01	9.33	0.09	0.02	0.08	4.46	4.39	4.65
2000-01	1125.54	7.02	0.43	0.02	0.06	1.51	1.45	2.03
2001-02	1354.74	8.45	0.31	0.02	-0.26	3.82	3.81	3.90
2002-03	1117.53	6.97	0.32	0.02	-0.02	1.92	1.88	2.24
2003-04	1191.58	7.43	0.12	0.02	0.04	1.60	1.60	1.78
2004-05	1256.74	7.84	0.20	0.02	0.03	2.07	2.06	2.33
2005-06	1184.59	7.39	0.10	0.02	-0.05	1.26	1.20	1.34
2006-07	1742.57	10.87	0.26	0.02	0.01	3.92	3.80	4.21
2007-08	1652.83	10.31	0.26	0.03	0.02	4.72	4.57	5.02
2008-09	1493.96	9.31	0.63	0.03	-0.05	3.27	3.47	3.88
2009-10	1337.59	8.34	0.27	0.03	-0.15	2.87	2.23	3.03
2010-11	841.80	5.25	0.35	0.02	0.07	0.19	0.23	0.64
2011-12	1709.11	10.66	0.33	0.02	-0.02	3.27	3.21	3.60
2012-13	1449.88	9.04	0.12	0.02	0.01	2.34	2.15	2.50
2013-14	1536.86	9.58	0.35	0.02	0.17	5.07	4.91	5.61
2014-15	1469.49	9.16	1.49	0.02	-0.06	2.58	2.93	4.02
Average	1352.12	8.43	0.28	0.02	0.00	2.92	2.91	3.23

Table - D.3 Water availability at Jamshedpur

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1985-86	1420.82	17.99	0.10	0.04	0.11	7.93	7.97	8.19
1986-87	1253.89	15.87	0.20	0.05	-0.07	6.24	5.51	6.42
1987-88	1233.68	15.62	0.45	0.05	-0.02	6.45	5.44	6.93
1988-89	1143.23	14.47	0.57	0.05	-0.27	5.25	6.33	5.60
1989-90	1424.85	18.04	0.50	0.05	0.30	6.15	6.33	7.00
1990-91	1364.01	17.27	0.17	0.05	0.02	8.96	10.08	9.21
1991-92	1243.95	15.75	0.43	0.05	-0.31	5.88	5.82	6.05
1992-93	1146.19	14.51	0.46	0.05	0.35	3.82	3.12	4.67
1993-94	1311.57	16.60	0.54	0.05	-0.18	6.08	5.34	6.50
1994-95	1697.50	21.49	0.43	0.05	0.02	12.19	14.52	12.70
1995-96	1477.05	18.70	0.13	0.06	0.05	8.79	11.58	9.02
1996-97	1224.77	15.50	0.59	0.06	0.05	7.07	11.49	7.77
1997-98	1625.12	20.57	0.16	0.06	0.21	9.10	12.97	9.53
1998-99	1143.75	14.48	0.28	0.06	-0.30	4.98	4.55	5.02
1999-00	1523.67	19.29	0.20	0.06	0.20	7.81	10.58	8.27
2000-01	1160.40	14.69	0.96	0.06	-0.03	3.80	3.34	4.80
2001-02	1327.74	16.81	0.54	0.06	-0.31	7.40	7.84	7.69
2002-03	1172.66	14.85	0.47	0.06	-0.04	4.98	4.58	5.48
2003-04	1233.31	15.61	0.18	0.07	0.15	5.02	3.84	5.40
2004-05	1170.48	14.82	0.36	0.07	-0.06	4.88	4.62	5.24
2005-06	1093.97	13.85	0.52	0.07	0.04	2.37	2.46	3.00
2006-07	1524.71	19.30	0.55	0.07	-0.01	8.15	8.38	8.76
2007-08	1524.99	19.31	0.62	0.07	0.03	8.96	8.72	9.69
2008-09	1514.05	19.17	1.10	0.07	-0.01	8.25	9.19	9.41
2009-10	1265.57	16.02	0.66	0.07	-0.25	5.76	5.32	6.24
2010-11	857.08	10.85	0.82	0.07	0.04	0.93	0.79	1.85
2011-12	1517.92	19.22	0.85	0.07	0.06	7.17	9.26	8.15
2012-13	1332.99	16.87	0.44	0.07	0.12	4.53	4.63	5.17
2013-14	1506.62	19.07	0.70	0.08	0.23	8.19	9.18	9.20
2014-15	1336.83	16.92	3.34	0.08	-0.13	7.37	7.13	10.65
Average	1325.78	16.78	0.58	0.06	0.00	6.48	7.03	7.12

Table - D.4 Water availability at Ghatsila

Year	Rainfall		Irrigation Support (ECII)	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1985-86	1411.31	19.97	0.12	0.06	0.11	9.04	7.70	9.33
1986-87	1261.49	17.85	0.21	0.06	-0.07	6.45	4.27	6.66
1987-88	1236.44	17.49	0.48	0.06	-0.02	7.49	5.21	8.01
1988-89	1137.45	16.09	0.61	0.06	-0.34	6.12	6.19	6.45
1989-90	1386.63	19.62	0.53	0.06	0.33	7.18	6.78	8.10
1990-91	1365.70	19.32	0.18	0.06	0.05	8.23	9.34	8.52
1991-92	1239.65	17.54	0.45	0.06	-0.35	6.64	5.01	6.80
1992-93	1145.77	16.21	0.49	0.07	0.53	4.10	3.15	5.19
1993-94	1290.54	18.26	0.56	0.07	-0.31	6.98	5.57	7.30
1994-95	1697.62	24.02	0.47	0.07	0.02	13.20	13.15	13.76
1995-96	1514.05	21.42	0.13	0.07	-0.02	9.00	8.26	9.19
1996-97	1251.09	17.70	0.63	0.07	0.06	7.87	7.11	8.63
1997-98	1639.10	23.19	0.17	0.07	0.14	10.61	11.34	11.00
1998-99	1140.93	16.14	0.31	0.08	-0.25	5.34	5.15	5.47
1999-00	1452.83	20.55	0.21	0.08	0.20	9.01	9.87	9.50
2000-01	1047.77	14.82	1.04	0.08	0.02	4.19	3.49	5.33
2001-02	1328.51	18.80	0.58	0.08	-0.38	8.10	7.94	8.38
2002-03	1151.45	16.29	0.51	0.08	-0.06	5.09	4.71	5.63
2003-04	1203.09	17.02	0.19	0.08	0.15	5.11	4.18	5.54
2004-05	1106.86	15.66	0.39	0.08	-0.09	5.06	4.98	5.45
2005-06	1033.01	14.61	0.53	0.09	0.02	3.09	3.05	3.73
2006-07	1517.28	21.47	0.59	0.09	-0.01	9.62	10.67	10.29
2007-08	1496.15	21.17	0.68	0.09	0.09	10.46	11.95	11.31
2008-09	1553.02	21.97	1.29	0.09	-0.07	9.27	10.11	10.57
2009-10	1220.68	17.27	0.72	0.09	-0.22	6.64	7.54	7.23
2010-11	789.51	11.17	0.91	0.09	0.03	0.92	1.86	1.95
2011-12	1494.22	21.14	0.94	0.09	0.05	8.59	13.88	9.68
2012-13	1317.85	18.64	0.48	0.09	0.08	5.27	6.68	5.93
2013-14	1487.53	21.04	0.75	0.10	0.32	9.14	9.01	10.31
2014-15	1345.05	19.03	3.66	0.10	-0.15	7.19	7.09	10.79
Average	1308.75	18.52	0.63	0.08	0.00	7.17	7.17	7.87

Table - D.5 Water availability at Govindpur

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1992-93	1431.83	6.33	0.32	0.01	0.10	2.25	1.89	2.69
1993-94	1481.06	6.54	0.28	0.01	0.11	2.58	2.33	2.99
1994-95	1924.34	8.50	0.31	0.02	-0.16	3.95	3.88	4.11
1995-96	1501.15	6.63	0.15	0.02	0.03	2.85	3.55	3.05
1996-97	1383.42	6.11	0.40	0.02	0.18	2.04	1.96	2.64
1997-98	1985.96	8.77	0.12	0.02	0.15	3.39	3.15	3.68
1998-99	1372.65	6.06	0.29	0.02	-0.18	1.92	2.18	2.05
1999-00	1946.78	8.60	0.10	0.02	0.03	4.25	4.93	4.40
2000-01	1291.31	5.71	0.43	0.01	-0.01	1.86	3.26	2.30
2001-02	1690.34	7.47	0.27	0.01	-0.09	3.00	4.21	3.19
2002-03	1267.37	5.60	0.38	0.02	0.02	1.62	2.26	2.04
2003-04	1474.77	6.52	0.28	0.02	-0.03	2.22	3.17	2.49
2004-05	1515.47	6.70	0.23	0.02	0.15	2.16	3.13	2.56
2005-06	1605.28	7.09	0.11	0.02	-0.05	3.32	3.07	3.40
2006-07	1897.57	8.38	0.35	0.02	-0.09	4.23	3.66	4.50
2007-08	2065.21	9.13	0.32	0.02	0.07	4.98	5.10	5.39
2008-09	1774.77	7.84	0.51	0.02	0.00	3.36	4.69	3.89
2009-10	1403.60	6.20	0.29	0.02	-0.04	2.55	3.19	2.83
2010-11	1277.25	5.64	0.50	0.02	0.09	1.38	1.85	1.99
2011-12	1643.72	7.26	0.42	0.02	-0.15	3.62	4.36	3.91
2012-13	1370.35	6.05	0.28	0.02	-0.08	1.81	2.05	2.03
2013-14	2180.86	9.64	1.14	0.02	0.34	5.30	6.74	6.80
2014-15	2086.02	9.22	1.18	0.02	-0.09	4.21	4.59	5.31
Average	1633.53	7.22	0.38	0.02	0.01	2.99	3.44	3.40

Table - D.6 Water resources availability in Subernarekha basin

Year	Rainfall	Q-Calibrated	ECII	DIL	GW Flux	Reservoir Flux	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9= 3+4+5+6+7+8
1985-86	44.46	14.58	1.20	0.12	1.14	0.00	0.53	17.56
1986-87	39.62	9.94	1.21	0.12	-0.57	0.00	0.52	11.22
1987-88	35.39	9.79	1.45	0.12	-0.24	0.00	0.52	11.63
1988-89	37.06	10.00	2.25	0.13	-1.27	0.00	0.57	11.68
1989-90	44.48	9.92	1.23	0.13	1.96	0.00	0.59	13.82
1990-91	43.69	13.36	0.61	0.13	-0.34	0.00	0.56	14.32
1991-92	33.56	10.85	1.65	0.14	-1.29	0.00	0.55	11.90
1992-93	35.62	9.11	1.69	0.14	1.20	0.00	0.59	12.72
1993-94	42.13	13.74	1.61	0.14	-0.08	0.00	0.51	15.93
1994-95	48.88	21.71	1.86	0.14	-0.80	0.00	0.53	23.43
1995-96	40.95	15.30	0.93	0.15	0.10	0.00	0.49	16.96
1996-97	37.27	11.64	1.97	0.15	0.74	0.00	0.59	15.10
1997-98	48.93	17.29	0.75	0.15	0.49	0.00	0.59	19.27
1998-99	33.51	9.47	1.77	0.16	-1.43	0.00	0.59	10.56
1999-00	44.55	15.97	1.16	0.16	0.86	0.00	0.54	18.68
2000-01	32.28	7.14	3.11	0.17	-0.25	0.00	0.51	10.68
2001-02	40.22	13.25	2.23	0.17	-0.50	0.00	0.58	15.73
2002-03	34.43	7.71	1.88	0.17	-0.07	0.00	0.53	10.22
2003-04	36.73	9.71	1.41	0.17	-0.10	0.00	0.58	11.77
2004-05	36.66	9.22	1.61	0.17	0.48	0.00	0.57	12.06
2005-06	37.61	10.67	1.38	0.18	-0.15	0.00	0.47	12.55
2006-07	48.17	19.28	2.22	0.18	-0.24	0.04	0.49	21.97
2007-08	50.26	20.32	2.12	0.17	0.33	-0.02	0.54	23.46
2008-09	46.39	16.91	3.52	0.17	0.01	-0.02	0.40	21.00
2009-10	34.65	10.46	2.39	0.17	-0.84	0.00	0.47	12.66
2010-11	26.61	1.42	3.13	0.18	0.19	0.10	0.46	5.49
2011-12	44.77	14.64	3.02	0.19	-0.74	-0.05	0.47	17.52
2012-13	37.24	8.17	1.90	0.19	-0.34	0.15	0.53	10.60
2013-14	48.94	16.02	3.67	0.19	1.45	-0.01	0.56	21.88
2014-15	36.45	10.35	8.34	0.19	-0.41	0.03	0.66	19.16
Average	40.05	12.26	2.11	0.16	-0.02	0.01	0.54	15.05

BRAHMANI-BAITARANI BASIN

Table - E.1 Water availability at Tilga

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+ 4+5+6
1985-1986	1080.521	3.306	0.134	0.004	0.012	1.052	1.523	1.201
1986-1987	1353.763	4.143	0.005	0.004	0.013	1.818	1.592	1.839
1987-1988	1410.774	4.317	0.165	0.004	0.007	2.104	1.808	2.280
1988-1989	1104.128	3.379	0.238	0.004	-0.055	1.448	1.998	1.635
1989-1990	1157.277	3.541	0.028	0.004	0.043	1.127	1.240	1.203
1990-1991	1393.185	4.263	0.010	0.004	-0.013	2.073	1.867	2.074
1991-1992	1239.356	3.792	0.021	0.004	0.005	1.699	2.150	1.729
1992-1993	847.595	2.594	0.359	0.004	-0.02	0.385	0.988	0.729
1993-1994	1184.454	3.624	0.034	0.005	0.005	1.518	1.881	1.562
1994-1995	1754.126	5.368	0.154	0.005	0.003	2.695	3.428	2.857
1995-1996	1270.088	3.886	0.002	0.005	-0.008	1.716	1.831	1.714
1996-1997	1276.364	3.906	0.222	0.005	-0.024	1.785	2.638	1.988
1997-1998	1833.42	5.610	0.600	0.005	0.08	2.243	2.789	2.928
1998-1999	1408.633	4.310	0.084	0.005	-0.052	1.944	2.455	1.982
1999-2000	1478.596	4.525	0.096	0.005	-0.038	2.408	2.776	2.472
2000-2001	1005.249	3.076	0.140	0.005	-0.043	1.036	1.195	1.139
2001-2002	1232.33	3.771	0.092	0.005	0.011	1.683	2.590	1.792
2002-2003	992.949	3.038	0.315	0.005	0.018	0.431	1.556	0.769
2003-2004	1264.831	3.870	0.183	0.005	0.026	1.107	2.236	1.322
2004-2005	1143.146	3.498	0.159	0.006	-0.025	1.272	1.684	1.411
2005-2006	1287.598	3.940	0.011	0.006	-0.011	1.490	1.768	1.496
2006-2007	1219.909	3.733	0.092	0.006	0.022	1.213	1.588	1.333
2007-2008	1224.104	3.746	0.119	0.006	-0.006	1.362	1.864	1.481
2008-2009	1323.308	4.049	0.145	0.006	-0.007	1.731	1.987	1.875
2009-2010	1146.397	3.508	0.401	0.006	0.004	0.890	1.624	1.301
2010-2011	1163.514	3.560	0.163	0.013	-0.006	0.765	0.899	0.934
2011-2012	1617.157	4.949	0.227	0.022	0.02	2.385	2.633	2.654
2012-2013	1415.436	4.331	0.191	0.022	0.021	1.275	1.913	1.509
2013-2014	1635.201	5.004	0.125	0.022	0	1.783	2.273	1.930
2014-2015	1352.665	4.139	0.115	0.023	-0.008	1.075	1.751	1.205
Avg	1293.87	3.959	0.154	0.007	-0.001	1.517	1.951	1.678

Table - E.2 Water availability at Jarikela

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8 = 3+4+5+6
1985-1986	1378.64	14.063	0.080	0.022	0.009	5.729	4.169	5.841
1986-1987	1314.60	13.410	0.047	0.023	-0.001	5.422	4.321	5.491
1987-1988	1295.45	13.215	0.537	0.023	-0.051	6.374	4.915	6.883
1988-1989	1141.70	11.646	0.644	0.024	-0.139	4.798	4.907	5.327
1989-1990	1267.32	12.928	0.195	0.024	0.171	5.025	3.612	5.415
1990-1991	1254.48	12.797	0.179	0.024	-0.004	5.583	5.748	5.783
1991-1992	1239.23	12.641	0.147	0.025	-0.144	5.176	4.515	5.204
1992-1993	954.76	9.740	0.632	0.025	0.146	2.823	1.903	3.626
1993-1994	1209.82	12.341	0.265	0.026	-0.136	4.470	3.777	4.625
1994-1995	1781.79	18.176	0.663	0.026	0.056	8.427	7.992	9.172
1995-1996	1264.90	12.903	0.050	0.027	0.017	5.276	4.749	5.369
1996-1997	1155.24	11.785	0.694	0.027	-0.072	5.722	6.867	6.371
1997-1998	1612.49	16.449	0.061	0.028	0.268	8.447	7.692	8.803
1998-1999	1167.86	11.913	0.175	0.028	-0.275	5.234	4.279	5.162
1999-2000	1431.59	14.604	0.119	0.029	0.080	7.559	6.228	7.788
2000-2001	1223.52	12.481	0.334	0.029	-0.118	6.918	3.729	7.163
2001-2002	1292.69	13.187	0.356	0.030	-0.164	5.477	5.397	5.698
2002-2003	1077.03	10.987	0.445	0.030	0.018	3.676	3.075	4.169
2003-2004	1297.69	13.238	0.665	0.031	0.165	6.229	4.239	7.090
2004-2005	1139.43	11.623	0.449	0.031	-0.161	5.795	3.540	6.114
2005-2006	1141.11	11.640	0.199	0.032	0.040	3.766	2.585	4.037
2006-2007	1363.03	13.904	0.308	0.032	0.077	7.427	4.347	7.844
2007-2008	1385.98	14.138	0.331	0.033	0.053	6.595	5.801	7.013
2008-2009	1427.92	14.566	0.649	0.034	-0.047	5.312	4.851	5.947
2009-2010	114.24	1.165	0.702	0.034	-0.160	3.823	2.215	4.398
2010-2011	4564.00	46.557	0.403	0.036	-0.032	2.538	1.083	2.945
2011-2012	1574.65	16.063	0.831	0.038	0.108	8.626	5.314	9.603
2012-2013	1391.40	14.194	0.441	0.039	0.043	5.080	2.810	5.604
2013-2014	1496.81	15.269	0.294	0.039	0.082	6.939	2.704	7.354
2014-2015	1148.53	11.716	0.744	0.040	-0.035	2.617	1.445	3.365
Avg	1370.263	13.978	0.388	0.030	-0.007	5.563	4.294	5.973

Table - E.3 Water availability at Panposh

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9 = 3+4+5+6+7
1985-1986	1334.06	24.80	0.78	0.04	0.08	-	10.45	-	11.35
1986-1987	1322.84	24.59	0.58	0.04	-0.08	-	11.03	-	11.57
1987-1988	1339.21	24.90	1.80	0.04	0.00	-	12.62	-	14.46
1988-1989	1159.57	21.56	2.03	0.04	-0.31	-	10.16	-	11.92
1989-1990	1248.21	23.20	0.93	0.05	0.26	-	8.70	-	9.94
1990-1991	1295.86	24.09	0.73	0.04	0.01	-	12.07	-	12.85
1991-1992	1258.43	23.39	0.78	0.04	-0.16	0.02	10.60	-	11.28
1992-1993	963.76	17.92	1.70	0.04	0.07	-0.12	5.68	-	7.37
1993-1994	1258.59	23.40	0.92	0.04	-0.10	0.00	9.41	-	10.27
1994-1995	1845.87	34.31	1.50	0.04	0.13	0.07	18.07	-	19.81
1995-1996	1283.19	23.85	0.59	0.04	-0.06	-0.05	10.86	-	11.38
1996-1997	1208.25	22.46	2.14	0.04	-0.13	0.00	10.47	-	12.52
1997-1998	1636.25	30.42	1.22	0.04	0.60	0.07	15.23	14.25	17.16
1998-1999	1203.03	22.36	0.83	0.04	-0.51	-0.07	10.47	11.26	10.76
1999-2000	1436.35	26.70	0.82	0.05	0.01	0.54	13.59	13.12	15.01
2000-2001	1131.57	21.04	1.33	0.05	-0.29	0.02	10.46	6.70	11.57
2001-2002	1298.95	24.15	1.18	0.05	-0.12	0.00	11.07	13.62	12.18
2002-2003	1054.09	19.59	1.43	0.05	0.05	-0.05	6.44	7.80	7.92
2003-2004	1289.23	23.97	1.69	0.05	0.29	-0.01	9.61	9.52	11.63
2004-2005	1139.09	21.18	1.65	0.05	-0.23	-0.03	9.05	7.60	10.49
2005-2006	1164.25	21.64	0.80	0.05	0.04	0.05	7.52	7.08	8.46
2006-2007	1305.79	24.27	1.13	0.05	0.12	0.00	11.16	9.86	12.46
2007-2008	1362.77	25.33	1.08	0.05	0.15	-0.03	12.17	13.58	13.42
2008-2009	1431.05	26.60	1.58	0.05	-0.01	-0.03	10.58	12.11	12.17
2009-2010	1124.23	20.90	2.30	0.05	-0.32	0.00	6.36	6.61	8.39
2010-2011	996.20	18.52	1.21	0.06	-0.03	0.05	4.72	3.20	6.01
2011-2012	1564.13	29.08	1.83	0.07	0.22	0.00	15.98	18.19	18.10
2012-2013	1398.94	26.01	1.35	0.07	0.04	-0.01	10.08	10.15	11.53
2013-2014	1466.00	27.25	1.09	0.08	0.10	0.00	13.19	11.71	14.46
2014-2015	1190.61	22.13	1.54	0.08	-0.07	-0.05	6.54	8.52	8.04
Avg	1290.34	23.99	1.28	0.05	-0.01	0.01	10.48	6.16	11.81

Table - E.4 Water Availability at Gomlai

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8 = 3+ 4+5+6
1985-1986	1334.06	27.77	1.40	0.05	0.14	12.06	10.20	13.65
1986-1987	1322.84	27.54	1.44	0.05	-0.18	11.99	10.11	13.3
1987-1988	1339.21	27.88	1.60	0.05	0.03	13.08	10.75	14.76
1988-1989	1159.57	24.14	1.56	0.06	-0.37	10.99	11.58	12.24
1989-1990	1248.21	25.99	1.50	0.06	0.25	9.60	8.88	11.41
1990-1991	1295.86	26.98	1.44	0.05	0.06	13.20	12.90	14.75
1991-1992	1258.43	26.20	1.45	0.04	-0.19	11.96	12.05	13.26
1992-1993	963.76	20.06	1.46	0.04	0.04	6.16	5.06	7.7
1993-1994	1258.59	26.20	1.46	0.05	-0.08	10.48	9.09	11.91
1994-1995	1845.87	38.43	1.46	0.05	0.19	20.14	22.97	21.84
1995-1996	1283.19	26.72	1.45	0.05	-0.12	11.76	10.17	13.14
1996-1997	1208.25	25.16	1.60	0.05	-0.14	11.08	13.29	12.59
1997-1998	1636.25	34.07	1.40	0.05	0.77	16.34	14.50	18.56
1998-1999	1203.03	25.05	1.40	0.05	-0.64	11.45	10.16	12.26
1999-2000	1436.35	29.90	1.41	0.05	0.02	15.70	14.74	17.18
2000-2001	1131.57	23.56	1.49	0.05	-0.37	11.79	7.23	12.96
2001-2002	1298.95	27.04	1.50	0.05	-0.10	13.32	16.01	14.77
2002-2003	1054.09	21.95	1.45	0.05	0.02	7.12	7.74	8.64
2003-2004	1289.23	26.84	1.51	0.05	0.35	10.41	10.31	12.32
2004-2005	1139.09	23.72	1.56	0.06	-0.25	9.87	8.17	11.24
2005-2006	1164.25	24.24	1.44	0.06	0.05	8.11	6.82	9.66
2006-2007	1305.79	27.19	1.48	0.06	0.07	12.28	10.78	13.89
2007-2008	1362.77	28.37	1.42	0.06	0.26	14.04	16.11	15.78
2008-2009	1431.05	29.79	1.45	0.06	0.03	11.59	13.35	13.13
2009-2010	1124.23	23.41	1.50	0.06	-0.49	7.23	6.31	8.3
2010-2011	996.20	20.74	1.44	0.07	-0.04	5.09	3.05	6.56
2011-2012	1564.13	32.56	1.47	0.08	0.91	17.29	15.88	19.75
2012-2013	1398.94	29.13	1.43	0.08	-0.02	11.28	8.27	12.77
2013-2014	1504.06	31.31	1.42	0.08	0.12	13.44	13.36	15.06
2014-2015	1191.29	24.80	1.52	0.07	-0.09	7.22	10.65	8.72
Avg	1291.64	26.89	1.48	0.06	0.01	11.54	11.02	13.08

Table - E.5 Water availability at Jenapur

Year	Rainfall mm	BCM	ECII BCM	DIL BCM	GW BCM	Reservoir BCM	Q- BCM	Q- BCM	Water BCM
1	2(a)	2(b)	3	4	5	6	7	8	9=3+4+ 5+6+7
1985-1986	1561.12	53.97	0.42	0.09	1.18	NA	22.80	19.06	24.49
1986-1987	1405.97	48.61	0.76	0.09	-0.63	-0.50	20.16	17.31	19.88
1987-1988	1312.79	45.39	2.71	0.09	0.01	0.48	16.85	15.26	20.14
1988-1989	1219.16	42.15	3.06	0.09	-0.62	-0.04	16.92	16.82	19.41
1989-1990	1432.76	49.54	1.73	0.10	0.74	-0.25	16.58	15.12	18.9
1990-1991	1454.99	50.31	0.74	0.09	0.20	0.07	21.64	19.80	22.74
1991-1992	1387.59	47.98	1.02	0.08	-0.81	0.11	22.29	21.67	22.69
1992-1993	1122.41	38.81	2.15	0.08	0.12	-0.04	11.98	11.14	14.29
1993-1994	1367.41	47.28	1.65	0.08	0.13	0.04	17.33	16.38	19.23
1994-1995	1929.85	66.72	1.99	0.09	0.44	-0.25	34.12	30.99	36.39
1995-1996	1336.85	46.22	0.69	0.09	-1.04	-0.11	17.99	15.71	17.62
1996-1997	1244.38	43.02	3.37	0.09	0.44	-0.19	15.27	16.69	18.98
1997-1998	1691.63	58.49	1.19	0.09	1.26	-0.13	24.98	20.61	27.39
1998-1999	1243.71	43.00	0.72	0.09	-1.33	0.33	16.40	15.23	16.21
1999-2000	1564.31	54.08	0.53	0.10	0.43	0.58	25.86	22.76	27.5
2000-2001	1133.84	39.20	0.93	0.10	-1.33	0.05	16.96	10.35	16.71
2001-2002	1526.83	52.79	0.91	0.10	0.31	-0.11	36.03	28.46	37.24
2002-2003	1071.88	37.06	2.47	0.10	-0.14	-0.40	9.85	10.79	11.88
2003-2004	1448.83	50.09	2.35	0.10	0.15	0.11	19.68	21.41	22.39
2004-2005	1182.15	40.87	2.60	0.10	0.06	0.13	13.15	12.54	16.04
2005-2006	1351.34	46.72	1.05	0.10	0.09	-0.03	14.70	16.55	15.91
2006-2007	1431.67	49.50	1.98	0.11	0.16	-0.73	19.35	14.81	20.87
2007-2008	1526.02	52.76	1.26	0.11	0.65	0.72	21.67	22.54	24.41
2008-2009	1525.88	52.76	2.01	0.11	-0.58	-0.02	20.43	19.88	21.95
2009-2010	1193.55	41.27	2.96	0.11	-0.74	-0.52	12.95	10.94	14.76
2010-2011	1034.65	35.77	1.57	0.12	0.14	0.22	6.63	5.41	8.68
2011-2012	1638.08	56.64	2.65	0.13	1.09	0.12	28.13	21.91	32.12
2012-2013	1441.54	49.84	1.48	0.13	-0.38	-0.01	17.41	14.03	18.63
2013-2014	1522.11	52.63	0.94	0.13	0.84	0.00	22.10	15.81	24.01
2014-2015	1288.37	44.54	3.20	0.12	-0.40	-0.05	11.72	15.88	14.59
Avg	1389.77	48.05	1.70	0.10	0.01	0.01	19.06	17.19	20.88

Table - E.6 Water availability at Champua

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8 = 3+ 4+5+6
1985-1986	1863.74	3.23	0.01	0.01	0.04	1.82	-	1.88
1986-1987	1298.72	2.25	0.00	0.01	-0.01	0.82	-	0.81
1987-1988	1150.95	2.00	0.04	0.01	0.04	0.75	-	0.84
1988-1989	1204.80	2.09	0.06	0.01	-0.08	1.01	-	0.99
1989-1990	1578.90	2.74	0.07	0.01	0.07	1.13	-	1.28
1990-1991	1636.22	2.84	0.00	0.01	0.19	1.31	-	1.50
1991-1992	1284.05	2.23	0.03	0.00	-0.03	1.06	1.12	1.07
1992-1993	1181.20	2.05	0.07	0.01	0.02	0.76	0.42	0.85
1993-1994	1283.28	2.23	0.05	0.01	0.00	0.81	0.98	0.86
1994-1995	1754.48	3.04	0.06	0.01	0.02	1.62	1.67	1.71
1995-1996	1275.57	2.21	0.00	0.01	-0.01	0.91	0.89	0.91
1996-1997	1327.66	2.30	0.06	0.01	0.04	1.02	1.00	1.11
1997-1998	1662.61	2.89	0.01	0.01	0.04	1.37	1.17	1.41
1998-1999	1203.42	2.09	0.02	0.01	-0.07	0.93	0.78	0.88
1999-2000	1589.43	2.76	0.01	0.01	0.04	1.30	1.95	1.35
2000-2001	1453.96	2.52	0.03	0.01	-0.04	1.15	0.77	1.15
2001-2002	1429.52	2.48	0.05	0.01	-0.01	1.19	1.30	1.23
2002-2003	1064.11	1.85	0.08	0.01	-0.01	0.44	0.48	0.51
2003-2004	1274.30	2.21	0.10	0.01	-0.01	0.80	0.93	0.90
2004-2005	1293.38	2.24	0.04	0.01	0.04	0.97	0.89	1.07
2005-2006	1395.13	2.42	0.01	0.01	0.03	0.86	1.14	0.90
2006-2007	1452.01	2.52	0.05	0.01	-0.12	1.22	1.18	1.16
2007-2008	1865.10	3.24	0.01	0.01	-0.03	2.19	1.73	2.18
2008-2009	1526.98	2.65	0.10	0.01	-0.02	1.28	1.42	1.36
2009-2010	1280.60	2.22	0.08	0.01	-0.03	0.78	0.77	0.84
2010-2011	1140.64	1.98	0.04	0.01	-0.01	0.55	0.44	0.59
2011-2012	1809.87	3.14	0.08	0.01	0.01	1.91	1.67	2.00
2012-2013	1297.68	2.25	0.06	0.01	-0.06	0.67	0.76	0.68
2013-2014	1613.47	2.80	0.03	0.01	0.08	1.36	1.25	1.48
2014-2015	1416.75	2.46	0.15	0.01	-0.01	0.60	1.08	0.75
Avg	1420.28	2.46	0.05	0.01	0.00	1.09	1.07	1.14

Table - E.7 Water availability at Anandapur

Year	Rainfall			DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9 = 3+4+5+6+7
1985-1986	1868.72	15.52	0.04	0.02	0.21	-0.10	8.97	8.77	9.14
1986-1987	1308.28	10.87	0.13	0.02	-0.11	-0.02	3.62	3.97	3.64
1987-1988	1208.98	10.04	0.70	0.02	0.08	0.19	2.72	2.17	3.71
1988-1989	1313.68	10.91	0.94	0.02	-0.38	-0.06	4.21	4.26	4.73
1989-1990	1615.38	13.42	0.59	0.02	0.45	-0.12	4.93	6.09	5.87
1990-1991	1615.87	13.42	0.17	0.02	-0.04	0.01	5.82	6.52	5.98
1991-1992	1333.35	11.08	0.38	0.02	-0.20	0.13	3.96	6.00	4.29
1992-1993	1140.25	9.47	0.81	0.02	0.10	0.02	2.26	2.73	3.21
1993-1994	1334.69	11.09	0.43	0.02	0.02	-0.04	3.61	4.59	4.04
1994-1995	1793.61	14.90	0.45	0.02	-0.03	0.06	6.63	7.92	7.13
1995-1996	1351.21	11.22	0.19	0.02	0.02	-0.13	3.68	5.25	3.78
1996-1997	1297.42	10.78	0.84	0.02	0.19	0.07	3.32	4.67	4.44
1997-1998	1766.13	14.67	0.10	0.02	0.14	-0.12	7.28	6.34	7.42
1998-1999	1204.79	10.01	0.18	0.02	-0.24	0.13	3.64	2.94	3.73
1999-2000	1706.64	14.18	0.09	0.02	0.10	-0.08	7.15	9.52	7.28
2000-2001	1317.54	10.95	0.43	0.02	-0.08	0.02	3.88	3.50	4.27
2001-2002	1551.22	12.89	0.61	0.02	-0.09	-0.10	5.84	4.89	6.28
2002-2003	1093.66	9.09	0.92	0.02	-0.03	0.21	1.29	1.92	2.41
2003-2004	1400.05	11.63	0.68	0.03	-0.05	-0.27	4.12	4.69	4.51
2004-2005	1320.54	10.97	0.65	0.03	0.19	0.26	2.91	3.45	4.04
2005-2006	1566.63	13.01	0.15	0.03	0.05	-0.08	5.53	5.29	5.68
2006-2007	1706.99	14.18	0.59	0.03	-0.05	-0.01	6.43	5.47	6.99
2007-2008	1890.94	15.71	0.14	0.03	-0.06	-0.10	9.52	8.60	9.53
2008-2009	1609.16	13.37	0.70	0.03	-0.08	0.21	5.43	5.25	6.29
2009-2010	1312.88	10.91	0.50	0.03	-0.05	-0.08	3.61	2.77	4.01
2010-2011	1136.40	9.44	0.66	0.03	0.15	0.08	1.34	1.31	2.26
2011-2012	1726.75	14.34	0.56	0.03	-0.01	-0.19	6.81	6.80	7.2
2012-2013	1358.63	11.29	0.35	0.03	-0.19	0.20	2.53	2.62	2.92
2013-2014	1699.99	14.12	0.15	0.03	0.39	-0.44	7.39	6.04	7.52
2014-2015	1443.41	11.99	0.94	0.03	-0.06	0.23	2.47	4.27	3.61
Avg	1466.46	12.18	0.47	0.02	0.01	0.00	4.70	4.95	5.20

Table - E.8 Water resources availability in Brahmani-Baitarani basin

Year	Rainfall	Q-Calibrated	Estimated Consumptive Irrigation Input (ECII)	DIL	GW Flux	Reservoir Flux	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
	1	2	3	4	5	6	7	8=2+3+4+5+6+7
1985-86	94.79	38.55	2.82	0.15	1.98	-0.10	0.99	44.39
1986-87	84.63	30.73	3.22	0.15	-0.89	-0.52	0.96	33.65
1987-88	74.19	21.44	6.98	0.16	-0.06	0.67	1.12	30.31
1988-89	76.30	25.94	7.60	0.16	-1.37	-0.10	1.12	33.35
1989-90	86.86	26.20	5.53	0.17	1.97	-0.37	0.98	34.48
1990-91	88.45	32.33	3.40	0.16	0.38	0.08	0.95	37.30
1991-92	84.22	32.58	4.15	0.15	-1.37	0.24	0.92	36.67
1992-93	68.23	20.02	5.16	0.15	0.30	-0.02	0.74	26.35
1993-94	81.33	27.64	4.95	0.16	0.32	0.00	0.92	33.99
1994-95	108.45	48.90	5.03	0.16	0.17	-0.19	0.71	54.78
1995-96	78.72	27.00	3.41	0.16	-1.01	-0.24	0.91	30.23
1996-97	73.22	20.22	7.94	0.17	0.91	-0.12	1.11	30.23
1997-98	100.30	39.17	3.71	0.17	1.52	-0.25	1.14	45.46
1998-99	73.52	23.71	3.84	0.17	-2.11	0.46	1.09	27.16
1999-00	97.53	41.57	2.87	0.18	1.23	0.50	1.01	47.36
2000-01	69.97	23.49	4.84	0.18	-1.92	0.07	1.10	27.76
2001-02	90.66	48.59	4.83	0.18	0.15	-0.21	0.45	53.99
2002-03	63.39	14.86	6.43	0.18	-0.36	-0.19	0.76	21.68
2003-04	88.08	31.16	5.54	0.19	0.31	-0.16	0.95	37.99
2004-05	73.03	21.02	5.71	0.19	0.40	0.39	1.11	28.82
2005-06	84.00	26.64	3.85	0.19	0.04	-0.11	1.00	31.61
2006-07	83.91	32.41	5.61	0.20	0.30	-0.74	0.75	38.53
2007-08	93.74	39.67	4.34	0.20	0.35	0.62	0.96	46.14
2008-09	86.77	32.34	6.25	0.20	-0.87	0.20	0.72	38.84
2009-10	74.12	22.87	6.08	0.21	-0.92	-0.61	0.80	28.43
2010-11	64.56	11.43	4.74	0.22	0.42	0.30	0.85	17.96
2011-12	96.41	43.43	6.11	0.22	0.28	-0.07	0.61	50.58
2012-13	79.05	24.20	4.64	0.23	-1.46	0.19	1.00	28.80
2013-14	94.05	37.64	5.40	0.23	1.95	-0.43	1.10	45.89
2014-15	77.64	19.37	6.69	0.22	-0.42	0.18	0.91	26.95
Avg	83.00	29.50	5.05	0.18	0.01	-0.02	0.93	35.65

ANNEXURE - F

MAHANADI BASIN

Table - F.1 Water availability at Bamnidih

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10=3+4+5+6+7+9
1985-86	1287.82	12.57	0.08	0.01	-0.05	0.00	4.29	4.89	0.20	4.52
1986-87	1250.17	12.20	0.09	0.01	0.01	0.00	2.71	5.34	0.23	3.05
1987-88	1458.58	14.24	0.10	0.01	0.03	0.00	5.35	3.92	0.07	5.56
1988-89	1777.35	17.35	0.14	0.01	-0.13	0.00	10.59	3.00	0.09	10.69
1989-90	1169.57	11.42	0.11	0.01	0.00	0.00	2.73	2.56	0.08	2.93
1990-91	1406.07	13.72	0.08	0.01	0.13	0.00	4.25	5.30	0.30	4.77
1991-92	1207.07	11.78	0.15	0.01	-0.08	0.00	4.95	4.65	0.11	5.14
1992-93	1054.45	10.29	0.13	0.01	-0.21	0.00	3.11	2.64	0.11	3.15
1993-94	1211.74	11.83	0.13	0.01	0.05	0.00	3.99	2.17	0.13	4.31
1994-95	1793.81	17.51	0.08	0.01	0.16	0.00	7.57	11.86	0.31	8.13
1995-96	1155.05	11.27	0.14	0.01	-0.09	0.04	2.91	2.41	0.12	3.13
1996-97	1206.60	11.78	0.12	0.01	-0.13	-0.23	3.88	3.46	0.13	3.78
1997-98	1494.10	14.58	0.06	0.01	0.48	0.73	2.50	3.40	0.33	4.10
1998-99	1219.20	11.90	0.14	0.01	-0.23	-0.99	3.73	5.38	0.15	2.81
1999-00	1241.39	12.12	0.12	0.01	0.01	-0.01	3.99	5.04	0.16	4.27
2000-01	1131.66	11.05	0.12	0.01	-0.12	0.27	2.72	2.46	0.15	3.16
2001-02	1529.78	14.93	0.09	0.01	0.03	0.16	5.72	7.88	0.13	6.13
2002-03	1021.20	9.97	0.13	0.01	-0.06	-0.16	2.40	3.13	0.15	2.47
2003-04	1510.52	14.74	0.08	0.01	0.23	1.11	3.65	7.28	0.09	5.16
2004-05	1335.40	13.03	0.10	0.01	-0.16	-0.48	4.34	4.38	0.16	3.96
2005-06	1155.27	11.28	0.09	0.01	-0.02	-0.27	1.59	4.12	0.14	1.54
2006-07	1239.29	12.10	0.13	0.01	-0.06	-0.25	5.11	3.17	0.09	5.03
2007-08	1042.19	10.17	0.58	0.01	-0.01	0.07	2.17	2.44	0.13	2.95
2008-09	1197.16	11.68	0.19	0.01	-0.01	0.27	2.91	1.80	0.13	3.50
2009-10	977.30	9.54	1.09	0.01	-0.13	-0.30	1.52	1.07	0.10	2.29
2010-11	979.46	9.56	0.44	0.01	0.07	0.25	0.83	1.50	0.12	1.72
2011-12	1758.16	17.16	0.57	0.01	0.09	0.48	6.96	4.33	0.12	8.23
2012-13	1601.43	15.63	0.30	0.01	-0.02	-0.05	5.52	2.38	0.18	5.94
2013-14	1337.71	13.06	0.48	0.01	0.16	0.77	1.97	2.09	0.25	3.64
2014-15	1320.12	12.89	0.16	0.01	-0.21	-0.12	3.53	3.42	0.07	3.44
Average	1302.32	12.71	0.21	0.01	-0.01	0.04	3.92	3.92	0.15	4.32

Table - F.2 Water availability at Jondhra

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10= 3+4+5+6+7+ 9
1985-86	1127.38	33.38	5.96	0.02	0.18	0	8.00	10.67	0.18	14.34
1986-87	1234.95	36.57	6.71	0.02	-0.11	0	8.60	12.29	0.2	15.42
1987-88	925.88	27.41	2.04	0.03	-0.06	0	6.75	4.1	0.07	8.82
1988-89	1079.06	31.95	2.10	0.03	-0.21	0	10.22	6.32	0.09	12.22
1989-90	1072.71	31.76	6.97	0.03	0.73	0	3.39	4.31	0.07	11.19
1990-91	1415.96	41.93	5.01	0.03	-0.32	0	16.19	16.45	0.27	21.18
1991-92	927.12	27.45	2.59	0.03	-0.05	0	10.39	6.99	0.1	13.06
1992-93	962.81	28.51	2.40	0.03	-0.18	0	11.09	5.75	0.1	13.44
1993-94	1131.53	33.5	1.93	0.03	0.15	0	12.53	8.48	0.11	14.75
1994-95	1736.01	51.4	4.75	0.03	0.85	0	23.42	21.43	0.27	29.32
1995-96	1083.22	32.07	2.38	0.03	-0.72	0	11.04	7.5	0.11	12.84
1996-97	1028.78	30.46	2.10	0.03	0.04	0	10.23	6.02	0.11	12.51
1997-98	1409.49	41.73	5.62	0.04	0.57	0	10.99	9.42	0.29	17.51
1998-99	1219.76	36.12	2.28	0.04	-0.51	0	9.77	6.56	0.14	11.71
1999-00	1261.08	37.34	1.87	0.04	0.22	0	14.60	8.19	0.14	16.87
2000-01	891.52	26.4	2.20	0.05	-0.71	0	6.75	2.22	0.14	8.43
2001-02	1390.78	41.18	6.68	0.05	0.21	0	14.13	9.53	0.11	21.18
2002-03	1048.93	31.06	2.11	0.05	-0.37	0	8.46	2.91	0.14	10.4
2003-04	1615.27	47.83	5.48	0.05	0.65	0	19.37	12.78	0.08	25.63
2004-05	1131.14	33.49	1.80	0.05	0.02	0	10.94	6.6	0.15	12.97
2005-06	1356.64	40.17	5.85	0.05	-0.05	0	11.65	12.86	0.13	17.63
2006-07	955.24	28.28	6.99	0.06	-0.35	0	7.13	7.52	0.08	13.91
2007-08	1021.68	30.25	6.83	0.06	-0.02	0	6.84	10.32	0.11	13.82
2008-09	950.77	28.15	6.24	0.06	-0.36	0	4.29	3.49	0.11	10.34
2009-10	957.48	28.35	10.39	0.06	0.12	0	1.33	4.32	0.09	11.99
2010-11	1145.84	33.93	7.40	0.06	0.49	0	5.34	9.21	0.11	13.39
2011-12	1170.92	34.67	6.98	0.06	-0.14	0	10.37	11.43	0.11	17.38
2012-13	1202.96	35.62	5.77	0.06	0.09	0	12.83	11.03	0.17	18.92
2013-14	1482.06	43.88	2.78	0.06	0.41	0	17.32	17.75	0.22	20.79
2014-15	1251.95	37.07	4.45	0.06	0.04	0	10.75	15.74	0.07	15.37
Average	1172.96	34.73	4.56	0.04	0.02	0	10.49	9.07	0.14	15.24

Table - F.3 Water availability at Basantpur

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9	10=3+4+5+6+7+9
1985-86	1190.88	69.99	12.42	0.04	0.37	0.03	16.63	24.12	0.61	30.10
1986-87	1229.93	72.29	11.88	0.04	-0.2	-0.02	14.99	24.91	0.68	27.38
1987-88	1023.04	60.13	5.68	0.04	-0.12	0.02	13.96	10.98	0.28	19.86
1988-89	1120.39	65.85	7.07	0.04	-0.54	-0.02	21.42	10.81	0.38	28.36
1989-90	1099.41	64.62	11.27	0.04	1.05	0.00	8.4	9.67	0.34	21.11
1990-91	1453.65	85.44	11.56	0.05	-0.15	0.00	27.28	34.71	0.89	39.63
1991-92	999.31	58.73	7.2	0.05	-0.32	0.00	19.85	20.65	0.35	27.14
1992-93	1043.59	61.34	8.51	0.06	-0.56	-0.09	19.49	18.39	0.36	27.77
1993-94	1122.96	66.00	6.91	0.06	0.34	0.14	19.41	17.76	0.4	27.25
1994-95	1791.55	105.3	15.87	0.06	1.27	-0.13	39.81	52.17	0.91	57.78
1995-96	1070.46	62.92	7.05	0.06	-1.09	0.02	17.91	18.92	0.37	24.31
1996-97	1032.71	60.7	6.04	0.06	-0.13	-0.34	17.25	13.04	0.38	23.26
1997-98	1380.43	81.13	11.23	0.06	1.31	0.79	16.56	19.3	0.91	30.86
1998-99	1155.97	67.94	5.88	0.06	-0.80	-1.09	14.76	17.96	0.49	19.31
1999-00	1184.59	69.62	5.69	0.06	0.22	0.06	22.39	20.80	0.52	28.94
2000-01	887.91	52.19	3.92	0.08	-1.15	0.28	11.49	7.68	0.48	15.10
2001-02	1438.97	84.57	14.27	0.08	0.41	0.57	26.67	30.65	0.40	42.41
2002-03	1022.75	60.11	5.95	0.08	-0.64	-0.43	13.58	8.36	0.51	19.05
2003-04	1594.62	93.72	15.24	0.08	1.32	1.66	27.52	32.01	0.43	46.25
2004-05	1130.45	66.44	6.38	0.08	-0.29	-0.61	17.2	18.15	0.53	23.29
2005-06	1288.23	75.71	10.91	0.09	-0.01	-0.34	16.69	26.57	0.44	27.77
2006-07	1089.08	64.01	14.43	0.09	-0.54	-0.37	18.68	24.17	0.28	32.56
2007-08	1131.85	66.52	14.1	0.09	0.04	-0.05	13.84	24.89	0.43	28.45
2008-09	1064.24	62.55	10.97	0.09	-0.69	0.28	12.87	13.49	0.41	23.93
2009-10	1004.11	59.02	19.77	0.09	0.06	-0.34	5.22	14.60	0.32	25.12
2010-11	1130.29	66.43	13.21	0.09	1.03	0.19	9.02	20.05	0.41	23.95
2011-12	1270.3	74.66	16.54	0.1	-0.40	0.78	22.11	22.67	0.36	39.49
2012-13	1304.15	76.65	13.75	0.1	0.10	-0.39	22.16	21.08	0.55	36.27
2013-14	1429.98	84.05	9.41	0.1	0.75	0.92	22.56	24.98	0.75	34.50
2014-15	1297.69	76.27	12.2	0.1	0.15	-0.11	17.36	27.17	0.27	29.97
Average	1199.45	70.5	10.51	0.07	0.03	0.05	18.24	21.02	0.48	29.37

Table - F.4 Water availability at Kantamal

Year	Rainfall		ECII	DIL	GW Flux	Res. Flux	Q-Calibrated*	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6		7	8	9	10=3+4+5+6+7+9
1985-86	1773.67	35.86	0.56	0.01	0.52	0.01	14.89	14.89	17.5	0.01	16
1986-87	1312.79	26.54	0.76	0.01	-0.01	0.01	6.43	6.43	10.6	0.01	7.21
1987-88	1051.95	21.27	1.07	0.01	-0.34	0.01	1.84	1.84	3.36	0.01	2.59
1988-89	921.87	18.64	1.22	0.01	-0.25	0	1.64	1.64	3.58	0.02	2.64
1989-90	1369.97	27.7	0.78	0.01	0.25	-0.02	4.98	4.98	6	0.01	6.01
1990-91	1845.39	37.31	0.6	0.01	0.48	0.02	16.67	16.67	21.4	0.01	17.79
1991-92	1326.39	26.81	1.16	0.01	-0.26	0.00	12.12	12.12	14.7	0.01	13.04
1992-93	1496.24	30.25	1.14	0.01	-0.2	0.00	13.33	13.33	13.1	0.01	14.28
1993-94	1366.39	27.62	1.05	0.01	0.26	0.02	8.46	8.46	8.43	0.01	9.81
1994-95	2002.64	40.49	0.7	0.01	0.06	0.00	19.27	19.27	21.2	0.01	20.06
1995-96	1220.07	24.67	0.96	0.01	-0.35	0	7.96	7.96	9.94	0.01	8.59
1996-97	853.91	17.26	1.04	0.01	-0.22	-0.01	2.07	2.07	3.86	0.01	2.91
1997-98	1205.89	24.38	0.76	0.01	0.51	0.00	5.33	5.33	9.98	0.01	6.62
1998-99	947.32	19.15	1.47	0.01	-0.31	0.00	0.95	0.95	3.63	0.01	2.14
1999-00	1024.23	20.71	1.14	0.01	0.08	0.01	2.8	2.8	6.87	0.02	4.06
2000-01	903.25	18.26	1.25	0.01	-0.26	0.00	2.92	2.92	6.41	0.02	3.95
2001-02	2049.93	41.44	0.82	0.01	0.22	0.00	22.83	22.83	22.6	0.01	23.9
2002-03	855.08	17.29	1.35	0.01	-0.27	-0.01	1.99	1.99	4.03	0.02	3.1
2003-04	1710.58	34.58	0.61	0.01	0.33	0.02	15.93	15.93	15.3	0.01	16.92
2004-05	1279.72	25.87	0.98	0.01	0	0.00	7.26	7.26	12.5	0.02	8.27
2005-06	1222.82	24.72	0.72	0.01	0.22	0.00	7.06	7.06	9.32	0.01	8.03
2006-07	1599.19	32.33	0.87	0.01	0.39	0.01	16.89	16.89	21.0	0.01	18.18
2007-08	1421.35	28.73	0.56	0.01	-0.34	0.00	15.29	11.71	16.7	0.01	11.96
2008-09	1450.21	29.32	1.01	0.01	-0.46	0.00	16.59	13.83	17.9	0.01	14.4
2009-10	1527.43	30.88	1.03	0.01	0.1	0.00	15.23	13.46	11.4	0.01	14.61
2010-11	1212.49	24.51	0.97	0.02	0.45	0.01	8.09	6.05	10.2	0.01	7.5
2011-12	1069.01	21.61	1.25	0.02	-0.39	0	7.99	6.26	6.62	0.01	7.15
2012-13	1284.38	25.97	1.58	0.02	0.09	-0.01	9.54	7.58	9.25	0.01	9.27
2013-14	1710.23	34.57	0.79	0.02	0.19	0.01	15.37	12.35	12.5	0.01	13.37
2014-15	1421.24	28.73	0.86	0.02	-0.03	0.00	14.28	11.09	14.4	0.01	11.95
Average	1347.85	27.25	0.97	0.01	0.02	0.00	9.87	9.2	11.5	0.01	10.21

** Including Import from Indravati River ** excluding import*

Table - F.5 Water availability at Tikarpara

Year	Rainfall		ECII	DIL	GW Flux	Reservoir Flux	Q-Calib*	Q-Calib	Q-Obs	Reservoir Evap	Water availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6		7	8	9	10=3+4+5+6+7+9
1985-86	1417	177.64	15.34	0.08	2.20	0.22	56.62	56.62	62.8	1.29	75.76
1986-87	1294.46	162.28	15.74	0.08	-0.98	0.18	38.27	38.27	59.5	1.36	54.65
1987-88	1093.25	137.06	9.26	0.09	-0.67	0.29	30.91	30.91	24.11	0.88	40.75
1988-89	1115.48	139.84	11.21	0.09	-1.74	0.26	38.18	38.18	23.92	1.16	49.15
1989-90	1223.24	153.35	15.07	0.09	2.28	0.2	24.92	24.92	29.03	0.99	43.55
1990-91	1498.69	187.88	14.55	0.1	0.99	0.19	61.09	61.09	71.18	1.56	78.47
1991-92	1151.11	144.31	11.22	0.11	-1.14	0.27	56.31	56.31	52.69	0.77	67.54
1992-93	1180.99	148.06	12.29	0.11	-1.41	0.19	54.01	54.01	52.8	0.84	66.02
1993-94	1241.75	155.67	10.36	0.11	0.85	0.41	50.33	50.33	41.68	1.02	63.07
1994-95	1894.38	237.49	19.31	0.11	1.99	0.06	104.91	104.91	124.77	1.58	127.96
1995-96	1124.76	141.01	10.43	0.11	-2.74	0.29	43.84	43.84	38.45	0.9	52.83
1996-97	1055.53	132.33	9.67	0.11	-0.25	-0.07	35.07	35.07	25.47	0.95	45.49
1997-98	1432.92	179.64	14.72	0.12	3.35	0.99	43.51	43.51	48.15	1.58	64.26
1998-99	1159.26	145.33	10.49	0.12	-2.02	-0.82	28.29	28.29	34.51	1.18	37.24
1999-00	1198.3	150.23	9.40	0.12	0.18	0.33	45.87	45.87	34.36	1.35	57.25
2000-01	902.82	113.18	7.82	0.14	-2.54	0.55	22.13	22.13	20.35	1.27	29.37
2001-02	1634.19	204.87	18.5	0.14	1.18	0.76	85.97	85.97	66.87	0.96	107.51
2002-03	1042.21	130.66	9.88	0.14	-1.12	-0.16	29.61	29.61	23.8	1.30	39.65
2003-04	1650.22	206.88	18.04	0.15	1.86	1.85	73.3	73.3	70.32	1.11	96.31
2004-05	1174.02	147.18	9.97	0.15	-0.04	-0.34	41.47	41.47	41.43	1.32	52.53
2005-06	1338.87	167.85	14.14	0.15	0.33	-0.15	41.22	41.22	46.82	1.15	56.83
2006-07	1262.94	158.33	18.50	0.15	-0.14	-0.17	61.31	61.31	61.94	0.77	80.42
2007-08	1286.75	161.31	18.01	0.16	0.31	0.1	50.59	47.01	55.02	1.09	66.68
2008-09	1291.34	161.89	15.10	0.16	-1.96	0.5	59.24	56.48	45.68	0.85	71.13
2009-10	1168.41	146.48	27.28	0.16	-0.16	-0.13	35.78	34.01	43.53	0.79	61.95
2010-11	1141.79	143.14	17.80	0.16	2.18	0.5	22.97	20.93	39.3	1.11	42.69
2011-12	1313.67	164.69	22.87	0.17	-0.77	1.04	55.44	53.72	45.23	0.93	77.96
2012-13	1371.38	171.92	17.89	0.17	0.22	0.02	55.75	53.78	47.08	1.27	73.36
2013-14	1406.85	176.37	13.58	0.18	1.38	1.18	51.29	48.27	51.64	1.43	66.02
2014-15	1514.64	189.88	16.25	0.18	-0.08	0.19	53.65	50.46	68.43	0.83	67.83
Average	1286.04	161.23	14.49	0.13	0.05	0.29	48.39	47.73	48.36	1.12	63.81

** Including Import from Indravati river ** excluding import*

Table - F.6 Water resources availability of Mahanadi basin

Year	Rainfall	Q-Calibrated	ECII	DIL	GW Flux	Reservoir Flux	Import to the Basin	Reservoir Evap.	Water availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9	10
1985-86	219.40	65.30	16.502	0.13	1.96	0.22	0.00	1.56	85.67
1986-87	203.00	44.82	16.782	0.13	0.10	0.18	0.00	1.68	63.69
1987-88	165.75	31.75	11.322	0.14	-1.20	0.29	0.00	1.12	43.42
1988-89	170.00	41.10	13.422	0.14	-1.66	0.26	0.00	1.64	54.90
1989-90	194.75	30.33	16.422	0.14	1.38	0.20	0.00	1.28	49.75
1990-91	230.05	67.34	15.732	0.15	2.78	0.19	0.00	1.87	88.06
1991-92	191.89	67.79	12.952	0.17	-1.90	0.27	0.00	1.06	80.34
1992-93	187.85	60.98	13.972	0.17	-1.61	0.19	0.00	1.08	74.78
1993-94	194.54	58.06	12.052	0.17	0.55	0.41	0.00	1.27	72.51
1994-95	292.30	117.74	20.522	0.17	2.22	0.06	0.00	1.90	142.61
1995-96	174.73	47.63	12.232	0.18	-2.54	0.29	0.00	1.14	58.93
1996-97	157.73	34.30	11.832	0.18	-0.36	-0.07	0.00	1.17	47.05
1997-98	219.58	50.79	15.922	0.18	3.30	0.99	0.00	1.88	73.06
1998-99	178.96	30.98	12.642	0.19	-1.86	-0.82	0.00	1.49	42.62
1999-00	190.39	56.48	10.952	0.19	-0.90	0.33	0.00	1.80	68.85
2000-01	137.94	19.56	10.572	0.21	-0.79	0.55	0.00	1.67	31.77
2001-02	252.65	99.70	20.042	0.21	-0.16	0.76	0.00	1.22	121.77
2002-03	165.26	37.75	11.912	0.21	-0.85	-0.16	0.00	1.74	50.60
2003-04	252.96	84.51	19.212	0.21	1.48	1.85	0.00	1.37	108.63
2004-05	179.07	43.67	11.622	0.22	0.71	-0.34	0.00	1.73	57.61
2005-06	215.29	53.07	15.572	0.22	0.35	-0.15	0.00	1.41	70.47
2006-07	205.10	74.57	20.382	0.23	-0.08	-0.17	0.00	1.01	95.94
2007-08	206.49	55.17	20.132	0.23	0.80	0.10	3.57	1.36	77.79
2008-09	203.86	64.62	17.702	0.23	-2.06	0.50	2.76	1.06	82.05
2009-10	188.52	42.40	29.962	0.24	-0.70	-0.13	1.77	1.06	72.83
2010-11	180.41	23.97	19.942	0.24	2.07	0.50	2.04	1.41	48.13
2011-12	198.11	58.55	24.222	0.25	-0.40	1.04	1.72	1.15	84.81
2012-13	211.09	60.45	19.542	0.26	-0.12	0.02	1.96	1.43	81.58
2013-14	226.93	62.02	15.452	0.26	0.98	1.18	3.02	1.62	81.51
2014-15	205.47	58.57	17.842	0.26	0.43	0.19	3.19	0.99	78.28
Average	200.00	54.80	16.24	0.20	0.06	0.29	0.67	1.41	73.00

PENNAR BASIN

Table - G.1 Water availability at Chennur

Year	Rainfall		ECII	DIL flux	GW flux	Q-Calibrated	Q-observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8	9=3+4+5+6+8
1985-86	407.20	15.25	6.82	0.09	-1.12	0.00	N.A	0.05	5.84
1986-87	431.39	16.15	4.55	0.10	-0.51	0.00	N.A	0.04	4.18
1987-88	675.65	25.30	7.36	0.10	1.50	0.00	N.A	0.04	9.01
1988-89	732.86	27.44	5.67	0.10	0.91	7.22	N.A	0.04	13.95
1989-90	705.30	26.41	6.84	0.11	0.09	2.85	2.90	0.05	9.92
1990-91	513.85	19.24	6.80	0.11	-0.84	0.00	1.38	0.04	6.10
1991-92	625.25	23.41	6.41	0.11	0.45	0.00	1.67	0.05	7.02
1992-93	501.80	18.79	4.30	0.12	-1.35	0.43	0.60	0.06	3.56
1993-94	677.50	25.37	5.95	0.12	0.62	0.00	1.36	0.04	6.73
1994-95	510.15	19.10	6.90	0.13	-0.93	0.00	0.88	0.04	6.15
1995-96	629.73	23.58	5.27	0.13	-0.22	2.13	0.89	0.04	7.37
1996-97	973.73	36.46	4.07	0.14	2.66	12.44	6.55	0.06	19.36
1997-98	595.89	22.31	7.13	0.14	-1.49	1.00	1.58	0.04	6.82
1998-99	775.36	29.03	5.50	0.15	1.45	2.32	3.79	0.05	9.45
1999-00	511.44	19.15	5.03	0.15	-2.82	1.01	1.06	0.06	3.43
2000-01	744.24	27.86	5.74	0.16	0.93	3.91	3.35	0.05	10.79
2001-02	689.53	25.82	5.31	0.16	1.30	6.45	3.05	0.05	13.27
2002-03	381.86	14.30	4.42	0.17	-4.60	2.59	0.26	0.04	2.63
2003-04	627.47	23.49	6.67	0.18	-0.17	0.00	0.56	0.05	6.74
2004-05	465.15	17.42	4.70	0.19	-2.80	1.55	1.37	0.06	3.68
2005-06	826.21	30.93	4.64	0.19	6.24	0.00	3.45	0.05	11.11
2006-07	466.84	17.48	4.48	0.20	-3.55	1.38	1.90	0.04	2.57
2007-08	983.13	36.81	4.57	0.21	3.93	7.73	4.79	0.06	16.48
2008-09	719.06	26.92	6.34	0.22	0.43	0.40	2.21	0.04	7.43
2009-10	677.07	25.35	6.50	0.23	-0.54	0.64	3.23	0.04	6.87
2010-11	825.47	30.91	4.18	0.24	0.55	6.21	4.40	0.05	11.18
2011-12	542.30	20.30	6.70	0.25	-1.63	0.00	2.44	0.04	5.37
2012-13	548.66	20.54	4.79	0.26	-1.84	1.06	0.65	0.04	4.27
2013-14	653.11	24.45	4.46	0.27	1.19	1.39	3.40	0.04	7.31
2014-15	566.94	21.23	4.89	0.28	-1.16	0.00	2.73	0.01	4.01
Avg.	632.81	23.69	5.57	0.17	-0.11	2.09	2.33	0.05	7.75

Table - G.2 Water availability at Nellore

Year	Rainfall		ECII	DIL flux	GW flux	Reservoir flux	Q-Calibrated	Q-observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8	9	10=3+4+5+6+7+9
1985-86	512.38	27.77	9.05	0.16	-1.53	0.00	0.00	4.83	0.15	7.82
1986-87	479.05	25.97	6.58	0.16	-1.07	0.02	0.00	4.89	0.13	5.82
1987-88	731.35	39.64	9.81	0.17	1.96	0.05	0.00	0.51	0.13	12.11
1988-89	762.10	41.31	7.67	0.17	0.99	-0.06	9.56	4.09	0.13	18.46
1989-90	723.38	39.21	9.37	0.17	0.03	0.08	3.04	0.64	0.14	12.83
1990-91	626.82	33.97	8.96	0.18	-0.66	0.23	3.39	0.78	0.11	12.21
1991-92	754.17	40.88	8.27	0.18	0.86	0.03	5.83	3.81	0.15	15.32
1992-93	546.27	29.61	6.25	0.19	-2.18	-0.31	2.20	0.17	0.17	6.31
1993-94	753.96	40.87	8.05	0.19	1.46	0.33	2.74	1.14	0.13	12.89
1994-95	623.82	33.81	9.03	0.19	-0.77	0.03	1.56	0.56	0.12	10.16
1995-96	654.40	35.47	7.34	0.20	-0.90	-0.19	3.49	0.02	0.12	10.06
1996-97	1,075.41	58.29	5.55	0.21	3.57	0.37	20.59	7.28	0.18	30.46
1997-98	664.14	36.00	9.92	0.21	-2.30	-0.17	4.13	1.18	0.13	11.92
1998-99	799.69	43.34	7.71	0.22	1.50	-0.05	4.16	3.38	0.14	13.68
1999-00	525.42	28.48	7.33	0.22	-4.89	-0.14	2.13	0.03	0.17	4.83
2000-01	763.32	41.37	8.02	0.23	0.90	0.04	5.04	1.12	0.15	14.38
2001-02	787.55	42.69	7.69	0.24	2.30	0.31	9.91	3.70	0.14	20.58
2002-03	423.31	22.94	8.34	0.24	-6.95	-0.52	3.46	0.04	0.11	4.68
2003-04	705.40	38.23	8.63	0.25	-0.01	0.00	0.00	0.08	0.16	9.04
2004-05	513.95	27.86	7.01	0.26	-3.95	0.06	2.85	0.02	0.17	6.39
2005-06	898.27	48.69	7.11	0.27	10.02	0.55	0.06	2.17	0.14	18.15
2006-07	502.06	27.21	8.35	0.28	-5.55	-0.33	1.71	0.05	0.12	4.58
2007-08	1,036.92	56.20	6.05	0.29	6.17	0.98	10.96	0.40	0.18	24.61
2008-09	734.11	39.79	8.74	0.30	0.01	-0.50	3.01	0.06	0.13	11.68
2009-10	728.81	39.50	9.62	0.31	-0.76	0.07	1.90	0.15	0.13	11.26
2010-11	878.76	47.63	5.93	0.32	0.63	0.67	9.61	1.52	0.15	17.30
2011-12	604.58	32.77	9.08	0.33	-2.08	-0.47	1.80	0.32	0.12	8.77
2012-13	580.00	31.44	6.83	0.34	-2.17	-0.83	2.41	0.07	0.11	6.69
2013-14	647.62	35.10	6.07	0.35	1.05	0.74	1.45	0.03	0.12	9.78
2014-15	546.20	29.60	6.72	0.37	-1.80	-0.47	0.00	0.01	0.04	4.86
Avg.	686.11	37.19	7.83	0.24	-0.20	0.02	3.90	1.43	0.14	11.92

Table - G.3 Water resources availability in the Pennar basin

Year	Rainfall	Q-Calibrated	ECII	Irrigation Support imported from neighbouring basin		GW flux	DIL flux	Reservoir flux	Reservoir Evaporation	Water Availability
				from Tungabhadra HLC	from Srisailam Dam					
	1	2	3	4	5	6	7	8	9	10=2+3-4-5+6+7+8+9
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1985-86	30.64	0.00	9.45	0.40	0.95	-1.57	0.16	0.00	0.15	6.84
1986-87	28.11	0.00	6.99	0.43	1.06	-1.09	0.17	0.02	0.13	4.72
1987-88	41.73	0.00	10.21	0.39	1.15	2.00	0.17	0.05	0.13	11.02
1988-89	43.88	9.45	7.97	0.17	1.16	1.01	0.17	-0.06	0.13	17.35
1989-90	41.31	2.99	9.65	0.17	1.09	0.03	0.18	0.08	0.14	11.81
1990-91	37.77	3.43	9.31	0.17	1.04	-0.67	0.18	0.23	0.11	11.38
1991-92	44.76	6.05	8.61	0.35	0.76	0.88	0.18	0.03	0.15	14.80
1992-93	31.91	2.22	6.59	0.26	0.99	-2.22	0.19	-0.31	0.17	5.39
1993-94	43.87	2.85	8.44	0.23	1.00	1.49	0.19	0.33	0.13	12.21
1994-95	37.08	2.00	9.30	0.38	0.98	-0.79	0.20	0.03	0.12	9.51
1995-96	36.89	3.32	7.67	0.31	0.91	-0.92	0.20	-0.19	0.12	8.99
1996-97	64.08	20.87	5.83	0.14	0.74	3.65	0.21	0.37	0.18	30.23
1997-98	39.08	4.32	10.36	0.34	1.17	-2.35	0.22	-0.17	0.13	10.98
1998-99	44.98	4.15	8.13	0.26	1.10	1.53	0.22	-0.05	0.14	12.75
1999-00	30.25	2.18	7.71	0.28	1.04	-4.99	0.23	-0.14	0.17	3.84
2000-01	43.48	5.02	8.31	0.25	0.99	0.92	0.23	0.04	0.15	13.44
2001-02	49.06	10.25	8.01	0.24	0.80	2.34	0.24	0.31	0.14	20.26
2002-03	24.41	3.53	8.75	0.41	1.25	-7.09	0.25	-0.52	0.11	3.36
2003-04	41.20	0.00	8.94	0.36	1.02	-0.01	0.26	0.00	0.16	7.98
2004-05	30.06	2.98	7.38	0.36	1.05	-4.03	0.26	0.06	0.17	5.42
2005-06	51.27	0.01	7.52	0.21	0.96	10.23	0.27	0.55	0.14	17.55
2006-07	29.05	1.77	8.73	0.17	1.26	-5.66	0.28	-0.33	0.12	3.48
2007-08	61.63	11.16	6.33	0.15	0.73	6.29	0.29	0.98	0.18	24.34
2008-09	42.81	2.92	9.15	0.27	1.26	0.01	0.30	-0.50	0.13	10.48
2009-10	41.14	1.73	10.22	0.38	1.31	-0.78	0.31	0.07	0.13	9.99
2010-11	51.10	9.85	6.21	0.21	0.83	0.64	0.32	0.67	0.15	16.80
2011-12	36.37	1.95	9.42	0.47	1.43	-2.12	0.33	-0.47	0.12	7.32
2012-13	34.29	2.18	7.25	0.37	0.96	-2.21	0.35	-0.83	0.11	5.52
2013-14	36.35	1.50	6.30	0.21	0.98	1.07	0.36	0.74	0.12	8.90
2014-15	31.33	0.00	7.19	0.22	1.28	-1.84	0.37	-0.47	0.04	3.81
Avg.	40.00	3.96	8.20	0.29	1.04	-0.21	0.24	0.02	0.14	11.02

EFR BETWEEN MAHANADI AND PENNAR BASIN

Table - H.1 Water availability at Anakapalli

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9= 3+4+5+7+8
1985-86	1091.23	2.20	0.54	0.01	0.06	0.00	--	0.01	0.62
1986-87	1334.55	2.69	0.23	0.01	0.01	0.75	--	0.01	1.00
1987-88	1224.46	2.47	0.23	0.01	-0.01	0.63	--	0.01	0.87
1988-89	1023.08	2.06	0.19	0.01	-0.03	0.51	--	0.01	0.69
1989-90	1481.86	2.99	0.31	0.01	0.00	1.34	--	0.01	1.68
1990-91	940.05	1.90	0.33	0.01	-0.22	0.67	--	0.01	0.81
1991-92	1014.16	2.05	0.24	0.01	-0.02	0.48	0.28	0.01	0.72
1992-93	1032.86	2.08	0.21	0.01	0.03	0.84	0.62	0.01	1.09
1993-94	758.95	1.53	0.20	0.01	-0.06	0.19	0.12	0.00	0.34
1994-95	967.42	1.95	0.36	0.01	0.15	0.32	0.35	0.01	0.86
1995-96	1034.85	2.09	0.58	0.01	-0.09	0.42	0.97	0.01	0.94
1996-97	1119.16	2.26	0.12	0.01	-0.03	0.79	1.15	0.01	0.90
1997-98	1089.92	2.20	0.29	0.01	-0.01	0.18	0.10	0.01	0.48
1998-99	1340.60	2.70	0.56	0.01	-0.01	0.62	1.39	0.01	1.19
1999-00	963.71	1.94	0.25	0.01	0.00	0.09	0.18	0.01	0.35
2000-01	931.04	1.88	0.24	0.01	0.02	0.50	0.25	0.00	0.78
2001-02	1065.70	2.15	0.25	0.01	0.00	0.49	0.25	0.01	0.76
2002-03	799.18	1.61	0.31	0.01	-0.09	0.07	0.03	0.00	0.30
2003-04	1374.22	2.77	0.35	0.01	0.12	0.57	0.30	0.01	1.06
2004-05	1195.66	2.41	0.23	0.01	-0.07	0.59	0.33	0.01	0.77
2005-06	1495.34	3.02	0.27	0.01	0.10	1.21	0.99	0.01	1.61
2006-07	2142.52	4.32	0.37	0.01	-0.01	2.18	0.65	0.01	2.57
2007-08	2097.78	4.23	0.39	0.02	0.02	1.60	1.15	0.02	2.05
2008-09	1128.91	2.28	0.35	0.02	-0.08	0.56	0.34	0.00	0.85
2009-10	1137.76	2.30	0.67	0.02	0.03	0.00	0.08	0.01	0.72
2010-11	1614.84	3.26	0.22	0.02	0.07	1.25	1.71	0.01	1.57
2011-12	877.97	1.77	0.61	0.02	-0.12	0.00	0.87	0.01	0.51
2012-13	1268.21	2.56	0.24	0.02	0.04	0.97	1.45	0.01	1.27
2013-14	1163.70	2.35	0.72	0.02	0.06	0.19	0.74	0.01	0.99
2014-15	1181.35	2.38	1.08	0.02	-0.02	0.00	0.41	0.01	1.08
Avg. excluding 2014-15	1196.89	2.41	0.34	0.01	0.00	0.61	0.62	0.01	0.98

Table - H.2 Water availability at Kashinagar

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9= 3+4+5+6+8
1985-86	1519.84	12.04	0.25	0.01	0.25	3.38	1.75	0.03	3.92
1986-87	1409.75	11.16	0.44	0.01	-0.02	2.68	2.28	0.02	3.13
1987-88	1280.88	10.14	0.28	0.01	0.00	2.11	0.73	0.02	2.41
1988-89	1246.77	9.87	0.38	0.01	0.03	2.87	2.32	0.02	3.31
1989-90	1609.02	12.74	0.63	0.01	0.10	3.55	2.26	0.02	4.32
1990-91	1816.75	14.39	0.47	0.01	0.08	5.76	6.38	0.01	6.33
1991-92	1638.85	12.98	0.48	0.01	-0.06	5.22	3.41	0.01	5.67
1992-93	1614.48	12.78	0.50	0.01	-0.02	4.89	4.18	0.01	5.40
1993-94	1116.73	8.84	0.33	0.01	-0.03	1.94	1.37	0.02	2.27
1994-95	1903.03	15.07	0.63	0.01	0.05	6.17	4.02	0.01	6.87
1995-96	1395.02	11.05	0.40	0.01	-0.07	3.65	4.16	0.02	4.01
1996-97	1029.00	8.15	0.34	0.01	-0.02	1.62	1.29	0.02	1.98
1997-98	1353.64	10.72	0.33	0.02	0.01	2.49	1.63	0.02	2.87
1998-99	1361.26	10.78	0.43	0.02	0.01	2.53	1.81	0.03	3.01
1999-00	1173.87	9.30	0.33	0.02	0.03	1.77	1.48	0.02	2.15
2000-01	1058.27	8.38	0.45	0.02	-0.06	1.54	1.14	0.02	1.97
2001-02	1576.45	12.48	0.56	0.02	0.11	4.08	2.16	0.02	4.78
2002-03	959.05	7.59	0.46	0.02	-0.17	1.33	0.63	0.02	1.66
2003-04	1553.01	12.30	0.44	0.02	0.19	4.70	3.48	0.02	5.37
2004-05	968.27	7.67	0.30	0.02	-0.13	2.01	2.75	0.02	2.22
2005-06	1314.67	10.41	0.47	0.02	0.08	3.00	2.65	0.03	3.59
2006-07	1399.74	11.08	0.70	0.02	0.14	5.07	6.42	0.02	5.94
2007-08	1389.25	11.00	0.56	0.02	-0.10	3.70	3.97	0.02	4.19
2008-09	1358.47	10.76	0.56	0.02	-0.06	4.24	3.07	0.02	4.78
2009-10	1547.91	12.26	0.53	0.02	-0.10	3.83	2.81	0.03	4.30
2010-11	1464.83	11.60	0.61	0.02	0.23	2.47	3.14	0.03	3.36
2011-12	989.32	7.83	1.12	0.02	-0.17	1.08	1.96	0.03	2.08
2012-13	1320.92	10.46	0.58	0.02	0.05	2.71	2.27	0.04	3.38
2013-14	1772.01	14.03	1.53	0.02	0.09	3.87	3.85	0.03	5.53
2014-15	1477.17	11.70	1.24	0.02	0.10	0.90	5.28	0.02	2.29
Avg.	1387.27	10.99	0.54	0.02	0.02	3.17	2.82	0.02	3.77
Avg. excluding 2014-15	1384.17	10.96	0.52	0.02	0.01	3.25	2.74	0.02	3.82

Table - H.3 Water availability at Purushottampur

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	7	8	9	10= 3+4+5+6+7+9
1985-86	1394.43	9.77	0.68	0.03	0.31	2.97		0.03	4.02
1986-87	1509.55	10.57	0.35	0.03	0.14	3.64	--	0.03	4.18
1987-88	1136.20	7.96	0.66	0.03	0.03	1.28	--	0.02	2.02
1988-89	1291.13	9.04	0.74	0.03	-0.35	2.72	--	0.02	3.16
1989-90	1625.27	11.38	0.63	0.03	0.45	2.87	--	0.03	4.00
1990-91	1608.58	11.26	0.45	0.03	-0.06	4.40	--	0.03	4.84
1991-92	1504.43	10.54	0.36	0.03	-0.15	4.24	--	0.02	4.51
1992-93	1474.81	10.33	0.41	0.03	-0.01	3.56	--	0.03	4.02
1993-94	1273.80	8.92	0.50	0.03	-0.18	2.61	1.43	0.02	2.99
1994-95	1931.79	13.53	0.44	0.03	0.12	5.65	2.98	0.02	6.27
1995-96	1340.57	9.39	0.90	0.03	0.06	2.83	3.46	0.03	3.85
1996-97	970.00	6.79	0.81	0.03	-0.08	1.01	1.09	0.02	1.79
1997-98	1417.18	9.92	0.51	0.03	0.18	2.49	1.61	0.02	3.24
1998-99	1263.71	8.85	1.00	0.04	-0.16	1.62	2.69	0.03	2.53
1999-00	1352.27	9.47	0.51	0.04	0.15	2.22	1.56	0.02	2.94
2000-01	1070.45	7.50	0.85	0.04	-0.10	1.55	0.98	0.02	2.36
2001-02	1459.05	10.22	0.73	0.04	-0.05	2.35	2.42	0.03	3.09
2002-03	1108.66	7.76	0.72	0.04	-0.05	1.24	0.88	0.02	1.97
2003-04	1574.97	11.03	0.35	0.04	0.21	4.15	3.34	0.03	4.78
2004-05	925.42	6.48	0.68	0.04	-0.19	1.04	1.10	0.05	1.62
2005-06	1583.71	11.09	0.33	0.04	0.21	3.19	2.75	0.04	3.80
2006-07	1478.81	10.36	0.71	0.04	-0.01	4.26	2.91	0.03	5.03
2007-08	1454.82	10.19	0.94	0.04	-0.23	2.95	2.62	0.03	3.74
2008-09	1254.47	8.79	1.01	0.04	0.10	2.36	2.07	0.02	3.53
2009-10	1483.73	10.39	1.10	0.04	0.06	2.10	2.20	0.03	3.33
2010-11	1579.45	11.06	0.77	0.04	0.26	2.33	2.81	0.04	3.44
2011-12	1068.13	7.48	1.50	0.04	-0.27	0.35	1.02	0.01	1.63
2012-13	1463.31	10.25	0.89	0.04	0.06	2.32	1.50	0.07	3.38
2013-14	2024.34	14.18	1.39	0.04	0.18	5.93	5.10	0.05	7.60
2014-15	1413.43	9.90	1.89	0.04	-0.05	0.00	2.73	0.03	1.91
Average	1401.22	9.81	0.76	0.04	0.02	2.48	2.24	0.03	3.52
Average excluding 2014-15	1400.79	9.81	0.72	0.04	0.02	2.77	2.21	0.03	3.57

Table - H.4 Water Availability at Srikakulam

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	9= 3+4+5+6+8
1985-86	1193.77	10.32	0.95	0.03	0.22	0.73	--	0.05	1.98
1986-87	1298.45	11.22	0.51	0.03	0.07	2.98	--	0.03	3.63
1987-88	1101.16	9.52	0.48	0.03	-0.09	1.34	--	0.03	1.78
1988-89	1154.72	9.98	0.58	0.03	0.01	2.14	--	0.02	2.78
1989-90	1740.89	15.05	0.77	0.03	0.53	3.95	--	0.03	5.30
1990-91	1441.56	12.46	0.66	0.03	-0.38	3.86	--	0.03	4.19
1991-92	1480.55	12.80	0.86	0.03	-0.05	4.41	3.73	0.03	5.27
1992-93	1535.33	13.27	0.55	0.03	-0.02	3.84	3.34	0.03	4.43
1993-94	1110.78	9.60	0.33	0.03	-0.11	1.90	1.45	0.02	2.17
1994-95	1587.49	13.72	0.59	0.03	0.46	3.57	3.09	0.03	4.68
1995-96	1283.56	11.09	1.06	0.03	-0.30	2.28	3.08	0.05	3.12
1996-97	1066.48	9.22	0.44	0.04	-0.06	2.10	2.54	0.02	2.54
1997-98	1107.73	9.57	0.45	0.04	-0.07	1.71	1.23	0.03	2.15
1998-99	1246.68	10.77	1.11	0.04	0.12	1.43	2.44	0.05	2.76
1999-00	1056.90	9.13	0.49	0.04	0.04	1.20	1.22	0.03	1.80
2000-01	1015.40	8.78	0.62	0.04	-0.07	1.85	1.34	0.02	2.46
2001-02	1422.82	12.30	1.01	0.04	0.15	3.12	2.01	0.03	4.34
2002-03	846.68	7.32	0.56	0.04	-0.36	1.35	0.55	0.02	1.61
2003-04	1526.77	13.20	0.88	0.04	0.38	3.73	2.37	0.02	5.05
2004-05	1131.09	9.78	0.34	0.04	-0.22	2.96	1.74	0.03	3.15
2005-06	1331.40	11.51	0.63	0.04	0.28	3.15	1.92	0.06	4.16
2006-07	1738.35	15.02	1.60	0.04	-0.02	8.88	4.67	0.05	10.55
2007-08	1769.52	15.29	0.88	0.04	0.12	7.18	3.76	0.08	8.30
2008-09	1448.56	12.52	0.94	0.04	-0.37	6.04	2.78	0.03	6.67
2009-10	1297.21	11.21	1.47	0.04	0.19	0.86	2.16	0.06	2.62
2010-11	1499.84	12.96	0.68	0.04	0.25	2.91	5.91	0.05	3.94
2011-12	1013.63	8.76	1.47	0.04	-0.42	0.78	1.72	0.04	1.91
2012-13	1317.55	11.39	0.99	0.04	0.16	2.49	2.60	0.04	3.72
2013-14	1526.57	13.19	1.66	0.04	0.16	1.75	3.54	0.05	3.66
2014-15	1387.29	11.99	2.92	0.04	-0.03	0.00	4.07	0.02	2.95
Average	1322.62	11.43	0.88	0.04	0.02	2.90	2.64	0.04	3.79
Average excluding 2014-15	1320.39	11.41	0.81	0.04	0.02	2.91	2.57	0.04	3.82

Table - H.5 Water resources availability in EFR between Mahanadi & Pennar

Year	Rainfall	Q-Calibrated	ECII	DIL	GW Flux	Import	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1985-86	93.72	19.39	4.57	0.17	1.28	7.42	1.71	19.70
1986-87	96.60	28.07	4.61	0.17	0.20	8.27	1.10	25.88
1987-88	91.18	21.35	4.41	0.17	0.48	7.42	1.37	20.36
1988-89	90.23	23.61	5.10	0.17	-0.97	8.09	1.73	21.55
1989-90	130.81	37.19	5.54	0.18	6.32	8.44	1.79	42.58
1990-91	97.45	38.10	4.13	0.18	-3.99	7.48	1.30	32.24
1991-92	104.51	38.47	2.58	0.18	-0.70	6.07	1.64	36.10
1992-93	97.71	27.94	4.67	0.18	-0.72	6.42	1.29	26.94
1993-94	80.13	16.04	5.22	0.18	-0.79	7.44	0.95	14.16
1994-95	116.55	37.71	4.03	0.19	4.09	8.22	1.69	39.49
1995-96	92.20	27.56	5.44	0.19	-3.08	6.00	1.63	25.74
1996-97	95.74	25.75	3.68	0.19	0.53	6.45	2.21	25.91
1997-98	91.31	21.98	4.84	0.19	-0.63	8.18	1.50	19.71
1998-99	100.33	25.84	5.74	0.20	-0.35	8.08	2.35	25.70
1999-00	80.02	13.53	4.86	0.20	-0.38	7.94	1.40	11.67
2000-01	85.76	18.43	6.54	0.20	-0.12	7.28	1.69	19.46
2001-02	95.76	24.86	5.12	0.21	-0.26	5.80	1.38	25.51
2002-03	63.53	13.55	6.04	0.21	-5.75	4.34	0.98	10.70
2003-04	106.58	24.98	6.02	0.21	2.81	3.44	1.78	32.36
2004-05	77.87	14.92	6.26	0.22	-1.84	4.78	1.12	15.89
2005-06	110.89	32.74	4.62	0.22	4.99	6.13	1.84	38.28
2006-07	110.21	45.10	7.80	0.22	-1.95	8.67	1.83	44.33
2007-08	118.65	35.67	5.96	0.22	1.61	7.12	2.38	38.72
2008-09	92.11	25.32	7.85	0.22	-1.85	7.28	1.91	26.17
2009-10	92.15	15.14	8.68	0.22	0.70	8.19	1.69	18.24
2010-11	124.92	40.80	4.30	0.23	1.89	5.23	1.98	43.97
2011-12	71.14	9.05	10.83	0.23	-4.40	7.65	1.24	9.30
2012-13	105.34	29.03	5.58	0.23	0.92	3.72	1.78	33.82
2013-14	111.61	31.38	9.76	0.23	1.84	7.22	1.71	37.70
2014-15	84.92	1.63	15.40	0.24	-1.77	6.77	1.49	10.21
Average	97.00	25.50	6.00	0.20	-0.06	6.85	1.62	26.41

EFR BETWEEN PENNAR AND KANYAKUMARI BASIN

Table - I.1 Water availability at Chengalpet sub-basin

Year	Rainfall		ECII	GW flux	DIL flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8=3+4+5+6
1985-86	960.60	15.61	1.75	0.09	0.11	1.21	0.93	3.17
1986-87	659.45	10.72	2.30	-0.80	0.11	0.00	0.01	1.61
1987-88	902.42	14.66	1.49	0.34	0.12	0.00	0.03	1.95
1988-89	773.63	12.57	1.85	-0.07	0.12	0.00	0.01	1.90
1989-90	890.32	14.47	1.10	0.13	0.12	0.30	0.03	1.66
1990-91	695.99	11.31	1.88	-0.26	0.12	0.00	0.05	1.74
1991-92	1,169.06	19.00	1.21	0.81	0.13	4.37	0.93	6.52
1992-93	673.21	10.94	1.91	-0.67	0.13	0.42	0.08	1.79
1993-94	1,074.98	17.47	1.78	0.58	0.13	1.84	0.23	4.34
1994-95	936.88	15.22	1.46	0.24	0.13	0.49	0.18	2.33
1995-96	814.18	13.23	1.71	-0.58	0.14	0.30	0.09	1.56
1996-97	1,252.61	20.35	1.01	0.88	0.14	4.13	1.85	6.16
1997-98	777.37	12.63	1.40	-0.55	0.14	1.22	1.09	2.22
1998-99	1,064.22	17.29	1.51	0.29	0.15	1.82	1.33	3.76
1999-00	698.28	11.35	2.17	-1.10	0.15	0.00	0.03	1.22
2000-01	931.52	15.14	1.23	-0.01	0.15	0.70	0.01	2.06
2001-02	671.47	10.91	2.42	0.20	0.15	0.00	0.07	2.77
2002-03	377.26	6.13	3.05	-1.32	0.16	0.00	0.01	1.89
2003-04	707.79	11.50	2.52	0.86	0.16	0.00	0.00	3.53
2004-05	747.12	12.14	1.40	-0.63	0.16	0.16	0.02	1.10
2005-06	1,258.03	20.44	1.64	1.89	0.17	3.66	0.46	7.36
2006-07	762.71	12.39	2.09	-1.25	0.17	0.06	0.02	1.07
2007-08	1,057.08	17.18	1.51	0.97	0.17	0.42	0.16	3.07
2008-09	896.31	14.56	2.19	-0.53	0.18	1.19	0.17	3.02
2009-10	838.72	13.63	1.99	-0.12	0.18	0.00	0.05	2.05
2010-11	1,015.09	16.50	1.40	0.56	0.18	0.51	0.18	2.65
2011-12	955.88	15.53	1.72	-0.59	0.19	0.55	0.10	1.87
2012-13	1,025.53	16.66	1.71	-0.35	0.19	1.17	0.01	2.73
2013-14	755.66	12.28	2.31	-0.43	0.20	0.00	0.01	2.08
2014-15	758.42	12.32	1.67	0.00	0.20	0.00	0.00	1.87
Avg.	870.06	14.14	1.78	-0.05	0.15	0.82	0.27	2.70

Table - I.2 Water availability at Vilupuram on river Ponnaiyar

Year	Rainfall		ECII	GW flux	DIL flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8=3+4+5+6
1985-86	804.62	10.65	1.62	0.20	0.08	0.00	0.09	1.90
1986-87	801.73	10.61	1.20	-0.17	0.08	0.25	0.04	1.36
1987-88	845.20	11.18	1.45	0.20	0.09	0.00	0.06	1.74
1988-89	736.49	9.74	1.41	-0.38	0.09	0.72	0.04	1.83
1989-90	829.61	10.98	0.74	0.24	0.10	0.11	0.01	1.19
1990-91	614.23	8.13	1.34	-0.19	0.10	0.00	0.00	1.25
1991-92	1,022.37	13.53	0.85	0.68	0.10	2.39	1.01	4.02
1992-93	698.98	9.25	1.07	-0.39	0.11	0.46	0.19	1.25
1993-94	966.36	12.79	1.47	0.36	0.11	0.57	0.33	2.51
1994-95	770.88	10.20	1.15	-0.18	0.12	0.39	0.08	1.48
1995-96	736.78	9.75	1.31	-0.22	0.13	0.00	0.00	1.22
1996-97	1,090.32	14.43	0.78	0.63	0.13	2.51	1.71	4.04
1997-98	745.61	9.86	1.02	-0.18	0.14	0.49	0.90	1.47
1998-99	1,029.56	13.62	0.99	0.12	0.14	1.57	0.80	2.82
1999-00	743.24	9.83	1.22	-0.35	0.15	0.01	0.06	1.03
2000-01	921.89	12.20	0.87	0.23	0.16	1.18	0.18	2.44
2001-02	628.56	8.32	1.54	-0.30	0.17	0.09	0.10	1.50
2002-03	330.58	4.37	1.70	-0.88	0.17	0.00	0.00	0.99
2003-04	653.63	8.65	1.71	0.66	0.18	0.00	0.00	2.55
2004-05	728.86	9.64	1.01	-0.16	0.19	0.00	0.15	1.05
2005-06	1,221.50	16.16	0.85	1.14	0.20	2.61	1.86	4.80
2006-07	727.44	9.62	1.30	-1.09	0.21	0.29	0.01	0.70
2007-08	1,028.46	13.61	0.98	0.35	0.22	0.48	0.21	2.03
2008-09	904.87	11.97	1.15	-0.20	0.23	0.67	0.21	1.85
2009-10	780.68	10.33	1.29	-0.10	0.24	0.20	0.01	1.63
2010-11	1,047.86	13.86	1.03	0.69	0.25	0.42	0.39	2.38
2011-12	874.07	11.56	1.39	-0.64	0.26	0.01	0.12	1.02
2012-13	727.85	9.63	1.76	-0.28	0.27	0.00	0.02	1.75
2013-14	774.25	10.24	1.33	0.01	0.29	0.00	0.00	1.62
2014-15	862.27	11.41	1.16	0.33	0.30	0.00	0.00	1.79
Average	821.62	10.87	1.22	0.00	0.17	0.51	0.29	1.91

Table - I.3 Water availability at Paramakudi in river Vaigai

Year	Rainfall		ECII	GW flux	DIL flux	Calibrated Runoff	Observed Runoff	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8=3+4+5+6
1985-86	827.49	4.70	0.93	0.08	0.03	0.00	0.01	1.05
1986-87	758.89	4.31	1.85	-0.04	0.03	0.00	0.00	1.84
1987-88	1,140.04	6.48	0.63	0.38	0.04	0.38	0.03	1.43
1988-89	784.46	4.46	1.75	-0.28	0.04	0.00	0.00	1.51
1989-90	1,071.43	6.09	0.58	0.17	0.04	0.35	0.03	1.14
1990-91	989.85	5.63	1.34	-0.03	0.04	0.00	0.01	1.35
1991-92	1,093.81	6.22	0.71	-0.21	0.04	0.28	0.00	0.81
1992-93	1,120.35	6.37	1.25	0.22	0.04	0.06	0.18	1.57
1993-94	1,360.48	7.73	1.10	-0.20	0.04	1.64	0.53	2.58
1994-95	1,202.03	6.83	0.57	0.39	0.04	0.61	0.26	1.62
1995-96	897.88	5.10	1.70	-0.27	0.04	0.00	0.00	1.48
1996-97	1,118.54	6.36	1.27	0.15	0.05	0.00	0.01	1.47
1997-98	1,343.10	7.63	0.81	0.15	0.05	1.61	0.45	2.62
1998-99	1,505.64	8.56	1.09	0.04	0.05	1.61	0.51	2.79
1999-00	1,121.93	6.38	1.26	-0.11	0.05	0.36	0.02	1.57
2000-01	1,188.21	6.75	0.59	-0.08	0.05	0.58	0.01	1.14
2001-02	629.22	3.58	2.30	-0.11	0.05	0.00	0.02	2.24
2002-03	580.10	3.30	2.30	-0.16	0.05	0.00	0.00	2.20
2003-04	654.32	3.72	2.29	-0.14	0.06	0.00	0.00	2.21
2004-05	1,361.26	7.74	0.52	0.43	0.06	0.44	0.02	1.45
2005-06	1,541.07	8.76	0.79	0.16	0.06	1.70	0.24	2.72
2006-07	980.55	5.57	1.44	-0.23	0.06	0.00	0.04	1.28
2007-08	1,686.11	9.58	1.02	0.34	0.06	1.11	0.18	2.54
2008-09	1,232.92	7.01	0.82	-0.26	0.07	0.82	0.06	1.44
2009-10	1,321.96	7.51	1.53	-0.17	0.07	0.47	0.02	1.90
2010-11	1,536.90	8.74	0.97	0.27	0.07	0.98	0.07	2.29
2011-12	2,188.99	12.44	0.95	0.07	0.07	4.38	0.03	5.47
2012-13	1,552.17	8.82	1.14	-0.34	0.07	1.88	0.00	2.75
2013-14	1,076.68	6.12	1.81	-0.22	0.08	0.00	0.00	1.67
2014-15	1,394.32	7.93	0.18	0.58	0.08	0.20	0.02	1.04
Avg.	1175.36	6.68	1.18	0.02	0.05	0.65	0.09	1.91

Table - I.4 Water availability at Murappanad in river Tambraparani

Year	Rainfall		ECII	GW flux	DIL flux	Calibrated Runoff	Observed Runoff	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2a	2b	3	4	5	6	7	8=3+4+5+6
1985-86	783.84	3.59	0.43	0.03	0.05	0.00	0.29	0.51
1986-87	484.37	2.22	0.82	-0.24	0.05	0.00	0.23	0.63
1987-88	1,038.76	4.76	0.35	0.39	0.05	0.52	0.34	1.32
1988-89	560.49	2.57	0.69	-0.32	0.05	0.00	0.24	0.43
1989-90	1,043.89	4.79	0.37	0.17	0.05	0.91	0.38	1.50
1990-91	1,028.92	4.72	0.19	0.38	0.05	0.30	0.52	0.92
1991-92	1,086.48	4.98	0.42	-0.16	0.05	0.21	0.39	0.53
1992-93	1,256.44	5.76	0.18	0.08	0.05	1.09	1.00	1.40
1993-94	1,245.44	5.71	0.58	0.27	0.05	0.82	1.21	1.72
1994-95	1,170.98	5.37	0.35	-0.13	0.05	0.36	0.56	0.64
1995-96	753.62	3.46	0.71	-0.32	0.05	0.00	0.24	0.44
1996-97	890.39	4.08	0.77	0.01	0.05	0.00	0.22	0.84
1997-98	1,130.63	5.18	0.49	0.31	0.05	0.20	0.88	1.05
1998-99	1,295.98	5.94	0.75	-0.09	0.05	0.66	0.42	1.38
1999-00	1,075.61	4.93	0.20	-0.04	0.05	0.57	0.39	0.79
2000-01	1,008.51	4.62	0.37	0.02	0.05	0.00	0.45	0.45
2001-02	560.57	2.57	0.84	-0.14	0.05	0.00	0.28	0.76
2002-03	586.94	2.69	0.85	-0.03	0.05	0.00	0.30	0.88
2003-04	650.70	2.98	0.91	-0.04	0.05	0.00	0.28	0.93
2004-05	1,618.92	7.42	0.25	0.31	0.05	1.06	0.94	1.67
2005-06	950.85	4.36	0.59	0.03	0.05	0.00	0.66	0.66
2006-07	1,418.21	6.50	0.17	0.08	0.05	1.94	1.37	2.25
2007-08	1,539.00	7.06	0.48	0.12	0.05	0.87	0.75	1.53
2008-09	1,027.21	4.71	0.31	-0.17	0.05	0.66	0.69	0.85
2009-10	993.07	4.55	0.62	-0.06	0.05	0.33	0.46	0.95
2010-11	1,521.96	6.98	0.27	-0.13	0.05	1.16	0.35	1.36
2011-12	2,026.29	9.29	0.36	0.05	0.05	2.56	0.36	3.02
2012-13	1,378.79	6.32	0.20	-0.13	0.05	1.45	0.17	1.57
2013-14	1,142.69	5.24	0.67	0.02	0.05	0.00	0.40	0.74
2014-15	1,252.93	5.74	0.04	0.44	0.05	0.58	0.62	1.11
Avg.	1084.08	4.97	0.48	0.02	0.05	0.54	0.51	1.09

Table - I.5 Water resources availability in EFR between Pennar & Kanyakumari basin

Year	Rainfall	Q- Calibrated	ECII	GW flux	DIL flux	Reservoir Evaporation	Water Availability
1	2	3	4	5	6	7	8=3+4+5+6
	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1985-86	104.04	12.64	12.74	0.84	0.49	0.48	27.18
1986-87	72.71	1.07	17.03	-4.37	0.50	0.32	14.56
1987-88	104.02	8.72	11.08	3.35	0.52	0.46	24.14
1988-89	77.89	2.63	17.02	-4.94	0.54	0.34	15.60
1989-90	100.00	6.34	9.99	2.22	0.57	0.45	19.57
1990-91	84.21	6.30	13.11	-0.58	0.59	0.33	19.76
1991-92	109.30	33.15	9.77	-8.83	0.61	0.46	35.17
1992-93	86.40	9.15	12.31	1.06	0.64	0.31	23.47
1993-94	119.53	24.27	12.87	4.11	0.67	0.35	42.27
1994-95	105.19	15.52	10.18	0.42	0.69	0.46	27.27
1995-96	77.70	0.59	16.56	-5.89	0.72	0.35	12.32
1996-97	122.70	23.92	11.43	4.81	0.76	0.39	41.30
1997-98	100.46	19.84	11.46	-0.32	0.79	0.40	32.17
1998-99	117.50	20.69	12.11	0.95	0.82	0.37	34.94
1999-00	88.85	8.07	12.45	-3.85	0.86	0.33	17.86
2000-01	93.24	5.50	9.74	-0.42	0.90	0.44	16.17
2001-02	57.38	0.85	20.59	-0.99	0.94	0.29	21.68
2002-03	40.80	0.00	22.18	-7.82	0.98	0.28	15.63
2003-04	56.29	0.00	22.00	2.45	1.03	0.33	25.81
2004-05	101.67	14.13	9.09	1.39	1.08	0.42	26.12
2005-06	136.24	36.04	12.61	6.85	1.13	0.37	56.99
2006-07	88.61	12.67	13.12	-5.89	1.18	0.34	21.43
2007-08	125.22	12.57	11.08	6.08	1.24	0.44	31.41
2008-09	102.88	19.40	12.24	-3.31	1.30	0.33	29.96
2009-10	93.59	9.40	16.33	-1.46	1.36	0.33	25.96
2010-11	138.34	23.80	10.18	2.91	1.43	0.37	38.69
2011-12	145.29	31.12	11.62	-1.17	1.50	0.39	43.46
2012-13	116.54	12.63	14.88	-3.31	1.58	0.36	26.13
2013-14	80.55	0.00	18.78	-2.59	1.65	0.36	18.21
2014-15	92.92	4.13	7.50	3.32	1.74	0.26	16.94
Average	98.00	12.50	13.41	-0.50	0.96	0.37	26.74

MINOR RIVERS DRAINING INTO MYANMAR (BURMA) AND BANGLADESH BASIN

Table - J.1 Water availability at Manipur sub-basin

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Reservoir Evap.	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8	10= 3+4+5+6+8
1985-86	1403.22	24.44	0.70	0.03	0.19	9.15	N.A.	0.31	10.38
1986-87	1438.71	25.06	0.21	0.03	-0.23	8.42	N.A.	0.48	8.90
1987-88	1730.12	30.14	0.32	0.03	-0.05	12.39	N.A.	0.32	13.02
1988-89	1462.91	25.48	0.20	0.03	0.23	7.75	N.A.	0.46	8.67
1989-90	1887.72	32.88	0.02	0.03	-0.04	15.96	N.A.	0.51	16.48
1990-91	2060.41	35.89	0.14	0.03	0.00	18.45	N.A.	0.37	19.00
1991-92	2005.53	34.93	0.02	0.03	0.00	17.38	N.A.	0.39	17.82
1992-93	1979.49	34.48	0.19	0.03	-0.04	17.44	N.A.	0.37	17.99
1993-94	1668.66	29.07	0.58	0.03	-0.02	12.91	N.A.	0.29	13.79
1994-95	1405.62	24.48	0.77	0.03	-0.05	7.12	N.A.	0.36	8.23
1995-96	1533.84	26.72	0.28	0.03	0.04	9.38	N.A.	0.54	10.27
1996-97	1485.77	25.88	0.24	0.03	-0.09	8.69	N.A.	0.39	9.26
1997-98	1571.93	27.38	0.56	0.04	-0.10	10.57	N.A.	0.38	11.44
1998-99	1348.58	23.49	0.73	0.04	0.00	6.90	N.A.	0.26	7.92
1999-00	1679.99	29.26	0.17	0.04	0.00	11.86	N.A.	0.54	12.60
2000-01	1376.26	23.97	0.29	0.04	0.00	7.37	N.A.	0.49	8.20
2001-02	1451.04	25.28	0.35	0.04	0.00	7.69	N.A.	0.38	8.45
2002-03	1364.37	23.77	0.41	0.04	0.00	7.94	N.A.	0.53	8.93
2003-04	1662.13	28.95	0.32	0.04	0.00	11.13	N.A.	0.51	12.00
2004-05	2323.29	40.47	0.02	0.04	-0.07	16.41	N.A.	0.50	16.91
2005-06	1477.30	25.73	0.18	0.04	0.00	9.52	N.A.	0.46	10.20
2006-07	1509.12	26.29	0.91	0.04	0.00	10.39	N.A.	0.30	11.64
2007-08	1869.78	32.57	0.06	0.04	0.00	14.59	N.A.	0.40	15.09
2008-09	1946.85	33.91	0.21	0.04	0.00	17.78	N.A.	0.20	18.23
2009-10	1581.64	27.55	0.43	0.05	0.00	8.61	N.A.	0.42	9.50
2010-11	1849.81	32.22	0.21	0.05	0.00	14.25	N.A.	0.39	14.89
2011-12	1818.55	31.68	0.64	0.05	0.00	14.62	N.A.	0.33	15.63
2012-13	1449.82	25.25	1.03	0.05	0.00	13.06	N.A.	0.26	14.40
2013-14	1416.17	24.67	0.50	0.05	0.00	7.70	N.A.	0.35	8.59
2014-15	1276.63	22.24	0.99	0.05	0.00	6.10	N.A.	0.39	7.54
Avg.	1634.51	28.47	0.39	0.04	-0.01	11.38	N.A.	0.40	12.20

Table - J.2 Water availability at Mizoram sub-basin

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Q-Observed	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	7	8= 3+4+5+6
1985-86	2325.40	28.41	0.13	0.01	0.00	14.23	N.A.	14.37
1986-87	2493.80	30.47	0.07	0.01	0.00	14.44	N.A.	14.53
1987-88	3190.88	38.98	0.15	0.01	0.00	21.26	N.A.	21.42
1988-89	3074.93	37.57	0.07	0.01	0.00	19.91	N.A.	20.00
1989-90	3560.94	43.50	0.08	0.01	0.00	25.63	N.A.	25.73
1990-91	3880.95	47.41	0.04	0.01	0.00	28.68	N.A.	28.73
1991-92	2995.05	36.59	0.04	0.01	0.00	19.61	N.A.	19.66
1992-93	3340.51	40.81	0.08	0.01	0.00	23.33	N.A.	23.43
1993-94	3310.16	40.44	0.04	0.02	0.00	23.58	N.A.	23.63
1994-95	1326.40	16.20	0.30	0.02	0.00	4.89	N.A.	5.20
1995-96	2664.89	32.56	0.08	0.02	0.00	15.72	N.A.	15.82
1996-97	2265.06	27.67	0.11	0.02	0.00	12.67	N.A.	12.80
1997-98	2747.63	33.57	0.12	0.02	0.00	16.79	N.A.	16.93
1998-99	2550.82	31.16	0.15	0.02	0.00	15.19	N.A.	15.36
1999-00	3088.34	37.73	0.08	0.02	0.00	20.23	N.A.	20.33
2000-01	2467.64	30.15	0.07	0.02	0.00	14.94	N.A.	15.03
2001-02	2833.60	34.62	0.01	0.02	0.00	19.08	N.A.	19.11
2002-03	2270.83	27.74	0.01	0.02	0.00	14.12	N.A.	14.15
2003-04	2852.96	34.85	0.01	0.02	0.00	20.61	N.A.	20.64
2004-05	2696.15	32.94	0.03	0.02	0.00	15.10	N.A.	15.14
2005-06	1713.35	20.93	0.03	0.02	0.00	9.59	N.A.	9.64
2006-07	2196.54	26.84	0.21	0.02	0.00	11.37	N.A.	11.60
2007-08	2540.58	31.04	0.11	0.02	0.00	15.05	N.A.	15.19
2008-09	2789.76	34.08	0.09	0.02	0.00	17.18	N.A.	17.30
2009-10	1850.75	22.61	0.10	0.02	0.00	12.41	N.A.	12.53
2010-11	2309.09	28.21	0.04	0.07	0.00	13.63	N.A.	13.74
2011-12	2108.96	25.77	0.19	0.07	0.00	11.78	N.A.	12.04
2012-13	1724.52	21.07	0.17	0.08	0.00	11.93	N.A.	12.18
2013-14	1809.14	22.10	0.01	0.08	0.00	8.81	N.A.	8.90
2014-15	1803.71	22.04	0.03	0.08	0.00	8.32	N.A.	8.43
Avg.	2559.44	31.27	0.09	0.03	0.00	16.00	N.A.	16.12

Table - J.3 Water availability at Tripura sub-basin

Year	Rainfall		ECII	DIL	GW Flux	Q-Calibrated	Water Availability
	mm	BCM	BCM	BCM	BCM	BCM	BCM
1	2(a)	2(b)	3	4	5	6	8= 3+4+5+6
1985-86	1963.62	3.42	0.09	0.01	-0.02	2.13	2.20
1986-87	2649.25	4.62	0.00	0.01	-0.03	3.16	3.14
1987-88	2966.34	5.17	0.01	0.01	-0.09	3.72	3.65
1988-89	3343.04	5.83	0.00	0.01	0.14	4.14	4.28
1989-90	3276.92	5.71	0.00	0.01	-0.04	4.24	4.21
1990-91	3466.71	6.05	0.00	0.01	-0.05	4.46	4.43
1991-92	3056.78	5.33	0.00	0.01	-0.09	3.90	3.83
1992-93	3031.84	5.29	0.00	0.01	0.00	3.76	3.77
1993-94	3160.15	5.51	0.00	0.01	0.00	3.95	3.96
1994-95	1807.57	3.15	0.05	0.01	0.21	3.69	3.96
1995-96	2665.80	4.65	0.00	0.01	-0.06	3.06	3.01
1996-97	2062.89	3.60	0.00	0.01	-0.02	2.19	2.17
1997-98	2635.58	4.60	0.02	0.01	-0.08	3.11	3.07
1998-99	2486.04	4.34	0.05	0.01	0.00	2.87	2.93
1999-00	2926.00	5.10	0.00	0.01	0.00	3.55	3.56
2000-01	2175.63	3.79	0.01	0.01	-0.04	1.97	1.95
2001-02	2385.79	4.16	0.00	0.01	0.03	2.78	2.82
2002-03	2188.71	3.82	0.01	0.01	0.06	1.82	1.90
2003-04	2509.86	4.38	0.01	0.01	-0.02	3.04	3.03
2004-05	2583.29	4.51	0.00	0.01	0.02	2.97	3.01
2005-06	1701.10	2.97	0.00	0.01	-0.07	1.70	1.64
2006-07	1812.37	3.16	0.07	0.01	0.00	1.71	1.79
2007-08	2472.65	4.31	0.03	0.01	0.00	2.73	2.77
2008-09	2166.69	3.78	0.02	0.01	0.00	2.32	2.35
2009-10	2277.69	3.97	0.01	0.01	0.00	2.45	2.47
2010-11	1866.57	3.26	0.02	0.01	0.00	1.55	1.58
2011-12	1931.31	3.37	0.10	0.01	0.00	1.94	2.05
2012-13	2229.86	3.89	0.03	0.01	0.00	2.53	2.57
2013-14	1663.60	2.90	0.03	0.01	0.00	1.51	1.55
2014-15	2087.71	3.64	0.03	0.01	0.00	1.76	1.80
Avg.	2451.71	4.28	0.02	0.01	-0.005	2.82	2.85

Table - J.4 Water resources availability in Minor rivers draining into Myanmar (Burma) and Bangladesh basin

Year	Rainfall	Irrigation Support	DIL	GW Flux	Reservoir Flux	Q-Calibrated	Reservoir Evap.	Water Availability
	BCM	BCM	BCM	BCM	BCM	BCM	BCM	BCM
1	2	3	4	5	6	7	8	9=3+4+5+6+7+8
1985-86	52.85	0.91	0.05	0.17	0.00	25.51	0.31	26.94
1986-87	56.53	0.28	0.05	-0.27	0.00	26.02	0.48	26.56
1987-88	69.83	0.49	0.05	-0.14	0.00	37.36	0.32	38.08
1988-89	64.30	0.27	0.05	0.37	0.00	31.80	0.46	32.95
1989-90	77.21	0.11	0.05	-0.08	0.00	45.83	0.51	46.42
1990-91	84.82	0.18	0.05	-0.05	0.00	51.59	0.37	52.15
1991-92	73.85	0.06	0.06	-0.09	0.00	40.89	0.39	41.31
1992-93	76.89	0.27	0.06	-0.04	0.00	44.53	0.37	45.19
1993-94	70.96	0.62	0.06	-0.02	0.00	40.44	0.29	41.39
1994-95	42.95	1.12	0.06	0.16	0.00	15.70	0.36	17.39
1995-96	60.81	0.36	0.06	-0.02	0.00	28.16	0.54	29.10
1996-97	54.65	0.35	0.06	-0.12	0.00	23.55	0.39	24.23
1997-98	62.33	0.70	0.06	-0.18	0.00	30.47	0.38	31.43
1998-99	55.81	0.93	0.06	0.00	0.00	24.96	0.26	26.21
1999-00	67.77	0.25	0.06	0.00	0.00	35.63	0.54	36.49
2000-01	54.89	0.38	0.07	-0.04	0.00	24.28	0.49	25.18
2001-02	60.47	0.36	0.07	0.03	0.00	29.55	0.38	30.38
2002-03	52.65	0.44	0.07	0.06	0.00	23.88	0.53	24.98
2003-04	64.26	0.34	0.07	-0.02	0.00	34.78	0.51	35.68
2004-05	60.41	0.06	0.07	-0.05	0.00	34.48	0.50	35.07
2005-06	47.44	0.21	0.07	-0.07	0.00	20.80	0.46	21.47
2006-07	53.02	1.19	0.07	0.00	0.00	23.48	0.30	25.04
2007-08	64.38	0.20	0.08	0.00	0.00	32.37	0.40	33.04
2008-09	67.89	0.33	0.08	0.00	0.00	37.29	0.20	37.89
2009-10	55.64	0.53	0.08	0.00	0.00	23.48	0.42	24.51
2010-11	65.44	0.27	0.13	0.00	0.00	29.43	0.39	30.22
2011-12	56.33	0.92	0.13	0.00	0.00	28.33	0.33	29.72
2012-13	52.92	1.24	0.13	0.00	0.00	27.52	0.26	29.15
2013-14	52.30	0.54	0.14	0.00	0.00	18.02	0.35	19.04
2014-15	50.39	1.06	0.14	0.00	0.00	16.18	0.39	17.77
Avg.	61.00	0.50	0.07	-0.01	0.00	30.21	0.40	31.17