Chapter 5
Hydrology and Water Assessment

5.1 General

Planning for water resources development in a basin requires careful assessment of the available water resources and reasonable needs of the basin in foreseeable future for various purposes such as drinking, irrigation, hydro-power, industries, navigation etc. Hydrological studies are carried out to assess the available quantity of water in a given basin. This chapter deals with the assessment of water balance in the Godavari basin upto Inchampalli barrage site, in the basins lying enroute the link alignment, in the Krishna basin upto the Nagarjunasagar dam site and simulation study of Inchampalli reservoir. The Isohyetal map of Godavari & Krishna basins are given in **Plate No. 5.1** & **5.2** respectively.

5.2 Hydrological analysis

NWDA has prepared water balance study reports at Inchampalli barrage site on river Godavari, Nagarjunasagar dam site on river Krishna and of the basins lying enroute the link alignment. The methodology adopted by NWDA for computing the water balance of a sub-basin is discussed in the following paragraphs.

5.2.1 Surface water availability

Observed flow data at the terminal G&D site and the rainfall observed at various raingauge stations in and around the catchment of a sub-basin are collected. To these observed flows, year-wise upstream utilisations are added to get virgin yields. Weighted rainfall for the catchment upto the G&D site and for the whole sub-basin are worked out. Using these virgin flows and weighted rainfall upto the G&D site, a rainfall-runoff relationship (linear/non-linear) is developed by statistical methods. Using the best fit equation and weighted rainfall for the entire sub-basin, monsoon yields are computed. To the monsoon yields, non-monsoon yields are added for arriving at annual gross yields for the entire sub-basin. The annual gross yields thus arrived at are arranged in

descending order, from which 50% and 75% dependable annual gross yields are obtained.

The overall surface water available in a sub-basin is arrived at by summing up the yield (at 50% and 75% dependabilities separately), and imports and by deducting the exports if any, from the sub-basin.

5.2.2 Water requirement

The requirements of water at the ultimate stage for various uses viz. irrigation, domestic, industrial and hydro power are worked out as follows:

a) Irrigation needs: The requirements for irrigation are worked out for all the existing, ongoing and proposed major, medium and minor projects in a sub-basin. For this purpose, all the projects planned by the States as per their Master Plans are considered. The designed annual utilisation is considered for the existing and ongoing projects. The requirements for future projects are determined by adopting intensities of irrigation as 150%, 125% and 100% for major, medium and minor projects respectively. For assessing the crop water requirements by climatological approach, the potential evapo-transpiration values for various stations as given in the IMD scientific report No.136 (1971) or 'Estimation of Weekly Potential Evapo-transpiration and Climatic Soil Water Balance for 144 locations in India, 2008' as available are adopted. In the case of a deficit basin, if the ultimate annual irrigation considering all the existing, ongoing and future major, medium and minor projects works out to less than 30% of the maximum culturable area of the sub-basin, the requirements are calculated by increasing the annual irrigation to 30% of the maximum culturable area of the sub-basin. And in the case of a surplus basin, the annual irrigation at the ultimate stage is increased to 60% of the maximum culturable area or to such maximum percentage that may be possible to utilise the entire available waters of the sub-basin. 50% of such increased annual irrigation is considered to be under future medium projects and the remaining 50% under future minor schemes.

b) Domestic needs: The requirement of water for domestic consumption by the rural and urban human population and for the livestock is estimated by projecting the rural, urban human population and the livestock of the catchment

to 2050 AD using the available census data. Per capita per day water requirement of 70 litre, 135 litre and 50 litre is considered for the rural and urban human population and livestock respectively. The requirement of 50% of the rural human population and of the entire livestock is considered to be met from groundwater and the requirement for the remaining 50% of rural population and the entire urban population is considered to be met from surface water.

c) Industrial needs: In the absence of relevant data to estimate precisely the industrial water needs, industrial requirement is taken to be equivalent to the total domestic requirement for human population and livestock. The entire industrial requirement is considered to be met from surface water.

d) Hydro power needs: Requirement for the hydro power is taken to be the evaporation losses at the reservoirs with hydro-power production. Wherever the evaporation data of the projects is available, the same is made use of and wherever the data is not available, the same is worked out from the surface area of water in the reservoir, assuming suitable evaporation depths.

5.2.3 Regeneration

The regeneration is considered as (a) 10% of the net utilisation for irrigation from all the existing, ongoing and future identified major and medium projects, and (b) 80% of the domestic and industrial uses to be met from the surface water.

5.2.4 Water balance

The total water requirement of a sub-basin, worked out on the methodology outlined above, is deducted from the overall surface water availability at 75% and 50% dependabilities to determine the water balances (surplus/deficit) at those dependabilities respectively.

5.2.5 Water balance at Indravati sub-basin

The water balance study of the Indravati sub-basin was revised and circulated in 2015. The details of water balance study as extracted from the report are presented below.

The river Indravati is one of the northern tributaries of the Godavari in its lower reach. The Indravati sub-basin lies between latitudes 18^{o} 27’ N and 20^{o} 41’ N and longitudes 80^{o} 05’ E and 83^{o} 07’ E. The river Indravati rises at an altitude of about 914 m near Thuamal Rampur village in the Kalahandi district of Odisha on the western slopes of the Eastern Ghats. It flows westward through the Kalahandi, Nowrangapur and Koraput districts for a length of 164 km and after forming the boundary between Odisha and Chhattisgarh States for a length of 9.5 km, enters the Bastar district of Chhattisgarh. After flowing 233 km in Chhattisgarh, it turns south and flows along the boundary of Chhattisgarh and Maharashtra for about 129 km and joins Godavari at the junction of the boundaries of Maharashtra, Chhattisgarh and Telangana States. The important right bank tributaries of the Indravati are Bhaskal, Narangi, Boardhing, Nibra, Kotri and Bandia. The important left bank tributary is Nandiraj. The Indravati sub-basin has a catchment area of 41665 km^2 and lies in the states of Odisha, Chhattisgarh and Maharashtra.

There are six gauge and discharge sites on the main river Indravati in the Indravati sub-basin, maintained by Central Water Commission. There is one gauge and discharge site on Jouranala at Gindangigura maintained by Odisha State Government. The observations at Gidangigura G&D site are stopped during the year 1996. The catchment area of the Indravati sub-basin upto the Pathagudem site is 40000 km^2 which covers 96 percent of the area of the Indravati sub-basin. Observed monthly flow data are available at the Pathagudem site for the period from 1965-66 to 2010-11. The data for the period 1975-76 to 2010-11 have been used in the hydrological studies since observed monthly flows at the Gidangigura G&D site on the Jouranala which is situated just upstream of its confluence with Sabari, are available from 1975-76 only. For assessing the actual upstream utilisations, both the kharif and rabi utilisations are considered as utilisations during the monsoon period, since the Rabi utilisations are drawn from the storages during the monsoon period. These utilisations are inclusive of evaporation losses.

The gross monsoon (virgin) yields of the sub-basin have been worked out by considering the observed yields at the Pathagudem G&D site, the observed yields of the Jouranala upstream of its confluence with the Sabari, the gross upstream utilisations and regeneration at 10 percent of the net Kharif utilization. There are 13 raingauge stations in and around the Indravati sub-basin and monthly observed rainfall data for these raingauge stations are available for varying periods from 1901 to 2010. Relationship between gross monsoon runoff values at the Pathagudem G&D site and corresponding weighted average monsoon rainfall values of the catchment is established by regression analysis and the non-linear equation is found to be the best fit equation based on lower values of standard error. The non- linear equation adopted is $X_1 = 0.00374408 * X_2^{1.6533}$. The percentage of non-monsoon yield to gross monsoon virgin yield has been worked out and found to be 5.64%. The annual gross yields thus arrived have been arranged in descending order from which the 75 percent and 50 percent dependable gross yields of the Indravati sub-basin have been found to be 21166 Mm^3 and 25531 Mm^3 respectively.

There is an existing import into this sub-basin of 420 Mm^3 of water from Upper Kolab project of Sabari sub-basin and 85 Mm^3 from the proposed Inchampalli project of Lower Godavari sub-basin. Thus, the total import to the Indravati sub-basin works out to 505 Mm^3.

There is an existing export of 2407 Mm^3 from Upper Indravati project of Indravati sub-basin and 728 Mm^3 from the proposed Lower Indravati project to Tel sub-basin of Mahanadi basin. Thus, the export from this sub-basin works out to 3135 Mm^3. Besides this, the natural flows through Jouranala of Indravati waters to the Sabari to the tune of 1352 Mm^3 and 1806 Mm^3 at 75 % and 50% dependabilities as export. Thus, the total export from Indravati sub-basin works out to 4487 Mm^3 and 4941 Mm^3 at 75% and 50% dependabilities respectively.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin from the overall availability and duly considering import and regeneration. The ultimate surface water requirement for irrigation in the basin is given in Table 5.1 below.

Table-5.1
Ultimate Surface Water Requirement for irrigation in Indravati sub-basin.

Category	Annual irrigation (ha)				Annual utilization (Mm^3)			
	Chhattisgarh	Odisha	Maharashtra	Total	Chhattisgarh	Odisha	Maharashtra	Total
1. Existing Projects								
a) Major								
(i) In basin	0	0	0	0	0	0	0	0
(ii) Import	0	54507	0	54507	0	420	0	420
b) Medium	28352	19143	0	47495	253	151	0	404
c) Minor	36905	48334	5155	90394	129	208	18	355
Sub-total	65257	121984	5155	192396	382	779	18	1179
2. Ongoing Projects								
a) Major	0	0	0	0	0	0	0	0
b) Medium	2529	0	2380	4909	23	0	21	44
c) Minor	15385	2076	0	17461	137	10	0	147
Sub-total	17914	2076	2380	22370	160	10	21	191
3. Proposed Projects								
a) Major								
(i) In basin	248180	214928	0	463108	1686	1504	0	3190
(ii) Import	12142	0	0	12142	85	0	0	85
b) Medium	158928	7320	0	166248	1207	55	0	1262
c) Minor	184644	35400	84600	304644	1126	216	516	1858
Sub-total	603894	257648	84600	946142	4104	1775	516	6395
Total	**687065**	**381708**	**92135**	**1160908**	**4646**	**2564**	**555**	**7765**

10% of the net irrigation use by the major and medium projects is considered as regeneration. The total regeneration works out to 482 Mm^3.

The requirement of water for the rural and urban population and for livestock has been computed by projecting them to 2050 AD. The total domestic water needs are assessed to be 313 Mm^3 as shown in **Table 5.2** below:

Table-5.2
Domestic water requirement by 2050 A.D. in Indravati sub-basin.

Category	Population ('000)	Per capita daily needs (litre)	Water requirement (Mm^3)
Odisha			
Rural	934	70	24

Urban	946	135	47
Livestock	1094	50	20
Sub-total			91
Chattisgarh			
Rural	1754	70	45
Urban	1775	135	87
Livestock	3535	50	65
Sub-total			197
Maharashtra			
Rural	235	70	6
Urban	237	135	12
Livestock	403	50	7
Sub-total			25
Sub-basin			
Rural	292	70	75
Urban	295	135	146
Livestock	5032	50	92
Grand total			**313**

The surface water requirement works out to 184 Mm^3 and groundwater requirement is 129 Mm^3. 80 percent of this surface water utilised in the sub-basin for domestic purpose which comes to 147 Mm^3 is considered to be available as return flows to the streams.

There is one existing hydro-electric project in the sub-basin., viz. The Upper Indravati multi-project with an installed capacity of 600 MW (4 x 150 MW). There is a proposal to construct 11 hydro-electric projects in the sub-basin viz., 1. Bhopalpatnam-I (480 MW), 2. Bodhghat (240 MW), 3. Chitrakot (30 MW), 4. Gundra Matnar (30 MW), 5. Kutru-I (50 MW), 6. Kutru-II (75 MW), 7. Nugur-I (60 MW), 8. Nugur-II (30 MW), 9. Bhopalpatnam-II (180 MW) on the Indravati river, 10. Kodur (160 MW) on Kotri river, a

tributary of Indravati and 11. Bandia (25 MW). The total evaporation losses from the on-going and proposed hydroelectric projects 1608 Mm^3.

Total surface water requirement for irrigation from the existing, on-going and identified future projects works out to 7765 Mm^3. In addition, domestic water requirement 184 Mm^3, Industrial water requirement 313 Mm^3 and evaporation losses from hydro-electric projects 1608 Mm^3 are also considered to be met from surface water resources.

Thus, the total surface water requirement in the sub-basin works out to 9870 Mm^3.

The water balance in Muneru sub-basin, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.3** given below.

Table-5.3
Surface water balance in Indravati sub-basin

Unit: Mm^3

1	**Availability**		
	a)	Gross annual yield	
		i) At 75% dependability	21166
		ii) At 50% dependability	25531
	b)	Surface water import (+)	505
	c)	Export (-)	3135
	d)	Natural export to Sabari through Journala (-)	
		i) At 75% dependability	1352
		ii) At 50% dependability	1806
	e)	Overall availability	
		i) At 75% dependability	17184
		ii) At 50% dependability	21095
2	**a)**	**Surface water requirement for**	
		i) Irrigation use	7765

	ii)	Domestic use	184
	iii)	Industrial use	313
	iv)	Hydropower needs	1608
		Sub-total	9870
3.	**Regeneration (+)**		
	i)	Domestic use	147
	ii)	Industrial use	250
	iii)	Irrigation use	482
		Sub-total	879
4.	**Surface water balance**		
	a)	**At 75% dependability**	**(+) 8193**
	b)	**At 50% dependability**	**(+) 12104**

Source: Technical Study No. WB/ 42 prepared by NWDA in December, 2015

5.3 Hydrological and water balance studies of the Godavari basin between SRSP and Inchampalli barrage site

This para deals with the assessment of surface water resources of Godvari basin between Sri Ram Sagar Project and Inchampalli barrage site.

5.3.1 Computation of gross annual yields

The methodology adopted for working out the gross annual yields for the catchment between Sri Ram Sagar Project and Inchampalli barrage site is discussed below.

The water availability and the culturable area are not spread proportionately in the vast catchment area of the Godavari basin upto the Inchampalli barrage site. Due to this anomaly, the water balance situation is also not uniform in the basin area. Especially in the upper reaches of the Godavari basin more culturable area is available than that can be brought under irrigation by the available water resources. Preliminary studies conducted so far on water balance in respect of different sub-basins of the Godavari basin revealed that the water available upto Sri Ram Sagar Project in the Godavari basin is not fully sufficient to bring the available culturable area under irrigation. Further, it is also seen that the yield available below Sri Ram Sagar

Project in the Godavari basin is such that it gives rise to sizeable surplus water after meeting all the surface water requirements. It is seen that the surplus water available below Sri Ram Sagar Project can not be possibly carried to the upper reaches of the Godavari basin by gravity. To eliminate the cumulative effect of the water deficit in the upper reaches of the basin on the water balance study at the Inchampalli barrage site, the catchment area of the Godavari basin between Sri Ram Sagar Project and Inchampalli barrage site is considered. Hence, for the purpose of water balance study, the area of the Godavari basin upto the Inchampalli barrage site is taken to be comprising of the areas of the following sub-basins of Godavari basin namely (i) part of the Middle Godavari sub-basin below Sri Ram Sagar Project (ii) Maner (iii) Penganga (iv) Wardha (v) Pranhita (vi) Indravati and (vii) part of Lower Godavari upto Inchampalli barrage site.

The catchment area of river Godavari between Sri Ram Sagar project and Inchampalli barrage site is 177249 km^2. The catchment includes Middle Godavari sub-basin below Sri Ram Sagar project, Maner, Penganga, Wardha, Pranhita, Indravati and small part of the Lower Godavari sub-basin upto the Inchampalli barrage site. The areas of each of these sub-basins are mentioned in **Table 5.4** below:

Table-5.4

Area of the Sub-basins between Sri Ram Sagar Project and Inchampalli barrage site in the Godavari Basin.

Sub-basin	**Area in km^2**	**Remarks**
Middle Godavari below the Sri Ram Sagar project	11916	Part
Maner	13106	Full
Penganga	23898	Full
Wardha	24087	Full
Pranhita	61094	Full
Indravati	41665	Full
Lower Godavari upto Inchampalli barrage site	1483	Part
Total	**177249**	

The yield series of the Godavari basin between the Sriramsagar project and the Inchampalli barrage site for the period from 1901-02 to 2010-11 is developed by adding the year wise monsoon and non-monsoon yields of each of the sub-basins of this portion of the Godavari basin.

For the part catchment of the middle Godavari sub-basin below Sri Ram Sagar project, the monsoon yield series for the period from 1901-02 to 2010-11 has been arrived at by deducting the yields of the Middle Godavari sub-basin upto Sri Ram Sagar project from the corresponding monsoon yields of the Middle Godavari sub-basin. These yields have been obtained by developing relationship between rainfall and runoff and selecting the best fit equation. The non-monsoon yield series of the above catchment has been estimated by considering the percentage of the observed non-monsoon yields to the observed monsoon yields of the catchment. The annual yield series of the Middle Godavari sub-basin below Sri Ram Sagar project has been estimated by adding the monsoon yields and non-monsoon yields of the corresponding years.

The monsoon yield series of the Maner, Penganga, Wardha, Pranhita and Indravati sub-basins of the Godavari basin for the period from 1901-02 to 2010-11 have been taken from the respective water balance study reports. The non-monsoon yield series have been computed by considering the percentages of the observed non-monsoon yields to the observed monsoon yields of the respective sub-basins. The monsoon and non-monsoon yields of the same years are added to arrive at the annual yield series of the sub-basins.

The monsoon yield series for the portion of the catchment area of the Lower Godavari sub-basin upto Inchampalli barrage site for the period from 1901-02 to 2010-11 has been estimated on prorata basis from the yields of the whole sub-basin, since the area of the sub-basin upto Inchampalli barrage site is very small. The non-monsoon yield series of the catchment has been computed by taking the percentage of observed non monsoon runoff to the observed monsoon runoff as given in the water balance study report of the sub-basin (February, 2016). The monsoon and non-monsoon yields of the same years are added to get the annual yield series of the catchment for the period from 1901-02 to 2010-11.

The gross annual yield series for the period from 1901-02 to 2010-11 of each sub-basin as estimated above are added to arrive at the gross annual yield series of the Godavari basin between Sri Ram Sagar project and Inchampalli barrage site. From this, the 75% and 50% dependable yields have been assessed and found to be 59652 Mm^3 and 74585 Mm^3 respectively. Details are furnished in **Annexure 5.1.**

5.3.2 Import and Export

There are existing imports of 1692 Mm^3 to the Maner sub-basin and 1206 Mm^3 to the lower reaches of the Middle Godavari sub-basin from the upper reaches of the Middle Godavari sub-basin through the existing Sri Ram Sagar Project stage–I. A quantity of 420 Mm^3 of water is proposed to be diverted from the Sabari sub-basin to the Indravati sub-basin through the ongoing upper Kolab major project. There are proposals for importing 651 Mm^3 of water to the Pranhita sub-basin and lower reach of Middle Godavari sub-basin from the Sri Ram Sagar Project stage–II through the Saraswati canal system and 566 Mm^3 into Maner sub-basin through the SRSP flood flow canal. Thus, the existing import of water works out to 4535 Mm^3. There is one ongoing major project ie J. Chokka Rao LIS in Lower Godavari sub-basin from which a quantity of 519 Mm^3 of water is imported to Maner sub-basin. There is no proposed import into the catchment. Thus, total import from existing, ongoing and proposed projects works out to 5054 Mm^3.

There is no export of water from any existing project to outside the basin. There is an ongoing export to divert 2407 Mm^3 of water from Indravati sub-basin to Penganga sub-bain. There is ongoing export of 655 Mm^3 of water to Upper Godavari sub-basin from the Upper Penganga project. There is ongoing export of 1020 Mm^3 of water for irrigation and 1336 Mm^3 for drinking and industrial water supply from Pranhita sub-basin to Musi sub-basin through Pranhita–Chevella project. There is a proposed export of 728 Mm^3 of water from Indravati sub-basin to Tel sub-basin of Mahandi basin. Thuas, the total export from the catchment of Godavari basin between SRSP and Inchampalli barrage site is 6146 Mm^3. In addition to this, there is a natural export of 1352 Mm^3 and 1806 Mm^3 at 75% and 50% dependabilities respectively from Indravati sub-basin to the Sabari sub-basin of the Godavari basin through Jauranala stream. This natural export is also considered.

5.3.3 Computation of various requirements

a) Irrigation needs

Surface water needs for irrigation have been assessed by considering the ultimate annual irrigation. The annual irrigation and utilisation from all the existing, ongoing and proposed major, medium and minor projects in the catchment works out to 6316181 ha and 44839 Mm^3 respectively. This annual utilisation is inclusive of the evaporation losses and import of 5054 Mm^3.The surface water requirement for irrigation from all the existing, ongoing and future major, medium and minor projects is given in **Table 5.5**. The details of existing, ongoing and identified future projects are furnished in **Annexures 5.2 to 5.4.**

Table-5.5

Surface water requirement for ultimate irrigation in the catchment of Godavari basin between SRSP &Inchampalli barrage site

Category	Annual irrigation (ha)					
	Telan-gana	Maha-rashtra	Madhya Pradesh	Chhattis-garh	Odisha	Total
Existing	718910	963297	246181	65362	121984	2115734
Ongoing	752295	454492	182382	20294	2076	1411539
Proposed	117429	1248956	560037	604838	257648	2788908*
Total	**1588634**	**2666745**	**988600**	**690494**	**381708**	**6316181**
Category	**Annual utilisation (Mm^3)**					
	Telangana	Maha-rashtra	Madhya Pradesh	Chhattis-garh	Odisha	Total
Existing	6354	6189	1721	383	779	15426
Ongoing	6203	3748	1104	181	10	11246
Proposed	681	7591	4011	4109	1775	18167*
Total	**13238**	**17528**	**6836**	**4673**	**2564**	**44839**

* Includes water requirement of 1913 Mm^3 for additional area of 364014 ha considered in the catchment as per the norms of NWDA

The regeneration from irrigation uses at 10% of the net water utilisation from all the existing, ongoing and identified future major and medium projects and from all imports is 3082 Mm^3. The details are given at **Table 5.6.**

Table-5.6
Regeneration from irrigation projects

Project category	In basin utilization from major and medium projects (Mm^3)	Import (Mm^3)	Total (Mm^3)	Net utilization (Mm^3)	Regeneration (Mm^3)
Existing	7749	4535	11067	9899	990
Ongoing	9409	519	9928	8961	896
Proposed	13573	0	13573	11912	1191
Total	**30731**	**5054**	**35785**	**30772**	**3077**

b) Domestic needs

The requirements of water for domestic consumption computed by projecting the rural and urban human population and the livestock by 2050 AD are given in **Table 5.7**. The domestic requirement for the entire urban population and 50% of the rural population to be met from surface water sources works out to 1504 Mm^3.

Table-5.7
Domestic water requirement in Godavari basin between SRSP and Inchampalli barrage site by 2050 AD

Category	Population ('000')	Daily needs per capita (litres)	Water reqt. (Mm^3)
Rural	23988	70	614
Urban	24276	135	1197
Livestock	28642	50	519
Total			**2330**

c) Industrial needs

In the absence of relevant data on the industrial water needs, the industrial needs by 2050 AD have been assumed to be of the same order as that of

domestic water requirement which is 2330 Mm^3. This is proposed to be met in full from surface water resources.

The regeneration at 80% of the domestic and industrial water uses to be met from surface water resources are 1203 Mm^3 and 1864 Mm^3 respectively.

d) Hydro-power needs

In the catchment of Godavari basin between Sri Ram Sagar project and Inchampalli barrage site, there is one hydropower project viz. Pench HEP. The evaporation loss from this project is 125 Mm^3. There is an ongoing hydropower project in the basin ie Upper Indravati and the evaporation loss from this project is 131 Mm^3. In addition, there are 16 proposed hydro power projects and their total evaporation loss is 1654 Mm^3. Thus, the total evaporation loss from all the existing, ongoing and proposed hydropower projects comes to 1910 Mm^3. The details are given in **Table 5.8.**

Table-5.8
Evaporation losses from hydro-power projects

Sub-basin	Project	Status	Evaporation loss (Mm^3)
Wardha (G-8)	Dindora barrage	Proposed	**94**
Pranhita (G-9)	Pench	Existing	125
	Nahara	Proposed	13
	Son	Proposed	40
	Deo	Proposed	18
	Amla	Proposed	12
	Sub-total		**208**
Indravati (G-11)	Upper Indravati	Ongoing	131
	Bodhaghat	Proposed	195
	Chitrakot	Proposed	116
	Gundra	Proposed	44
	Matnar	Proposed	2
	Kutru – I	Proposed	105
	Kutru – II	Proposed	210
	Nugur – I	Proposed	369
	Nugur – II	Proposed	56

Kodur	Proposed	310
Bhopalpatnam-I	Proposed	64
Bhopalpatnam-II	Proposed	6
Sub-total		**1608**
Grand total		**1910**

e) Water requirement below the confluence of Indravati

The earlier proposed Inchampalli project was abandoned by Govt. of Telangana and in place of that several other lift schemes are contemplated downstream of Inchampalli. The details of these schemes are collected from Govt. of Telangana and are incorporated in the report while updating the water requirements. Further there are committed requirements of Godavari water for Polavaram project, Godavari delta and other lift irrigation schemes downstream of Inchampalli barrage site. Details are given in **Table 5.9**

Table 5.9

Water requirement below Inchampalli barrage site

Andhra Pradesh

1.	Polavaram	9203	Mm^3
2.	Dowlaiswaram	7510	Mm^3
3.	Torrigedda	68	Mm^3
4	Vegeswarapuram	28	Mm^3
5	LIS at Polavaram	133	Mm^3
6	Chagalnadu LIS	81	Mm^3
	Total	**17023**	**Mm^3**

Telangana

1	P.V.Narasimha Rao Kanthalapally	1992	Mm^3
2.	a) Sitarama LIS	1416	Mm^3
	b) Dummagudem evaporation losses	83	Mm^3
3.	Devadula / Godavari LIS	1699	Mm^3
4	Bhakta Ramadasu LIS	156	Mm^3
	Total	**5546**	**Mm^3**
Total downstream requirements		**22569**	**Mm^3**

The contribution from the intermediate catchment between Inchampalli barrage site and Dowlaiswaram barrage estimated at 75% dependability is 5864

Mm^3 (pro-rata basis). In addition to this, 8933 Mm^3 of the surplus flows from Sabari sub-basin at 75% dependability are also available. The net requirement to be met downstream of Inchampalli works out to 7772 Mm^3. The regeneration from this use is not considered since the use is on downstream of the Inchampalli barrage site.

5.3.4 Water Balance

The water balance has been worked out by deducting the ultimate water requirements for various uses like irrigation, domestic, industrial and hydro power including the committed water requirements downstream of Inchampalli from the overall availability duly considering the regeneration, import and export. The computation of surface water balance of the Godavari basin between SRSP and Inchampalli barrage site is given in **Table 5.10.**

Table-5.10

Surface water balance in the Godavari basin between SRSP and Inchampalli barrage site

Unit: Mm^3

1. Availability	
(a) Gross annual yield	
i) At 75% dependability	59652
ii) At 50% dependability	74585
b) Surface water import (+)	5054
c) Surface water export (-)	6146
d) Surface water export through jauranala (-)	
i) At 75% dependability	1352
ii) At 50% dependability	1806
e) Overall availability	
i) At 75% dependability	**57208**
ii) At 50% dependability	**71687**
2. Surface Water Requirement for(-)	
i) Irrigation	44839

ii) Domestic	1504	
iii) Industrial use	2330	
iv) Hydro-power needs	1910	
v) D/s committed requirements	7772	
Sub-total	**58355**	**58355**
3. Regeneration (+)		
i) Irrigation	3082	
ii) Domestic	1203	
iii) Industrial use	1864	
Sub-total	**6149**	**6149**
4. Surface water balance		
a) At 75% dependability		**(+) 5002**
b) At 50% dependability		**(+) 19481**

Source: Technical Study No. WB/ 99 prepared by NWDA (March, 2018).

The water balance study at the Inchampalli barrage site shows a net surplus of 5002 Mm^3 at 75% dependability. The entire surplus along with the unutilized waters of Chhattisgarh in Indrāvati sub-basin is proposed to be diverted through Inchampalli–Nagarjunasagar link.

The water balance of Indravati is presented as **Annexure 5.6**.

5.4 Hydrological and water balance studies of sub-basins lying enroute the link

The hydrological water balance studies of sub-basins namely Muneru, Palleru, Musi of Krishna basin lying enroute the Inchampalli– Nagarjunasagar link canal are described in the following paras.

5.4.1 Hydrological and water balance studies of Muneru sub-basin of Krishna basin

The National Water Development Agency prepared water balance study report of Muneru sub-basin of Krishna basin in March, 2016. The details of water balance study as extracted from the report are presented below.

The river Muneru is a left bank tributary of the river Krishna. The Muneru sub-basin lies between north latitudes 16^{o} 37' and 16^{o} 37' and east longitudes 79^{o} 09' and 80^{o} 51'. The river Muneru originates in Warangal district and traverses for a length of 196 km before joining the river Krishna. Akeru and Wyra respectively are the two important right and left bank tributaries of the river Muneru. The sub-basin has a catchment area of 10409 km^2 and forms 4.02 percent of the Krishna basin. The catchment area of the sub-basin lies in Telangana and Andhra Pradesh.

A Gauge and Discharge site is available on the river Muneru at Keesra maintained by the Central Water Commission. The catchment area at this site is 9854 km^2 which covers 94.7% of the total catchment area of the sub-basin. The observed flow data for the period from 1965-66 to 2012-13 of the G & D site have been used for the hydrological studies.

There are 12 raingauge stations in and around the Muneru sub-basin. The weighted average monsoon rainfall of the catchment of each year upto the Keesra Gauge and Discharge site for the period from 1965-66 to 2012-13 have been computed by Thiessen polygon method. Similarly, weighted average monsoon rainfall of the entire sub-basin have also been computed for each year for the period from 1901-02 to to 2012-13.

For assessing the actual upstream utilizations, both the kharif and rabi requirements have been accounted for monsoon utilizations, since the rabi requirements are drawn from the storages filled during the monsoon period including evaporation losses. The upstream utilizations both for the kharif and rabi seasons in respect of the four existing medium projects have been worked out from the actual month wise utilization particulars for these projects located in the sub-basin. The quantum of return flows to the stream was considered at

10% of the net water utilized from these irrigation projects whose designed annual utilization is 85 Mm^3 or more. The upstream utilizations for kharif and rabi in respect of tanks and other sources using surface water have been estimated considering the year wise area irrigated and assuming a delta of 0.45m.

There is an existing import of 1274 Mm^3 from the left bank canal of Nagarjuna Sagar project and 896 Mm^3 from Kakatiya canal stage-I of Sri Ram Sagar Project. 207 Mm^3 of water will be imported through the ongoing J. Chokka Rao Devadula LIS located in Lower Godavari sub-basin. The import through the ongoing Kakatiya canal stage-II of Sri Ram Sagar Project is 219 Mm^3 of water. Thus, the total import works out to 2596 Mm^3.

The gross monsoon yields of the sub-basin have been worked out by considering the observed yields at the Keesra Gauge and Discharge site, the annual upstream utilizations and the return flows both from in-basin and imported waters. Similarly, the gross non-monsoon yields were arrived at from the observed yields at Keesra Gauge and Discharge site after accounting for the return flows from the rabi utilizations.

Relationship between the gross monsoon run-off and the corresponding weighted monsoon rainfall of the catchment upto Keesra Gauge and Discharge site were established by regression analysis considering the following linear and non-linear forms of equations.

a) $Y = ax + b$
b) $Y = ax^b$

Where ‘Y’ is the monsoon virgin yield in mm and ‘X’ is the weighted average monsoon rainfall in mm and ‘a and b’ are constants.

The coefficient of correlation and the standard error of estimation were computed in each case. The best fit equation was selected based on the least standard error of the estimation. The best fit equation for the monsoon period was obtained as $X_1 = 6.81095 \text{ e-}07 (x_2)^{(2.86475)}$ and has been adopted for assessing the monsoon yields of the Muneru sub-basin.

The monsoon yields of the sub-basin for the period 1901-02 to 2013-14 have been computed by substituting the corresponding weighted average monsoon rainfall values of the Muneru sub-basin in the above best-fit equation. The annual gross yield series has been developed by adding the gross monsoon yield and non-monsoon yield for the period from 1901-02 to 2013-14 from which the 75% and 50% dependable annual gross yields of the Muneru sub-basin have been obtained as 1277 Mm^3 and 2049 Mm^3 respectively.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin from the overall availability and duly considering import and regeneration.

The ultimate surface water requirement for irrigation in the basin is furnished in **Table 5.11.**

Table-5.11
Ultimate surface water requirement in Muneru sub-basin

Category	Annual irrigation (ha)			Annual utilization (Mm^3)		
	Andhra Pradesh	Telangana	Total	Andhra Pradesh	Telangana	Total
1. Existing Projects						
a) Major						
(i) In basin	0	0	0	0	0	0
(ii) Import	0	251098	251098	0	2170	2170
b) Medium	6648	15285	21933	93	207	300
c) Minor	7697	44456	52153	49	283	332
Sub-total	**14345**	**310839**	**325184**	**142**	**2660**	**2802**
2. Ongoing Projects						
a) Major						
(i) In basin	0	0	0	0	0	0
(ii) Import	0	86005	86005	0	426	426
b) Medium	0	0	0	0	0	0
c) Minor	0	1300	1300	0	8	8
Sub-total	**0**	**87305**	**87305**	**0**	**434**	**434**
3. Proposed Projects						
a) Major						
(i) In basin	0	0	0	0	0	0
(ii) Import	0	0	0	0	0	0
b) Medium	6141	0	6141	41	0	41

c) Minor	0	3104	3104	0	15	15
Sub-total	**6141**	**3104**	**9245**	**41**	**15**	**56**
Total	**20486**	**401248**	**421734**	**183**	**3109**	**3292**

10% of the net irrigation use by the major and medium projects having 85 Mm^3 or more designed annual utilisation is considered as regeneration. The total regeneration works out to 277 Mm^3.

The requirement of water for the rural and urban population and for livestock has been computed by projecting them to 2050 AD. The total domestic water needs are assessed to be 195 Mm^3 as shown in **Table 5.12.**

Table 5.12

Domestic water requirement of the Muneru sub-basin by 2050 AD

Category	Andhra Pradesh	Telangana	Total
Population			
Rural	548409	1316754	1865163
Urban	555029	1332651	1887680
Livestock	387621	2561840	2949461
Water requirement			
Rural (70 lt/day)	14	34	48
Urban(135 lt/day)	27	66	93
Livestock(50 lt/day)	07	47	54
Surface water (Mm^3)	**34**	**83**	**117**
Ground water (Mm^3)	**14**	**64**	**78**
Regeneration (Mm^3)	**27**	**66**	**93**

The entire requirement for the urban population and 50 per cent of the requirement for the rural human population are proposed to be met from the surface water resources. The domestic requirement to be met form surface water resources works out to 117 Mm^3.

Information regarding water needs of the existing, ongoing and proposed industries in the sub-basin is not readily available. In the absence of relevant information, the water requirement for industrial use has been assumed to be of the same order as that for domestic use which is 195 Mm^3.

80% of the domestic and industrial water use, to be met from surface water resources is considered as regeneration to the stream.

The water balance in Muneru sub-basin, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.13.**

Table-5.13
Surface water balance in Muneru sub-basin

Unit: Mm^3

1	**Availability**		
	b)	Gross annual yield	
		i) At 75% dependability	1277
		ii) At 50% dependability	2049
	b)	Surface water import (+)	2596
	c)	Export (-)	Nil
	d)	Overall availability	
		i) At 75% dependability	3873
		ii) At 50% dependability	4645
2	**a)**	**Surface water requirement for**	
		i) Irrigation by in basin and imported water	3292
		ii) Domestic use	117
		iii) Industrial use	195
		iv) Hydropower needs	Nil
		Sub-total	3604
3.	**Regeneration (+)**		
		i) Domestic use	93
		ii) Industrial use	156
		iii) Irrigation use	277
		Sub-total	526
5.	**Surface water balance**		

a)	**At 75% dependability**	**(+) 795**
b)	**At 50% dependability**	**(+) 1567**

Source: Technical Study No. WB/ 44 prepared by NWDA in March, 2016

5.4.2 Hydrological and water balance studies of Palleru sub-basin of Krishna basin

The National Water Development Agency prepared water balance study report of Palleru sub-basin of Krishna basin in the year 2014. The details of water balance study as extracted from the report are presented below.

The catchment area of the Palleru sub-basin is 3263 km^2. There is one Gauge and Discharge site maintained by the Central Water Commission at Palleru bridge. The catchment area of the sub-basin upto Palleru bridge site is 2928 km^2 which is 89.8% of the total sub-basin area. The monthly observed discharge data of the Palleru river at the Palleru bridge site for the period from 1971-72 to 2006-07 have been considered for the analysis.

Rainfall data available for 9 rain-gauge stations in and adjacent to the sub-basin are considered in the study. Missing data have been estimated using standard statistical methods. Weighted average monsoon rainfall of the catchment upto Palleru bridge for each year for the period from 1971-72 to 2006-07 and for the entire Palleru catchment for each year for the period from 1901-02 to 2011-12 have been computed by Thiessen Polygon method.

There is an existing designed import of 590 Mm^3 from the Nagarjunasagar project left bank canal located in Lower Krishna sub-basin to the Palleru sub-basin. There is no major project existing in the sub-basin.

The monthly and annual utilization data for the existing Palleru medium project have been obtained from the irrigation department of Government of erstwhile Andhra Pradesh for the period from 1971-72 to 2006-07. The annual utilizations through minor schemes have been computed by taking the year-wise areas irrigated through tanks and other sources collected from Bureau of Economics and Statistics and adopting a delta of 0.7m and 0.45m in the case of tanks and other sources respectively.

Considering the monthly observed flow data, existing utilizations in the catchment, estimated return flows at 10% of the net irrigation use during kharif season from the command of existing projects including import through Nagarjunasagar left bank canal (which have annual utilisation of 85 Mm^3 or more) upto Palleru bridge and the reservoir losses of the medium project, gross monsoon yields upto Palleru bridge have been computed for each year for the period from 1971-72 to 2006-07.

A rainfall run-off relationship has been developed for the monsoon period (June to November) by regression analysis using the values of monsoon weighted rainfall and gross monsoon yields of each year for the period from 1971-72 to 2006-07 considering both linear and non-linear forms of equation.

The linear equation was considered as the best-fit equation and is assumed to hold good for the entire sub-basin as the catchment area upto Palleru bridge site covers 89.8% of the sub-basin area. The non-monsoon percentage is worked out considering non monsoon yields and gross monsoon yields.

Using the best-fit equation and the weighted average monsoon rainfall of the entire sub-basin for each year for the period from 1901-02 to 2011-12, the monsoon yield series for the entire sub-basin have been assessed and to this, non-monsoon yields have been added for arriving at annual yield series. The gross annual yield series thus arrived have been arranged in descending order and the 50% and 75% dependable yields of the sub-basin are obtained as 448 Mm^3 and 628 Mm^3 respectively.The ultimate surface water requirement for irrigation in the basin is furnished in the Table **5.14.**

Table -5.14
Ultimate surface water requirement for irrigation by 2050 AD as assessed in the Palleru sub-basin

Category	Annual irrigation (ha)	Annual utilization (Mm^3)
Existing projects		
Import	75918	590
Major	- -	- -
Medium	7952	113
Minor	25102	202

Total	**108972**	**905**
Ongoing projects		
Major	- -	- -
Medium	- -	- -
Minor	1378	10
Total	**1378**	**10**
Identified projects		
Import	232887	1817
Medium	- -	- -
Minor	3265	16
Total	**236152**	**1833**
Grand total	**346502**	**2748**

This includes existing import of 590 Mm^3 through NSLBC and proposed import of 1817 Mm^3 through Kakatiya canal stage-II of Sri Ram Sagar Project. 10% of the net irrigation use by the major and medium projects having annual utilization of 85 Mm^3 or more is considered as regeneration. The regeneration works out to 250 Mm^3.

The requirement of water for domestic use by the rural and urban human population and for livestock has been computed by projecting the rural and urban human population and livestock of the sub-basin to 2050 AD. The total domestic water needs are assessed to be 81 Mm^3 as shown in **Table 5.15.**

Table -5.15
Estimated domestic water requirement in the Palleru sub-basin by 2050 AD

Category	Population	Per capita daily needs (litre)	Water requirement (Mm^3)
Rural	517265	70	13
Urban	612876	200	45
Livestock	1262823	50	23
Total			**81**

The entire urban water requirement and 50% of rural water requirement is proposed to be met from surface water resources and this works out to be 52 Mm^3. The regeneration at 80% of the surface water utilized for domestic purpose is considered to be available as return flows which works out to

42 Mm^3. Details of the water requirement of the existing or proposed industries are not available. It is therefore, assumed that the total industrial water requirement would be of the same order as domestic water requirement, which is 81 Mm^3 and is proposed to be met from surface water sources. The regeneration at 80% of the surface water utilised is considered to be available as return flows to the stream which comes to 65 Mm^3. The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin from the overall availability and duly considering the regeneration. The water balance in Palleru sub-basin, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.16.**

Table-5.16
Surface water balance in Palleru sub-basin Unit : Mm^3

1	**Availability**		
	a)	Gross annual yield	
		i) At 75% dependability	448
		ii) At 50% dependability	628
	b)	Surface water import (+)	2407
	c)	Export (-)	Nil
	d)	Overall availability	
		i) At 75% dependability	2855
		ii) At 50% dependability	3035
2	**a)**	**Surface water requirement for**	
		i) Irrigation by in basin and imported water	2748
		ii) Domestic use	52
		iii) Industrial use	81
		iv) Hydropower needs	Nil
		Sub-total	2881
3.	**Regeneration (+)**		
		i) Domestic use	42
		ii) Industrial use	65
		iii) Irrigation use	250
		Sub-total	357
4.	**Surface water balance**		

a)	**At 75% dependability**	**(+) 331**
b)	**At 50% dependability**	**(+) 511**

Source: Technical Study No. WB/ 43 prepared by NWDA, 2014

5.4.3 Hydrological and water balance studies of Musi sub-basin of Krishna basin

The National Water Development Agency prepared water balance study report of Musi sub-basin of the Krishna basin in the year 2014. The details of water balance study as extracted from the report are presented below.

The catchment area of the sub-basin is 11212 km^2. There is a Gauge and Discharge site of the Central Water Commission at Damercharla located on Musi river before its confluence with the Krishna river. The site intercepts an area of 11050 km^2 which is 98.6% of the total sub-basin area. The monthly observed discharges of Musi river at Damercharla site for the period from 1968-69 to 2011-12 have been used in the studies.

There are 19 rain-gauge stations in and around the sub-basin. The weighted average monsoon rainfall of the catchment upto Damercharla site for each year for the period from 1968-69 to 2011-12 and for the entire catchment of Musi sub-basin for each year for the period from 1901-02 to 2011-12 have been computed by Thiessen Polygon method.

There is one existing medium project namely Musi and two drinking water supply schemes for Hyderabad city (Osmansagar and Himayatsagar) in the sub-basin. The actual utilizations from these projects/schemes during the kharif and rabi seasons for each year for the period 1968-69 to 2011-12 have been collected from the concerned Departments. The actual irrigated area from the minor schemes (tanks and other sources) have been collected from the Bureau of Economics and Statistics and the utilizations have been estimated considering a delta of 0.70m for tanks and 0.45m for other sources. While assessing the monsoon utilizations, the sum of the utilizations during the kharif and rabi seasons have been considered as the monsoon utilizations since the rabi utilizations are drawn from the gains in the storage during monsoon period.

There is an existing designed import of 647 Mm^3 from Nagarjunasagar left bank canal and 69 Mm^3 from Manjra water supply scheme. In addition, there is an existing import of 64 Mm^3 from Nagarjunasagar project for domestic water supply to Hyderabad/Secunderabad twin cities. The quantum of water to be imported from ongoing Alimineti Madhava Reddy project (Srisailam LBC), Kakatiya canal (stage-II of SRSP), Flood flow canal (stage-II of SRSP), J. Chokka Rao LIS, Dr. B.R. Ambedkar Pranhita-Chevella sujala sravanthi and Singur water supply scheme are 186 Mm^3, 130 Mm^3, 91Mm^3, 499 Mm^3, 2185 (1336+849) Mm^3 and 113 Mm^3 respectively. Thus, the total import into this sub-basin from other sub-basins works out to 3984 Mm^3.

The gross monsoon yields at Damercharla site have been computed for each year for the period from 1968-69 to 2011-12 by adding to the observed monsoon yield, the upstream utilizations and evaporation losses from existing project and deducting the return flows, which have been assumed as 10% of the net kharif utilization (from in-basin as well as imported waters) from projects having designed annual utilization of 85 Mm^3 or more and 80% of domestic water supplies. The effect of carryover storage of Musi project has also been considered in arriving at gross monsoon yield.

A rainfall-runoff relationship for the monsoon period at Damercharla site has been developed by regression analysis using the weighted average monsoon rainfall and the corresponding monsoon gross yield for the period from 1968-69 to 2011-12 considering both linear and non-linear forms of equations. The non-linear equation $y = \mathbf{1.0446e\text{-}03 \times}^{\mathbf{1.7352}}$ is taken as the best-fit equation and is assumed to hold good for the entire sub-basin. The non-monsoon yields are worked out from the percentage of non-monsoon yield to the monsoon gross yield.

Using the best-fit equation and the weighted average monsoon rainfall of the entire sub-basin for each year for the period from 1901-02 to 2011-12, the monsoon gross yield series for the entire sub-basin have been developed and to this non-monsoon yields have been added in arriving at annual gross yield series. The gross annual yield series thus arrived has been arranged in descending order from which the 50% and the 75% dependable yields are found to be 1137 Mm^3 and 847 Mm^3 respectively.

The ultimate surface water requirement for irrigation in the basin is furnished in **Table 5.17.**

Table-5.17

Ultimate surface water requirement for irrigation in Musi sub-basin

Category	Annual Irrigation (ha)			Annual utilization ($Mm^{3)}$		
	Inbasin	**Import**	**Total**	**Inbasin**	**Import**	**Total**
Existing projects						
Major	16929	82909	99838	266	647	913
Medium	6170	--	6170	62	--	62
Minor	65517	--	65517	459	--	459
Sub-total	**88616**	**82909**	**171525**	**787**	**647**	**1434**
Ongoing projects						
Major	--	377412	377412	--	2242	2242
Medium	--	--	0	--	--	0
Minor	16	--	16	negligible	--	0
Sub-total	**16**	**377412**	**377428**	**--**	**2242**	**2242**
Proposed projects						
Major	--	--	0	--	--	0
Medium	--	--	0	--	--	0
Minor	22807	--	22807	130	--	130
Sub-total	**22807**	**--**	**22807**	**130**	**--**	**130**
Grand total	**111439**	**460321**	**571760**	**917**	**2889**	**3806**

10% of the net water utilisation from all the existing, ongoing and identified future major and medium projects having annual designed utilisation of 85 Mm^3 or more is considered as regeneration to the streams. The total regeneration works out to 314 Mm^3.

The requirement of water for domestic use in the rural and urban human population and for livestock has been computed by projecting the rural and urban human population and livestock of the basin to 2050 AD. The total domestic water needs are assessed to be 803 Mm^3 as shown in **Table 5.18.**

Table-5.18
Estimated domestic water requirement in the Musi sub-basin by 2050 AD

Category	Population	Per capita daily needs (litre)	Water needs (Mm^3)
Rural	2885901	70	74
Urban	8883553	200	649
Livestock	4385044	50	80
Total			**803**

The entire urban water requirement and 50% of rural water requirement is proposed to be met from surface water resources and this works out to be 686 Mm^3. 80% of the surface water utilized for domestic purpose is considered to be available as return flows and it works out to 549 Mm^3.

Information regarding water needs of the existing, ongoing and proposed industries in the sub-basin is not readily available. In the absence of relevant information, the water requirement for industrial use has been assumed to be of the same order as that for domestic use which is 803 Mm^3. 80% of industrial utilisation is considered as return flows to the streams, which works out to 642 Mm^3.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin, duly considering the regeneration, import and export. The water balance in Musi sub-basin, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.19.**

Table-5.19
Surface water balance in Musi sub-basin

1	**Availability**	**Mm^3**
	a) Gross annual yield	

	i) 75 % dependability			847
	ii) 50% dependability			1137
	b) Import (+)			3984
	c) Export (-)			0
	d) Overall availability			
	i) 75 % dependability			4831
	ii) 50% dependability			5121
2	**Requirement for (-)**			
	i) Irrigation use		3806	
	ii) Domestic use		686	
	iii) Industrial use		803	
	iv) Hydropower needs		0	
		Sub-total	**5295**	**5295**
3	**Regeneration (+)**			
	i) Irrigation use		314	
	ii) Domestic use		549	
	iii)Industrial use		642	
		Sub-total	**1505**	**1505**
4	**Balance at**			
	i) 75% dependability			(+)1041
	ii) 50% dependability			(+)1331

Source: Technical Study No. WB/ 42 prepared by NWDA, 2014

5.5 Hydrological and water balance studies of the Krishna basin upto Nagarjunasagar dam site

The catchment area from the source of the Krishna river upto the Nagarjunasagar dam site includes the independent catchments of 8 upper sub-basins i.e., Upper Krishna, Middle Krishna, Ghataprabha, Malaprabha, Upper Bhima, Lower Bhima, Tungabhadra and Vedavathi and part of the Lower Krishna sub-basin upto Nagarjunasagar dam site. The catchment extends over an area of 220705 km^2 which works out to 85.2% of the total catchment area of the Krishna basin and lies in the States of Maharashtra (69425 km^2), Karnataka (113271 km^2) and Telangana & Andhra Pradesh (38009 km^2). The hydrological studies in respect of all the above sub-basins have been carried out by NWDA and the annual yield series of each sub-basin

have been developed. The annual gross yield series of the catchment of Krishna basin upto Nagarjunasagar dam site for the period from 1951-52 to 1983-84 have been arrived at, by summing up the annual yield series of the Lower Krishna sub-basin upto Nagarjunasagar dam site to the annual yield series of the 8 upstream sub-basins. From this series, the 75% and 50% dependable annual gross yields are determined to be 58423 Mm^3 and 67346 Mm^3 respectively.

There is no import of water from any sub-basin/basin into the catchment. There is an existing export of 12269 Mm^3 from various projects to other sub-basins of Krishna basin, Pennar basin & westward diversion. There is an ongoing export of 3059 Mm^3 through various projects to Musi sub-basin, Pennar basin and for water supply to Chennai city. Besides, there is a proposed export of 394 Mm^3 to the Pennar basin. Thus, the total export from the catchment of Krishna basin upto Nagarjunasagar will be 15722 Mm^3.

Surface water needs for irrigation have been assessed by considering the ultimate annual irrigation at minimum of 30% C.C.A. The surface water requirement for irrigation from all the existing, ongoing and future major, medium and minor projects is given in **Table 5.20.**

Table-5.20
Surface water requirement for ultimate irrigation in the catchment of Krishna basin upto Nagarjunasagar dam site

State	Project category	Annual irrigation (ha)	Annual utilisation (Mm^3)
Maharashtra	Existing	441320	3917
	Ongoing	646974	6007
	Proposed	507713	3219
	Additional area	209499	1260
	Sub-total	**1805506**	**14403**
Karnataka	Existing	1363649	12043
	Ongoing	946962	7032
	Proposed	497360	3921
	Additional area	153645	1155

	Sub-total	**2961616**	**24151**
Telangana &	Existing	331391	3335
Andhra Pradesh	Ongoing	104398	845
	Proposed	19984	136
	Additional area	182616	1360
	Sub-total	**638389**	**5676**
Total	Existing	2136360	19295
	Ongoing	1698334	13884
	Proposed	1025057	7276
	Additional area	545760	3775
	Grand total	**5405511**	**44230**

The regeneration from irrigation use at 10% of net water utilisation from all the existing, ongoing and identified future major and medium projects having designed annual utilization of 85 Mm^3 or more is worked out to 2789 Mm^3. The requirement of water for domestic consumption computed by projecting the rural and urban human population and the livestock to 2050 AD are given in **Table 5.21**. The domestic water requirement in the catchment works out to 3348 Mm^3.

Table-5.21
Domestic water requirement in Krishna basin upto Nagarjunasagar dam site by 2050 AD

Category	**Population ('000')**	**Daily needs per capita (litres)**	**Water requirement (Mm^3)**
Rural	61605	70	1576
Urban	35077	200	2560
Live stock	37144	50	677
Total			**4813**

The domestic requirement for the entire urban population and 50% of the rural population to be met from surface water sources works out to 3348 Mm^3. In the absence of relevant data on the industrial water needs, the industrial needs by 2050 AD have been assumed to be of the same order as that of domestic

water requirement which is 4813 Mm^3, which is proposed to be met surface water resources.

The regeneration at 80% of the domestic and industrial water uses to be met from surface water resources are 2681 Mm^3 and 3849 Mm^3 respectively.

The total evaporation losses of all the hydel projects in the catchment have been taken as hydro power needs which is worked out to be 1154 Mm^3. The water balance has then been worked out by deducting the ultimate water requirements for various uses like irrigation, industrial, domestic and hydro power from the overall availability duly considering the regeneration, import and export. The computation of surface water balance of the Krishna basin upto Nagarjunasagar dam site is given in **Table 5.22.**

Table-5.22
Surface water balance at Nagarjunasagar dam site in Krishna basin

Unit : Mm^3

1.	**Availability**		
	(a) Gross annual yield		
	i) At 75% dependability		58423
	ii) At 50% dependability		67346
	b) Surface water import (+)		Nil
	c) Surface water export (-)		15722
	d) Overall availability		
	i) At 75% dependability		**42701**
	ii) At 50% dependability		**51624**
2.	**Surface water requirement for**		
	i) Irrigation	44230	
	ii) Domestic	3348	
	iii) Industrial use	4813	
	iv) Hydro-power needs	1154	
	Sub-total	**53545**	**53545**
3.	**Regeneration (+)**		
	i) Irrigation	2789	
	ii) Domestic	2681	
	iii) Industrial use	3849	
	Sub-total	**9319**	**9319**

4.	**Surface water balance**	
	a) At 75% dependability	**(-) 1525**
	b) At 50% dependability	**(+) 7398**

Source: Technical Study No. WB/139 prepared by NWDA,

The water balance at the Nagarjunasagar dam site shows a net deficit of 1525 Mm^3 at 75% dependability.

The water balance of Muneru, Palleru, Musi sub-basins of Krishna basin and water balance of Krishna basin at Nagarjunasagar dam site are presented as **Annexure 5.7.1 to 5.7.4.**

5.6 Simulation studies at Inchampalli

Simulation studies are required to be carried out to assess the dependability of the storages involved, to cater various demands envisaged for the project. In respect of Godavari (Inchampalli)- Krishna (Nagarjunasagar) link project, two reservoirs/ponds are involved viz (i) the Inchampalli barrage pond from which the proposed Inchampalli – Nagarjunasagar link canal takes off and (ii) the existing Nagarjunasagar reservoir which is the outfall reservoir for the link project.

5.6.1 Computation of inflows into Inchampalli

Inchampalli barrage has been proposed on the river Godavari just downstream of the confluence of river Indravati with Godavari. The requirements between SRSP and Inchampalli consist of the requirements of Middle Godavari sub-basin below SRSP, Maner, Penganga, Wardha, Pranhita, Indravati and Lower Godavari sub-basin upto Inchampalli barrage site. These are given in **Annexure 5.5.** The gross annual yield series for the years from 1981-82 to 2010-11 at Inchampalli have been worked out by adding the annual yields of the above mentioned catchment areas. The surplus annual yield series from each sub-basin have been worked out by deducting the requirements in the catchment from the gross yields and adding the water requirement for the proposed irrigation and HEP of Chhattisgarh. These details are given in **Annexure 5.8**. The net annual yields at Inchampalli are divided into daily

inflows based on the flow data at Perur G&D site (maintained by CWC) which is located on Godavari just downstream of Inchampalli site. Further, since the basis of phase-I diversion hinges on the surplus of Indravati sub-basin (including unutilized waters of Chhattisgarh), the net annual yields of Indravati sub-basin are also divided into daily inflows based on the flow data of Pathagudem G&D site on Indravati just before its confluence with the Godavari. Based on the daily simulation at Inchampalli with the net surplus yield series in both the above cases, the abstracts of simulation at Inchampalli barrage site for the period from 1981 to 2010 are given in **Annexure 5.9 and 5.10** respectively.

The Inchampalli barrage is proposed with a storage capacity of 450 Mm^3. The area-capacity table of Inchampalli pond is given in **Annexure 5.11**

5.7 Demands from Inchampalli Pond

5.7.1 Demands of Inchampalli – Nagarjunasagar Link

Inchampalli barrage– Nagarjunasagar link envisages to carry 7000 Mm^3 of water during the monsoon to meet the following demands:

i) 755 Mm^3 and 629Mm^3 (total 1384 Mm^3) of water for enroute irrigation requirements of Kakatiya canal stage–II and Srisailam left bank canal respectively.
ii) 339 Mm^3 for enroute irrigation requirements under Gottimukkala feeder
iii) 140 Mm^3 to meet domestic and industrial water requirements of the areas enroute the link canal.
iv) 142 Mm^3 of transmission losses enroute the link canal from Inchampalli barrage– Nagarjunasagar.
v) 4996 Mm^3 of water by transfer to Nagarjunasagar to meet the requirements of Nagarjunasagar and for further diversion to other southern river basins.

The computation of all the above demands and their monthly distribution are dealt in detail in Chapter 8: Water and Irrigation Planning.

5.7.2 Arrangement for diversion of water through Inchampalli – Nagarjunasagar link canal – its integration with SRSP stage II, SLBC etc.

5.7.2.1 Command area under Kakatiya canal stage–II of Sri Ram Sagar Project stage–II

Government of erstwhile Andhra Pradesh had proposed to provide irrigation to an area of 178055 ha in the drought prone Warangal plateau, Nalgonda and Khammam districts by utilizing 684 Mm^3 of water through Kakatiya canal Stage – II of Sri Ram Sagar Project stage–II. The proposal suffers from the fact that enough water is not available at Sri Ram Sagar dam site to cater to these needs. The proposed link canal can cater to the irrigation needs of the command area under Kakatiya canal stage–II partly by lift and partly by gravity. The lift involved is about 55 m for lifting and supplying water from Inchampalli–Nagarjunasagar link to Kakatiya canal. The cropping pattern for Kakatiya canal stage–II was originally designed by the Govt. of erstwhile Andhra Pradesh keeping in view the water availability situation at SRSP. In the present study, in view of proposed supplementation of Godavari waters through the link project, the month wise crop water requirements for the command area are worked out based on the prevailing cropping pattern in respect of existing projects in the region.

5.7.2.2 Command area under Srisailam left bank canal

Govt. of erstwhile Andhra Pradesh has proposed to provide irrigation to 109250 ha of endemically drought prone upland areas in Nalgonda district by lifting 743 Mm^3 of water from the Nagarjunasagar reservoir through Alimineti Madhava Reddy Lift Irrigation Scheme (AMRLIS). This area had originally been proposed under Srisailam left bank canal. Four pumps 18 MW each are installed to lift the water to a static head of about 92 m to command the area. As the proposed Inchampalli barrage–Nagarjunasagar link canal is passing through this command area, the same is proposed to be taken over by the link canal. In the present proposal, it is assessed that out of 109250 ha, an extent of 51304 ha that lies to the left side of the proposed link canal spreading between the link canal and the existing NSLB canal could be irrigated directly by the link canal by utilising 218 Mm^3 of water. The canal distributary network system of the AMRLIS as planned by the Irrigation Department and being executed can be

utilized without major modifications to command this area. The balance requirement of 411 Mm^3 of water will be lifted from the Nagarjunasagar reservoir utilizing the existing pumping system to cater to the irrigation needs of the balance ayacut of 57946 ha that has been proposed under AMRLIS high level canal. Computation of crop water requirement for the proposed enroute command area under the Srisailam Left Bank Canal is given in Chapter 8.

5.7.2.3 New area under Gottimukkala feeder

Govt. of Telangana has proposed with NWDA to consider providing irrigation to new areas in the water short Nalgonda district from the link. Accordingly, a feeder canal is proposed to take off from the existing Musi reservoir upto ongoing Gottimukkala project to irrigate a new upland area of about 80000 ha situated at about 392 m . The feeder canal will be about 116 km and the lift involved would be 196.5 m which will be executed in three stages of 64.5 m, 58 m & 74 m at RDs 0.00 km, 75.00 km & 95.00 km of the feeder respectively. The annual utilization in the proposed command would be 339 Mm^3. Computation of crop water requirement for the proposed new command area is given in Chapter 8.

5.8 Results of Simulation

The simulation of the Inchampalli pond is carried out considering the daily inflows into the pond and daily possible diversion from the pond. Two scenarios viz. considering (i) the net annual yield series from the catchment of Godavari between SRSP and Inchampalli and (ii) the net annual yield series from only Indravati sub-basin(including unutilized waters of Chhattisgarh) have been taken up for simulation. In both the cases the daily diversion is considered as 62.2 Mm^3. In the first scenario, it is seen that about 5244 Mm^3 can be transferred at 75% success rate and the envisaged diversion of 7000 Mm^3 can be effected with a success rate of 56%. Likewise, in the second scenario, it is found that about 5634 Mm^3 can be transferred at 75% success rate and the envisaged diversion of 7000 Mm^3 can be effected with a success rate of 39%. The abstract of simulation at Inchampalli project for both the scenarios are given in **Annexures 5.9 & 5.10** respectively. However, there is possibility of ensuring diversion of 7000 Mm^3 at 75% success rate by increasing the daily diversion

appropriately, since adequate flows are available at the site during the monsoon period.

From the daily diversions through the Inchampalli - Nagarjunasagar link as obtained from the simulation of Inchampalli pond, irrigation, domestic and industrial uses and transmission losses enroute this link canal are deducted to arrive at the net inflows into the Nagarjunasagar reservoir through the link.

5.9.1 Floods and drainage

(a) Godavari at Inchampalli barrage

The design flood discharge for barrage has been computed to be 71030 cumec.

(b) Krishna at Nagarjunasagar

The construction of the Nagarjunasagar Dam was commenced in the year 1956 and completed by the year 1967 The 1000 year design flood at the dam is 58340 cumec, while the routed flood is 45310 cumec. The maximum observed flood recorded at the dam is 30050 cumec.

(c) Pennar at Somasila

The design flood at the dam is 19680 cumec. The maximum discharging capacity at FRL (100.58 m)/MWL (101.80 m) is 19680/22375 cumec.

(d) Cauvery at Grand Anicut

The flood discharging capacity of Grand Anicut is 3327.22 cumec. The maximum flood levels at front and rear are 60.84 m and 58.60 m respectively against a full pond level of 59.22 m.

5.9.2 River geometry

The river geometry of Godavari, Krishna, Pennar and Cauvery river systems are shown in **Plate 2.1 to 2.4.**

5.10 Ground water recharge

The proposed diversion through the 1210.841 km long canal is expected to recharge the ground water enroute the canal as well as in the command area.

The project area is situated in the sub-basins of Lower Godavari (G-10) in Godavari basin, Muneru (K-12) and Palleru (K-11) in Krishna basin, Basin of streams between Krishna and Gundlakamma, Gundlakamma basin, Basin of streams between Gundlakamma and Pennar, Pennar delta sub-basin of Pennar basin, Basin of streams between Pennar and Palar, Palar basin, Basin of streams between Palar and Cauvery and Cauvery delta sub-basin of Cauvery basin. The districts that are traversed by the link and in which its command area lies are Warangal, Khammam and Nalgonda in Telangana, Guntur, West Godavari, Prakasam, Nellore and Chittoor in Andhra Pradesh and Tiruvallur, Vellore, Kanchipuram, Tiruvannamalai, Villupuram and Cuddalore of Tamil Nadu. As per the "Dynamic Groundwater Resources of India (As on 31st March, 2013)", the ground water potential, existing draft, balance and stage of utilisation in these districts of the project area are given in **Table 5.23.**

Table 5.23
Ground water particulars of districts in the project area

Unit: Mm^3

State/District	Net annual availability	Draft for irrigation	Projected demand for D&I (2025 AD)	Availability for future irrigation
Telangana				
Warangal*	1814	1236	135	443
Khammam*	1329	506	92	731
Nalgonda*	1908	1272	182	454
Andhra Pradesh				
Guntur	1247	392	142	713
Prakasam	1510	544	176	790
Nellore	2550	903	110	1537
Chittoor	1780	953	135	692
Tamil Nadu				
Tiruvallur	818	321	258	239
Vellore	564	536	145	-27
Kanchipuram	922	564	71	287
Tiruvannamalai	1015	1026	114	-125
Villupuram	1581	1392	57	132
Cuddalore	1452	556	344	552
Tanjavur	740	789	26	-75
Chennai	17	0	30	-13

Source: Dynamic Groundwater Resources of India (As on 31st March, 2017), CGWB Publication June-2019
** erstwhile districts of Telangana*

5.11 Navigation

There is no proposal of providing navigation in the proposed Godavari (Inchampalli) - Cauvery (Grand Anicut) link canal.