Engineering/Science/Technology Civil/WR/EE/GIS

WATER USE EFFICIENCY OF KADDAM NARAYANA REDDY PROJECT

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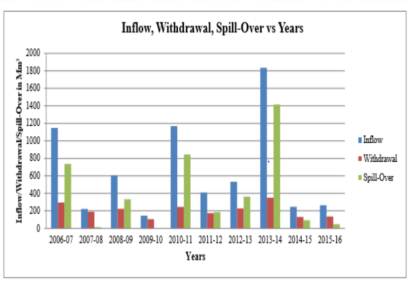
GRAPHICAL ABSTRACT



ABSTRACT

Kaddam reservoir located in Kaddam mandal of Adilabad district in Telangana is taken into consideration for the present study. It is one of the major irrigation systems in Telangana. Central Water Commission (CWC) is the top technical organisation under the Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, in the field of water resources development in India. CWC has developed a method for performance evaluation as well as studies in Water Use Efficiency (WUE). Using this methodology the WUE of present irrigation system (KNR reservoir) is calculated. And also the WUE is calculated based on Michael's (2014) approach. Reservoir inflow, outflow and storage data are taken as input and reservoir efficiency is calculated. Velocity details are taken along the length of the canal and losses in the canal are calculated. From the losses the conveyance efficiency is calculated. Gross Water Requirement (GWR) is calculated using Modified Penman method. Seepage and percolation losses of the field are known from the irrigation department. From these losses the on-farm application efficiency is calculated. By comparing the released water from the reservoir and GWR value from

Modified Penman method, it is estimated that there is no drainage problem in the irrigation system, because the GWR value is more than the supplied value. Finally the two method results are analyzed and given the conclusions.

***Keywords* ---WUE, reservoir efficiency, conveyance efficiency, on-farm application efficiency, drainage efficiency and GWR**

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I. INTRIDUCTION

Irrigation was practiced in India started from time immemorial. The large scale expansion of irrigation works in the Indian sub-continent during the 19th century and the first half of the 20th century is due to efforts of three great engineers and visionaries like Sir Arthur Cotton, Major P.T. Cautley and Sir M. Visveshwaraiah. Post-independence development of irrigation works in India was on the basis of classification of works into major, medium and minor projects. Since 1978, the basis of classification of irrigation projects was culturable command area of the project. The irrigation potential is increased after independence. During the initial five year plans and the annual plans, the gross irrigation potential increased from 22.6 million ha in 1950-51 to 106.61 million ha in 1997-2002 and expected to reach an ultimate potential of 145 million ha in the near future.

After independence and during the first two five year plans, the main focus of the government was to develop irrigation systems to improve food security. Many major and medium irrigation systems were conceived and implemented but it was later noticed that there was large difference between the irrigation potential created and actual utilisation. Studies by various agencies showed that the irrigation systems were performing below the planned level. The performance of the irrigation systems suffered from low WUE, distribution losses, poor operational maintenance and management of soil salinity, water logging, tail end problems and unable to take necessary steps for improving the system. The present study focuses on these aspects to study the WUE of an existing system. The study is undertaken the calculation of WUE of KNR irrigation project and identifying the measures for improving the WUE.

II. METHODOLOGY AND STUDY AREA

Methodology:

WUE is calculated using two different methods. In the first method, the WUE is calculate based on CWC guidelines for the irrigation project performance and in the second method, the WUE is calculate using yield and ET of the crop using the method suggested by Michael, (2014).

Method 1: CWC guideline

WUE (broadly suggested by the ICID and CWC (CWC, 2014)) is the product of four efficiencies, viz., reservoir storage efficiency, conveyance efficiency, on-farm application efficiency and drainage efficiency.

Reservoir storage efficiency is the ratio of maximum live storage capacity in a particular year to the designed live storage.

Conveyance efficiency (W_C) is the ratio of total water delivered at the outlet to the water released at the project head work.

On-farm application efficiency (W_O) is the ratio of the water available for crops to the water released through canal system.

The drainage efficiency (W_D) is the ratio of total annual water drained from the system to total annual water delivered to the system plus effective rainfall minus water used by crops.

Method 2: Michael's (2014) approach

The overall Irrigation Efficiency is the product of reservoir storage efficiency, conveyance efficiency and application efficiency. WUE is the ratio of production (of crops) per unit of water applied. It is expressed as the weight of crop produce per unit depth of water over a unit area, i.e., kg/cm per hectare. Two distinct terms are used in expressing water use efficiency.

i. Crop water use efficiency: It is the ratio of crop yield (Y) to the amount of water depleted by the crop in the process of evapotranspiration (ET) as shown in Eq. 2.1.

$$\text{Crop water efficiency} = \frac{Y}{ET} \tag{2.1}$$

ii. Field water use efficiency: It is the ratio of crop yield (Y) to the total amount of water used in the field (WR) as shown in Eq. 3.2

$$\text{Field water efficiency} = \frac{Y}{WR} \tag{2.2}$$

Reservoir storage efficiency (W_R) defines the efficiency with which water is stored in a reservoir. Reservoir storage efficiency is expressed by Eq. 2.3

$$W_R = 100\left(1 - \frac{V_e+V_s}{V_t}\right) = 100\left(\frac{V_o+\Delta S}{V_t}\right) \tag{2.3}$$

where,
Ve= Evaporation volume from the reservoir
Vs = Seepage volume from the reservoir
Vi = Inflow to the reservoir during a time interval
Vo = Volume of outflow from the reservoir during a time interval
∆S = Change in reservoir storage during the time interval
The ∆S term is often neglected when long time periods are considered.

Water conveyance efficiency is used to measure the efficiency of water conveyance systems associated with the canal network, water courses and field channels. It is expressed as follows in Eq. 2.4

$$W_C = \frac{W_f}{W_d} \times 100 \tag{2.4}$$

where,
W_f= Water delivered to the irrigated plot
W_d= Water diverted from the source

Water application efficiency is important to apply the water on the land as efficiently as possible. Water application efficiency is calculated as given in Eq. 2.5

$$W_A = \frac{W_s}{W_f} \times 100 \tag{2.5}$$

where,
W_S = Water stored in the root zone of the plants
W_f = Water delivered to the field

Study Area:

Kaddam Narayana Reddy (KNR) project is selected for the study. The location map of Kaddam reservoir is given in Fig 2.1.

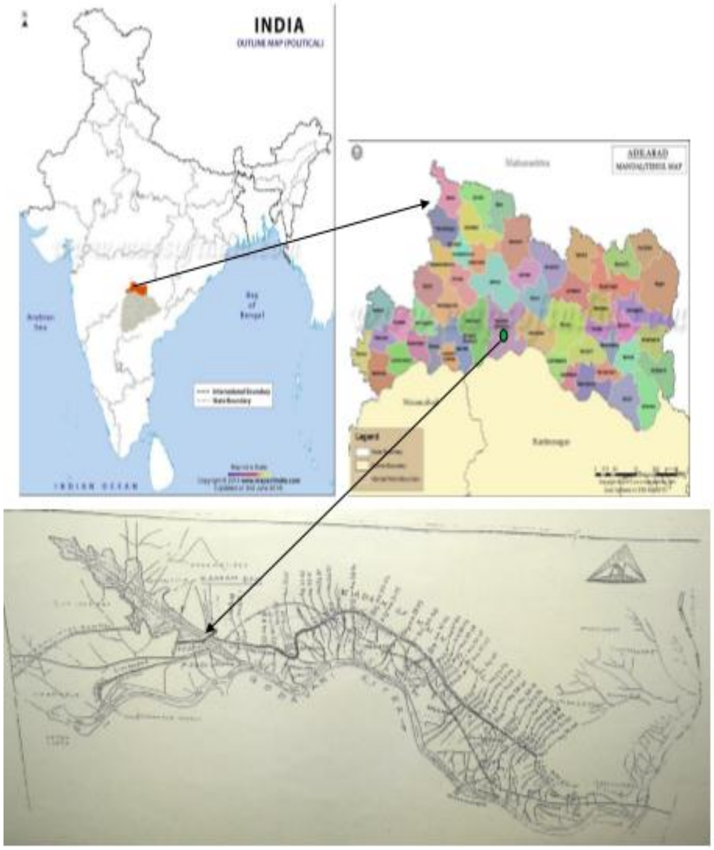

Fig 2.1 Location Map of Kaddam Reservoir

KNR reservoir is constructed across the river Kaddam, a tributary to river Godavari, intended to irrigate an extent of 68.150 acres (27.58 ha) in the year 1958. The salient features of Kaddam canal details are presented in Table 2.1. A view of KNR reservoir is shown in Fig. 2.2

Table 2.1 Canal Details

CANAL	L.F Main Canal	R.F Channel
Length of canal	73.60 kms	8.0 kms
Discharge	1100 cusecs (31.1 m^3/s)	55 cusecs (1.6 m^3/s)
No.of distributaries	35(D1 to D42)	4(Minors)
Ayacut	66,800 acres (27033.6 ha)	1,700 acres (688 ha)
Cropping pattern	Paddy	Paddy
Villages benefitted	93 Villages	5 Villages
Rehabilitation	-Nil-	-Nil-

Fig. 2.2 KNR Reservoir

III. APPLICATION TO STUDY AREA

The methodology discussed in Chapter 3 is applied to the selected study area, i.e., the KNR reservoir. This Chapter gives the results of studies carried out to calculate WUE and optimisation studies to carry out sensitivity analysis and suggest the optimal cropping pattern. Flow duration curves are generated from reservoir inflows. The results obtained are presented in the form of tables and graphs, and discussed.

Method 1: CWC approach

Reservoir storage efficiency (W_R): Reservoir storage efficiency (WR) defines the efficiency with which water is stored in a reservoir. WR is the ratio of maximum live storage capacity in a particular year to the designed live storage. Table 3.1 shows the status of the reservoir storage (CWC, 2014). Fig 3.1 shows the pictorial representation of the inflow, withdrawal and spill over values. The design live storage and dead storage in the Kaddam reservoir is found to be 136.6 M.Cum and 78.7 M.Cum. The reservoir storage efficiency which is obtained using the design live storage and calculated storage was 37.21%.

Table 3.1 Status of the Reservoir Storage

Year	Month	Storage (on the first day of the month) (Mm^3)	Inflow during the month (Mm^3)	Withdrawal (Mm^3)	Spill-Over (Mm^3)	Balance (2+3-4-5) (Mm^3)	Losses		Net storage (6-7-8) (Mm^3)
							Evaporation (Mm^3)	Seepage losses (approx) (Mm^3)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2015	June	0	98.95	0	0	98.95	3.67	1.70	93.58
	July	93.58	35.27	0	47.42	81.43	2.83	2.71	75.89
	Aug	75.89	44.77	23.44	0	97.22	3.04	3.04	91.14
	Sept	91.14	82.27	37.77	0	135.65	2.91	3.20	129.53
	Oct	129.53	3.29	34.19	0	98.63	2.82	3.44	92.36
	Nov	92.36	0	34.85	0	57.51	1.88	1.80	53.83
	Dec	53.83	0	5.98	0	47.85	1.55	1.51	44.79
	Jan	44.79	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0
	April	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0
	total		264.5	136.2	47.42		15.27	14.09	

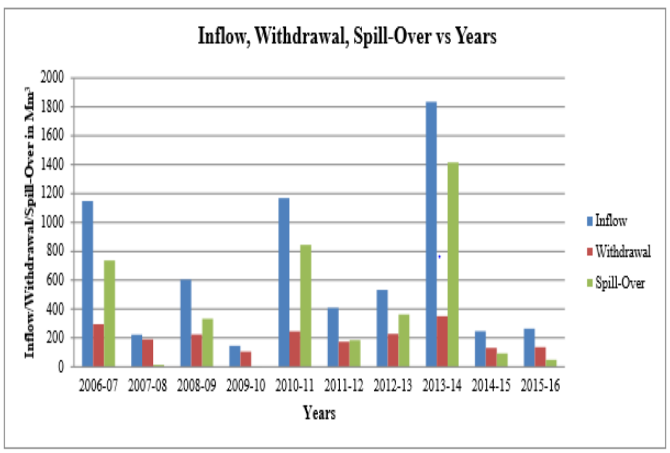

Fig 3.1 Inflow, Withdrawal, and Spill-Over vs Years

Conveyance efficiency (WC)- Conveyance efficiency is the ratio of water delivered at the inlet to the water released at the project head work. The starting point of the left main canal along with Distributory Beyond Manair (DBMs) is shown in Fig 3.2 and the Table 3.4 shows the canal flow details from 1.56 km to 20.36 km including seven DBMs. DBM-7 is located at 15.62 km from the starting point of the canal and having an irrigated area 200 ha.

Table 3.4 Left Main Canal Flow Details

Location	Length (m)	Depth (m)	Width (m)	Time (sec)	Velocity (m/s)	Corrected Velocity (m/s)	Discharge (m^3/s)
1.56 km	20.00	1.35	10.00	38.20	0.52	0.416	5.616
DBM-1	5.00	0.40	1.30	10.52	0.47	0.376	0.196
DBM-2	10.00	0.70	2.30	20.00	0.50	0.400	0.644
DBM-3	10.00	0.70	1.18	17.00	0.59	0.472	0.390
DBM-4	5.00	0.45	1.20	6.56	0.76	0.608	0.328
DBM-5	5.00	0.25	2.36	16.7	0.30	0.240	0.142
DBM-6	5.00	0.18	1.05	7.38	0.68	0.544	0.103
DBM-7	5.00	0.65	0.92	8.27	0.60	0.480	0.287
20.36 km	20.00	0.80	9.70	43.12	0.464	0.371	2.879

Fig. 3.2 Starting Point of the Left Main Canal

Table 3.5 shows the conveyance efficiency in main canal and Table 3.6 shows the conveyance efficiency of DBM-7. The calculation of losses and the process of calculation of conveyance efficiency in left canal and the canal efficiency for right canal and DBM-7 are in Table 3.5 and 3.6. The product of left canal efficiency and DBM-7 gives the overall efficiency of the left main canal system. The average of left canal and right canal efficiency gives the canal system efficiency. Left, right canals and DBM-7 inflows are 5.616m3/s, 0.16m3/s and 0.36m3/s respectively and calculated losses in left, right canals and DBM-7 are 2.737m3/s, 0.06m3/s and 0.13m3/s respectively. From these losses, conveyance efficiency for left, right canals and DBM-7 are 51.26%, 62.2% and 63.80% respectively. The Kaddam canal system efficiency was found to be 47.45%.

Table 3.5 Conveyance Efficiency in Main Canals

Location	Range	Discharge (m^3/s)	Effective length (m)	Avg. Wetted Perimeter (m)	Conveyance Loss Factor ($m^3/s/Mm^2$)	Total Loss (m^3/s)	Water Delivered (m^3/s)	η_{c} (%)
Left Canal	1.56km-20.36km	5.616	18,800.00	12.00	24.894	2.737	2.879	51.26
Right Canal	0.2km-1.0km	0.160	800.00	3.11	24.920	0.06	0.10	62.20

Table 3.6 Conveyance Efficiency in DBM 7

Location	Range	Discharge (m^3/s)	Effective length (m)	Avg. Wetted Perimeter (m)	Conveyance Loss Factor (m^3/s /Mm^2)	Total Loss (m^3/s)	Water Delivered (m^3/s)	η_c (%)
DBM 7	0.6km-2.5km	0.36	1900	2.22	30.82	0.13	0.23	63.80

On-farm application efficiency (W_A): On-farm application efficiency is the ratio of actual water required by the crops and the water supplied through surface irrigation considering rainfall in command area. The Table 4.10 indicates the actual crop water requirement for paddy in Kharif season using modified penman formula. Using a combined seepage and percolation loss value of 180 mm, on-farm application efficiency is found to be 25% and the water released from the reservoir is 136.2 M.Cum (801 mm).

Table 3.10 Crop Water Requirement by Modified Penman Method

Month	ETo (mm)	K_c	ET crop (mm)	Add for nursery (mm)	Add for land Preparation (mm)	P (mm)	Add for Minimum Depth (mm)	Norm RF (mm)	R_e (mm)	NIR (5+6+7+8+9-11) (mm)	FIR (mm)	GIR (mm)
1	3	4	5	6	7	8	9	10	11	12	13	14
Paddy in Kharif												
July	124.4	1.10	136.84	40.00	160.00	90	50	186.4	130.8	346.04	432.55	617.93
Aug	117.2	1.10	128.92	0.00	0.00	90	0	113.20	92.70	126.22	157.78	225.39
Sep	115.3	1.10	126.83	0.00	0.00	90	50	182.4	129.2	137.66	172.08	245.82
Oct	123.2	0.95	117.04	0.00	0.00	90	0	6.40	6.33	200.71	250.89	358.41
Total										810.63	1013.3	1447.6

Drainage Efficiency (W_D): The drainage efficiency is the ratio of total annual water drained from the system to the total annual water delivered to the system plus effective rainfall minus water used by crops. The total quantity of water released to the fields (136.2 Mm3) is less irrigation water requirements as per Modified Penman method (246.1 Mm3) and also total quantity of water released to the fields plus rain water component 258.57Mm3 (136.2 Mm3+122.4 Mm3) is less than of crop water requirement plus the groundwater potential 398.42 Mm3 (246.1 Mm3+152.32 Mm3). This indicates that there is no drainage problem.

Overall efficiency or WUE: The overall efficiency is 12% obtained from the results. As per CWC standards the overall efficiency is 33.8%. The WUE is 4.5% obtained from the results. As per CWC standards the WUE is 32.11%.

Method 2:Michael's (2014) approach

The reservoir efficiency which is obtained using the volume of outflow, change in storage and inflow volume was 33.05%. Conveyance efficiency is obtained using the water delivered to the irrigation plot and water delivered from the source. Water application efficiency which is obtained using the water delivered and water stored in the root was 51.26%. Overall irrigation efficiency was 4%. Crop water use efficiency is obtained by considering crop yield and evapotranspiration was 144.42 kg/cm per ha. Field water use efficiency is obtained by considering crop yield and water used in the field was 352.1 kg/cm per ha.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

- Since the entire T.S. and Adilabad region have low rainfall and less irrigation facilities developed. The crops are generally grown during Kharif season.
- The design live storage in the Kaddam reservoir is found to be 136.6 M.Cum, whereas the calculated live storage is 50.827 M.Cum. So, the reservoir storage efficiency which is obtained using the design live storage and calculated storage was 37.21% using CWC approach, 2014 and 33.05% using Michael's approach, 2014.
- The Kaddam canal system efficiency was found to be 47.45% by using both approaches.
- Using a combined seepage and percolation loss value of 180 mm, on-farm application efficiency is found to be 25% and the water released from the reservoir is 136.2 M.Cum (801 mm).
- The total quantity of water released to the fields (136.2 Mm3) is less than the irrigation water requirements as per Modified Penman method (246.1 Mm3). Further, the sum of total quantity of water released to the fields and rain water component is 258.57Mm3 (136.2 Mm3+122.4 Mm3), which is less than sum of crop water requirement and the groundwater potential which is 398.42 Mm3 (246.1 Mm3+152.32 Mm3). This indicates that there is no drainage problem.
- The overall efficiency was 12% and WUE was 4.5 %. The overall irrigation efficiency was 4 %, crop water use efficiency was 144.42 kg/cm per ha and field water efficiency was 352.1 kg/cm per ha as calculated using Michael's approach, 2014.
- By comparing overall efficiency concluded that the CWC approach give better results than Michael's approach.

Recommendations:

- The canal lining is not properly maintained and there are so many damaged portions along the length of the canal. To mitigate this new lining should be provided for reducing losses in the canal.
- There is no proper maintenance of the canals and most DBMs are covered with vegetation. Proper maintenance of the DBMs and the canal is essential to lower the seepage losses.
- Measurements for losses in the field are to be taken. This information leads to improvement in the application efficiency.

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