

Original Research Article

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Development of Rotational Water Allocation Plan for Jaisamand Irrigation Project

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ABSTRACT

The study was conducted to develop a rotational water allocation plan on the basis of water requirement of crops with reference to a command of Right Main Canal (RMC) of Jaisamand dam situated on Gomtiriver. Diagnostic analysis of water distribution system was conducted to study the operational problems in entire network of RMC and it revealed that there was lack of knowledge among the farmers about optimum water requirements. Canals required maintenance to avoid from a large wastage of water as seepage through cracks on entire RMC. Seasonal crop water requirement for Rabi crops (wheat, gram and barley) were determined using the values of ET_0 and K_c with consideration of conveyance and application losses. The seasonal crop water requirement for wheat, barley and gram were as 45.60, 32.16 and 35.29 cm respectively. The Field Water Use Efficiency for wheat, barley and gram was 59.20, 46.64 and 17.00 kg/ha-cm respectively. The Crop Water Use Efficiency for the same crops was found as 103.57, 80.09 and 27.93 kg/ha-cm respectively. The conveyance efficiency of RMC was found as 80.62 %, whereas for Phadi, Jhadol and Dingri minor it was found as 75.95 %, 70.68 % and 65.62 %, respectively. It was found that maximum time required i.e., 3.24 days for group no.7, whereas the minimum time required i.e., 0.66 day for group no. 2. Thus all farmers even on tail end were getting their fair shares in proportional to land holding.

Keywords

Rotational water allocation plan, Irrigation project, Diagnostic analysis etc.

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Introduction

The rapid increase in agricultural production will be required to meet area under irrigation or by increasing the yields of existing cropped area when using similar or even reduced water resources (Shah and Dalwadi, 2011). Irrigation water is one of the most important inputs in irrigated agriculture. In India, the total irrigated area is only one third of the total cropping area but it produces about two third of total agriculture production (Upadhyaya *et al.*, 2010). So to fulfil the future demand, it is necessary to increase the total

irrigated area and increase the efficiency of irrigation systems. Poor irrigation performance typical in many irrigated areas around the world resulted in important social, economic and environmental problems, so that the modernisation of these areas is required to ensure their profitability and sustainability. The social and economic importance of irrigation, the existence of many aged irrigation and the planned new irrigation developments make it necessary to diagnose the present water use at the

irrigation level. Obtaining satisfactory performance is crucial to sustaining increased agricultural production and realizing an acceptable return on the productive and hydrological impacts of internal irrigation processes to assist agents involved in crop production, water management and water policy to improve the performance of irrigated areas (Perry and Allen, 2009 and Molden *et al.*, 2010).

A deficit of water occurring in a certain stage of a crop growth may cause a greater reduction in yield than the same amount of deficit occurring in some other growth stages. To overcome the problems of low-overall efficiency of projects and limited water resources, there is need to improve irrigation system planning, operation and management (Mishra *et al.*, 2013). System performance monitoring, evaluation and diagnostic analysis are keys to appreciate the improvement of efficiency in irrigation projects.

In recent years, several canal automation and control algorithms have come in vogue. However, due to lack of financial resources the vast majority of irrigation projects in India are not in a position to adopt these advanced technologies. Thus, with the existing infrastructure, the only alternative for such projects is to improve the functioning of the main system through a better delivery schedule (Singh, 2012).

Improving water use efficiency requires the development of satisfactory means to estimate evapotranspiration. Hence the estimation of evapotranspiration is of most importance in water resource planning and management and irrigation development. It is particularly important in arid and semiarid areas because of the scarcity of water for irrigation purposes (Joshi and Singh, 1994). The studies on water budgeting and evapotranspiration for various

crops are utmost important for the purpose of scientific planning and scheduling irrigation (Meshram *et al.*, 2011). Generally the head reach farmers apply more water than it is needed. This creates problems of water logging and salinity. It is therefore, necessary to go for an improved method of irrigation distribution in which the water is assured to all farmers equitably and timely i.e. as per predetermined schedule (Li *et al.*, 2005). This study was aimed at helping both reservoir managers and farmers in decision-making. In Jaisam and irrigation system the overall operation of the system was not up to the mark. Hence, it was proposed to develop a suitable operational plan for efficient allocation of water resources in the command area under right main canal in Jaisam and Irrigation Project.

Materials and Methods

Details of Jaisamand dam with canal command

The Jaisamand lake catchment is located in the Udaipur district which falls in sub-humid region of Rajasthan bounded by 73⁰45' to 74⁰25' E Longitude and 24⁰10' to 24⁰35' N Latitude. The lake with a gross capacity of 41460 ha-m and live storage of 29614 ha-m, is Asia's second largest artificial water storage reservoir built across the Gomati river (Sharma, 2011). The GCA and CCA of dam is 37282 ha and 16000 ha respectively. Total length of dam is 399 m and total width is 100 m.

Catchment area

The gross catchment area of the project is 1857 km². The area is mostly hilly and covered by forest with small patches of cultivation. The free catchment area at the dam site is 1654 km² and the intercepted catchment area is 159 km².

Command area

The command area is in Sarada tehsil of Udaipur district. There are 37 villages in the command area. The command area is in a predominantly tribal belt. The total irrigated area in the Rabi season is 16000 ha. The culturable command area of left and right main canal is 13815.5 ha and 2185.89 ha respectively.

The command area has red loam soils. The crops grown in the past for the Rabi season includes wheat, mustard, gram, barley fodder. The soil erosion problem does not exist in the command area.

Canal system

The distribution system consists of two main canals; the Right Main Canal and the Left Main Canal. The right main canal covers the length of 22.86 km, while the left main canal covers the length of 51.09 km.

Right main canal (RMC)

The canal has been designed as a trapezoidal lined section with a bed slope of 1:3000 and side slope of vertical. The bed width at head is 2.45 m with full supply depth as 0.72m. The culturable command area is 2185.89 ha. The length of main canal of RMC is 22.86 km and rated discharge at the head is $1.53\text{m}^3/\text{s}$. The total area under GCA, CCA and ICA is 2626.104 ha, 2185.89 ha and 1732.252 ha respectively.

Left main canal (LMC)

The length of left main canal is 51.09 km. It is designed to carry a discharge of $7.56\text{m}^3/\text{s}$. The canal is designed as a trapezoidal lined section throughout its length with side slope vertical. The total area under CCA is 13815.5 ha.

Minors

The distribution system comprised of 28 minors involving total length of 60.12 km. Total six minors i.e., Pahadi, Khankal, JhadolSarsia, Dingri and Veerpura were off taking from RMC and twenty two minors from the LMC.

Study area

In the present study, the Right Main Canal (RMC) of Jaisamand Irrigation Project was selected purposely because RMC covered suitable percent area of total command for our project operations. Details of the minors situated on RMC are given in Table 1.

Out of six minors on RMC, three minors *viz.* Pahadi, Jhadol and Dingri were selected for presented study each from head, middle and tail end of the RMC.

Diagnostic analysis

Diagnostic analysis is an investigation method that examines an irrigation system as it actually operates or not as it is prescribed to operate. It is an interdisciplinary method which involves farmers in the examination of an operating irrigation system with its interrelated components.

The diagnostic analyses of the study area are conducted on following basis:

Existing physical status of the irrigation system

Water distribution system in the area was surveyed for the diagnostic analysis of the existing physical status of the main canal, minors and outlets. Damaged canal lining, gates and outlets were observed at number of locations in entire canal network. Physical status of system depends on knowledge of the

farmers of the command area about how much water should be applied for proper growth of plants.

Silt deposition in canals/minors

Silt deposition was investigated at number of locations before irrigation and after irrigation. Siltation in canals/minors causes chances of overtopping, which results in wastage of water. Thus, farmers have to face with the problem of water logging in the low lying areas; therefore, it is necessary to investigate siltation in canals/minors.

Analysis of water quality

The water samples obtained from canal as well as wells located in the head, middle and tail reaches of the command were checked for quality and physical ability for irrigation purpose.

Crop water requirements

The reference evapotranspiration (ET_0) in study area were determined by using 'CROPWAT 8.0' software (FAO, 1992). For this purpose, metrological parameters for the period (1994 to 2014) were collected from nearest meteorological observatory of CTAE, MPUAT Udaipur, Rajasthan.

The input parameters of the software are basic information's on the climatic station such as country name, station name and climatic data for calculation of crop water reference evapotranspiration.

Crop-coefficients for calculation of crop water requirements were selected with the help of FAO-56 (Allen *et al.*, 1998). The values of reference evapotranspiration were calculated using CROPWAT software according to sole standard Penman-Monteith formula recommended by FAO 56.

Irrigation system performance

The irrigation system performance was evaluated by considering irrigation efficiencies as conveyance efficiency, crop water use efficiency and field water use efficiency.

Water Conveyance Efficiency (E_c) = Water flowing in the canal / Water flowing out of canal (1)

Conveyance losses were calculated by the following formula,

Conveyance losses per km (%) = (1-outflow/inflow) x 100 (2)

Crop water use efficiency is the ratio of crop yield (Y) to the amount of water depleted by the crop in the process of evapo-transpiration (ET).

Water use efficiency = Y/ ET (3)

Field water use efficiency is the ratio of crop yield (Y) to the total amount of water used in the field Water Requirement.

Field water use efficiency (kg /ha-cm) = Y/WR (4)

Rotational water allocation plan

It is the most suitable organisational method for distributing limited resources among large number of farmers reliably and equitably. It eliminates all drawbacks of traditional irrigation system.

It would facilitate application of water to an individual farm which is efficient and can be well managed by farmers. All farmers will receive their fair share of water irrespective of his position on field channel and social and economic status. The irrigation efficiencies

will improve and more area will come under irrigation (Das *et al.*, 2014).

Roster of turns

When water is delivered in the watercourse, it requires some time to reach up to each delivery point (called Nakka). This time of filling is called Bharai. Similarly it requires some time to empty through each delivery point, this time of emptying is called Jharai.

Total time of each farmer (hours) = Calculate time to satisfy FIR with fixed supply of water + his Bharai- his Jhara. (5)

(Bharai is zero for all farmers except the last.)

Method of development of a rotational water allocation plan

The rotational Water Allocation plan was on the basis of area of group in each outlet.

Step1:- Consider cycle period of each outlet in 15 days.

Step 2:- Calculate total area for different groups under of farmers.

Step 3:- The water allocation time factor is calculated by dividing time period of 15 days by total area under outlet.

Step 4:-Time required for each group has been calculated by multiply time factor and area of each group.

Step 5:- Prepare water allocation plan in time per unit area for 15 days.

Results and Discussion

Diagnostic analysis

Water distribution network and canals

There was no any proper water distribution system in this command area. The farmers at head reaches use more water than tail reaches

(Arya, 2005). Water logging problem was not observed in area during irrigation season but some amount of seepage was observed in the command area.

Phadi minor

Phadi minor has maximum length of 7.20 Km. It off-takes from head of RMC at RD 5100 meter and sluice gate was observed in damaged condition. The Pahadi minor having design discharge capacity of 0.179 m³/s against it measured discharge was found 0.105 m³/s. The silt load carried with water in the minor was not significant. Nevertheless, canal water is in general, silt free, but silting in canal was occurred due to the entry of run-off water in the canal at many places. Tail end farmers were not getting sufficient quantity of water due to improper bed slope.

Jhadol minor

Jhadol minor off-takes from middle of RMC at RD 20070 m. This minor has maximum length 3.0 Km. This minor in the command with total Culturable Command Area (CCA) of 358.56 ha. The lining is rectangular and having design discharge capacity of 0.290 m³/s against it measured discharge was found 0.205 m³/s. The damaged canal lining and stone barriers in Jhadol minor are shown in Figure 3. Farmers at tail portion were not getting water properly since many years because the farmers at head end were using more water than actual requirements.

Dingri minor

Dingri minor is situated at tail end of RMC and off takes at RD 22560 m. There was a major problem of water shortage in this minor due to being situated at the tail end and seepage through cracks. Water covers only one third length of this minor. Therefore, no control on flow or regulation (opening or

closing) can be practiced. The pipe outlets were also found tempered or oversized in the canal network. The unauthorized outlets were also found on Dingri minor of Right Main Canal and the minor was weed infested at many places which create obstruction in water supply.

Tail enders were getting water from others sources such as wells, tube wells, etc. Bed of this minor was fully damaged and required maintenance.

Physical/Structural

Canal lining

There was lack of knowledge among the farmers of the command area about how much water should be applied to the field for sustainable crop yield. There was canal lining exists in entire canal network. Some cracks in canal lining were also observed at number of locations in canal network which requires maintenance to avoid wastage of water through seepage from cracks. Most of the

farmers irrigate their fields until water does not stop in the canals.

Water courses

The water courses being the responsibility of farmers were not maintained regularly and particularly by middle reach farmers, as a result of which almost some water courses were damaged and weed infested, vegetative at Jhadol minor. Due to improper maintenance and tempering of networks by the farmers, the water courses off taking even from the head of distributaries or minors were not in condition to supply the adequate quantity of water to its tail reach fields.

Gates and pipe outlets

The majority of gates were found tempered or damaged. The pipe outlets were also found tempered or oversized in the canal network. The observations were also made for additional unauthorized outlets and found as three outlets on Phadi minor, two on Jhadol and six outlets on Dingri minor.

Fig.1 Location map of Jaisamand Command Area

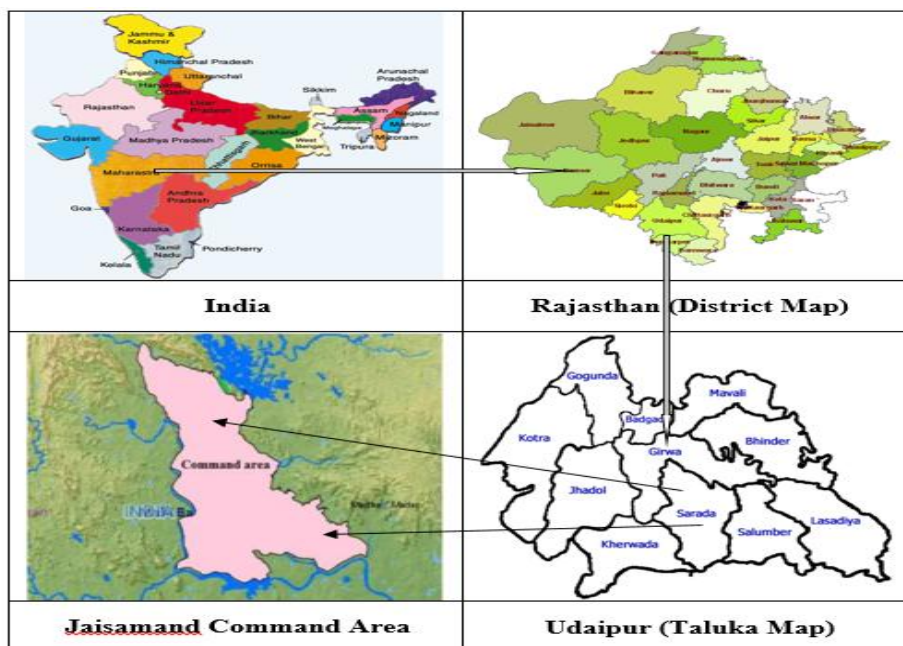


Fig.2 Siltation at Pahadi Minor



Fig.3 Damaged Jhadol Minor at starting and middle of minor



Table.1 Details of minors on Right Main Canal (RMC)

Sr. No.	Minors	GCA (ha.)	CCA (ha.)	ICA (ha.)	Discharge (m ³ /s)
1	Phadi	429.6	358.56	268.75	0.115
2	Khankal	434.64	362.24	289.76	0.120
3	Jhadol	696.9	580.75	464.60	0.201
4	Sarsia	214.644	178.24	143.096	0.064
5	Dingri	683.46	569.82	455.856	0.199
6	Veerpura	166.54	138.42	110.45	0.045

Table.2 Outlet details of Jhadol Minor

Outlet	GCA (ha.)	CCA (ha.)	ICA (ha.)	Discharge (m ³ /s)
1L	25.35	15.54	10.41	0.019
2R	14.35	9.35	5.65	0.020
3L	22.73	18.73	12.85	0.018
4R	20.24	16.28	14.32	0.021
5L	48.86	42.86	36.15	0.019
6R	18.83	13.83	9.32	0.018
7L	37.18	35.18	29.15	0.020
8R	45.54	30.61	25.23	0.020
9L	12.41	9.41	5.32	0.019
10R	74.50	65.25	58.75	0.017
11L	49.88	43.80	30.12	0.015
12R	34.88	30.92	26.32	0.014
13L	48.77	40.55	34.28	0.016
14R	80.22	75.45	65.85	0.017
15L	35.25	23.64	18.36	0.016
16R	20.22	18.55	15.63	0.012
17L	19.28	17.25	14.50	0.010
18R	25.35	16.75	13.35	0.090
19L	15.45	12.40	9.69	0.060
20R	18.45	15.25	10.45	0.080
21L	12.25	10.68	6.71	0.010
22R	18.55	15.86	12.89	0.009

Table.3 The values of ET_c and irrigation requirement of rabi crops

Fortnight	Period	ET _c (mm)			Eff. rainfall (mm)	Irrigation water requirement (mm)		
		Wheat	Barley	Gram		Wheat	Barley	Gram
1 st	1-15 October			19.67	7.05			12.62
2 nd	16-31October			22.68	7.05			15.63
3 rd	1-15 November	16.16	12.15	30.88	1.82	14.34	10.33	29.06
4 th	16-30November	19.28	13.38	36.41	1.85	17.43	11.53	34.56
5 th	1-15 December	28.32	20.55	32.88	0.72	27.6	19.83	32.16
6 th	16-31December	35.29	32.07	33.69	0.73	34.56	31.34	32.96
7 th	1-15 January	35.15	31.94	25.39	1.45	33.7	30.49	23.94
8 th	16-30 January	42.69	37.07	13.25	1.45	41.24	35.62	11.8
9 th	1-15 Feb	46.24	27.71		1.65	44.59	26.06	
10 th	16-28 Feb	37.61	12.46		2.05	35.56	10.41	
Total		260.74	187.33	214.85		249.02	175.61	192.73

Table.4 Conveyance efficiency of the water distribution system

Sr. No.	Minors	Conveyance efficiency (%)			
		Head	Middle	Tail	Average
1	RMC	85.00	84.56	83.55	85.04
2	Phadi	81.12	80.02	79.38	80.17
3	Jadhol	77.23	76.52	74.23	75.99
4	Dingri	72.23	71.20	69.15	70.86
Overall Average					78.02

Table.5 Water use efficiency for wheat, barley and gram in canal command

Crops	ET _c (cm)	IR (cm)	Conveyance Efficiency	Application Efficiency	Water requirement (cm)	Crop yield qt/ha	FWUE Kg/ha-cm	CWUE Kg/ha-cm
Wheat	26.07	24.90	0.78	0.7	45.60	27	59.20	103.57
Barley	18.73	17.56	0.78	0.7	32.16	15	46.64	80.09
Gram	21.48	19.27	0.78	0.7	35.29	6	17.00	27.93

Table.6 Rotational water allocation plan for R-4 outlet of Jhadol minor

Outlet No.	Group of farmers	Area (ha)	Discharge (Cumec)	Time (min)	Time (h)	Time (day)	Supply Time (hr-min)	
R-4								
	1	1.77	0.0085	2347.02	39.12	1.63	Mon (7:00 AM)	Tue (10:07 PM)
	2	0.72	0.0085	954.72	15.91	0.66	Tue (10:07 PM)	Wed (02:02 PM)
	3	1.96	0.0085	2598.96	43.32	1.80	Wed (02:02 PM)	Fri (09:23 AM)
	4	0.85	0.0085	1127.10	18.79	0.78	Fri (09:23 AM)	Sat (04:10 AM)
	5	0.82	0.0085	1087.32	18.12	0.76	Sat (04:10 AM)	Sat (10:17 PM)
	6	2.95	0.0085	3911.70	65.20	2.72	Sat (10:17 PM)	Tue (03:29 PM)
	7	3.52	0.0085	4667.52	77.79	3.24	Tue (03:29 PM)	Fri (09:16 PM)
	8	2.35	0.0085	3116.10	51.94	2.16	Fri (09:16 PM)	Sun (01:12 PM)
	9	1.34	0.0085	1776.84	29.61	1.23	Sun (01:12 PM)	Tue (06:50 AM)
	Total	16.28						

Obstructions in the canals

It was observed that farmers put obstruction in canals and don't allow water to move down stream. This problem occurs more during in night time. Stone barriers were placed in canals to increase the head and thereby increase discharge at the outlets.

Analysis of water quality

The water samples from canal were collected from upper reach of command. EC and pH of

canal water is 1.10 dS/m and 6.95 respectively. The ground water samples for quality analysis were collected from the villages in head, middle and tail reach of RMC. The well water was being used by the tail end farmers where canal water does not reach. The samples were collected from the open wells in use for the irrigation in tail end reaches away from the canal in the villages. It was found that EC and pH at Batukha (head), Jhadol, pilodar, (middle), Dingiri (tail), 1.90 dS/m, 2.1 dS/m, 1.82 dS/m and 1.30 dS/m, and 7.27, 6.80 and 7.12 respectively.

Crop water requirement

Crop evapotranspiration (ET_c)

The seasonal ET_c values of wheat, barley and gram were found as 260.74, 187.33 and 214.85 mm respectively. It was observed that wheat showed higher ET_c values followed by gram and barley. Similar results were obtained by Bhakar and Singh (2001) and Nirmal (2011).

Effective rainfall

Effective rainfall was calculated by USDA Soil Conservation Service method using CROPWAT 8.0 software.

Irrigation system performances

The conveyance efficiency found decreasing trend due to growing vegetation, siltation and damages at canal and minors (Fig. 2). Therefore, conveyance efficiency decreased from head to tail reaches of canals. It was observed that high FWUE and CWUE found in wheat crop followed by barley and gram respectively. Such results were also reported by Abdelhadi *et al.*, (1999) and Akkuzu *et al.*, (2007).

Rotational water allocation plan

The rotational plan was developed for outlets on selected minor (Jhadol minor) of Jaisamand command area (Fig. 1). Rotation was done from head to tail of these minor's outlets. The CCA of R-4 outlet i.e. 16.28 ha was multiplied by design discharge i.e. 0.290 cumec and divided by total CCA of Jhadol minor, which gave the discharge 0.0085 cumec. On the basis of water distribution system, whole cropped area was divided in different outlets for rotation and outlet numbering was done from head to tail. Out of 22 outlets on Jhadol minor, calculation was

done for fortnight irrigations of R-4 outlet of Jhadol minor to develop the rotational allocation plan throughout the growing period of each crop. It was known that each outlets were operated for 15 days i.e., 21600 min. The CCA of the R-4 outlet is 16.28 ha. The correction factor was calculated by dividing the total time minutes of 15 days by total area. Then this correction factor was multiply by the area of each group for allocating water. It was found that maximum time required i.e., 3.24 days for group No.7. Whereas the minimum time required i.e., 0.66 day for group no. 2. In this way all farmers even on tail end are getting their fair shares in proportional to land holding. As per the information of existing irrigation schedule, the prepared rotational water allocation plan inferred equitable distribution of water in proportion to land holdings of the farmers. Similar observations were also made by Gorantiwar and Smout (2005) for different project (Table 6).

The farmers in the upper reach apply more water than water requirements of crops with belief that more water means more production. This is because of lack of knowledge about optimum water requirements of crops. The physical status of the canal system is very poor. Majority of gates was found tempered or damaged. The water logging problem is observed mainly in low laying areas of command. Siltation and debris occurs in the low lying areas due to being damaged outlets and overtopping at number of locations in the canals. The vegetation and weed infestation also observed mainly in minors and water courses. The seasonal crop water requirement for wheat, barley and gram were found as 45.60, 32.16 and 35.29 cm respectively. The FWUE for wheat, barley and gram here resulted as 59.20, 46.64 and 17.00 kg/ha-cm respectively. The CWUE for were found as 103.57, 80.09 and 27.93 kg/ha-cm respectively. It was

observed that the high FWUE and CWUE were observed in wheat crop followed by barley and gram. The conveyance efficiency of RMC was found as 85.04 per cent. The conveyance efficiencies were found as 80.17 per cent, 75.99 per cent and 70.86 per cent for Phadi, Jhadol, Dingiri minors, respectively. As per the rotational water allocation plan the maximum time to irrigate i.e. 3.24 days was obtained for group no. 7 due to higher land holdings (3.52 ha). Whereas the minimum time to irrigate i.e. 0.66 days was obtained for group no. 2 due to lower land holdings (0.72 ha). Using the developed rotational water allocation plan on fortnight basis for R-4 outlet of Jhadol minor, the equitable distribution of water in proportion to land holdings of farmers were allocated in head, middle and tail end farmers, so that tail end farmers can also take their fair share of water.

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