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On-Farm Balancing Reservoir Design on the Basis of Canal Water Availability and Ground Water Quality

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ABSTRACT

Balancing reservoir is an intermediate water storage tank between the watercourse and the farm. Even in high rainfall areas, agriculture is not sustainable in the absence of water storage structures. Inflow components i.e. water availability of canal water, groundwater and rainfall occurrence over the balancing reservoir. The outflow components mainly water requirements for crops and evaporation from surface area of water balancing reservoir, balance the water storage capacity that mitigates the water demand of the crops and on the basis of balancing components deciding the design of water balancing reservoir. A comparative analysis reveals that the part of this capacity results from a very significant development of balancing reservoir (particularly in the smaller range of sizes) in the time interval, probably as a response to rapidly declining canal supplies. The rainfall trend analysis shows that the rainfall occurrence at probability at 50% chance is 370.8 mm which occurs once at two years of recurrence interval that shows the occurrence of surface as well as subsurface water to the study areas. A fundamental implication is that field 'losses' such as seepage and percolation do not necessary to represent losses at a larger scale.

Keywords: Water balancing reservoir; Sirsa Irrigation Circle; ground water; canal water; crop water requirement

INTRODUCTION

Water balancing reservoir is also called as*diggies* or tanks or farm pond or intermediate storage structures. Water balancing reservoir is a farmer's intervention to mitigate the effects of scarce and unreliable canal water supply to the farm or fields. Through this intervention, farmers first construct a small pond in their farm or field, called a water balancing reservoir, to store the canal water or tube well water supply. Thereafter, they pump the water out from a water balancing reservoir to irrigate the crops, through field channels or micro-irrigation technologies i.e. drip irrigation or sprinkler irrigation. A water balancing reservoir helps in providing reliable water supply to farm or fields for increasing the irrigation performance by increasing the crop area, crop yield, crop diversification and net value added economic benefits at the farm level (Amarasinghe*et al.,* 2008). Panda (2010)studied the optimum sizing of on-farm reservoir for various cropping systems in rainfed uplands of eastern India. Tube wells and canals are the major sources of irrigation in Sirsa district. Presently, about 90% of the net area sown is irrigated by canal as well as tube well against the state average of about 81% and national average of about 40% of the total net area irrigated in the district, about 80% receives supply from the canal irrigation system. Although SIC has an extensive network of canal systems, they supply water from the upstream is often not sufficient to provide sufficient water at all the time to the farmers farm or fields (Singh *et al.,* 1997). The areas irrigated by different sources in Sirsa district i.e. tube well, tanks and canal is 41374 Sq. km, 6.77 Sq. km. and 2640 Sq. km. respectively (Gupta and Sharma, 2008). The groundwater situation in Sirsa district is highly variable both in quality and water table depth. Groundwater quality is a major issue in the utilization of groundwater in the Sirsa district. Groundwater quality is measured by salinity content or electrical conductivity (EC). Keeping in mind the potential salinity of groundwater, it has been classified into three broad categories: good (EC < 2 dS m^{-1}), marginal (EC 2-6 dS m^{-1}) and poor (EC > 6 dS m^{-1}). Sometimes, the marginal quality groundwater is further referred to as sub-marginal (EC 2-4 dS m^{-1}) or marginal (EC 4-6 dS m^{-1}) quality water. The deep groundwater quality in the northern and extreme southern part of the SIC was quite poor. However, over the years, relatively better quality groundwater layer has been converted into the saline groundwater. Generally the prompted farmers in these areas to install shallow tube wells for irrigation to the farm or fields because the water level is near to the earth surface. Haryana State Minor Irrigation and Tube wells Corporation (HSMITC) (2001) prepared groundwater quality map and presented that the shallow groundwater quality was good in about 28%, marginal in 64% and poor in 8% areas of the Sirsa district. Continuous use of marginal or poor quality groundwater for irrigation to

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agricultural crops always creates the risk ofsalinity development in the soil and balancing reservoir turbidity (Chou and Wu, 2010). In Sirsa district, the State Government operates deep direct irrigation and augmentation tube wells and farmers operate shallow tube wells for irrigation to farm or fields. The augmentation tube wells supply water to canals for conjunctive use. A major portion of groundwater use takes place through farmers owned shallow tube wells. The number of tube wells increased from 8,217 in the year 1976 to about 57,171 in the year 2011-12. That shows the increasing interest of the farmers to use of groundwater for irrigation of the farm. However, the increase in the intensity of tube wells is mainly concentrated in the regions where groundwater is of relatively better quality but not in poor quality groundwater regions (Gupta and Sharma, 2008).

The average groundwater level in Sirsa district has risen from 18 m below the ground surface in 1974 to 1.15 m below ground surface in 2013. Generally rising trend in groundwater levels was observed in the areas that underlain with the poor to marginal quality groundwater and declining trend in groundwater levels underlain with the good quality groundwater. The declining ground water levels are mainly due to over exploitation of good quality groundwater for irrigation of major growing crops in Sirsa district (Jhorar*et al.* 2003, Singh *et al.* 2006). This paper introduces the proposed framework of balancing reservoir existence in the study areas on the basis of canal water availability and groundwater quality.

MATERIALS AND METHODS

Study area

The present study was carried out in Sirsa, mostly the north western part of Haryana state with a total geographical area of 4277 sq. km. is located between the latitudes of $29^0 13'$N and $29^0 59'$N and longitudes of $74^0 30'$E and $75^0 7'$E at an average elevation of 204 mts. above mean sea level. The total cultivable

Fig. 1. Study areas. Coloured areas indicate the selected research sites

areas are 0.425 m ha; in which net sown areas are 0.390 m ha and net irrigated areas are 0.338 m. ha. The climate of Sirsa district can be classified as tropical desert, arid and hot. The mean annual temperature is 25 ^{0}C. May and June are the hottest months with 30 years normal maximum temperature of 41-46 ^{0}C. January is the coldest month with a mean daily maximum temperature of 21 ^{0}C and a minimum 5 ^{0}C. The mean annual rainfall is 300-350 mm of which as much as 80% is received during monsoon months of July to September. The district has mainly two types of soils viz. Sierozem and Desert soils and soil textures varies from sandy to sandy loam (District Plan Report, 2010-11). The selected areas are shown in fig. 1.

Hydraulic parameters of water balancing reservoir or tank

Vora*et al.,* (2008)studied on farm pond technology for enhancing crop productivity in Bhalarea of Gujarat by using different parameters of farm pond. Southern Regional Aquaculture Centre (1991) calculated surface and storage volume of tank and pond by using simple mathematical equations. TheSecondary data of water balancing reservoir (viz. length, width and depth) collected from horticulture department, Sirsa helped in the calculation of surface area and storage capacity of tank. Water balancing reservoir size was determined based on the total area and canal water availability.

Balancing reservoir water balance components

Panda (2010) and Jayatilaka*et al.,* (2001) evaluated the size of the water balancing reservoir largely depends on the irrigation management strategies of the crops to be grown in the command area and the natural inflow and outflow components of the structure. The inflow components consist of canal supply, tube well supply and the rainfall on surface area of the water balancing reservoir, whereas the outflow components are the seepage and evaporation losses. Hence, a mass balance of the inflow and outflow components of the crop fields as well as the water balancing reservoir including the irrigation demand of crops seems to be a correct approach, for making a decision on the size of the water balancing reservoir for a particular period of rainfall events. The daily water balance in balancing reservoir is described by Water-budget equation

$$dS = I - O \qquad \text{[Eq.1]}$$

Where, I = Total inflow components,

O = Total outflow components and

dS = Change in storage.

INFLOW COMPONENTS

Rainfall on the surface area water balancing reservoir surface

Rainfall on the balancing reservoir water spread area is determined as:

$$RT = TA \times R \qquad \text{[Eq.2]}$$

Where, RT = rainfall on balancing reservoir (m^3/day),

R = daily rainfall (m/day),

TA = water spread area balancing reservoir (m^2).

Availability of canal water

Thecanal operation and rostering data collected from Nehrana Water Services Division, Sirsa, Haryana. Sirsa Irrigation Circle is part of the Bhakra Irrigation Project and has an extensive canal network is shown in Fig. 2. The irrigation system consists of a large network of main canals, branch canals, distributaries, minors and watercourses. The canal water availability and command area values calculated from canal map of Sirsa district. The principle of warabandi allocates the right to irrigate in proportion to landholdings. To estimate the canal water availability, land holding size was multiplied with duty of water (1.5 mm/day).

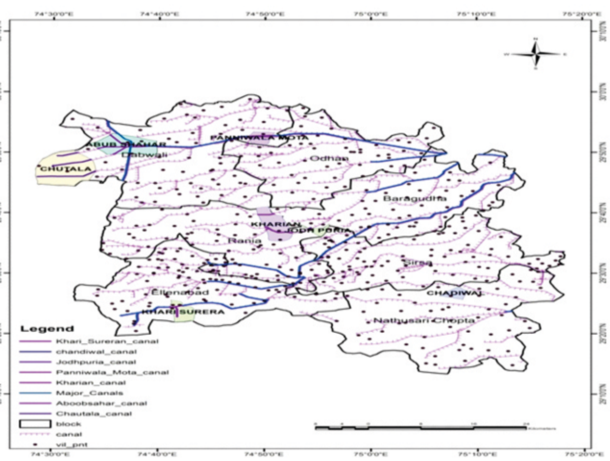

Fig. 2. Canal networks distribution in selected research site

Availability of ground water

Groundwater availability and quality data obtained from Central Ground Water Board, Faridabad. Groundwater potential collected data i.e. net annual groundwater availability, existing gross ground water draft for irrigation, net groundwater availability for future irrigation development, groundwater level in different observation wells monthly ground water table data depth in last one decade and groundwater quality (i.e. pH, EC, etc.) and other cationic and anionic parameters helped in deciding the quality of groundwater for irrigation and also for design of balancing reservoir.

OUTFLOW COMPONENTS

Evaporation

Sakthivadivel*et al.* (1997) calculatedthe reduction of balancing reservoir water due to evaporation from over the tank surface is computed as

$$E = Ep \times TA \quad (3)$$

Where, E = evaporation (m^3/day), Ep = pan evaporation (m/day) and TA = top area (m^2).

Seepage and percolation

The seepage and percolation water through the balancing reservoir bed and the embankment (referred to as the balancing reservoir seepage) represents a significant component of the balancing reservoir water reduction. The constructed tanks were RCC. So, there are no seepage or percolation losses from balancing reservoir.

Estimation of crop water requirement in study area

Thecrop water requirement of the main *Kharif* and *Rabi* season crops (i.e. cotton, guar, wheat, mustard/toria, gram etc.) of reference crop evapotranspiration (ET_0) on the monthly basis by using CROPWAT model based on Penman-Monteith's semi-empirical equation. Then by using these values of reference crop evapotranspiration along with K_C values and effective rainfall, irrigation water requirement was calculated in CROPWAT. The input data is entered in different popped up windows for the CROPWAT model and reference crop evapotranspiration and the irrigation water requirement values are displayed in the form of table and graphs.

RESULTS AND DISCUSSION

Surface area and storage capacity of water balancing reservoir

The storage capacity of the water balancing reservoir is important for the efficient operation of a canal as well as tube well water supply system. The Storage capacity is the function of storage area of water balancing reservoir. The maximum depth of water was 4.57 m at full capacity of reservoir. The irrigation was given to *kharif* and *rabi*crops in the vicinity of existing balancing reservoir in the farmers farm. The loss of water through evaporation and seepage varied depending on water storage time. The balancing reservoir changes linearly with change in surface area are shown in Fig. 3.

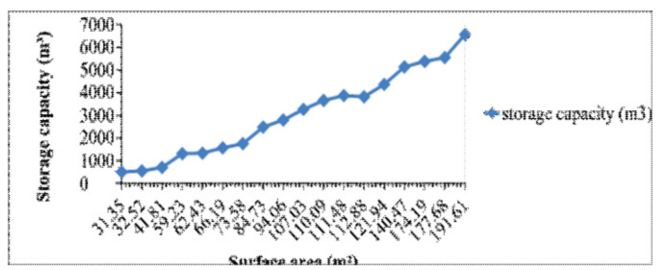

Fig. 3. Change in storage capacity with changes in surface area

Rainfall analysis

The Sirsa district receives the mean annual rainfall 300-350 mm. of which as much as 80% is received during monsoon months of July to September. During winter season the probability (or at 75% chance) of getting rain is 282 mm, which is lesser than mean annual rainfall. Past 15 years data shows that there is a probability of drought occurrence in once in every two years. The table (1) represents the recurrence interval at 50%, 75% and 90% chance of occurrence of normal rainfall. The conclusion shows the probability of getting average annual rainfall (300- 350 mm) is at 50% chance. Probability (P) and Recurrence Interval (RI) of annual one-day maximum runoff series based on 15 years annual rainfall data (N). Rainfall occurrence from years 1985 to 2010 is shown in Fig. 4.

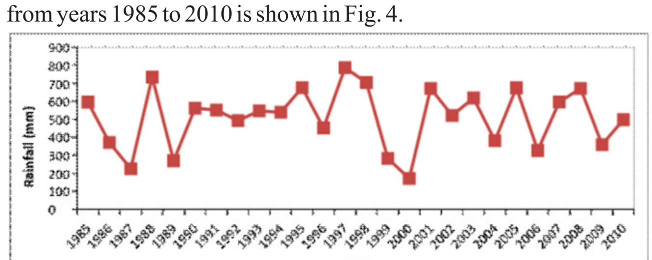

Fig. 4. Rainfall pattern in the year from 1985 to 2010

Table 1 : Recurrence interval (RI) at 50%, 75% and 90% chance

Year	Rainfall (mm)	Rank (m)	Probability P= m/ N+1	RI = 1/P	RI=1/P (P=50%)	RI=1/P (P=75%)	RI=1/P (P=90%)
1997	787	1	0.012	79.70	2	1.33	1.11
1988	734.8	2	0.026	37.240	2	1.33	1.11
1998	703.8	3	0.042	23.793	2	1.33	1.11
1995	675.5	4	0.058	17.137	2	1.33	1.11
2005	675.1	5	0.072	13.702	2	1.33	1.11
2001	671.2	6	0.088	11.353	2	1.33	1.11
2008	671	7	0.102	9.728	2	1.33	1.11
2003	617.9	8	0.127	7.848	2	1.33	1.11
2007	595.8	9	0.148	6.731	2	1.33	1.11
1985	595.3	10	0.165	6.053	2	1.33	1.11
1990	562	11	0.192	5.20	2	1.33	1.11
1991	550.9	12	0.213	4.674	2	1.33	1.11
1993	546.6	13	0.233	4.281	2	1.33	1.11
1994	538.6	14	0.255	3.918	2	1.33	1.11
2002	521.18	15	0.282	3.541	2	1.33	1.11
1992	492.1	16	0.318	3.138	2	1.33	1.11
1996	451.9	17	0.368	2.717	2	1.33	1.11
2004	381	18	0.460	2.172	2	1.33	1.11
1986	370.8	19	0.498	2.004	2	1.33	1.11
2009	359	20	0.542	1.845	2	1.33	1.11
2006	326.8	21	0.623	1.603	2	1.33	1.11
1999	282.1	22	0.753	1.327	2	1.33	1.11
1989	269.6	23	0.822	1.215	2	1.33	1.11
1987	225.5	24	0.919	1.088	2	1.33	1.11
2000	171.1	25	0.938	1.066	2	1.33	1.11

Canal water availability

Adequate water supply to irrigated crops is the primary concern of a canal water supply system. Tyagi(1998) studied the performance of irrigation system (Fatehabad Branch) at farm as well as watercourse level. The average relative water supply (ratio of water supply and water demand over a period of time) was observed to be 0.72 in summer and 0.65 in winter at the head reach and 0.58 in summer and 0.50 in winter at the tail reach of watercourses of SIC. This clearly indicates the unavailability of canal water supply to meet the demands of growing crops in the farmer's farm or fields. The decrease in discharge from head reach to tail end indicates that considerable seepage losses occur in the watercourses of canal system. This clearly shows the need for proper management of the watercourses to avoid seepage losses during canal operations. The observed value of discharge in selected watercourses is given in table 2.

Table 2 : Observed discharge in head and tail reaches of watercourses

Distributory	Watercourse Name	CCA (acre)	Number of outlets	Location	Discharge (Litres/s)
Chautala	RD 0-80820	17783	29	Head	1503.87
				Tail	1173.02
Abubshahar	RD 0-3000	1981	3	Head	157.91
				Tail	123.17
Sadewa	RD 0-104565	28508	41	Head	2557.41
				Tail	1994.78
Sheranwali	RD. 0-208966	55203	102	Head	5904.93
				Tail	4605.85
Mammarkhera	RD10900-193970	57708	83	Head	10027.54
				Tail	7821.48

Ground water availability

Decrease in supply of canal water or unavailability of sufficient quantity of canal water does not meet the crop water requirement at the critical stages of growth of plants. So, full fill the sufficient availability of water to the crops to introduce the groundwater for irrigation by conjunctive use. The availability of groundwater in different district is shown in Fig 5.

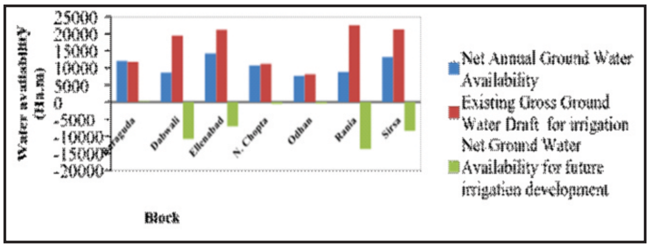

Fig. 5. Groundwater availability for irrigation in visited areas

Ground water quality

The ground water quality parameters (i.e. cationic as well as anionic) pH, EC, Ca, Mg, Na, Cl, HCO_3 and SO_4 etc. of blocks of Sirsa district were calculated in laboratory and presented in table (3). The pH value varies 7.91-8.25 which has normal value with irrigation water (i.e. 6.5-8.4) and EC varies 3.04-5.66. The EC value is higher than the normal value of irrigation water (i.e. 0.2-2dS/m), not suitable for direct irrigation to the major growing crops to selected areas. Anionic parameters also helps in deciding the groundwater quality and conjunctive use with canal water.

Table 3 : Ground water quality parameters of selected research areas

Blocks	pH	EC (dS/m)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Chloride (mg/l)	Bicarbonate (mg/l)	Sulphide (mg/l)
Dabwali	8.25	5.66	134	179	467	897	686	899
N. Chopta	7.85	3.04	174	178	471	744	495	776
Odhan	7.91	4.83	154	179	582	633	726	1012
Rania	8.14	2.52	146	129	430	589	601	1403

Table 4 : Peak water requirement of different major crops of selected research areas

Crop	Cropping Season	Peak value of ET_0 (mm/day)	Peak K_c	Peak crop water requirement (m^3/month/ha)
Drip irrigation				
Kinnow	January –December	5.7	0.65	801.58
Flood irrigation				
Cotton	June –October	5.74	1.2	1489.2
Guar	July-October	4.95	1.05	1303.05
Wheat	October-March	3.54	1.15	688.79
Mustard	September-January	4.14	1.15	760.29
Gram	October-March	3.54	1.15	738.19

Peak water requirement of major crop in growing season

Peak water requirement of major crop i.e. Cotton, Guar, Wheat, Mustard, Kinnow and Gram etc. is calculated by using peak value of ET_0 and K_c is given in Table 4.

Water balance for *kharif* and *rabi* crops

The water balancing in canal command is calculated on the basis of inflow and outflow components of the balancing reservoir. The depth of water application to field is 0.1016 m. and tube well discharge is 135.46 m^3/hr. The outflow and inflow components of the water balancing reservoir are determined on the basis of peak water requirement to the cropped land. The negative and positive value balancing showed the deficit and excess water availability in the balancing reservoir. The water balancing values also determined the quantity of groundwater added in the balancing reservoir for conjunctive use that the tank fulfils the extra quantity of water to the crops at the various growth stages of plants and when canal water supply is unavailable. Water balance in the balancing reservoir helped in the design of the new balancing reservoir on the basis groundwater and canal water availability to the cropped lands.

CONCLUSION

Water balancing reservoir is innovative way of water storage to areas where canal water supply is uneven and groundwater is poor because it stored canal water as well as groundwater for longer interval. It is generally helpful to farmers' of insufficient canal water supply to irrigate crops at its critical growth stage where water application is necessary. Storage capacity is the function of storage areas that implied that storage capacity increases with increase in surface area at constant water depth. On the of basis inflow components i.e. water availability of canal water, groundwater and rainfall occurrence over the balancing reservoir and outflow components i.e. water requirements to crops and evaporation from surface area of water balancing reservoir, balance the water storage capacity can't mitigate the annual water supply-demand to the crops. These components helped in designing the optimum size of balancing reservoir of farmer's field on the basis of inflow and outflow components. Negative values showed the deficit in storage of water and positive value showed the excess of canal water in the tank. The excess values of canal water decides the quantity of groundwater added to the tanks that reduce the gap between supply and demand of water to the crops at the various growths stages of plants.

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REFERENCES

Amarasinghe UA, Bhaduri A, Singh OP, Ojha A andAnand BK, 2008 Cost and benefits of intermediate water storage structures: Case study of diggies in Rajasthan. In Proceedings of the CGIAR Challenge Program on Water and Food and 2nd International Forum on Water and Food. Addis Ababa, Ethiopia, Vol. 3, pp. 79-82.

Chou FN F and Wu C. 2010 Reducing the impacts of flood-induced reservoir turbidity on a regional water supply system. *Advances in Water Resources*, *33*(2), 146-157.

District Plan Report, 2010-11 Sirsa District, Haryana

Gupta S. and Sharma A. 2008. Water year report sirsa, Haryana (2007). Chandigarh, India: Central Ground Water Board.

Jayatilaka CJ, Sakthivadivel R, Shinogi Y, Makin IWandWitharana P. 2001 Predicting water availability in irrigation tank cascade systems: The cascade water balance model. Research Report **48** Colombo, Sri Lanka: International Water Management Institute.

Jhorar RK, AAMFR. Roest CWJ. 2009. Assessment of alternative water management options for irrigated agriculture. *Agricultural Water Management***96**(6): 975-981.

Panda SN.2010. Optimum sizing of on-farm reservoir for various cropping systems in rainfed uplands of Eastern India. *Rainwater Harvesting and Reuse through Farm Ponds* 60.

Sakthivadivel R, Fernando N and Brewer JD.1997 Rehabilitation planning for small tanks in cascades: A methodology based on rapid assessment.*Research Report* 13. IWMI, Colomb.

Singh R. Refsgaard JC, Yde L, Jorgensen GHandThorsen M. 1997 Hydraulic-hydrological simulations of canal-command for irrigation water management. *Irrigation and Drainage Systems* 1**1**(3): 185-213.

Singh R, Van Dam JCandFeddes RA. 2006 Water productivity analysis of irrigated crops in Sirsa district, India. *Agricultural Water Management*.**82**(3): 253-278.

Tyagi NK. 1998. Diagnostic analysis and some approaches for improving water delivery performance in the Bhakra canal command. Proceedings of the 5th IT IS network international meeting FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

Vora MD, Solanki HB andBhoi KL, 2008 Farm pond technology for enhancing crop productivity in *bhai* area of Gujrat-A case study. *Journal of Agricultural Engineering*. 45 (1)32-37.

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