Seepage Losses Assessment in Water Conveyance System of Nuh Branch Canal Network in Mewat District, Haryana State of India

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Abstract- **Water is the most vital input in agriculture that has highly significant contributions in providing stability to food grain production and food self-sufficiency as well as food security in India. This resource can be optimally used and sustained for future generations only when quantity of water is assessed very well. In the present study, the seepage losses that are the major losses through the canal conveyance system were quantified. The total estimated seepage loss was found to be 165399.84 x 10^3 cubic meters during the entire year out of which the monsoon season seepage was 4167.21 x10^3 cubic meters while the rest 171232.63X10^3 cubic meters were in non-monsoon season, respectively. The monsoon season seepage losses in the Nuh sub-branch canal and distributaries namely Uleta, Dubalu, Ujina, Kalanjar and Pondiary were estimated to be 3130.13, 655.30, 117.96, 175.35, 53.22, 35.25 (x10^3) cubic meters respectively. Similarly, the total seepage losses in the non-monsoon season from the entire conveyance system was estimated as 171232.63x10^3 cubic meters. Estimated seepage losses from Nuh –branch canal and distributaries of the Sub-distributaries of Nuh namely; Uleta, Dubalu, Ujina, Kalanjar and Pondiary were 6838.09, 176.33, 270.43, 649.43, 163.92, 50.10, 8148.31 (x10^3 cubic meters) respectively in the district. The study emphasizes that there is an urgent need for making the conveyance system leak proof so that more area can be covered with saved water.**

Index Terms- **Canal water, Groundwater, Runoff, Water balance, Mewat District**

I. INTRODUCTION

Water is one of the most crucial, important and limiting factor of production (WAPDA, 1965, FAO, 1977). It is hard to produce a single grain without adequate amount and quality of water (IIMI, 1996, IWMI, 2002). Adequate supply of water throughout the entire growth period of a crop results into maximum production and resources sustainability i.e. without the degradation of quality of the resources (Singh, 1998, Krysanova et al., 2005, Shah, 2009). In India, nearly two third of the total cultivated area is still under the rainfed situation with limited or no irrigation facilities (Irrigation Commission, 1972, IIMI, 1996, Singh and Singh, 2004, World Bank, 2010). During post independence era in India the major emphasis of planners had been on developing the irrigation facilities (Sharma and Chawala, 1975, 1979, Malhotra, 1982, Stephen et al., 2010). Eventually a huge network of main canals, sub-main and branch canals, major and minor distributaries, water courses and open channels constitute the irrigation conveyance system which have been created in all projects (Irrigation Commission, 1972, Garg and Chawala, 1970, Vedula et al., 2005, Swamee, 2000). Due to the country being resources poor and economically backward; majority of the canals could not be properly lined right from the beginning of their construction (Chahar, 2007). Hence, the huge amount of water that has been diverted using large, medium and small dams got lost in transit and the efficiency of the system reduced substantially (Morel Saytoux 1964, Chow, 1973, Wachyan and Ruston, 1987, Dukker et al., 1994, Foster and Choudhary, 2009, Stephen et al, 2010). The assessment of water resources is an important requirement for optimization of the crops production with available irrigation water (Yangchan, et al., 2006).

The assessment of water resources of a region requires adequate and reliable hydrological records (Aggrawal, et al., 2009). The assessment of total water resources potentials of an area includes quantification of utilizable surface and groundwater resources (Chowdary, et al., 2009). Often when the canal water is inadequate for irrigation of the crops; farmers resort to conjunctive use of surface and ground water for better yields and enhanced productivity. In some cases they have also tried to line the canals and prevented the water losses due to seepage (Shah, 2003, Shah et al., 2004, Nikbakht, 2006). In order to provide lining in the canals to check the excessive seepage modeling studies have also been conducted by different workers and many approaches have been followed to model this phenomenon (Wauwer, 1961, Koupaila 1964, Weller, 1981, Christopher 1981, Decon, 1983, Alam and Bhutta, 2004).

Inadequacy of canal water should mainly be attributed to the two major losses associated with the water conveyance i.e. seepage losses from the wetted surface area and evaporation losses from the open water surfaces as well as the wetted exposed surfaces to the sun plus the evapotranspiration from the water weeds, algal growth and growth of weeds in the body or side walls. When water is

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conveyed from a resources rich region (Dam site/head works) to a resources poor region or dry area; the conveyance system consisting the main and branch canals and its accessories as well as the water losses resulting from the seepage often become quite big. The sizes of different components of the conveyance system are standardized by engineers (Harr, 1962, Mc Atreer Jeppson, 1968, Garg and Chawala, 1970, Weller, 1993, Foster et al., 2002). However, there is no control whatsoever of planners on the soil properties which keeps on changing rapidly as the canal progresses forward and thus the capacities of water absorption by them which we call as seepage losses that also keeps on changing (Siddiqui et al., 1993, Shahid et al., 1996, Skogerboe et al., 1999). In the North Western part of India, soils are largely light in nature (Manuel et al., 2006, Singh, 2002,
Kalra at al., 2003) belonging to loamy sand and sandy loam or sandy textural classification which depict a very high seepage rate in general.

Many studies to measure and quantify the seepage rates have been undertaken in the past (Bauwer, 1961, Bauwer and Rice, 1968, Bodla, et al., 1998, Smith and Turner, 1982) employing different instruments. Further, many indirect estimation methods of canal seepage based on the flow behavior studies through porous medium have also enriched our scientific knowledge and understanding of the seepage behavior (Subramanya et al., 1973, Sharma and Chawala, 1975, 1979). What is lacking in this science is the characterization of seepage rates and documentation with regards to each and every open channel which is primarily unlined (Wachyan and Rushton,1987, Karad et al., 2013, Christensen, 1984, Swameem 1994, 1995). This would result in scientifically estimating the seepage losses as well as developing procedures and plans/ methodologies for providing proofing against such large losses (Bredhoeft and Young 1983, Foster et al., 2002, 2006, 2002-2006, 2009).

Quantitative estimation of seepage losses from the entire conveyance system of the canal network therefore assumes a very high significance (Morel Seytoux, 1964, ICID, 1967, Dhillon, 1968, Kraadtz, 1977, Kacimove, 1992) which will result in assessing the balance amount of water available for irrigation. The managers and planners would therefore be better equipped for proper allocation of the actual amount of water available to them for maximizing the production and productivity. Also, efforts need to be initiated for decreasing the high seepage losses using mechanical measures (Zhukovskey, 1930, Uchdadiya and Pate, 2014, Wolde-Kirkos and Chawla, 1994, Swamee et al., 2001, 2002, Burt et al, 2010).

Mewat district of Haryana state of India is socio-economically one of the most backward districts of Haryana (NAIP, ICAR, 2009). Highly saline ground water and low crop productivity are the main features of the Mewat district of Haryana. The total water resources potential of the Nuh block includes both surface and groundwater. Although the surface water resources include the canal water and runoff water from the streams; the direct surface runoff water can also be used for irrigation when it is conserved or stored properly. Thus, it can also be considered as the alternative surface water resource yet its magnitude is very less. The groundwater was another major source of irrigation water in the Block that can be obtained directly by exploration by mean of shallow and deep tube wells. But the most parts of the block were suffering with highly saline groundwater and salt affected soils and therefore, small percentage (15 percent) of groundwater is available for irrigation in the Block and remaining 85 percent of groundwater was un-usable for irrigation (Kaur et al., 2009). Inadequacy of both types of water forced the district to import the same through a canal network namely Nuh branch canal from out side the district. Later the canal water became the prime source of surface water resources available for irrigation in the block for quite some time till the canal water supplied dwindled. While, runoff water contributes only small amount of surface water resources potential of the block (Khan, 2007). In a nutshell, the total water resources available for irrigation in the Nuh block include the canal water remaining after seepage and other losses, groundwater available for irrigation up to safe draft (limit) and the runoff water from study area when it is conserved and stored properly. As the Nuh block is representative block of Mewat district of Haryana state of India; the same was taken as the study area. Most parts of the Block were suffering with water deficit and problems of poor quality groundwater (Kaur, et al., 2009). These scenarios represent water as the main limiting resource for agricultural production in the block. Therefore, the present study was conducted keeping the view to quantify the seepage losses and trying to minimize the same for efficient management of the water resources as the same is one of the key issues to increase the agricultural production in the district and thereby help in feeding the ever increasing population.

II. THE STUDY AREA

Nuh block, which is the representative block of Mewat district (Haryana), lies between 27^o 59' 30.4" to 28^o 13' 40.3" North latitude and 76^o 57' 20.5" to 77^o 10' 58.38" degree East longitude. The study area falls under Survey of India (SOI) Topo- sheet no. 53 H/4 and 53 D/16. It covers a portion of the Indo-Gangetic plain and lies to the west of Yamuna River and south-west of Delhi, and form the southern part of Haryana and north eastern part of Rajasthan. The location map of study area is presented in Figure 1. The geographical area of the study area is 463.66 sq. km (46366 ha). The population of the Nuh block is 212855, including the male 112553 (52.88 per cent) and the female 100302 (47.12 per cent), during 2001 census. The total literacy percentage was 33.63 per cent, including male 73.79 per cent and female 26.21 per cent (as per Census 2001). The total number of villages in the Nuh block is 114. The total water resource potential of the Nuh block constituted canal water, ground water and runoff water. Canal water was one of the major sources of surface water for irrigation in the Nuh block. The canal water obtained in Nuh block for irrigation is from the western Yamuna canal branch. Nuh sub-branch (Indri, Nuh and Bhiraoti distributeries), Uleta distributery, Dubalu distributery, Ujina distributery, Kalanjar distributery and Pondiary distributery were the main distributaries for the canal water supply in Nuh block.

2.1 Assessment of canal water availability

Canal water is one of the major sources of water for irrigation in the Nuh block. The average water supply through the canal (i.e. the canal water available to the crops) was estimated for years (2008-09) using the data available from the office of Irrigation Engineer, Mewat Water Supply Services, Nuh

Division, Haryana. The canal water availability to the crops can be estimated by following equations (Equation 1):

Canal water availability for irrigation =Water supply at the canal head - Seepage losses during conveyance (1)

Where, water supply at the canal head = Q (m^3/sec) × Operating time of canal (sec); and Q = average discharge in the canal (m^3/sec).

Canal water which is the prime source of surface water resources available in the block for irrigation, was estimated to be 21316.23 ha-m based on the canal water supply on annual basis while runoff water was found to have contributed only in small amounts which was estimated to be about 2398.48 ha-m. Further, the total water (includes both surface and groundwater) resources potential of the Nuh block situated in the Mewat District, Haryana State of India was also assessed and quantified. While the total water availability (only canal and groundwater) for irrigation in Nuh block was assessed to be 22281.63 ha-m; the total water availability potential (including runoff) was assessed to be 24680.12 ha-m.

2.2 Assessment of groundwater resources availability

Groundwater was second major important source of irrigation to the crops in the Nuh block. The average groundwater availability through the tube wells was estimated for year 2008-09 from data available from the Regional Office of Central Ground Water Board (CGWB), Chandigarh, Haryana. The groundwater availability to the crops was estimated by water balance approach (Mishra, et al., 2001,Sahuquillo, 2002, Scibek, et al., 2007). The objective of the groundwater balance study was to know the volume of groundwater available for sustainable pumping. For the estimation of the groundwater availability to the crops, total annual amount of groundwater recharge, numbers of observation wells, pre-monsoon and post-monsoon groundwater levels were recorded.

The groundwater balance equation (Panda *et al.*, 1996) was used (Equation 2):

$$\Delta S = TGWR \pm TGWD \quad (2)$$

Where, TGWR = total groundwater recharge; TGWD= total groundwater draft; and ΔS = change in groundwater storage.

Availability of the groundwater, another major source of irrigation water in the block, was simultaneously assessed by water balance approach to be about 6436 ha-m but the net groundwater available for irrigation was estimated to be only 965.40 ha-m because the almost 85 per cent of groundwater was unusable for irrigation due to highly saline groundwater. Although, the inter seasonal irrigation system planning for waterlogged sodic soils was recommended by Panda, et al., 1996, Akkuzu, et al., 2007and Murray et al., 1992, yet the same can't be practiced as the rainy season rainfall is insufficient for the same. Hence, irrigation with saline water is making the soil in the block, salt affected and less productive to unproductive. Therefore, concerted efforts would be required to arrest the seepage losses from the canal supplies as well as use the collected rainwater very prudently mainly due to saline nature of the ground water.

2.3 Assessment of groundwater recharge

The main sources of groundwater recharge were inflows from the adjoining area, recharge from rainfall and seepage from major conveyance systems such as rivers, canals and drains. Equation 3 explains the above:

$$TGWR = GR_r + GR_c + GR_a \quad (3)$$

Where, GR_r = groundwater recharge from rainfall;

GRc = groundwater recharge from seepage of canal network; and GR_a = groundwater recharge due water application losses.

2.4 Assessment of groundwater draft/ withdrawal

Major portion of groundwater withdrawal was used for irrigation in the block. Ignoring the other uses of groundwater, amount of annual groundwater withdrawal was estimated on the basis of area of different crops and their irrigation water requirements. It is assumed that the deficit in irrigation water supply was met from groundwater pumping.

2.5 Assessment of runoff water availability

Assessment of runoff water from the study area is desirable because it is one of the alternative sources of water for irrigation use. The runoff water from the study area was estimated by using the empirical formula already prepared for the particular basin under which study area nearly belongs (Bhadra et al., 2010). The required data is the average annual rainfall for the year 2002 to 2009 obtained from the Weather Station, Office of the CEO, at Nuh block of Mewat District. The appropriate empirical formula for the runoff estimation from the study area was taken from Jha et al., 2005 (Equation 4):

$$R = 0.354P^{0.11} \quad (4)$$

This formula was developed for Yamuna Basin at Tajewala (Haryana) having catchment area 11,150 km^2. In this equation P represents annual precipitation in centimeters and R represents annual runoff in million cubic meters (MCM), respectively. This formula has been used for estimation of runoff in Nuh block (Mewat), Haryana.

III. THEORETICAL BACKGROUND OF THE ESTIMATION OF SEEPAGE LOSSES IN WATER CONVEYANCE

Indian Standards (BIS code) for assessing the canal seepage losses for India was formulated in 1993 and reaffirmed in 2004 (Anonymous, 2004). However, in the present study the estimation of seepage losses from canal network was done according to Tyagi et al. (1995) which was applied for seepage estimation in the Ghagger river basin that has similar conditions as Nuh (Mewat). Simple *in-situ* vibratory soil compaction of earth lined canals was tested to determine the impact on seepage losses (Akkuzu, 2011, 2012, David, et al., 2011). Commercial equipment was used for vibratory compaction of long sections of five irrigation district earthen canals. Ponding tests were conducted before and after compaction. When the sides and bottoms of the canals were compacted, seepage reductions of about 90% were obtained; reductions of 16–31% were obtained when only sides were compacted (Alam and Bhutta, 1964, Carter, 1970, Belaineh, et al., 1990, Alam and Bhutta, 2004).

For computing seepage, hydraulic data such as daily discharge, monthly discharge and number of running days for each major/ minor distributary were compiled from records of the office of Irrigation Engineer, Mewat Water Supply

Services, Division Nuh, Haryana. Following calculation procedure was followed for estimation of seepage losses; the perimeter (P_w) was computed by using following formula (Yangchan et al., 2006) (Equation 5):

$$P_w = 4.75 \times Q^{0.5} \quad (5)$$

Where, P_w = wetted perimeter (m); and Q = average discharge in the canal (m^3/sec)

Wetted area (A_w) was calculated by formula given below (Equation 6):

$$A_w = P_w \times L \quad (6)$$

Where, A_w= wetted area of conveyance system (x10^6 sq. meter); L= length of canal (m)

Seepage loss coefficient per million square meter of wetted area was calculated for lined and unlined channels separately by formula given below (Equation 7):

$$S_c = 0.35Q^m \quad (7)$$

Where, m = 0.58669 usually for Lined channel and 1.8621 for unlined channel

Seepage losses (S_l) are calculated by formula given below (Tyagi, 1989; Yangchan *et al.*, 2006) (Equation 8) :

$$S_l = T_r \times A_w \times S_c \quad (8)$$

Where, S_l = Seepage loss (m^3); S_c = Seepage losses factor in cumec per 10^6 sq. meter of wetted area; and T_r = Operating time (sec)

The seepage losses from unlined main canal, branches, distributaries and watercourses were considered as deep percolation, which ultimately contributed to groundwater recharge in the study area. Tyagi, (1989) determined the wetted perimeter and wetted areas for different channels and estimated seepage loss coefficient for lined and unlined canal channels.

IV. RESULTS AND DISCUSSION

4.1 Canal water resources potential of Nuh Block, Mewat (Haryana)

Monthly discharges of irrigation water through each distributery of canal network in Nuh block during 2008-09 was taken from the office of the Irrigation Engineer, Mewat Water Supply Service, Nuh for the estimation of irrigation water volume at head of canal, estimation of seepage losses and estimation of total canal water availability. The irrigation water volume at head of canal distributaries was estimated for six month basis i.e. monsoon and non-monsoon (Table 1). The seepage losses were estimated from each distributaries separately which is presented in Table 2. Then, the total canal water availability was estimated for each distributery by deducting respective seepage losses from the water volume at the head of distributery (Table 3). Results shows the Nuh sub-branch was the major channel including Nuh, Indri and Bhiraoti distributaries provided canal water in the Nuh block was 5271.35 ha-m during monsoon (*Kharif*) season and 11435.01 ha-m during non-monsoon (*Rabi*) season. The irrigation water volume at head of all canal networks for Nuh block was estimated to be 10288.29 ha-m during monsoon (*Kharif*) season and 17938.09 ha-m during non-monsoon (*Rabi*) season. The seepage losses were estimated from each distributery separately. The seepage loss was highest for Nuh sub-branch as this sub-branch was longest and having longest wetted area. Then, the total canal water availability was estimated for each distributery by deducting respective seepage losses from the water volume at the head of distributery. Nuh sub-branch provided highest canal water availability for Nuh block. Figure 2 and 3 presents the comparisons of volume discharge at the head, seepage losses and total water availability in respective distributaries. The total canal water availability was estimated to be 9871.57 ha-m during monsoon season and 17123.26 ha-m during non-monsoon season. The total annual canal water available for irrigation was estimated to be 26994.83 ha-m.

4.2 Groundwater resources potential of the Nuh Block, Mewat (Haryana)

Despite the water being of highly saline in nature in large part of the block, the Nuh block is dominantly irrigated by groundwater, and in the recent past, irrigation by groundwater has increased, especially in the area where crops are grown only in the non-monsoon (*Rabi*) season. There are eight observation wells in the study area. The pre and post monsoon groundwater levels were recorded by the Regional Centre of Central Ground Water Board (CGWB) at Nuh. For the present study, groundwater data have been obtained from the Regional Office of Central Ground Water Board (CGWB), Chandigarh, Haryana. The groundwater balance is given in Table 4. The annual groundwater recharge and annual groundwater draft was estimated to be 8538.00 ha-m and 2102 ha-m respectively. Then, the total groundwater balance was estimated to be 6436.00 ha-m. Nuh block was mainly irrigated by shallow tube wells. Groundwater in Nuh block of Mewat district was mainly saline at all levels in almost 85 percent of block including highly salt affected groundwater of 63.4 percent and moderately saline groundwater with highly salt affected land of 22.6 percent (Kaur et al., 2009). Therefore, the actually available fresh groundwater; usable for irrigation; was estimated to be only 965.40 ha-m.

4.3 Runoff water resources potential of the Nuh Block, Mewat (Haryana)

Direct runoff is also channelized to cropped areas for irrigation in Nuh block where it is possible. The runoff volume is estimated from the annual rainfall using an empirical formula given by Jha and Smakhtin, 2005. The annual runoff volume is calculated as below:

Total annual precipitation of the Nuh block is 846 mm or 84.6 cm. Total runoff volume (MCM)

R = 0.354 $(84.6)^{0.11}$ = 0.57679 MCM = 57.68 ha-m

This is for (11,150 km^2 area)

Area of Nuh Block = 46366 ha = 463.66 km^2

So, the total runoff for study area (Nuh Block) = (57.6785/11,150) ×463.66 ×1000 = 2398.49 ha-m

Direct runoff is also channelized to cropped areas for irrigation in Nuh block where it is possible. The runoff volume is estimated from the annual rainfall using an empirical formula given by Jha and Smakhtin, 2005. The annual runoff volume for Nuh block was estimated to be 2398.49 ha-m which was just 5 per cent of the annual rainfall of the block.

4.4 Total existing water resources potential for irrigation in Nuh block, Mewat (Haryana)

The total water resource potential of Nuh block constituted the canal and ground water; and in addition, runoff water. Annual canal water was estimated to be 266645.30 ha-m and other losses (water course losses and leaching requirement) excluding the seepage was taken as 20 percent of total water availability. Hence, net water availability for irrigation from canal network was calculated to be 21316.23 ha-m. The annual groundwater availability was estimated to be 6436 ha-m. The most of the part (85 percent) of groundwater in Nuh block was highly saline (not usable for irrigation) and moderately saline (can be used only with high limitation for irrigation). Therefore, the net groundwater available for irrigation was 965.40 ha-m. Total water available for irrigation in existing conditions was 22281.63 ha-m. The surface runoff was also estimated as the alternative for irrigation. It was estimated to be 2398.49 ha-m. The total water resource potential of the Nuh block is given in Table 5.

4.5 Seepage losses in water conveyance system in the canal network of Nuh Block, Mewat (Haryana)

The conveyance system of Nuh branch canal was surveyed extensively for identification of the problems of general operation and maintenances and seepage was found to be a big issue. The general maintenance of the canal was found to have weakened over all these years and it appeared that the system was not in active operational state. The interviews were conducted from the beneficiaries having farm adjoining the canal distributor or minors. It was noted that due to lack of supplies from the head works, the canal seldom works at its full supply levels. Hence, the irrigation department as well as farmers has lost genuine interest in its operation and maintenance. The channel bottom having got silted developed vegetation over the period which has grown to form not the bushes but trees sometimes well developed ones. The trees have spread their deep rooted networks across the canal bottom which helped the canals side slope to get fractured and increase the seepage losses. The channel bottom having got silted developed vegetation over the period which has taken deep roots resulting into fractured the side walls and bottoms of the trapezoidal channel cross section. This results into colossal water losses in form of seepage when canal is operated. Similar observations were also made by researchers in other parts of the globe (Harr, 1962, Jeppson, 1968, Muskat, 1982, Goyal and Chawla, 1997, Foster, et al.,2009). The part of Nuh branch canal was provided with lining using poor quality materials with lining using poor quality materials which developed cracks and fissures over the time due to alternating freezing in winters and thawing in the summer seasons.

The total estimated seepage loss from the conveyance system of canals was found to be 165399.84x 10^3 cubic meters during the entire year out of which the monsoon season seepage was 4167.21x10^3 cubic meters while the rest 171232.63x10^3 cubic meters were in non-monsoon season, respectively. The monsoon season seepage losses in the Nuh sub-branch canal and distributaries namely Uleta, Dubalu, Ujina, Kalanjar and Pondiary were estimated to be 3130.13, 655.30, 117.96, 175.35, 53.22, 35.25 (x10^3) cubic meters respectively. Similarly, the total seepage losses in the non-monsoon season from the entire conveyance system was estimated as 171232.63x10^3 cubic meters. Estimated seepage losses from Nuh –branch canal and distributaries of the Sub-distributaries of Nuh namely; Uleta, Dubalu, Ujina, Kalanjar and Pondiary were 6838.09, 176.33, 270.43, 649.43, 163.92, 50.10, 8148.31 (x10^3 cubic meters) respectively in the district. This is clear from the above that a huge amount of water is being regularly wasted from the canal network which if could be save may be able to provide full irrigation to a substantial area and life saving irrigation to almost triplefold area.

The seepage loss rate in the Nuh branch canal was found to be quite high primarily due to the soil characteristics. The soil of the region belongs to the sandy loam texture with very high to high rate of hydraulic conductivity. It is therefore, evident that the seepage losses will be quite high. It is however, notices that the availability of water in Agra canal and the Nuh branch canal has been dwindling over the past few years. The number of days the water is available in the canal has been reduced substantially as well as the water discharge (the total wetted surface and area cross section of the open channel) reduced significantly the seepage losses also have come down. As compared to h designed discharge neither the discharge nor other prosperities have kept a pace with time and hence, the seepage losses have also changed. As reported in earlier sections farmers are not solely dependent on the canal water for irrigation but the tube wells are also playing an major role in irrigation the area selected for this study. It is therefore, convenient to say that in almost all canal commands the conjunctive use is being practiced (Akkuzu, 2012, Martin, 2015).

4.6 Strategies for arresting the conveyance losses for enhancing water availability for irrigation

Advantage of the seepage losses in Nuh branch canal have been reported in form of increased ground water tables along the canals. More or less similar reports have also been made in literature for other canal networks in other regions of the country and the world (Kraatz, 1971, 1977, Vishnoi and Saxena, 2014). Anthropogenic interventions such as damage to the channel bottoms etc. have also been reported. Stealing the water by puncturing the side walls etc. root growth and rat holes etc. have been found (Bakry and Awad, 1997, Anonymous, 2004). All these activities have also contributed significantly in the seepage losses from the canal hence, the standard theories for determining the seepage losses and modeling the seepage behavior from line and unlined canals have resulted into simple determination of evapotranspirtion. The standard theories as suggested by (Koradiya and Khasiya, 2014) could not be successfully applied and validated. However, farmers were found practicing the conjunctive use as reported by other workers too across the canals (Manuel, et al., 1999, Singh, 2002. In the North Western part of India, where soils are largely light in nature as well as the ground water is saline it has been recommended that the canals should be essentially provided with lining so as to avoid the huge seepage losses which otherwise will join the saline aquifers and become unusable (Siddiqui et al., 1993, Shahid et al., 1996, Skogerboe et al., 1999). Also, prudent use of the available water with most modern methods of water applications such as drip irrigation system, growing of short duration crops requiring loess water and such varieties which are salt tolerant and less water requiring are the strategies suggested to farmers in view of decreasing water availability.

4.7 Strategies for conjunctive use of surface and ground water for optimizing the production and productivity

As the water availability could not be increased beyond a certain limit and the ground water salinity restricted the use of it extensively for crop production, a conjunctive use of surface and ground water available was suggested to farmers on the lines of ecommendations made by researchers worldwide (Coe, 1990, Ejaz, and Peralta, 1995, Karamouz, et al., 2004. Dudley and Fulton, 2005. Jang and Chen, 2009, Hosein, et al., 2011, Hanson, et al., 2012.). In other parts of the country in India too, farmers are resorting to the conjunctive use of surface and ground water but their ground water is of good quality in contrast with Nuh block (Mishra et al, 2012). It is therefore, advised to farmers that they should adopt modern methods of irrigation application that are more efficient as well as the water should be used in conjunction for lease effects on the soil quality and resources sustainability of the production system (Bredehoeft and Young, 1983, Christopher, 1981, Azaiez and Hariga, 2001, USBR, 1991, Upmanu, 1995, Blomquist, et al., 2001, Buechler and Devi 2003).

V. SUMMARY AND CONCLUSIONS

The assessment of water resources is very important consideration for optimization of crop production with available irrigation water. The total water resources potential includes the surface water (canal water and runoff) and groundwater (tube well water). The annual canal water run for irrigation in Nuh Block during 2008-09 was 28226.38 ha-m while the actual water available for irrigation after seepage losses, application losses and other losses was 21316.23 ha-m. The annual net groundwater balance for irrigation was estimated to be 6436.00 ha-m but the actual fresh groundwater usable for irrigation was estimated to be only 965.40 ha-m (15 percent). The annual runoff was estimated by the rainfall- runoff relationships. The average annual runoff water from Nuh Block was estimated to be 2398.49 ha-m. The total water availability for irrigation from canal and groundwater resources was estimated to be 22281.63 ha-m. The total water availability for irrigation including runoff stored water was estimated to be 24680.12 ha-m. There is a great uncertainty in measurement of seepage losses from canals due to a large number of factors (Martin, 2015). Any estimation can only be near to the measured one but not the exactly same (Alam, and Bhutta, 2004, Mishra, et al., 2012) despite the utmost care taken in measurements. However, in absence of sophisticated instrumentation for measurement of all parameters round the year the closest approximation to the reality could be worked out for satisfactory assessments. (Weller, 1981, Deacon, N.H.G., 1983, Weller and McAteer, 1993, Murray and Vander Velde. 1992).

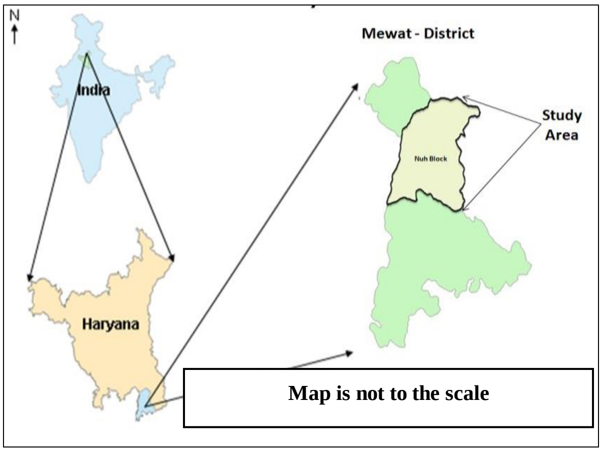

Fig. 1. Location of the study area, the Nuh block of Mewat district of the state of Haryana, India.

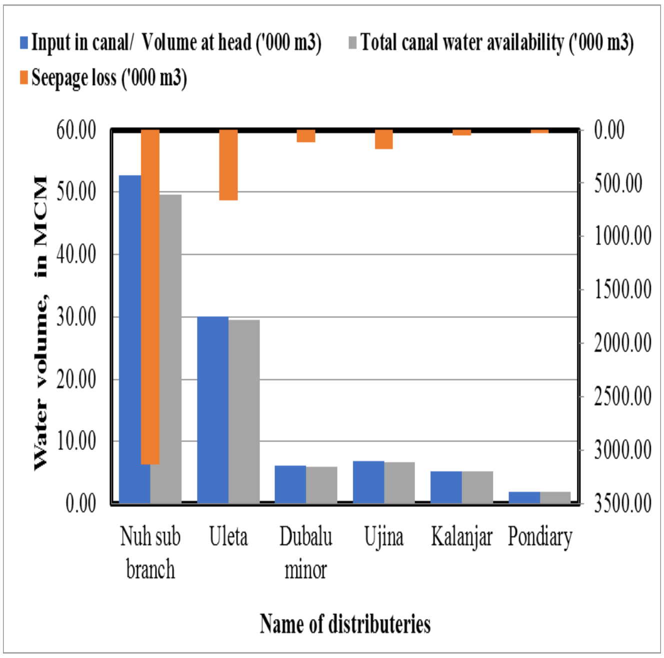

Fig. 2. Estimation of total canal water availability in Nuh block during *Kharif* season, 2008-09, in the Nuh block of Mewat district of the state of Haryana, India.

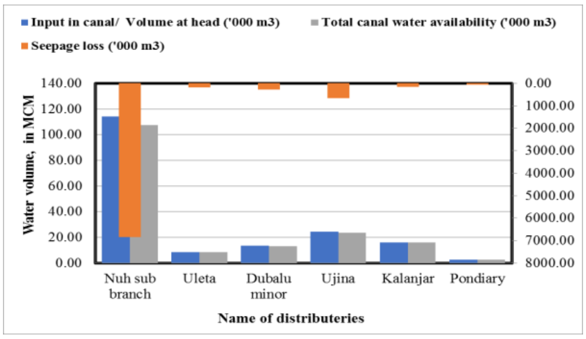

Fig. 3. Estimation of total canal water availability in Nuh block during *Rabi* season, 2008-09.

Table-1. Estimation of irrigation water volume at head of Nuh branch canal (ha-m) of Mewat district of the state of Haryana, India.

Names of distributaries	Average discharge (m^3/s)	Operating time (sec)	Volume at head ('000 m^3)	Volume at head (ha-m)
(A) Monsoon (*Kharif*) Season				
Nuh sub-branch	13.26	3974400	52713.53	5271.35
Uleta	5.27	5702400	30070.09	3007.01
Dubalu	1.67	3628800	6076.12	607.61
Ujina	2.66	2592000	6883.01	688.30
Kalanjar	1.63	3196800	5201.99	520.20
Pondiary	0.77	2505600	1938.17	193.82
Total			102882.91	10288.29
(B) Non-monsoon (*Rabi*) Season				
Nuh sub-branch	14.39	7948800	114350.11	11435.01
Uleta	2.68	3196800	8579.52	857.95
Dubalu	2.67	5011200	13378.07	1337.81
Ujina	4.83	5011200	24203.43	2420.34
Kalanjar	1.46	11059200	16170.39	1617.04
Pondiary	0.98	2764800	2699.41	269.94
Total			179380.93	17938.09
Annual total			282263.84	28226.38

Table-4. Annual groundwater balance of the of Nuh block of Mewat district of the state of Haryana, India.

Net recharge (MCM)	Net Draft (MCM)	GW Balance (MCM)	GW Balance (ha-m)
85.38	21.02	64.36	6436

MCM- Million Cubic Meter

Table-3. Estimation of total canal water availability (ha-m) in Nuh branch canal (ha-m) of Mewat district of the state of Haryana, India.

Names of distributaries	Input in canal/ volume at head ('000 m^3)	Seepage loss ('000 m^3)	Total canal water availability ('000 m^3)	Total canal water availability (ha-m)
(A) Monsoon (*Kharif*) Season				
Nuh sub-branch	52713.53	3130.13	49583.40	4958.34
Uleta	30070.09	655.30	29414.79	2941.48
Dubalu	6076.12	117.96	5958.17	595.82
Ujina	6883.01	175.35	6707.66	670.77
Kalanjar	5201.99	53.22	5148.77	514.88

Pondiary	1938.17	35.25	1902.91	190.29
Total	102882.91	4167.21	98715.70	9871.57
(B) Non-monsoon (*Rabi*) Season				
Nuh sub-branch	114350.11	6838.09	107512.02	10751.20
Uleta	8579.52	176.33	8403.18	840.32
Dubalu	13378.07	270.43	13107.64	1310.76
Ujina	24203.43	649.43	23554.00	2355.40
Kalanjar	16170.39	163.92	16006.47	1600.65
Pondiary	2699.41	50.10	2649.31	264.93
Total	179380.93	8148.31	171232.63	17123.26
Annual total				26994.83

Table-5. Total existing water resources potential for irrigation in Nuh block of Mewat district of the state of Haryana, India.

Particulars	Water availability	Other losses	Actual Water availability
Annual canal water availability (ha-m)	26645.30	5329.06 *	21316.23
Annual groundwater availability (ha-m)	6436.00	5470.60**	965.40
Total water availability (ha-m)	-	-	22281.63
Surface runoff (ha-m)	-	-	2398.49

*Other losses in canal irrigation including application losses, ET losses and special need, 20 percent of water availability;

**85 percent salt affected groundwater; unusable for irrigation

Table-2. Estimation of seepage losses during conveyance in Nuh branch canal in the district of Mewat, Haryana, India.

Monsoon (*Kharif*) Season

Name of distributaries	Length (km)	Average discharge (m^3/s)	Operating time (sec)	Perimeter (m)	Wetted area X10^6 m^2	Seepage loss coefficient (m^3/s)	Seepage loss ('000 m^3)	Seepage loss (ha-m)
Nuh sub-branch	28.55	13.26	3974400	17.30	0.49	1.59	3130.13	313.01
Uleta	11.35	5.27	5702400	10.91	0.12	0.93	655.30	65.53
Dubalu	11.17	1.67	3628800	6.15	0.07	0.47	117.96	11.80
Ujina	14.08	2.66	2592000	7.74	0.11	0.62	175.35	17.54
Kalanjar	5.90	1.63	3196800	6.06	0.04	0.47	53.22	5.32
Pondiary	11.19	0.77	2505600	4.18	0.05	0.30	35.25	3.53
Total							4167.21	416.72
Non-Monsoon *(Rabi)* Season								
Nuh sub-branch	28.55	14.39	7948800	18.02	0.51	1.67	6838.09	683.81
Uleta	11.35	2.68	3196800	7.78	0.09	0.62	176.33	17.63
Dubalu	11.17	2.67	5011200	7.76	0.09	0.62	270.43	27.04
Ujina	14.08	4.83	5011200	10.44	0.15	0.88	649.43	64.94
Kalanjar	5.90	1.46	11059200	5.74	0.03	0.44	163.92	16.39
Pondiary	11.19	0.98	2764800	4.69	0.05	0.35	50.10	5.01
Total							8148.31	814.83

ACKNOWLEDGEMENTS

The first author would like to wish to record their sincere appreciation and gratitude to Dr. B. S. Kalra, Principal Scientist, Water Technology Centre, IARI, New Delhi and the Chairman of his advisory committee suggesting the challenging topic for the research work. We are highly obliged to Dr. T. B. S. Rajput, Project Director, and a leader in Water Science and Technology, P.G. School, I.A.R.I., New Delhi for his valuable suggestions and constant encouragement during the course of research. We are highly grateful to Shri. R. A. Giri for help rendered in measurements of the canal seepage and related field works.

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