A note on practical methods of improving the conveyance efficiency on a government irrigation scheme

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Abstract

The conveyance efficiency measured on the Loskop Irrigation Scheme canal system was 67%. This low efficiency was mainly due to two major causes, namely incorrect run-time of water in the canal system and incorrectly calibrated measuring devices. During a ten-month trial period detailed attention was given to the correction of the above causes. During this trial period it was shown that canal network conveyance efficiency could be increased to 75%, resulting in a saving of an estimated 10 x $10^6 m^3$ of water annually.

Introduction

As the demand for water increases, minimisation of water losses in canal systems as a result of operational inefficiency becomes increasingly important.

Irrigated agriculture in South Africa, a sizeable proportion of which is supplied with water via canal networks, is showing a tendency towards higher water demand per unit area. This is due to more intensive crop production, made possible by more efficient farm management practices, fertilizer use and the planting of higher yielding crop cultivars. Increasing canal capacities in order to meet the higher water demand is often financially prohibitive. (Jensen, 1967); Palacios and Day, 1977; Bottrall, 1981) In South Africa it is more often true that extra water is not available for use by agriculture. Decreasing avoidable water loss from canals is often the only relatively inexpensive method available whereby existing water sources and supply networks are able to meet increasing water demands.

Avoidable losses occur as a result of inefficient management in the operation of the canal system relating, mainly, to incorrect programming of headwork releases, errors involved in water measuring structures and deficient maintenance.

In contrast "unavoidable" water losses from canals occur due to seepage and evaporation and can thus be related to surface area of water in the canal, wetted perimeter area of the canal and to the condition of the canal network. The evaporation loss, expressed as a percentage of total flow, is usually very low and has been estimated at approximately 0,3% of total volume (Butler, 1980; Reid and Muller, 1983). Seepage losses from concrete lined canals would appear to fluctuate between approximately 0,35 ℓs^{-1} per 1 000 m^2 wetted perimeter and 1,9 ℓs^{-1} per 1 000 m^2 (Kraatz, 1977; Butler, 1980). For design purposes Butler (1980) suggested a value of 1,9 ℓs^{-1} per 1 000 m^2 wetted perimeter which, if applied to elaborate canal systems, could result in an unavoidable loss rate of up to 15%. Seepage losses can also fluctuate widely due to water table depth influences. In an area such as the Vaalharts Irrigation Scheme, where generally high water table levels are found, canal seepage decreases to roughly 5% of the input volume (Streutker, 1981 and Muller, 1984). Such high water tables are however more the exception than the rule on State controlled irrigation schemes.

Coupled to the above evaporation and seepage losses are the losses due to operational wastage, i.e. errors in metering, start-up and shut-down losses and water rejected from the canal system due to unexpected drops in demand. These losses, which could also probably be classed as unavoidable, are estimated to fluctuate between 9% and 17% (Butler, 1980; Muller, 1984). Operational losses can also fluctuate widely according to the mode of water delivery, being lower for a constant delivery than for a system of variable delivery. Total scheme size, as well as farm size and flow rate also affect operational losses (Bos and Nugteren, 1982).

Canal conveyance efficiency, for the purpose of this study being defined as the ratio of the volume of water delivered to the farmer to the volume of water released at the canal headworks, can be derived by the use of the following equation (Bos and Nugteren, 1982):

$$Ec = \frac{V_d + V_2}{V_c + V_1}$$

Where

- Ec = conveyance efficiency
- V_c = volume of water at canal headworks (m^3)
- V_1 = inflow, if any, from other sources (m^3)
- V_d = volume of water delivered to the farmer (m^3)
- V_2 = non-irrigation deliveries from the conveyance system (m^3)

Using the above equation Bos and Nugteren (1982)

TABLE 1
CONVEYANCE EFFICIENCIES ON SOME STATE CONTROLLED IRRIGATION SCHEMES IN THE REPUBLIC OF SOUTH AFRICA

Scheme	Measured conveyance efficiency (%)	Scheduled area (ha)	Mean plot size (ha)
Hartbeespoort	66	13 093	10
Marico Bosveld	75	2 544	13
Sterk River	75	1 649	17
Rust De Winter	74	1 872	12
Loskop	75	16 090	25
Levubu	63	1 849	13
Vaalharts	86*	37 180	25
Mooi River	76	4 752	10
Vredendal	76	9 538	18

*This conveyance efficiency must be regarded as approximate

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calculated an upper limit conveyance efficiency of 79%. The losses suggested by Butler (1980), Streutker (1981) and Muller (1984) indicate upper limit conveyance efficiencies of 86% (high water table conditions) and 78% (low water table conditions), with a lower limit of 68%.

The conveyance efficiencies of several larger irrigation schemes in South Africa, as shown in Table 1, would appear to indicate that the water losses measured in the canal systems are not excessive, the exceptions being possibly the Hartbeespoort and Levubu Schemes, both of which suffer secondary problems, for instance excessive algal growth in the canals, causing lower efficiencies.

The pre-1980 conveyance efficiency measured on the Loskop Irrigation Scheme canal system was 67%. As this efficiency was low it was decided to investigate the causes relating to the low efficiency and improve the efficiency by reducing avoidable losses.

The Loskop irrigation scheme

The Loskop Scheme serves a total irrigated area of 16 090 ha. Individual properties are scheduled for 25 ha under irrigation with an annual water allocation of 7 700 m^3 ha^{-1}. The mean annual rainfall is in the region of 700 mm while evaporation, as measured from a standard American Class A pan, is approximately 2 200 mm per annum on average. Crops are grown throughout the year with cotton, tobacco, soya beans and citrus in summer and wheat and green peas in winter being the dominant crops.

The Scheme is served by a left bank main canal, 96 km in length, with secondary and tertiary canals totalling 320 km in length. There are, in total, 700 farm off-take points along this network. A right bank main canal with secondaries, totalling 62 km, serves 73 farm off-take points. The Scheme obtains its water from the Loskop Dam and the farmers are supplied with water on demand.

Methodology

During the period May 1978 to February 1980 the conveyance efficiency of the whole system was intensively monitored. The mean monthly conveyance efficiencies were calculated for high and low flows. During this observation period faults ranging from incorrectly installed gauge plates, non-calibrated farm off-takes, maladjustment of main canal radial gates, incorrectly calibrated long weirs and incorrectly installed Parshall flumes, to other defi-

TABLE 2
LOSKOP GOVERNMENT WATER SCHEME: MONTHLY DAM RELEASES AND CALCULATED CANAL CONVEYANCE EFFICIENCIES

	Period May 1978 to February 1980		Period March 1980 to January 1981	
Month	Releases $m^3 \times 10^6$	Conveyance efficiency %	Releases $m^3 \times 10^6$	Conveyance efficiency %
			1980	
March			9,96	77
April			2,77	77
1978				
May	12,44	60	13,60	74
June	15,68	72	14,78	78
July	13,66	70	16,23	77
August	19,78	71	16,30	78
September	17,53	72	18,31	77
October	13,41	66	18,86	76
November	13,04	66	4,86	70
December	13,48	69	4,65	66
1979			1981	
January	21,95	70	3,58	76
February	19,37	63		
March	11,05	70		
April	5,39	54		
May	6,20	61		
June	7,00	65		
July	6,89	61		
August	7,92	70		
September	8,06	66		
October	12,89	66		
November	5,02	77		
December	10,49	71		
1980				
January	10,28	70		
February	8,68	70		
Mean	11,83	67,3	11,26	75,1

ciencies such as untrained canal supervisors, inaccuracies in the run-time of water in the canals and the illegal abstraction of water, were noted. The run-time of water, for the purpose of this study, is defined as the length of time required for water to flow from the canal headworks to any given farm off-take point. The most critical faults were the incorrect run-times of water under variable climatic and demand conditions and incorrectly calibrated measuring devices.

By early 1980 the measuring devices had all been correctly calibrated and the correct run-time of water, under variable climatic and demand conditions, determined, with the result that reassessment of conveyance efficiency was possible. During the period March 1980 to January 1981 an intensive effort was made to ensure the timeous delivery of the correct volume of water to individual farmers. The major thrust in this direction was aimed at constantly adjusting headworks inflows and radial gates on the main canals in order to obtain the desired flows in conjunction with greater attention to detail by individual canal supervisors.

Results and discussion

The results of monthly canal flow determinations and conveyance efficiency calculations are shown in Table 2.

From the results shown in Table 2 it is apparent that no clear relationship between monthly flows and corresponding efficiencies exist.

During the period prior to March 1980 conveyance efficiencies varied from a low of 54% to a high of almost 78% with a mean efficiency of 67,3%. During the period after 1 March 1980 the efficiencies varied between a low of 66% and a high of almost 78%, with a mean of 75,1%.

It is of interest to note that the highest conveyance efficiency obtained, namely 78%, is for all practical purposes in exact agreement with the estimated maximum efficiency reported in the literature.

The limited results available indicate that increased management efficiency increased conveyance efficiency by an average of 7,8% which is equivalent to a saving of approximately 10 x $10^6 m^3$ of water per year.

Conclusion

The estimated upper limit of canal conveyance efficiency mentioned in the literature, for irrigation schemes having extensive canal networks, appears to be realistic and attainable. Increasing conveyance efficiency, however, requires constant all round attention to detail. As can be judged by the estimates given in Table 1, the current conveyance efficiencies on some of the larger irrigation schemes are within reach of the achievable upper limits of efficiency.

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