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WATER CONSERVATION AND WATER DEMAND MANAGEMENT IN AGRICULTURE : DEVELOPMENT OF WATER MANAGEMENT PLANS BY IRRIGATION WATER SUPPLIERS IN SOUTH AFRICA*

J.W Badenhorst M de Lange
M.E Mokwena R.J Rutherfoord

ABSTRACT

South Africa's Department of Water Affairs and Forestry will implement the first phase of its Water Conservation and Demand Management strategy for the agricultural sector through the development of Water Management Plans. These plans will be developed by Water User Associations in pilot areas first, to refine the approach and the required tools. A major challenge is to structure the requirements in such a way that it would also be possible for poorly resourced smallholder schemes to achieve the desired results.

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1. INTRODUCTION

1.1 The Water Conservation and Demand Management Initiatives : Where it fits into the Implementation of the National Water Act

South Africa is a semi-arid country, where water is a key strategic resource in the development of all sectors of the economy. Efficient management of our limited water resources is therefore an essential element of that development. The Department of Water Affairs and Forestry (DWAF) is in the process of developing a Water Conservation and Water Demand Management (WCDM) strategy for each water use sector, namely, Agriculture, Municipal, Industries, Forestry and Environment. The National Water Conservation and Demand Strategy (NWCDMS) will be incorporated into the National Water Resources Strategy (NWRS), which is a legal requirement of the new National Water Act (Act 36 of 1998). The Catchment Management Strategies of each of the 19 Water Management Areas, the National Pricing Strategy and other strategies currently being developed by DWAF will also contribute to the NWRS.

The Agricultural WCDM Strategy will be implemented through the development of Water Management Plans by Water User Associations (WUAs) and other irrigation water suppliers. These Water Management Plans will be similar to the Water Services Development Plans currently being developed by Municipalities. Irrigation water suppliers, such as Water User Associations (WUAs) or former Irrigation Boards, are now required in terms of the law to submit Water Management Plans to their Catchment Management Agency (CMA) and/or the Department of Water Affairs and Forestry (DWAF).

1.2 The Consultation Process to Implement WCDM in the Agricultural Sector

To enable WUAs to comply with the legal requirement to submit Water Management Plans, DWAF has consulted with the agricultural sector to develop guidelines for Water Management Plans that would be *practical, fair, effective* and *affordable*. This approach was strongly supported by participants in five public expert consultations held in March, April and June 2000 to develop a suitable approach and format for Irrigation Water Management Plans in discussion with the agricultural sector.

The workshops in the first round of consultation were held in four irrigation areas that have taken demonstrable steps to conserve water and that are regularly under water stress. Workshops were held in the Breede River valley in the Western Cape, Sundays River in Eastern Cape, Orange/Vaal area in Northern Cape and Olifants River in Northern Province/Mpumalanga. A national follow-up workshop was held on 8 June 2000 at Gariep Dam.

Water Management Plan a legal requirement

A key clause in the National Water Act is Section 29(1), which reads as follows: A responsible authority may attach conditions to every general authorisation or licence relating to water management by :

(i) specifying management practices and general requirements for any water use, including water conservation measures;

(ii) requiring the monitoring and analysis of and reporting on every water use and imposing a duty to measure and record aspect of water use, specifying measuring and recording devices to be used; and

(iii) requiring the preparation and approval of and adherence to, a water management plan.

1.3 The Water Management Plan Approach : Starting Simple, Improving Annually

The objective of the Water Management Plans is to improve agricultural water management by stimulating self-analysis and forward thinking on the part of farmers, their water suppliers, CMA, officials, consultants and advisors. WUAs will develop and implement their Plans in a progressive manner. The Water Management Plan may be very superficial to start with and may be lacking in certain data, but it will be improved annually when the WUA reviews its Plan.

Essentially, the process aims to conserve water, to improve water supply services to irrigation farmers and to enable them to use irrigation water more efficiently.

The focus is on WUAs, because they will be at the heart of agriculture's water management relationships and initiatives. Wherever this document speaks of WUAs, it also means to include Government Water Schemes and other irrigation water suppliers.

Water has to be conserved at all levels – from the source, right through to the points of use. However, the focus at this early stage of the process is on the activities of WUAs and how these are aimed at:

- Reducing water losses related to the WUA's storage and water distribution systems and management; and
- Enabling farmers to use water more efficiently on-farm.

The intended outcome of this initiative is to maintain vigorous and sustainable irrigated enterprises that use water more efficiently to improve the health of the environment and assure safe and reliable urban, rural and agricultural water supplies.

1.4 International Developments

Due to increasing demands for water and its ongoing depletion globally, water resources management has received considerable attention around the world for many years – and particularly in the last decade. Prominent in policy and strategy thinking are three particular universal trends, all of which are current features of the new South African Water legislation :

- Integrated water resources planning and management based on the river basin or catchment.
- A balance between policy and regulatory functions of central government and the decentralised management, operation and maintenance of water delivery through participation by the stakeholder and water user.
- A shift in the policy of water resource management, away from the development of new systems and infrastructures to provide more water, to the improved management of existing water resources and the improvement of water use efficiency and water conservation. These improvements are often implemented through Water Management Plans, with a focus on Best Management Practices.

A significant step is the decentralisation policy whereby the water users themselves, through the Catchment Management Agency (CMA) and Water User Association (WUA), have an important part to play in the process of planning, management, decision-making and administration. The users directly participate in, and are responsible for, water supply and distribution in their own farming area.

The development of Water Management Plans by the WUAs is central to the whole focus of water conservation and water demand management and this is where we are focussing in this programme. The participants in the workshops highlighted the following expected benefits with Water Management Plans :

- A tool firstly for WUAs' own management purposes, and secondly for the purposes of DWAF and the CMAs, such as the development of catchment databases and the National Water Balance.
- The Water Management Plan is a basis for planning and measurement, and will demonstrate progress with WCDM.
- A mechanism for sharing experience between WUAs.
- A basis for negotiation with other institutions, including WUAs, CMA, DWAF etc. and for international water negotiations.

1.5 Who gets the water?

Participants in every workshop wanted clarity on what happens to the water savings they manage to accomplish: will they be shooting themselves in the foot by investing money in improved practices just to lose the benefits of their efforts to other sectors?

From the field visits at leading practitioners it was clear that the economic and management benefits of water conservation have been the most significant incentives for improvement. Such economic benefits may include, depending on the crop type, markets and water supply costs, any of the following :

- improved yields
- improved quality of produce, especially for the export markets which pay large premiums for quality
- reduced water supply costs, and
- easier management, especially with automated systems (although this requires a higher level and more exacting type of management - there is little margin for error, and therefore increased risk).

Participants were assured that the National Water Act does not allow water to be taken away arbitrarily. The review of water allocations will be a separate process to the water conservation process and care will be taken not to disbenefit those who have invested in using water more productively.

2. WHAT IS A WATER MANAGEMENT PLAN?

Developing a Water Management Plan and reviewing it regularly is a major stimulus to efficiency, promotes co-ordinated action and facilitates negotiations with the CMA and other stakeholders. The process does not require expensive data-gathering, but uses existing data for its initial implementation and then aims to improve the data from year-to-year. Therefore, the WUA should be able to develop its own Water Management Plan without the assistance of external consultants, unless the WUA prefers to employ such help.

In a Water Management Plan, a WUA describes its current irrigation water use and conservation measures and sets out how it plans to implement Best Management Practices (BMPs) to improve its irrigation water supply services and to achieve water conservation and water demand management.

In its Water Management Plan a WUA goes through the following steps :

- **Step 1 :** Describe the WUA, its location and facilities, history, operating rules, etc. (see Part 2 : 1). This dovetails with WUAs' current development of their constitutions to be transformed from Irrigation Boards.
- **Step 2 :** Identify and adopt appropriate Benchmarks for irrigation water use and water management in the WUA area (see section 2 and Part 2 : 2).
- **Step 3 :** Develop a Water Account of the WUA's water resources and uses for auditing purposes (see section 2.2 and Part 2 : 3).
- **Step 4 :** Review progress and show plans for the implementation of Primary and Secondary BMPs for the WUA (see section 2.3 and Part 2 : 4).
- **Step 5 :** In later reviews of their WMPs, WUAs will have to motivate which "Secondary" BMPs they should not have to implement, through performing a Net Benefit Analysis. This is an analysis of the impact of the BMPs on the environment, possible third parties and any indirect economic impacts on the farmers and others.

2.1 What are benchmarks for irrigation water use?

The primary benchmarks for irrigation water use are firstly the crop water requirement of a specific crop (ET_{crop}) in a specific area at a specific time of year. ET_{crop} does not take irrigation efficiency factors into account.

Secondly, the ET_{crop} benchmark can be used to calculate the irrigation water requirements for a specific crop in a specific area and at a specific time of year by adjusting the crop water requirement for appropriate irrigation efficiency factors such as leaching requirements, irrigation application efficiency, effective rainfall and reasonable transmission losses (mainly evaporation). This Benchmark is not the "quota" or water allocation for irrigation, but rather a management tool for decision-making within a WUA.

These benchmarks can, in turn, be used to calculate the expected irrigation water requirements for the WUA as a whole (Equation 1 below).

The WUA should therefore make all reasonable effort :

- To calculate the irrigation water requirement for each crop grown in the WUA district, and
- To estimate, as closely as possible, the area of each crop grown, preferably averaged over more than one year, in the WUA district, and
- Using the above to calculate the monthly and annual irrigation requirements for the WUA.

2.1.1 Calculation of irrigation water requirement

Research on crop water use and irrigation requirements for a wide range of commercial crops in different climatic regions and on different soil types has been ongoing in South Africa for over 25 years. The results of this research have been effectively applied in many irrigation areas for almost as long a period. The agricultural sector in South Africa may therefore be well ahead of other sectors with regard to the establishment of benchmarks and operating guidelines for crop water use and irrigation requirements.

Despite this progress there remain many gaps in the information/data pool and the initiatives have been adversely affected by inconsistencies in approaches, duplication and uncoordinated effort.

The sector is, however, now in a position to focus on a standard approach to establishing benchmarks for crop water use and irrigation requirements for the many agro-climatic zones in which irrigation is practised in South Africa.

The standard approach to be applied universally is based on the following two components :

- the Penman-Monteith method of estimating reference evapotranspiration (ET_o) in any given zone and
- the FAO method of linking reference evapotranspiration to any given crop by way of a standard crop factor (K_c) for any given period during the growing season of the crop (FAO 56).

In contrast to the crop factors used with A-pan, reference evaporation, K_c can be adjusted consistently and with confidence to accommodate differences in climatic zone and farming practice. Because the short grass reference evapotranspiration already accounts for many of the implications of differences in climate, it is often possible to use a single set of crop coefficients for different climatic zones. The ET_0 – K_c approach has become a widely accepted international standard and has therefore been accepted by DWAFas a basis for establishing crop water requirement and irrigation requirement benchmarks.

The computer programme SAPWAT, which has recently become available, is structured in accordance with the recommendations of FAO 56. SAPWAT is therefore, available as an integral support tool for benchmarking.

The Pricing Strategy of the Department of Water Affairs and Forestry (DWAF) requires that SAPWAT be used as the procedure to calculate crop water requirements and irrigation requirements where new benchmarks are required. The Water Resource Planning Directorate also uses SAPWAT for basin studies and in the Water Balance Model. Furthermore, the Directorate of Water Utilisation is using SAPWAT as a tool in the registration of water use. It is therefore, logical that SAPWAT should be adopted as the primary tool for the calculation of the above benchmarks in the implementation of WC/DM in agriculture.

A major advantage of SAPWAT in this regard is its flexibility in accommodating best management practices that are specific to areas and situations.

Examples of practices that can be accommodated in the SAPWAT model include :

- Double cropping. Ensure that both summer and winter crops are accounted for. This should be evident in the calculation tables.
- Season length. Ensure that this is adjusted for the crop cultivar selected, local adaptability, frost etc.
- Irrigation method. Select the correct efficiency factor for the irrigation method used. Improved efficiencies should be targeted.
- Leaching requirement. Ensure that this is accounted for, and at the correct level for local conditions.
- Pre-plant irrigation. If it is a standard practice, build it into irrigation water requirements.
- Unusual climatic effects. For example, persistent drying winds.
- Special management features such as allowing for the use of water for frost protection, cooling etc.
- Special agronomic practices such as row spacing, population density etc.

The equation to estimate irrigation water requirements of, say, a WUA as a whole is :

$$IRR = \frac{\sum ARI*[(ET_O*Kc - REF)*0.001]*LRF/EFF}{(1-DUF)} \qquad (1)$$

Where :

IRR	=	Total water use by irrigation	[million m^3/a]
ARI	=	Total area under irrigation	[km^2]
ETo	=	Reference evapotranspiration from "short grass" (ET_0) (Penman-Monteith)	mm/m]
Kc	=	Crop coefficient (K_C) associated with ET_0 on a monthly basis	[factor]
REF	=	Effective rainfall	[mm/m]

LRF	=	Leaching requirement factor, with a recommended default value of 1.0	[factor]
EFF	=	System efficiency factor	[factor]
DUF	=	Distribution uniformity factor	

Reference evapotranspiration (ET_0) (Penman-Monteith)

SAPWAT's ET_0 database is available for 334 weather stations as illustrated in Figure 2.

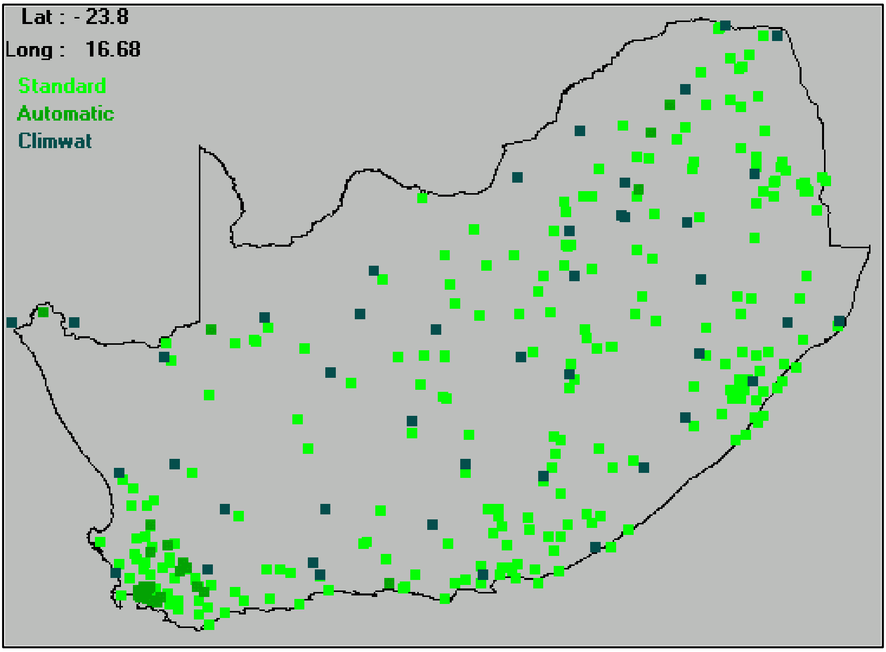

Figure 2. Map showing national distribution of SAPWAT ET_0 data stations

Penman-Monteith values will, in the near future, be available electronically from a website set up by ISC&W of ARC.

Customised weather stations can also be used to calculate ETo for specific sites.

Crop factor coefficient (K_C)

By definition, the Penman-Monteith reference evapotranspiration, ET_0, represents potential water use by a short grass crop that is never short of water. A crop coefficient is therefore required to convert it to potential evapotranspiration (Et_{crop}), or crop water requirement, of a specific crop, such that :

$$ET_{crop} = ET_0 * K_C$$

The SAPWAT computer programme allows the user considerable freedom to develop crop coefficients that are well suited to specific cropping circumstances.

Because the $ET_0 - K_c$ approach has been so well accepted internationally, a wealth of information is available. The crop coefficients developed for the sophisticated water accounting system used on the lower Colorado river in the USA are particularly useful reference values (13, 14) and have assisted with the approach to and determination of appropriate values for South Africa.

Typical crop coefficients expressed as monthly averages for individual crops or groups of crops and are given in Tables 1 to 6. This is a dynamic development process and these values should not be seen as permanent or absolute. As more details are available, the tables may be modified or extended.

To convert Et_{crop} to an estimate of irrigation requirements for that crop the following variables and efficiency factors have to be included in the equation.

Effective rainfall (REF)

An estimate of effective rainfall is an integral part of the equation for estimating irrigation water requirement. Based on reliable and long-term rainfall records, effective rainfall will be applied for the duration of a crop's growth which should match the period over which the crop coefficient, (K_C) applies for that particular crop (refer Tables 1-6).

The SAPWAT programme incorporates the calculation of effective rainfall on a monthly basis and uses an equation that was developed by the USDA Soil Conservation Services (15, 16) and now generally accepted. The equation has been satisfactorily tested under South African rainfall conditions (8).

Irrigation system efficiency (EFF)

The irrigation system efficiency factors (EFF) given in Table 1 represent realistic values based on current experience. Further research will allow these values to be refined in due course.

Table 1. Irrigation systemn efficiency factors (EFF)

Irrigation system	EFF
Flood irrigation	0,60
Sprinkler systems	0,70
Mechanical systems (eg: centre pivot)	0,75
Micro systems	0,80
Drip systems	0,85

Where a combination of systems apply in an irrigation area or Water User Association or Water Management Area – as will usually be the case - a simple weighted average of systems may be calculated. For example, in an area where 70% of irrigation is flood irrigation and 30% is sprinkler irrigation, the average system efficiency will be :

$$EFF = (0{,}60 \times 70\%) + (0{,}70 \times 30\%) = 0{,}63$$

The low efficiency for flood irrigation is seen to be partly due to a high rate of deep percolation or leaching below the rooting zone, rendering the water unavailable for crop growth. Much of the deep percolation from flood irrigation is assumed to return to the system as return flow.

In the IRR equation, the smaller the application efficiency factor (EFF), the larger will be the resulting IRR.

Leaching requirement (LRF)

In the IRR equation, the recommended default value for the leaching requirement factor (LRF) is 1.0, which means that there is no allowance for a leaching requirement.

Should there be a need to increase IRR to allow for a leaching requirement, then LRF would be greater than 1.0. For example, for a 10% leaching requirement, then LRF = 1.1 and IRR will be 10% larger. Where irrigation areas are known to have soil salinity problems and the leaching of salts from the soil is normal management practice (eg: Fish River , Eastern Cape), then LRF > 1.

Table 2. Crop coefficients for perennial crops and pastures in the summer rainfall areas

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Subtropical	0.80	0.80	0.80	0.80	0.80	0.80	0.65	0.65	0.65	0.65	0.70	0.70
Deciduous	0.85	0.78	0.64	0.50	0.27	0.27	0.27	0.27	0.55	0.85	0.85	0.85
Grape	0.73	0.63	0.45	0.35	0.20	0.20	0.15	0.15	0.15	0.21	0.31	0.53
Grape	0.70	0.70	0.55	0.35	0.31	0.31	0.31	0.31	0.31	0.35	0.60	0.67
Pasture	0.80	0.80	0.80	0.80	0.80	0.10	0.10	0.10	0.80	0.80	0.80	0.80
Lucerne (Frost)	0.80	0.80	0.80	0.80	0.80	0.10	0.10	0.10	0.80	0.80	0.80	0.80
Coffee	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Tea	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Olive	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Sugarcane	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Date	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Pineapple	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

Table 3. Crop coefficients for perennial crops and pastures in the winter rainfall areas

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Citrus	0.80	0.80	0.80	0.80	0.80	0.80	0.65	0.65	0.65	0.65	0.70	0.70
Grape	0.73	0.63	0.45	0.35	0.20	0.20	0.15	0.15	0.15	0.21	0.31	0.53
Deciduous	0.85	0.78	0.64	0.50	0.27	0.27	0.27	0.27	0.55	0.85	0.85	0.85
Pasture	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	1.00	1.00	1.00
Luceme (frost)	0.80	0.80	0.80	0.80	0.80	0.10	0.10	0.10	0.80	0.80	0.80	0.80
Grape	0.70	0.70	0.55	0.35	0.31	0.31	0.31	0.31	0.31	0.35	0.60	0.67

Table 4: Crop coefficients for annual field crops and pastures in the summer rainfall areas

Crop	Date From	Date To	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Miaze	1 Dec	15 May	0.38	1.09	1.20	1.08	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Wheat	1 July	30 Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.46	0.96	1.15	1.07	0.00
Soya	1 Dec	15 Apr	0.67	1.11	1.15	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Potato (Period 1)	1 Jan	30 Apr	0.26	0.79	1.15	1.15	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potato (Period 2)	1 Oct	31 Nan	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.80	1.14
Tobacco	15 Oct	15 Feb	1.09	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.71	1.15
Groundnut	1 Oct	28 Feb	1.14	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.50	1.09
Cotton	1Nov	30 Apr	0.91	1010	1.10	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.53
Ryegrass	1 Feb	30 Nov	0.00	0.50	0.96	1.05	1.05	1.00	0.50	0.96	1.05	1.05	1.00	0.00

Table 5: Crop coefficients for annual field crops and pastures in the winter rainfall areas

Crop	Date From	Date To	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Miaze	1 Oct	15 Feb	1.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.78	0.96
Wheat	15 May	15 Sep	0.00	0.00	0.00	0.00	0.23	0.46	0.77	1.05	0.31	0.00	0.00	0.00
Soya bean	1 Dec	15 Apr	1.10	1.20	1.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potato (Period 1)	1 Jan	31Apr	0.73	1.20	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potato (Period 2)	1 Oct	31 Sept	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.80	1.14
Potato (Period 3)	1 Aug	30 Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	1.05	1.00	0.78	0.00
Potato (Period 4)	1 Aug	31 Jan	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	1.20
Ryegrass	1 Feb	30 Nov	0.00	0.50	0.96	1.05	1.05	1.00	0.50	0.96	1.05	1.05	1.00	0.00

Table 6: Crop coefficients for vegetables

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Summer	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.79	1.09
Winter	0.00	0.00	0.46	0.52	0.95	1.10	0.00	0.00	0.00	0.00	0.00	0.00
Undifferentiated (Summer Rainfall)	0.00	0.00	0.43	0.57	0.86	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Undifferentiated (Winter Rainfall)	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.63	1.05

Conveyance losses (CLI)

Conveyance losses to field edge are expressed in the IRR equation as a proportion of IRR. Thus, if losses are estimated to be, for example, 20%, then CLI = 0.20 and the resulting IRR would be 20% larger.

2.2 What is Water Accounting and Water Auditing?

A water account or water balance summarises the annual volume of inflow, consumption and outflow from the geographical area served by the WUA. The water account crystallises the beneficial and non-beneficial consumptive uses in the WUA area as a basis for calculation of performance indicators. Performance indicators are particularly useful in identifying water savings opportunities. A water audit is done to establish whether the information in the Water Account and Disposal Reports are correct. DWAF currently audits the monthly Disposal Reports supplied by Government Water Schemes and follow this up with technical support for problem solving.

Each water use component in the WUA area is categorised in the Water Account to reflect the consequences of human intervention in the hydrological cycle (also see Figure 1). Inflows, consumptive uses and outflows are classified into various categories as defined below :

2.2.1 Inflows

- Gross inflow is the total amount of water flowing into the domain from rainfall, surface and groundwater sources.
- Net inflow is the gross inflow plus or minus any changes in storage.

2.2.2 Consumptive use

Consumptive use is a use or removal of water from a domain that renders it unavailable for further use.

- Process consumption is that amount of water diverted to produce an intended good, and is therefore considered beneficial use.
- Non-process consumption occurs when diverted water is "consumed" or depleted, but not by the process (or for the production) it was intended for. This could still be a beneficial use (eg: indigenous riverine vegetation), but it is mostly non-beneficial (e.g. evaporation, deep percolation that cannot

be retrieved for productive use). It is necessary to distinguish between seepage along the length of a canal and leakage through cracks and breaks in a canal. Each "water loss" must be analysed in the water account to show which fraction is actually "consumed" and thus unavailable for downstream use. Any reusable fraction is reflected as "outflow" (see below).

2.2.3 Outflow

Water flowing out of the system can be either committed or non-committed.

- Committed water is that part of outflow that is committed to other uses.
- Uncommitted outflow is water that is not depleted, nor committed, and is thus available for a use within a basin or for export to other basins, but flows out due to lack of storage or operational measures (e.g. stormwater). Water that leaks from a canal and returns to the river may also be considered as Uncommitted outflow.

2.2.4 Other definitions

- Available water is the net inflow less the amount of water set aside for committed uses and represents the amount of water available for use at the basin, service, or use levels.
- Non-consumptive uses of water are uses where benefits are derived from an intended use without depleting water (e.g. fishing).

Table 7 in Part 2 presents the proposed format for a Water Account by WUAs. To complete the table, the WUA can use its records (if available) of water releases and flow monitoring in the system. Otherwise, tables for ground water abstraction, drainage outside the domain (including mountain streams) and abstraction from farm dams can be used.

Source of data

All WUAs will have to produce monthly Disposal Reports for the CMA or the Directorate of Water Utilisation of DWAF. The Disposal Report captures actual data on water received and supplied by the WUA.

Total Year 92/93

Table 7. Water Accounting Report

Inflow	Diversions and abstractions from surface water sources (pumping and canals from dams and rivers)	460.43
	Abstractions from groundwater (pumping from boreholes) Abstractions from surface drainage outside the domain (including mountain streams)	0.00
	Abstraction from farm dams	0.00
Gross Inflow		**460.43**
Storage change	Storage change in reservoirs and balancing dams inside the domain	-0.80
Net Inflow		**459.63**
Consumptive use		
Process consumption (water used for production or other human purposes)		
	Irrigation	344.65
	Municipalities & Industry	13.51
	Domestic and Stock Water	4.93
	Other (specify)	
Total Process Consumption		**363.09**
Non Process Consumption (water that is used, but does not produce outputs for human processes)		
Beneficial		
	Ecological uses (e.g. indigenous riverine vegetation)	
Non-beneficial	Alien vegetation	
	Evaporation	25.08
	Seepage which is not usable down-stream	32.50
	Leakage which is not usable down-stream	
	Operational spills not usable down-stream (estimate fraction of operational spills not re-usable)	26.45
Total Non-process Consumption		**84.03**
Total Consumption		**447.12**
Outflow		
Committed	Committed to downstream use	6.82
	Operational spills that are used downstream (estimate reused fraction of operational spills)	5.85
	Subsurface drainage that is used downstream	
Total Committed Outflow		**12.67**
Uncommitted	Operational reusable spills not currently used by downstream users	
	End of canal outflows	
	Surface run-off not stored (e.g. storm-flow, reservoir operation losses)	
Total Uncommitted Outflow		**0.00**
Total Outflow		**12.67**
Available Water	Net Inflow - Committed Outflow	446.96

The disposal reports originated from the need to optimally manage on-demand water management systems.

The purpose of water distribution systems is to make water available at predetermined periods at a set flow rate at a specified point. To achieve this goal irrigation designers and managers have developed various water distribution systems, namely;

- **Downstream or User control**

  With this system the user abstracts water at any time through an automatic registering flow control valve. Most piped system and even automated canal systems can operate in this way. This is normally a very advanced and expensive system.

- **Mechanical extraction**

  Water is abstracted directly from rivers or canals mainly by means of pumps

- **Upstream or Supplier control**

  Upstream control is based on supplying water according to demand assessment. This method can be subdivided into two categories, namely;

- **Rotational delivery**

  Water is distributed evenly to all users on turn-to-use basis. In this case, the flow of water in the canals is not regulated and every user has the opportunity to abstract water from the canal at a certain predetermined date and time. The losses in this type of system are normally excessive, due to the lack of control.

- **Delivery on request**

  This system is more organised and more conservation orientated than the rotational delivery system and is used at the largest irrigation schemes in South Africa, namely; Loskop Irrigation Board, Pongola Irrigation Board, Riet River -, Mooi River -, Hartebeestpoort -, Groot Marico -, Sandvet -, and Vaalharts Irrigation Schemes. This system was developed over many years and works as follows :

Irrigators cannot abstract water that they need at will. Each irrigator must submit a written request on a regular basis, normally weekly. The capacity of the canals is not adequate to transport enough water for all the irrigators to abstract water simultaneously. Furthermore, it takes several hours for water being released at the source to reach the users and therefore the management of the scheme has to evaluate all requests, calculate the quantity of the release and determine the dates, times and volumes of the release to each irrigator.

The process to manage the system is schematically represented in Figure 1 and starts with the receipt of written request for water from each irrigator. These requests are normally done on a weekly basis. The irrigators complete application forms and deposit these forms in a special box. The scheme is normally divided into sections and the water control official of each section empties these boxes at a predetermined time. By using the requests the water control official compiles a feeder chart (which is a summary of the requests in his/her section) and a commission for each canal guard, which stipulates when each sluice should be opened and for how long. The sluices are normally set for a predetermined flow rate regulated by a constant upstream water depth created normally by a long weir in the canal.

Each canal's losses is calculated and added to the requested volume of water in order to determine the requested inflow into the specific canal.

The requests from all the different canals are summarised and losses in the main canal are added to determine the total amount of water that must be released at the source. At the end of a period (normally a week) a Disposal Report is produced to summarise all the requests and deliveries. These Disposal Reports summarise all the information as time goes by, until a final report at the end of each water year displays the results of the past year.

These weekly or monthly Disposal Reports should be used as a source of data for the Annual Summary Disposal Report and the Water Accounting Report of the Water Management Plan. An example of a Disposal Report is given in Table 5 in Part 2. A monthly audit of the correctness of the disposal report shows up problems with measurement or interpretation of data, that should be followed up with technical support, probably from DWAF or CMA in the first few years of implementation.

- **Location of Measurements: -** Ideally water should be measured at the entrance and exit of the WUA's borders as well as at the beginning of every secondary and tertiary canal or pipeline, along the main, secondary

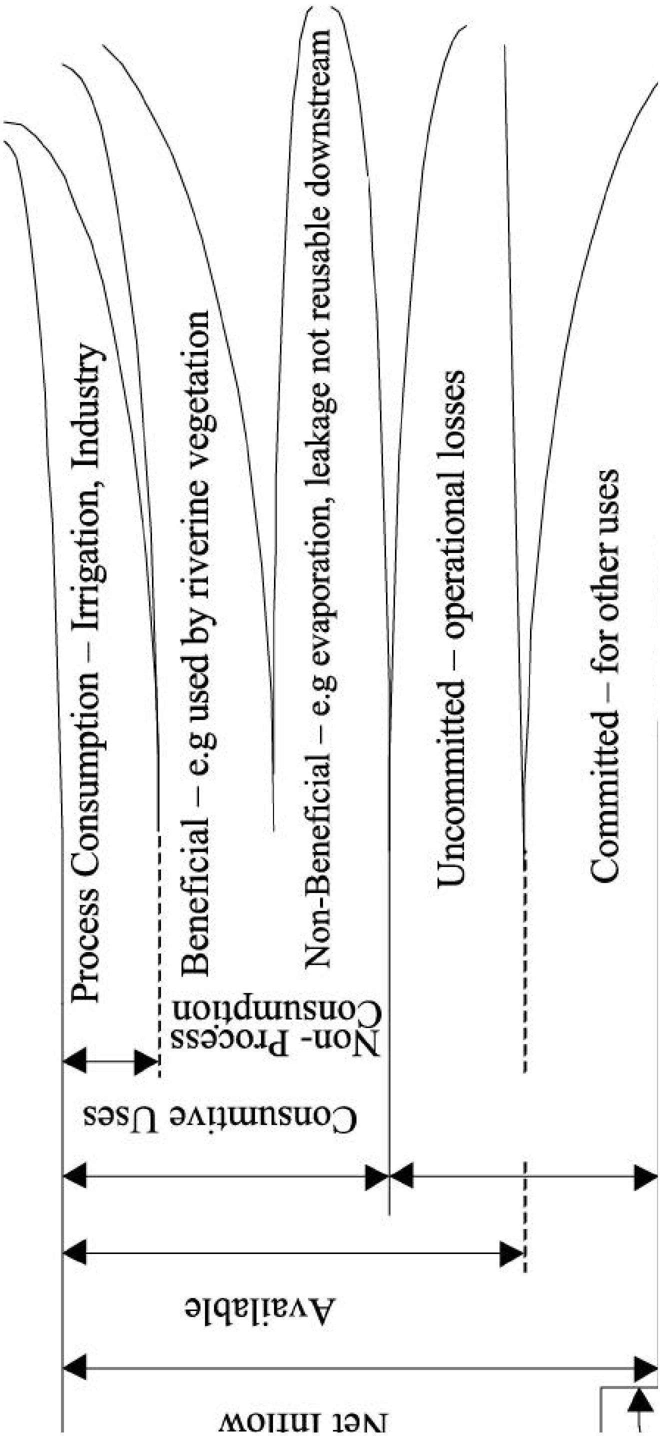

Figure 1 : Water Accounting Approach

and tertiary conduits, at the inlets and outlets of every balancing dam, at the end of every conduit and at the farm turnout. The first objective of water measurement is to manage the water distribution system, but also to analyse management problems. Ideally telemetry should be used.

- **Measuring devices: -** A wide range of measuring devices are available. In canals the Parshall Flumes used to be very popular but are lately being replaced by Crump Weirs. Flow depth recorders are normally used to record the flows through these measuring devices.

For the measurement of impure irrigation water in pipelines, the expensive high technology meters which are designed to provide high sensitivity and accurate measurement of clean, potable water, cannot be used. To measure the flow of water from dams and rivers therefore requires less sophisticated and less expensive type of water meter.

- **Accuracy of Measurements :** Good water accounting will point out inaccuracies in measurement, but it is still a very good idea to calibrate measuring devices. WUAs should check the dimensions of measuring structures in canals, since this can have a significant impact on their accuracy.
- **Interval of measurements :** Water measurement should be continuous and recorded as such. If it is not, the intervals between measurements should be as short as possible, hourly or daily.
- **Accounting intervals :** Disposal Reports are normally done weekly by summarising the continuously measured data of the past week. Monthly Disposal Reports are audited by DWAF. Annual Summary Disposal Reports are used to develop a Water Account to analyse beneficial use.
- **Operational losses :** For on-demand systems of water supply and distribution the accurate determination of canal losses is a task that is done daily. The more accurately these losses are determined the less are the losses at the end of the canals. In the cases where these losses are not determined and noted continuously it can be estimated as follows;
  - **Seepage losses :** Seepage losses are normally expressed in l/s per 1000 m^2 wetted area of the canal lining. According to Reid, Davidson and Kotze (1986) the seepage losses in concrete canals are between 0,35 to 1,9 l/s per 1000 m^2.
  - **Evaporation losses :** Evaporation losses are normally expressed in l/s per 1000 m^2 water surface that is exposed to the atmosphere.

According to Reid, Davidson and Kotze (1986), approximately 0,3% of the total stream is lost due to evaporation.

- **Leaks :** Leaks can only be detected by accurate measuring and accounting. By doing an accounting on a specific canal or pipeline it is sometimes possible to identify and quantify leaks.

- **Water Audits :** An annual audit of the Water Account should lead to a discussion between DWAF/CMA and the WUA on problem areas as highlighted by the analysis contained in the Water Account and performance indicators.

- **Farm audits :** Farm audits should also be based on a process of continuous irrigation scheduling. Scheduling of irrigation consists of the calculation of crop water requirements by using daily atmospheric data and the appropriate crop factor to calculate the Total Crop Water Requirement of a specific crop for that day. This requirement is subtracted from the soil water content while any precipitation or irrigation is added. The soil water content is monitored by an acceptable soil water measuring device on a regular basis (for example fortnightly) and the calculated soil moisture content is adjusted to reflect the measured value. A comparison of the summary of all the irrigation on a farm with the amount of water received will reveal the losses that occur. Furthermore, an analysis of the distribution of soil moisture through the soil profile during the growing season will reveal the possibility that water could have drained past the root zone. From the information gained from the irrigation scheduling process, a weekly or monthly water accounting should be done with an annual auditing as illustrated in Table 7.

2.3 What is a best management practice?

An important aid in improving efficiency is the concept of Best Management Practices (BMPs). A BMP is not some distant idealistic vision, but a generally accepted practice that has every chance of being attained. A BMP (also called an Effective Water Management Practice) is a policy, programme, practice, rule and/or regulation, or the use of devices, equipment or facilities which is:

- An established and generally accepted practice that results in more efficient use, conservation or management of water.
- A practice for which sufficient data are available from existing water management projects to indicate :

- That significant efficiency improvements or management related benefits can be achieved.
- That the practice is technically and economically reasonable and not socially or environmentally unacceptable, and
- That the practice is not otherwise unreasonable for most WUAs to carry out.

Two lists of BMPs are being developed nationally :

- **Primary BMPs, and**
- **Secondary BMPs.**

Some BMPs are high priority and are generally applicable to all WUAs – "Primary" BMPs. However, since priorities and conditions differ from one area to another, we also need a list of "Secondary" BMPs, all of which may not be applicable to any specific WUA. BMPs, therefore, do not imply standardisation and no BMP should be introduced unless it has been thoroughly evaluated to ensure that it would be beneficial to and sustainable by the WUA.

{Note: WUAs are required to implement all Primary and Secondary BMPs, except those secondary BMPs that are not applicable, achievable or desirable in their circumstances.}

2.3.1 Primary BMPs

Primary BMPs have to be addressed by all WUAs :

- The WUA's drawing up of the Water Management Plan is in itself a BMP. It gets people thinking and planning.

- The WUA's appointment (or nomination) of a person with responsibility for Water Conservation Coordination (quite apart from normal WUA management) is a major BMP. This person keeps an extra eye on leaks, spills, poor equipment maintenance or any management practices or policies of the WUA, CMA or DWAF that could affect the farmers' ability to use water efficiently.

Each WUA should decide whether this responsibility would be allocated to a Board member or WUA official and whether it would warrant a special appointment in larger WUAs. Many WUAs already have someone responsible for water supply planning and distribution, which in some instances is well positioned to play this role. Each WUA should discuss and define the tasks of their Water Conservation Coordinator according to their circumstances. These tasks should be described in their annual Water Management Plan.

The Water Conservation Coordinator could also be responsible for interaction with the Water Conservation Coordinators of other WUAs and of the CMA.

- The WUA ensures that information for improved on-farm water management is available to farmers. This may include the following :
    - information for irrigation scheduling
    - water quantity data [e.g. one WUA reported that they experienced a dramatic improvement in on-farm water management by their members as soon as they supplied weekly graphs to the users, clearly showing actual use to date against the member's allocation. Previously their weekly reports were in table form, and did not have the same impact.]
    - water quality data
    - climatic data

Study groups should be used to share experience among practitioners.

- The WUA measures the quality and quantity of inflows and outflows, losses and water supplied to its customers, and makes progress towards the use of acceptable measuring devices or techniques.

Actual water measurement and even automation of measurements is the goal, however, the use of crop water requirements is a manageable and achievable intermediate step to estimate water use, particularly as a seasonal planning figure for the WUA's water management.

WUAs need affordable, reliable and tamper-proof measuring devices for agricultural application, both on canals and pipelines. Information is required on accuracies of measuring devices, especially in canals.

Water quality measurement and management is extremely important and if water quality is not a problem yet, it will become one sooner or later. Water quality monitoring upstream and downstream of the WUA area would be a good start, and could be refined once a problem is detected.

- The WUA implements a water pricing structure that is related, at least in part, to the actual volume it supplies to its customers (farmers and others), to facilitate water conservation.

Innovative pricing structures could have a great impact on the productive use of water, especially where used in conjunction with voluntary, temporary water transfers between members of the WUA (see Secondary BMP: WUA facilitates voluntary water transfers). WUAs should explain their pricing models clearly in their Water Management Plans, since this could facilitate valuable sharing of experience and cross-fertilisation between WUAs.

Stepped tariff system already exists where a minimum annual charge covers the basic operational expenses of the WUA, even in wet, low irrigation years. Subsequent steps in the tariff generate income for a reserve fund for capital improvements, installation of measuring devices, etc.

- The WUA maintains and improves its infrastructure, according to a long-term maintenance plan, supported by a financial plan.
- The WUA positively promotes good communication between all concerned in water management. This could include reviews of DWAF or CMA procedures and policies on water supply and management and their influences on on-farm water use efficiency.
- The WUA controls unlawful withdrawals of surface and groundwater.

This is a legal duty of WUAs. This is also a principle function of WUAs as described in the National Water Act, Act No. 36, 1998, Schedule 5, Section 4.

Review of the Current Status and Progress with Primary BMPs

In its Water Management Plan, a WUA should review its BMPs, for example :

- Is there someone with specific responsibility for Water Conservation Co-ordination?
- What support services are available to farmers and WUA management?
- Does the WUA measure the water supplied to its customers?
- Are the WUA's accounts to its customers based on actual water use?

- Is there dialogue between DWAF, the CMA and the WUA — and what makes it work?
- What is planned for the future?

2.3.2 Secondary BMPs

All WUAs must address Secondary BMPs, unless a WUA can show that a specific Secondary BMP is not applicable, affordable or desirable to its circumstances.

- The WUA facilitates the availability of support services to enable farmers to use water more efficiently on-farm and for other people involved operationally (eg irrigation scheduling services and access to mobile labs. for farmers to have their on-farm equipment checked, or to have full on-farm water audits done). This does not mean that the WUA has to supply all these services itself, but that it should facilitate access to these services so that they are available to the WUA and its irrigation farmers. WUA may even consider the idea of including a small charge on all its members to subsidise scheduling services in its area.

- Coordinate the evaluation of WUA and private pumps, evaluating both energy and water efficiency.

WUAs or their clients may unknowingly be incurring excessive energy bills and reduced pumping efficiencies as a result of worn pump impellers. A simple test can detect this and the cost of repairs is quickly made up from savings in the diesel or electricity bill.

- The suitability of specific irrigation methods and crops to an area. What do people regard as being BMPs that could be promoted? [e.g. movable overhead sprinkler systems are no longer used on table grape vineyards in Western Cape].
- Reduction of losses by lining canals, balancing dams etc
- Better management procedures for water bailiffs and other management staff.
- Training of WUA personnel, including construction personnel.

The WUA should train its personnel in water distribution, water management and construction. These courses are already available from DWAF and WUAs should have access.

For instance, mistakes in the construction of Parshall flumes has lead to incorrect measurement. This is hard to correct after construction, but not difficult to construct correctly if construction personnel knew the importance of accurate construction.

- Facilitate the financing of capital improvements for on-farm irrigation systems.

This BMP is applicable mainly for the support of small farmers. In the case of the bigger WUAs farmers should approach financial institutions directly and it might be inappropriate for WUAs to get involved in such a sensitive issue.

- Facilitate voluntary water transfers

This a powerful tool to maximise productive use of the annual allocations to the WUA. The role of the WUA to ensure that this remains a regulated process and within the capacity of the WUA's water distribution system is very important.

- Eradication of invasive alien plants and construction and maintenance of soil conservation works.

Evaluating BMPs - Net Benefit Analysis

Each Secondary BMP should be evaluated in terms of its impact on the environment and third parties and any indirect effect it may have on the economic viability of the WUA, individual farmers or others.

3. CAPACITY BUILDING AND TRAINING FOR WATER CONSERVATION AND DEMAND MANAGEMENT IN AGRICULTURE

The focus of the Water Conservation and Demand Management Strategy is to establish an approach and a system in which there is a balance between centralised (top down) and decentralised (bottom up) water delivery management. For this bold "self-regulation" approach to succeed will require empowerment of all roleplayers in irrigation.

Empowerment, in turn, implies capacity building and training. Therefore, an essential element of the strategy will have to be a systematic and long-term initiative of enabling irrigators and the various levels of regulatory authorities to improve water use efficiency.

The main levels of intervention should be :

- Catchment Management Agency (CMA)
- Water User Association (WUA)
- Farmer (Irrigator)
- Technician and Labourers

At all the workshops the emphasis was placed on the WUA as the key area for capacity building and training.

Furthermore new WUAs – particularly those involving emerging farmers – should receive special attention and support w.r.t:

- Exposure to alternative types of irrigation
- Record keeping and financial management skills
- Making appropriate measuring devices available (with costs possibly subsidised)
- Guidance in drawing up Water Management Plans and related best management practices (including repair and maintenance of infrastructure and equipment)
- Training in understanding the National Water Act
- Sharing of experience and knowledge with established, commercial WUAs
- Introduction of computerised water management systems such as "WAS" as soon as possible
- Establishment of multi-purpose Information Centres in communities which could be used by WUA for information transfer and communication
- Training should be conducted in the vernacular and training material should be available in the language of choice.

On the established schemes the above capacity building elements are equally important with greater emphasis on water audits and best management practices. Participants stressed the need to keep the guidelines for the Water Management Plans as simple as possible in the early years, to minimise initial training requirements.

Training and motivation of government officials involved at "grass roots" will be an essential element of the overall strategy.

The Steering Committee for this study recommended that the training programme development and the preparation of appropriate training manuals should commence on the completion of this report. That process has begun and will be completed by the end of August 2000. These capacity building tools will then be tested during the pilot project phase of this programme.

Other interventions in the implementation of the strategy could include the setting up of local, national and occasional Discussion Forums that will allow free exchange of ideas, experience and knowledge in the subject of irrigation water conservation. It was clear from the workshops that there is a wealth of experience and practical knowledge within the sector, which could be shared and spread through discussion between WUAs.

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