LARGE-SCALE IRRIGATORS

By: JB Stevens & C Stimie

Guideline
5 of 9

Building Awareness and Overcoming Obstacles to Water Demand Management

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WATER DEMAND MANAGEMENT

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3. Bulk Suppliers of Potable Water
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Preface

The IUCN-RoSA (World Conservation Union-Region of Southern Africa office) managed a Water Demand Management (WDM) programme between 1997 and 2002 to study WDM practices and applications within the SADC member states. These studies indicated the urgent need for improved water resource and supply management in much of the region and the broad potential of WDM to be an important tool in achieving this aim.

Currently, IUCN-RoSA is committed to sharing the knowledge gathered in the studies to promote the adoption of sound WDM practices as a method of accelerating effective water resource and supply management throughout the region. These guidelines on building awareness of and overcoming obstacles to WDM are part of IUCN-RoSA's WDM sharing initiative. They have been written by a multi-disciplinary team assembled from several countries in the SADC region.

The guidelines comprise 9 separate booklets, aimed at all the people who can influence WDM outcomes or who should be responsible for actively promoting or implementing WDM, within different water management, supply, and user sectors. Since every water user and water resource or supply stakeholder can improve the quality of life for him/herself or others, by ensuring WDM plays an important role in his/her planning and actions, related to water management and usage, one or more of these booklets has been written with you in mind. The titles are listed on the inside of the back cove. Check the titles, see which apply to your situation, and obtain copies. They will help you to do your job better.

In these guidelines, WDM includes all actions that improve the efficiency and equity of water use. Efficient water usage includes using water in a manner that minimises pollution. Thus, WDM is not about getting poor people with insufficient water to use less, but about all users using water wisely so that everyone has sufficient water. In this context, WDM is seen as an integral part of Water Resource Management (WRM) and Water Supply Management (WSM).

When implemented effectively, WDM will:

- Reduce water supply costs per unit volume, while assisting to create more financially sound water supply institutions, through:
  - Postponing the development of new sources;
  - Reducing water wastage; and
  - Equitably reducing unpaid water bills;
- Ensure the delivery of sufficient water to meet the reasonable demands of all users, for domestic and productive water, at a reasonable cost in both water abundant and scarce areas, while assuring ecological sustainability, or, in the few situations where this is not practical, WDM will maximise equity and minimise deprivation;
- Improve the assurance of supply through ensuring that the demand does nor exceed the yield of the source;
- Prepare users and supply institutions to manage with less water as scarcity arises, through population increase, general development or climate change; and
- The prevention of all ongoing serious water pollution.

By definition, WDM, on balance, always produces positive outcomes. However, effective implementation requires:

- A good knowledge of current demands and usages;
- Planning and resources to introduce behavioural change within well-managed time frames; and
- Communication with other stakeholders upstream and downstream of your place in the water supply/usage chain.

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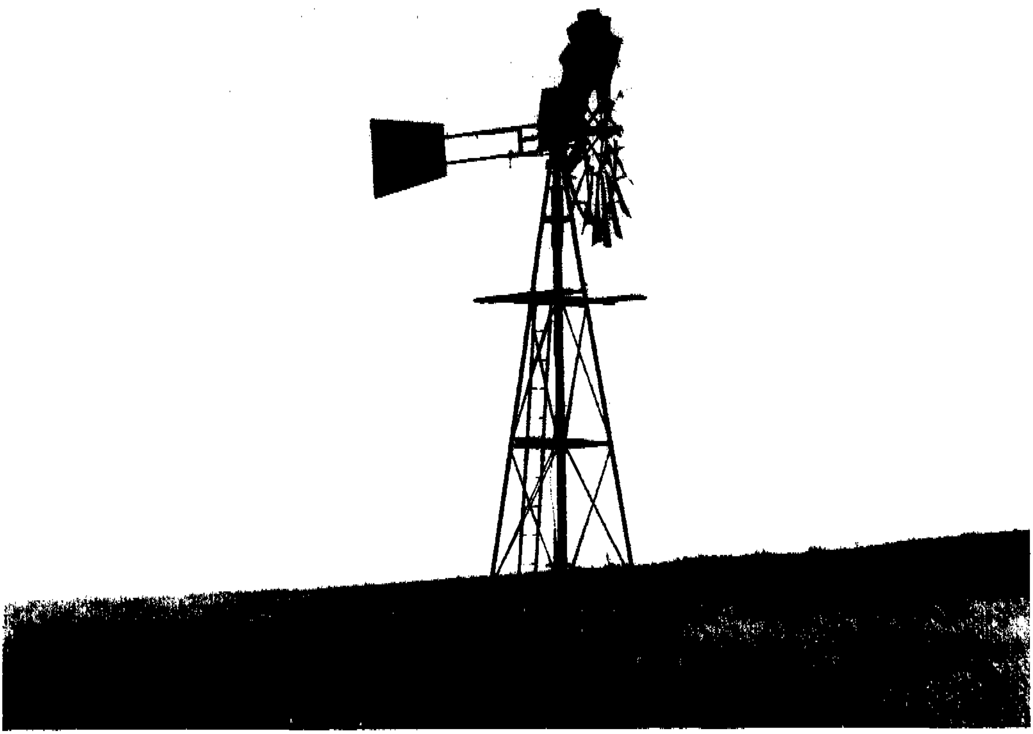

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Abbreviations and Acronyms

CMA	Catchment Management Agency
ET	Evapo-transpiration
Kc	Crop factor
M&E	Monitoring and Evaluation
O&M	Operations and Management
WUA	Water User Association
WMP	Water Management Plan

Introduction

Water resources in the Southern African Development Community (SADC) are highly variable, both over space and time. The northern portion of the region receives between 1000 mm and 4000 mm of precipitation in an average year, while the southern area typically receives 250 –1000 mm, with some areas receiving less than 50 mm per year. The problem

of low precipitation in many areas is compounded by the exceedingly high rates of potential evaporation, resulting in most of the region being dominated by an arid or semi-arid climate and landscape. Precipitation patterns are typically very seasonal, with a definite wet summer season and a relative dry winter season. In addition, wide meteorological variations occur naturally from one year to the next, often creating water shortages or severe drought, and occasionally excess rainfall and floods. In some areas of South Africa, rivers have experienced periods of ten consecutive years of less than average flows (Vd Merwe, 1995).

Due to high population demands and increasing scarcity of water, most of the river systems are completely exploited and under extreme pressure (Goldblatt et.al, 2000). About 190 million people live in southern Africa and, with a historic growth rate of roughly 3% per year, this region's population growth has been one of the fastest in the world. Today, more than half of the region's population has no access to safe water and sanitation services.

The region is also marked by an inequitable allocation of water among users. In addition, there is limited residual water for maintenance of ecological functions of the natural watercourses.

There is a general awareness that traditional water supply approaches are no longer adequate in meeting the rapidly growing demand for water, and that southern Africa needs to implement a paradigm shift from the traditional supply-oriented mindset towards one of water demand management (WDM) that is essential for the sustainability of water resources and the environment, as well as for economic efficiency and social equity. Few WDM measures have been implemented in southern Africa to date, however. Although WDM as an economic tool could be effective, without a comprehensive WDM campaign, including public education and earning-based approaches, it will have little effect.

1.1 Target readership

The purpose of this Guideline is to demonstrate a range of WDM techniques and technologies to role players in the irrigation sector, including:

- Bulk water suppliers;
- Financiers (commercial banks, semi-government banks, such as the Land Bank);
- Manufacturers of irrigation equipment;
- Research and development institutions;
- Irrigation consultants;
- Regulation and administrators – catchment management agencies (CMAs) and relevant government institutions;
- Service providers – water user associations (WUAs), irrigation boards, water services authorities, water utilities; and
- Endusers (large-scale irrigation farms/estates/agricultural industries.

1.2 Aims of the guideline

This Guideline highlights critical factors for the implementation of WDM on large-scale irrigation schemes. It also proposes measures and incentives to be adopted by governments, water institutions and farmers, to facilitate the implementation of WDM. Users who apply this guideline will see that it advocates a bottom-up approach, where the user, together with the water institutions, plans the strategy for efficient water use. Adopters of this strategy will perceive definite advantages in terms of water management, namely: an increase in production yields and quality, energy savings, and more realistic water pricing that will ensure sustainable irrigation practices.

Background

A review of the current water use in the urban and agricultural sectors in several southern African countries reveals that remarkably little WDM is practiced anywhere in the region (Rothert, 2000). Many countries have developed or are in the process of developing national policies, but only South Africa has legislated these policy guidelines. Many water providers in South Africa (e.g. Rand Water, Umgeni Water, Cape Metropolitan Council) in conjunction with municipal suppliers have begun developing specific WDM programmes, but only Hermanus appears to have a comprehensive programme in place. Windhoek, according to Rothert (1999), is the only city in southern Africa that has a comprehensive WDM programme in place.

Agriculture in southern Africa is a very important activity in terms of poverty eradication and economic development, but is also identified as one of the major inefficient water users in the region. Irrigation plays a disproportionally important role in the water supply sector because irrigated crops are generally two to three times more productive than rain-fed ones, and because it uses roughly 70% of the region's satisfied water demand, as been indicated in Table 1. Currently about 1,8 million hectares in the SADC region are under irrigation, which form approximately 7% of the arable land. Irrigation is largely reserved for high value crops such as fruit, vegetables, sugarcane and horticulture. Sugarcane occupies nearly 292 000 hectares alone (Rothert, 2000). Other irrigated crops that are produced include wheat, maize, cotton, coffee, tea, and tobacco. SADC countries rely on irrigation to varying degrees, from 0.5% of agriculture in Botswana to 36% in Swaziland.

Water demand for irrigation agriculture is expected to more than double by 2020, but its relative share of the total is expected to decrease, as urban demand is expected to outgrow all other sectors (Pallet, 1997). In general, the efficiency of irrigation is relatively low, and only 45% of the water delivered is believed to reach the crop root zone (Fruhling, 1996).

WDM is a management approach that aims to promote the efficient and equitable use of water through the application of selective incentives. WDM embraces a wide range of measures. These include:

- Protection of water quality;
- Reduction of wastage;
- Improved allocation of water among competing users;
- Appropriate pricing mechanisms;
- More efficient water usage; and
- Improved crop choice.

Despite the proven effectiveness of WDM, very few measures have been adopted in the irrigation sector to date. This is probably due to a lack of awareness on their applicability, the socio-economic implications, and a scarcity of resources, especially in the context of a developing region like southern Africa.

Table 1: Irrigated land and water demand for SADC countries (Rothert, 2000)

SADC Country	Area irrigated land % of arable (1993)	* Water use (million m^3/annum) (1995)	% of total water demand
Angola	2,5	750	27
Botswana	0,5	47	3
Lesotho	0,9	160	59
Malawi	1,7	1.820	70
Mauritius	17,0	460	Not available
Mozambique	4,0	3 000	93
Namibia	0,9	248	66
South Africa	10,3	12 764	54
Swaziland	35,8	331	65
Tanzania	5,0	10 450	85
Zambia	0,9	1 580	72
Zimbabwe	7,0	4 980	8
Total	**7,2 (Avg)**	**36 130**	**70 (Avg)**

* *Heyns, 1995. DWAF, S.A.*

Water demand focus

In most of the developing countries, agriculture is the largest user of water. Therefore, any savings from this sector can make a big difference in water allocation for other users. Yet neither managers of irrigation schemes nor farmers are always aware of the possible advantages of investing in water efficient practices. To encourage them to change their current practices and adopt some of the WDM practices, they should have the necessary information on the performance, cost and availability of different technologies and incentives. Much of this information needs to be collected and updated on a regular basis locally.

This section of the Guideline focuses on identifying the relevant factors that are of importance with reference to the following three areas: bulk conveyance, on-farm storage and conveyance, and field application rather than attempting the impossible task of giving detailed local information on each of these factors. Bulk water storage is also considered an important focus area for large-scale irrigation, but will not be discussed due to its inclusion in another Guideline.

Table 2 provides a conceptual framework of the factors that influence these main focus areas of irrigation management and, thus, the construction of a possible water demand strategy.

Table 2: Critical factors influencing WDM

	DESIGN	MANAGEMENT & ECONOMIC FACTORS	ADOPTION AND CAPACITY BUILDING
BULK WATER CONVEYANCE	<u>Equipment and infrastructure:</u> • Capacity of canal / pipe • Ease of management (off takes) • Alterations feasible to existing structure • Social impact (new route) <u>Soil and water:</u> • Impact of problematic soil types • Existing and new systems <u>Crop selection:</u> • Adapted crops • ET and climatic • Computer models	<u>Evaluation and monitoring:</u> • Balancing dams included • Seepage • Measure and record • Communication / publish • Water quality <u>Operation and management:</u> • Water audit • Water management plan • CMA/farmer linkage • Regulations • Market system • Flow control • Computer models <u>Water pricing and costs:</u> • Price system	<u>Adoption and incentives:</u> • Incentives versus punishment • Equity and market orientated • Real-time accounting (simple, appropriate) <u>Capacity Building:</u> • Good communication • Awareness programme / public education • Workshops • Training of officials and users

	DESIGN	MANAGEMENT & ECONOMIC FACTORS	ADOPTION AND CAPACITY BUILDING
BULK WATER CONVEYANCE *(continued)*	Financing: • Financing linked to water saving practices	(Realistic, affordable) • Historical rights • Volume • Service or demand orientation Licensing: • Upstream and downstream • Market information system • Web link	
ON FARM STORAGE AND CONVEYANCE	Equipment and infrastructure: • Capacity determination • Site / route selection • Safety measures • Storm water provision • Link to irrigation and bulk system • Flexible for operation and maintenance • Design for ease of management • Flexible for different cropping patterns • Optimal design (hydraulically and economically) Soil and water: • Suitability (lining) • Soil types: pipe selection and installation procedures • Soil types: canal lining and slope	Evaluation and monitoring: • Water management plan • Silt build-up • In and outflow mechanisms • Inspection to identify defects • Seepage and leaks • Pump efficiency • Water use audit Operation and management: • Metering • Inflow (bulk) and outflow (farm) • Operational techniques • Vegetation control of canals • Maintenance schedule • Operational costs • Ageing of infrastructure	Adoption and incentives: • Incentives for proper design • Cost benefit analysis • *Compatible farming systems* • Complexity (impact on management) • Constraints (monetary etc.) • Perceptions of users • Relative advantages perceived • Incentive system Capacity Building: • Awareness • Extension / study group • Training of contractors and sales representatives • Training of operators and their managers

	DESIGN	MANAGEMENT & ECONOMIC FACTORS	ADOPTION AND CAPACITY BUILDING
ON FARM STORAGE AND CONVEYANCE *(continued)*	Crop selection: • Management • Crop type (sensitivity, drought resistance) • Peak periods crop demand • High valued crops (Return on investment) • Flexible for different cropping patterns Financing: • Capital costs • Economic efficiency • Value of crops • Co-operative storage. • Water saving incentives	Water pricing and costs: • Pricing of water (off peak rates and additional costs) Licensing: • Flexibility	• Learning curve
FIELD APPLICATION	Equipment and infrastructure: • Optimal design over the long term • Robust, ease of management Design of upgrade Soil and water: • Water holding capacity • Application rate • Distribution characteristics • Soil potential Crop selection: • Water use requirements • High versus low value crops	Evaluation and monitoring: • System efficiency • Monitoring emitters • Power consumption • Water audit • Visual inspection of equipment Operation and management: • Irrigation scheduling • Measuring of application • Incentives (Bonus points) • Simple technology • Maintenance programme	Adoption and incentives: • Awareness • Scorecard • Relative advantages (observability) • Complexity • Climatic information Capacity Building: • Awareness • Extension support • Training – skills and knowledge

	DESIGN	MANAGEMENT & ECONOMIC FACTORS	ADOPTION AND CAPACITY BUILDING
FIELD APPLICATION *(continued)*	• Row versus orchards • Intensive versus *extensive crops* • Adapted crops • Intensive versus supplementary irrigation Financing: • Incentives (Tax credit, rebate) • Demand curve	Water pricing and costs: • Motivation / conservation • Irrigation system selection • Attitude towards paying for water used • Ability to pay for water used Licensing: • Irrigation scheduling needed • Intensive versus supplementary irrigation • Efficiency of water use • Water audit – Information	

3.1 Bulk water conveyance systems

Bulk water conveyance may be a canal or pipe that conveys water from a river or dam to several users. The role players involved are usually government, a Water User Association (WUA), water users, designers and contractors.

3.1.1 Planning, design and construction

Bulk water conveyance systems need to be planned properly because of its high establishment costs and its social and environmental impact. An environmental impact study should be conducted as part of the planning process for the development of a new system. Do not neglect social and equity considerations, e.g. the route of a proposed canal crossing properties or culturally sensitive areas, the inclusiveness and equity of how the benefits of any new infrastructure are to be shared. Proper consultation and facilitation will usually solve community related problems. With existing systems the designer should determine whether cost-effective alterations could be made to increase the manageability and effectiveness of the pipe or canal system. The cost of upgrading will depend on what percentage of the irrigation system has to be replaced.

It is important that the design of a bulk conveyance system will provide for the capacity, off-takes and necessary balancing. Each component must be designed with ease of management and sustainability in mind. For example, it should be simple to de-silt a canal. Furthermore, the designer must make sure that the slope and material of the canal or pipe are adequate.

A well-planned and designed system also needs to be successfully constructed. Experienced and accredited contractors should be used to, at least, supervise the construction of bulk water systems. Local skills are enhanced in providing assistance to the contractor.

Box 1: Orange-Riet WUA

The Orange Riet WUA has conducted a survey to determine the total area under irrigation as well the major crops grown within the WUA district. The area under production for each crop was determined with the use of satellite technology. This information was included in the database of the Orange-Riet WUA. The net monthly and annual irrigation requirements for the WUA were subsequently calculated. Farmers in this WUA are receiving a predetermined allocation based on the average crop water requirements as calculated on the combination of possible crops typically grown as based on 'crop grow norms' for the area. This allocation, however, includes additional water to safeguard farmers against very hot spells or other extreme climatic conditions. Farmers are paying a minimum tariff for 85% of the predetermined allocation as based on crop requirements and historical data. The rest (15%) could either be used for additional irrigated area (double cropping) or to sell to other farmers. This differentiated price structure serves as a motivation for farmers to use water more efficiently on the farm and also provide some flexibility in terms of their water management.

3.1.2 Soil and water

Well-drained, medium textured soils should be chosen for canal or pipe routes. Where problematic soils – e.g. swelling clays – have to be crossed, special provision must be made to protect the infrastructure. In some cases, an earth canal might be feasible and efficient in terms of seepage, but it also needs to be properly designed, operated and maintained, as is the case with a concrete-lined canal. In existing systems, an investigation should be done if the soil or the surrounding areas seem to give problems for the conveyance system. Cost-effective, corrective measures should then be taken. This could be physical alternatives or different operating procedures – e.g. keeping the canal wet.

3.1.3 Crop selection and water requirements

General trends for cropping patterns should be identified before conveyance systems are established and during the operation of it. An important benchmark for the *irrigation water use* is the crop water requirement of a specific crop (ETcrop) in a specific area at a specific time of the year. ETcrop does not take irrigation efficiency factors into consideration. The ETcrop *benchmark can be used to calculate the irrigation* water requirements for a specific crop, in a specific area, at a specific time of the year, by adjusting the crop water requirements for appropriate irrigation efficiency factors, such as leaching requirements, irrigation application efficiency, effective rainfall and reasonable transmission losses (mainly evaporation). This benchmark can be used as a management tool for decision-making within a WUA.

It is therefore imperative that a WUA should employ all reasonable effort to:

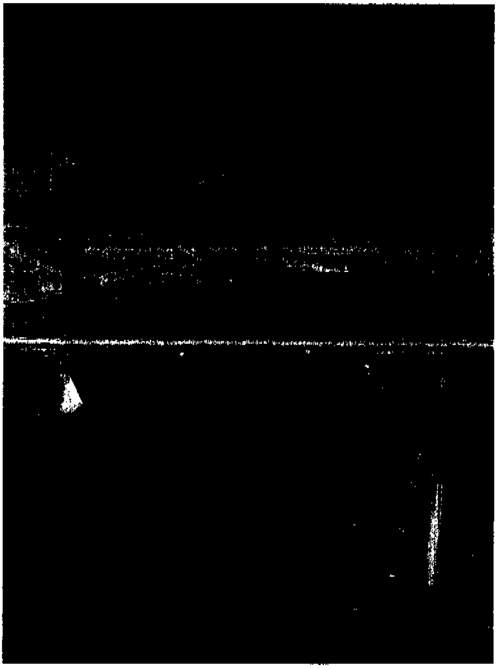
- Calculate the irrigation requirements for each crop grown in the WUA district;
- Estimate as closely as possible the area of each crop grown, preferably the average over *more than* one year in the WUA district; and
- Use the above to calculate the monthly and annual irrigation requirements for the WUA.

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. A standard approach, namely reference evapo-transpiration (ET) and crop factors (Kc) is accepted and applied by all the irrigation agencies in South Africa and the

majority in SADC. It is based on two components: the Penman-Monteith method of estimat-ing reference ET in any given zone; and the FAO method of linking ET to any given crop by way of standard Kc for any given period during the growing season of the crop (FAO 56). Because the Penman-Monteith method (short grass reference ET) already accounts for many of the differences in climate, it is often possible to use a single set of crop co-efficients for different climate zones. Computer models designed for planning and general management of a scheme are available and could be implemented by scheme managers to help them with daily management decisions.

Box 2: SAPWAT: a management tool used by irrigation management agencies in South Africa

A computer programme, SAPWAT, is a need for user-friendly and credible aid to planning of irrigation schemes and for water management by WUAs. SAPWAT is available as an integral support tool for benchmarking, and is used by the Department of Water Affairs and Forestry (DWAF) and water institutions in South Africa. SAPWAT is not a crop growth model, but helps scheme irrigation agencies as a procedure to calculate crop water requirements and irrigation requirements where new benchmarks are required. It is a planning and management aid that is supported by an extensive South African climate and crop database. A major advantage of SAPWAT is its flexibility in accommodating the needs of the user, and several options are provided to enable the user to replicate a specific situation and apply best management practices.



Financing of bulk water infrastructure is usually a contentious issue. The capital costs are usually very high and the cost/benefit ratio often marginally positive or even negative. Political or social considerations are often a higher priority than the economics – but this does impact on the whole lifespan of the infrastructure in terms of affordability. Best management practice in terms of financing means that the proposed work will contribute to WDM and water conservation. In these cases, the government could provide incentives, such as providing preferential interest rates.

3.1.4 Management

Knowledgeable and experienced people should be responsible for the planning and development of operational rules for an irrigation scheme. These rules should be contained in a Water Management Plan (WMP) as developed together with the users of the conveyance system. Other aspects of the WMP should include normal allocations to users and the administrative system to operate it. Special measures must be put in place for droughts or for maintenance work on the canal/pipe. Preventative maintenance is important to avert large-scale repairs later, which is usually linked to high costs and crop damage due to extended periods of no water.

Ageing of infrastructure and equipment is inevitable. If no maintenance is done on infrastructure, it tends to break down completely and must then be replaced at a very high cost. Constant maintenance will lengthen the useful life of infrastructure significantly. Monitoring and evaluation of the system for leaks, cracks, vegetative invasion and build-up of silt must be done on a regular basis. Without such inspections preventative maintenance will not be possible. This means fix it before it breaks down or its performance deteriorates badly.

An important management action (part of WMP) is a water audit at a chosen time interval to determine what volume entered the system, what was allocated, what exited the system and thus what was lost. This will give an indication of the state of the infrastructure, accuracy of allocation and discipline of the water users.

In many cases it would be advisable to employ a technical person to manage the bulk conveyance system as many complex conveyance systems necessitate the use of computer models to run them effectively.

As the bulk conveyance system is under the jurisdiction of the WUA, proper water measurement should be done at the intake of the system and at each outlet. Without this adoption of the management system by the users, it is very unlikely that effective water usage will take place.

3.1.5 Economic factors

Ideally water pricing should be realistic. This means that water users will pay in proportion to their use of water services, and that charges should cover the full cost of establishing and maintaining the service. In cases where the government has historically carried costs, the transfer of costs to users should be gradual, accompanied with visual explanations of costs. This is an economic technique used to support structural irrigation techniques. Training programmes should include these aspects. As a natural resource, water itself should be free – costs are linked to infrastructure and management thereof. When users are not paying for water in full, they tend to over-use the water because the greater portion of money is not paid by the user but by government.

In South Africa, the government used to subsidise the establishment of infrastructure, while the farmers carried all the operation and maintenance costs. In the Chokwe irrigation scheme, in Mozambique, the price of irrigation water has been heavily subsidised, and thus its contribution to total production costs is relatively small. This has led to over-use of water, allocations to relatively low value crops and to less productive production systems (Goldblatt et al., 2000). In Namibia, water is provided at a subsidy rate of 70% and, therefore, farmers perceived little economic incentive for changing their current practices (Heyns, 1997).

Water costing must be based on the actual volume used. If water measurement is not done at individual take-off, the area irrigated can be used for billing. This should be an interim measure and the WUA should determine the area irrigated at least twice per season. The main problem with an area-based system is that it does not encourage water saving by the users.

Historical or existing water rights should only be withdrawn after due consideration, because of the disruptive effects and possible legal actions against the WUA. Land could also

suddenly go out of production, which will affect the income of the WUA. New farmers should be properly introduced into the system to make sure that they can pay for their water use and that they will adhere to the operating rules.

Water trading is an exciting mechanism to encourage the judicious use of water. Unused water could be traded upstream or downstream to other farmers or other users, like industries or towns. This is, however, only possible at a well-run and transparent conveyance administration system. Internet technology would be good for real-time information for water trading – if enough users have access to it. Market information can also be posted on a Web page for a specific scheme.

Maintenance and replacement costs should also be taken into account in determining the feasibility of a scheme. To promote water saving techniques, incentives should be linked to the adoption of sound irrigation practices. This could be, for example, more accurate outlet devices or water measurement techniques.

3.1.6 Adoption and capacity building

Irrigators generally pay water levies that substantially underestimate the cost of bringing water to the field because the cost of irrigation is subsidised. In addition to artificially low prices, irrigators are paying water charges based on the *irrigated area, and not on actual water volumes* used. Consequently, there is little incentive for WDM. WDM introduces private market principles and the price system as a principal mechanism for the allocation and conveyance of bulk water to irrigators. This would shift responsibility for paying for water from communities to individuals, thereby ensuring that each individual is held accountable for their water management practices.

The WUAs and other irrigation water suppliers in South Africa will implement the WDM through the development of WMPs. These WMPs will be submitted to the CMA and DWAF in South Africa. The development and adoption of these WMPs should be done in a participative approach, where all relevant stakeholders are engaged. Guidelines should be developed that is practical, fair, affordable and effective.

In the adoption of new strategies or plans of management, farmers and other relevant stakeholders should be able to perceive that this new management strategy is offering certain relative advantages in terms of:

- The adopted methods must reduce water use or consumption;
- It must be socially beneficial in broad economic and equity terms; and
- That it is relatively easy to apply (simple, appropriate and easy to manage).

Market-oriented solutions often direct innovation in socially desirable directions; whereas regulation more frequently does not induce role players to seek new, efficient solutions. By not receiving accurate information about the true costs of resource use, the farmer inevitably fails to employ resources in an optimal manner. The application of private market principles to public problems like WDM offers certain advantages, but an incremental approach towards adoption of some of these principles is needed. The incentive system of the private market system, if adopted as a working model, offers a new method of allocating water in situations of scarcity. This system of allocation will, at the same time, lead to a broader range of alternatives for management decisions.

Other evaluation criteria that will be used by potential adopters apart from technical or 'engineering efficiency' include evaluation of the social, cultural, economic and environmental acceptability.

WDM relates to the transformation from supply-driven to service-oriented water delivery. It also means changes to governance of the system for goal setting, which includes the decision on the service to be provided by the system itself. For this self-regulation approach to succeed, the empowerment and building of managerial capacity by all role players in irrigation is needed.

The performance of operation of an irrigation system is influenced by both the institutional as well as the individual capacity of the management agency to apply the operational rules defined by the designer. Knowledge in the field on how to design and implement service-oriented control and management is often lacking and capacity building is needed.

Box 3: Possible new roles has been identified for private irrigation agencies

- Water management planning
- Monitoring of association performance (M&E)
- Reorientation towards support advisory services to farmers' organisations
- Ground water monitoring, and abstraction metering and control
- Environmental monitoring and enforcement
- Development of new policies and regulations for specific areas
- Arbitrating disputes
- Project planning, design and construction
- Empowerment of farmers through facilitation of appropriate training programmes.

Strengthening of management capacity and skills of WUA officials and personnel in the following aspects is imperative to be able to take up their new roles as indicated:

- Drawing up of a simple WMP. It gets people to think and plan.
- Capacity of WUA officials should be built to enable them to help the farmer with a water audit at farm level. Lack of knowledge and understanding of the consumer and water usage patterns could be reflected in poor planning and implementation of a WMP.
- Training in the use of M&E tools: inspection of irrigation systems, planning of maintenance or rehabilitation priorities, preparing of an O&M (Operations and Management) plan.
- Good and effective communication skills that will be of need for effective interaction between WUA and other stakeholders covered by the WMP.
- Effective interaction between the farmers (users) and the WUA and other relevant agencies in the design and implementation of WMP is imperative for sustainability of WDM strategies. In the past, irrigators had virtually no say in the design and management of schemes. Very important is the inclusion of women in the participatory approach to be followed, as they are important role players in smallholder irrigation in southern Africa.
- Advanced managerial skills and the ability to interpret large volumes of data that have been collected in accordance with the WMP.
- Monitoring and control of water quality.
- It is expected of an effective WUA to interact with farmers and irrigators on a regular basis beyond the farm gate. This means being prepared to facilitate the training and capacity building of farmers.

3.2 On-farm storage and conveyance

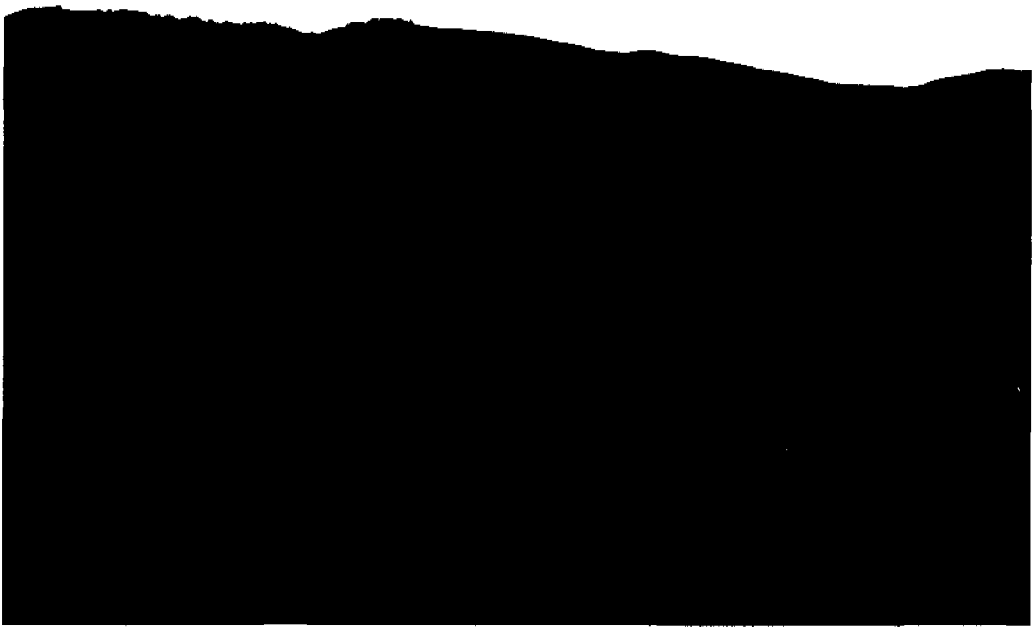
On-farm storage comprises storage dams and/ or balancing dams. Balancing dams can usually be filled from a canal and the full level mark equals the height of the full flow level of the relevant canal. Some storage dams can also store rainwater.

On-farm conveyance systems comprise pipelines and/or canals that transport water from the farm edge to the field. They also include any pump stations that may exist on the farm.

3.2.1 Planning, design and construction of on-farm storage and conveyance systems

Planning of on-farm storage and conveyance systems should form part of a total integrated plan. As far as practical, the construction of such systems should not interfere with farming operations, nor should they cause any detrimental environmental impact. The planner should be clear what the farmer intends to do with these systems, in both the short and long term.

On-farm storage provides the farmer with some flexibility in terms of the water he receives and the irrigation practices he applies. Design of farm dams must have adequate capacity to balance the scheme's inflow schedule with the farmer's irrigation schedule. The dam site and soil must be suitable and if not, the most cost-effective dam liner should be prescribed and installed. The most typical problems with dams are seepage and faulty valves. Many of these problems can be prevented with proper design and operational rules as well as with proper



training in operation and maintenance. Storm water provision needs to be made for any dams and for the safety of people and infrastructure.

It is important that both the hydraulic and management aspects of the design of a conveyance system are optimised. Ease of management is a key factor to be considered by the designer. Designers tend to focus on capacity and strength only, and often neglect practical operational aspects. For example, provisions must be made for scouring a pipeline and allowing accumulated air to escape during refilling.

Vandalism should be minimised as far as possible where it is a problem. In the design of pipelines and their associated inline valves water hammer must be taken into account. Many pipelines fail because of this phenomenon.

Another important aspect to consider is flexibility. It might be useful to provide for future expansion if there is scope for it. It is important to make provision for different cropping patterns and/or different application systems. Farmers' irrigation options are often constrained by the design of their on-farm storage and conveyance systems. Such constraints can often be eliminated by a better system design.

Farm canals are often problematic in terms of seepage. Many farm canals are not properly designed and therefore inefficient. A well-managed canal is a very cost-effective means of

conveying water. If soil is not suitable or problematic, the canal must be lined or pipes used instead.

The construction of dams and canals must be done according to recognised standards from the start to finish. The laying of pipes also has recognised standard procedures, which must be adhered to. Buried mistakes often surface after a long period and are always accompanied by high costs and inconvenience.

Drainage of irrigated lands is a recognised practice that improves the productivity of fields, particularly in heavy clay and duplex soils. Although adequate drainage does not reduce water use, it does increase production and, hence, water use efficiency. The correct design, planning and construction of drainage systems is important to ensure that surface run-off from the farm is not causing environmental damage or pollution to water sources.

3.2.2 Soil and water

A comprehensive soil survey must always form part of the planning and design of on-farm storage and conveyance systems. If the soil is not suitable, an appropriate liner should be used. A water balance should be calculated to determine the volume of water to be stored to best complement the irrigation practices.

Installation procedures must also be part of the design and must be applicable to the specific situations. Generic procedures are often inadequate.

3.2.3 Crop selection

Water in the form of precipitation or irrigation is one of the most critical crop inputs. Water must be supplied in sufficient quantity, of desired quality when the plant needs it at the lowest cost with least impact on the environment.

The selection of appropriate crops for the specific farming system will depend on:

- An estimate of how much water is needed (crop water requirements). Drought tolerance *does exist between different* crop types and varieties;
- How continuous the supply or the recharge rate is, especially during the time of need when conditions are the driest and water supply usually the lowest;
- The quality of water must match the needs of the crop to be irrigated (sensitivity to salts and other micro elements);
- How the location of the water supply from the storage impacts the design and cost of the irrigation system, i.e. horizontal distances and vertical lift;
- The repercussions if adequate water is not available, for example, when protecting a crop from frost is needed;
- Whether the amount of water needed is *environmentally sustainable* (effects on water table, quality and quantity of water in adjacent bodies); and
- The climate will influence the crop water requirements – crops will require more water on hot and windy days.

3.2.4 Management

Operation of a dam is simple, but it is very important to do it accurately. Valves/sluices should be opened and closed when they are supposed to be – otherwise there will be wastage or a shortage of water.

Maintenance of dams includes checking and lubricating valves/sluices, clearing vegetation on the dam wall and inspecting for seepage through the wall. De-silting should also be done according to a regular schedule, to maintain the capacity of the dam. Water measurement could take place where water flows into the dam. This system should ideally be a logging device so that the volume used can be recorded.

An underground pipeline can operate for more than 30 years without any problem provided the following procedures are adhered to:

- The line must be completely filled slowly to avoid water hammer. For large pipelines this is best done through a bypass valve;
- At all other times valves must be opened and closed very slowly; and
- The line must be scoured at regular intervals e.g. every six months.

Maintenance of pipelines mainly comprises the regular inspection of valves, other in-line equipment and above ground sections. Farmers should also be on the look out for signs of leaks from underground pipeline sections. If there is doubt, isolated sections can be pressure tested at normal working pressure. All leaks detected must be repaired properly as soon as possible.

The operation of canals is similar to that of pipelines, but the water control is done with sluices and not with valves. Setting sluices at the correct flow rate is important for accurate control. Canals need to be cleaned at regular intervals, taking care not to damage the canal itself. A very important and often neglected maintenance activity linked to canals is the regular control of vegetation on the sides. Grass that hang in the water can reduce the flow of water significantly.

3.2.5 Economic factors

The most important economic factor is that the dam and conveyance system must be designed cost-effectively in the context of both the farming system and the bulk water supply. Crops and area irrigated should all be considered when dams are established.

Farm storage gives a farmer more flexibility in buying water at off-peak rates and using it optimally. Co-operative storage should also be considered since it can sometimes reduce capital costs considerably.

A well designed and well run conveyance system is an advantage to the farmer in terms of reliability and to the country in terms of water saving. Incentives to encourage this type of system should be considered.

3.2.6 Adoption and capacity building

Adoption of a given suitable practice like on-farm storage and a well designed conveyance system is determined to a large degree by a farmer's perceived self-interest. Profitability is an important element of self-interest. Irrigators will only build on-farm storage and a well conveyance system if it makes economic sense. The economic factors, which will influence decision on whether to make provision for on-farm storage, will be influenced by:

- The additional capital and possible operating costs;
- The estimated value of the expected increased yield;
- The increased reliability of the water supply;
- The risk of the estimated increased profit not being achieved, and
- The net return on the additional capital invested.

Farmers are, in general, motivated by an ambition to maximise profit and to live comfortably, which is moderated by a preference to minimise risk and a wish to care for their workers and to live in solidarity with their neighbours.

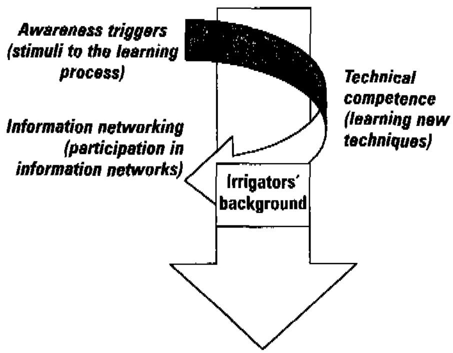
The economic activity around the farm is also influenced by local conditions (drought or good season) and the external market place. Therefore, the farmer will evaluate the compatibility of obtaining additional capacity with the complexity of implementing such a system. The impact on the management capacity and/or need for additional resources will be considered. If complexity of management requires an increase of risk to be taken by the farmer as well as increased costs, it is likely that no investment will be undertaken.

Thirdly, there should be incentives available (like rebates, soft loans, tax credit, etc.) for farmers who make use of well designed and effective on-farm storage and conveyance. The lack of financial capacity (net farm income) is often a major constraint to the adoption of good practice. Irrigators usually tend to try and save on the minimum standards and capacity of the designed conveyance infrastructure, and are not always aware of the indirect costs associated with such a decision. This is because the relative advantages of a proper designed conveyance system is mainly reflected in low operational costs and the effectiveness of delivering irrigation water.

Education and training play an important role in making farmers aware of alternative practices and in enabling them to adopt such practices. The WUAs should play an important role in raising the general awareness among irrigators

of the benefits, as well as risks, associated with the implementation of different practices. It is of utmost importance that clear and concise information on the costs and benefits of alternative designs of conveyance systems are available to and are assimilated by farmers. Making information available about irrigation systems is often not enough and WUAs need to learn what turns it into 'effective information' under different situations, as not all farmers learn in the same manner.

Box 4: A model of the learning process of farmers



3.3 Field application

Farmers often differ in the learning sources they access, the manner in which the information is obtained and the motivation for learning. WUAs should help individual farmers and farmer study groups to assess their specific situation and identify their specific needs for on-farm water storage and conveyance. Irrigators should be informed of any licensing conditions that prevail in terms of on-farm storage capacity and of how it may affect decision-making.

The irrigation hardware system and its operation are called the field application in this document. Field application is therefore the reason for all the upstream efforts and infrastructure. It is the most important aspect of an irrigation farm or estate in terms of achieving effective irrigation.

3.3.1 Planning, design and construction

Planning of an irrigation system is essential. The design has to establish exactly what the farmer intends with his/her irrigation operation and what his/her future plans are. The availability of land and water must be determined as accurately as possible and if permits are required they should be attended to. An important factor in effective irrigation is the capacity of the system to supply the total seasonal crop water use. This requires a knowledge of the expected crop water use for the whole season as well as a knowledge of the irrigation supply, storage distribution and application system capacity to apply the required water.

Design of application systems is complex and critical. The same economic optimisation as used for conveyance systems design should be aimed for when designing application systems. The capacity of the system is very important and must be determined according to crops, soil, climate, storage and the bulk conveyance scenario. Moreover, the system must be suited to the water holding capacity, infiltration rate and depth of the soil. Current and possible future cropping patterns must also be taken into account when designing the system.

A critical factor that is often neglected in designs is the ease of management and operation of the system. The easier the system operating instructions, the more likely the operators are to carry them out. Systems should be robust and easy to maintain by semi-skilled persons. A comprehensive operations and maintenance manual must always form part of any design contract. It is recommended that the designer train the farmer and operators in the use of the system once it has been installed.

When upgrades are being designed, it is important that the designer understands, as best as possible, what the previous designer intended and why. Only then can he make meaningful changes to improve the system.

3.3.2 Crop selection

The potential of soils should be known before new systems are implemented. This is because high potential soil is suitable to certain crops and unsuitable to others.

Farmers often select a specific type of irrigation system according to their personal preferences, but soil types, crop types and environmental conditions should also be taken into account:

- Match the crop to suit the soil conditions.
- Different crops and varieties have different water requirements and will influence the prediction of water demand.
- An understanding of the crop growth stages and relative water requirements is needed to schedule irrigation effectively.

- Different cultivation practices, such as minimum tillage; inter-cropping and mulching are techniques that can be used in conjunction with specific irrigation methods to ensure that irrigation water is used efficiently. A good example is the Chokwe Irrigation Scheme, in Mozambique, where the agronomic practices include minimum tillage, and mulching that played a substantial role in the adoption of more efficient water usage practices.
- The selection of relative high value crops and the effect on the net returns on investment. In Namibia, table grapes are grown with water requirements of approximately 2100 mm per annum, but being a relative high valued crop, it will yield a gross margin of about $36 000/ha.
- The irrigation system (conveyance and application) must cope with the period of maximum crop water demand. The inability to apply sufficient water during hot, dry periods will severely affect the quality and quantity of crop production.

The selection of specific crops for the farm will determine the maximum daily water usage requirements, and hence both the required rate of water delivery and hence the required irrigation infrastructure (e.g. conveyance system, pumps) should be selected and designed to provide flexibility for the farmer.

3.3.3 Management

The optimal operation of an irrigation system is difficult without reliable feedback. Even very large estate farmers still operate their irrigation systems far below the optimum level. The loss of fertilizer below the root zone and water logging problems are typical in irrigation schemes. Farmers often want to 'make sure' that they give enough water without realising the detrimental effects of over-irrigation.

Irrigation scheduling is a key element of irrigation management, and is the process of planning and providing crops with the amount of water needed, when they need it and no more. It involves monitoring, record keeping and calculations to determine field water capacity, losses and gains. In order to schedule properly the soil moisture status should be monitored and recorded on a regular basis. Irrigation scheduling can be done using very simple technologies, ranging from a soil auger, spade, self manufactured probes and wetting front detectors, up to very sophisticated methods. Making farmers fully aware of the detrimental effects of over-irrigation will make reducing water wastage and regulation easier.

Box 5: Irrigation scheduling methods for farmers

1. Atmospheric measurements
   - Pan evapo-transpiration
   - Automatic weather stations
   - Estimating evapo-transpiration
2. Soil moisture measurements
   - Feel method ('feel testing')
   - Soil auger/spade
   - Probe
   - Tensiometer
   - Electric resistance sensors
   - Heat dissipation sensors
   - Neutron probes
   - Gravimetric methods
   - Capacitancy measurements
   - Wetting Front Detector
3. Plant stress indicators
   - Leaf water potential
   - Sap flow
   - Canopy measurement (temperature and radiation)
   - Visual symptoms
4. Computer based irrigation scheduling methods

Maintenance of the mechanical parts of an irrigation system should be done regularly. For example, it is extremely important for the nozzles of a sprinkler irrigation system to operate in their specified orifices. These nozzles should be replaced every year. The cost of nozzles is negligible in relation to the benefit of better distribution of water to the crops.

Although drip irrigation is generally efficient when it is well managed, flood irrigation should not be dismissed as a matter of principle. Properly designed, constructed and operated flood irrigation systems are very efficient in terms of water use, with the benefit of very low running costs. Laser levelled flood irrigation in the USA and South Africa is still practiced widely and sometimes preferred above centre pivots.

Governments should consider incentives for the use of efficient irrigation systems. These incentives could be built up from the bottom where the farmer awards his block manager for efficient water utilisation.

3.3.4 Economic factors

Provided the WUA adopts sound WDM policies, when effective irrigation scheduling is done, the farmer will be able to determine and plan whether he needs to buy more water, or can expand his area under irrigation. Alternatively he/she may decide to hire out some of his/her water conveyance and application equipment or even to lease out some of his/her land. The latter is not recommended as a long-term arrangement. Farmers should be encouraged to own the land they use.

Once a culture of water saving is established, the local WUA will institute local water audits. To be effective, these water audits need to start at the field level and accumulate up to the source of the water for the scheme or farm, in order to give the full picture of water used.

Sound higher-level government WDM policies and laws facilitate sound WDM policies at lower levels, including at the WUA and individual farm level.

3.3.5 Adoption

The practices applied by irrigators on the farm are determined by the economical, social and environmental consequences. Therefore, most irrigators are unlikely to modify their current irrigation methods on the basis of information or advice alone.

Appropriate scheduling enables producers to maximise profitability while reducing the traditional number of irrigations, thereby conserving water, energy, labour and plant nutrients. Adoption of irrigation scheduling is a dynamic process that is determined by various factors, including farmers' perceptions of the relative advantages and disadvantages of new technologies when compared with existing technologies, and the efforts made by extension officers to disseminate water efficient practices and technologies. Other factors, which influence adoption, are the traditional ones: resource endowments, socio-economic status, demographic characteristics, and access to credit, markets and other institutional services.

The slow adoption of new application technologies is a perplexing issue. In addition to market and policy considerations, a principal reason may be that the focus of attention in southern Africa has been at the farm level, and not at the level of the operation of the main water storage and supply system. Farmers will not invest in water saving technologies if the water service is not reliable and if the economic incentives for saving water, energy, labour are not strong enough. Many important management objectives can only be realised if the main water distribution system is operated efficiently. Only then can high returns be achieved from agricultural extension services and the increased use of other complementary inputs.

From a *farmer's* perspective, implementation of an innovation involves trade offs between:

- Some form of immediate additional investment and long-term expected returns;
- Current yield and future yields;
- Higher yields and its production costs, and
- Higher yields and its related risk.

For a change of behaviour to occur, the farmer must have a sense of dissatisfaction with the current method of irrigating and believe that it is within his or her capability to improve. The following part of the document looks at best management practices for the implementation of critical aspects in a WDM strategy.

Box 6: Natural Resource Management Plan for a WUA

It is imperative that every WUA should be able to compile a Natural Resource Management Plan (NRMP) for the specific area under their jurisdiction. This plan should include the following elements that should serve as indicators of the current state of natural resources:

- Water (quantity, quality)
- Soil
- Climate
- Crops and natural vegetation
- Financial capacity
- Management capacity

For each of these elements of a NRMP, an appropriate management plan could be developed on a WUA level, like for instance a Water Management Plan.

Best Management Practices

Best Management Practices (BMP) is an important aid in improving efficiency. It is a policy, programme, practical rule or regulation, or the use of appropriate devices, equipment and facilities. Each country will have to develop its own strategy according to its own needs and available resources. The following BMPs to be implemented in a WDM strategy for the different focus areas were identified, and have, as far a possible, been linked to key role players (in brackets).

4.1 Bulk water conveyance

Performance of irrigation schemes is determined by a combination of physical, institutional and policy factors.

BMP 1 (Government) Train and accredit local designers and contractors for the planning, design and installation of bulk water conveyance systems and provide incentives for WUAs when they make use of these service providers, such as irrigation improvement funds as part of a 'smart' subsidy system that encourage investment of the users in maintenance and upgrading of their schemes.

BMP 2 (WUA) Use accredited service providers for the planning, design and construction of bulk water conveyance systems that will ensure the accommodation of effective management practices.

BMP 3 (WUA) *Conduct a Natural Resource Audit* (NRA) of the bulk water conveyance system at regular intervals and report the results to the CMA and users.

BMP 4 (WUA) Monitor (measure and record) water inflows and outflows related to the system and provide user-friendly reports to users and CMAs.

BMP 5 (WUA) Develop a WMP for the bulk water conveyance operation system, with full participation of water users to ensure ownership by all stakeholders.

BMP 6 (WUA) Develop a transparent and effective two-way communication system between the users and the WUA for scheduling and other relevant information on marketing produce, farming practices, climatic conditions, policy etc. Part of this communication system would be a reference database for general WUA information and relevant research findings.

BMP 7 (WUA) Support ongoing research and development of adapted crop varieties (not genetically modified varieties), improved irrigation technologies, water management tools and appropriate computer models, applicable to local farming practices.

BMP 8 (WUA/Government) Train all role players involved in the management, operation and maintenance of conveyance systems so that they have the necessary knowledge and skills to promote successful and sustainable irrigation practices and the functioning of related institutions through extension services.

This would typically include training in:

- Drafting of a WMP;
- The use of appropriate M&E tools and techniques;
- Preparing and implementation of an O&M plan;
- Conducting of technical and natural resource audits;
- Project planning and implementation; and
- The use of computer models to manage water allocation and canal flow systems.

BMP 9 (WUA) Implement an innovative and realistic water pricing mechanism, which is acceptable to all relevant stakeholders. This mechanism should be an incentive in itself to promote the judicious use of water as a valuable commodity without encouraging farmers to abandon irrigation farming, or blocking or discouraging emerging farmers from entering this line of business.

BMP 10 (CMA) Introduce pilot testing of WDM measures in representative WUAs as needed.

Box 7: Making WDM work

The town of Hermanus, in the Western Cape Province of South Africa, faced a serious water shortage in the late 1990s that threatened any further development in the town. One option to alleviate the problem was to build an additional storage dam, but the construction of such a dam was not an attractive solution, for supplying additional water for mostly luxury domestic use, from the point of view of environmental considerations, other competing needs, or cost. The municipality, with assistance of the national water authorities then decided to convince users to manage their water usage better. Subsequently, a steeply escalating block water tariff system was introduced. Initially, no significant changes in water usage were experienced. Then the municipality started to issue accounts showing customers their historic water usage and the tariffs with user-friendly graphs, and to publicise the need for the town's customers to manage water usage better. The outcome was that the total water usage for the town decreased beyond expectations and the need for an additional dam has fallen away indefinitely.

4.2 On-farm storage and conveyance

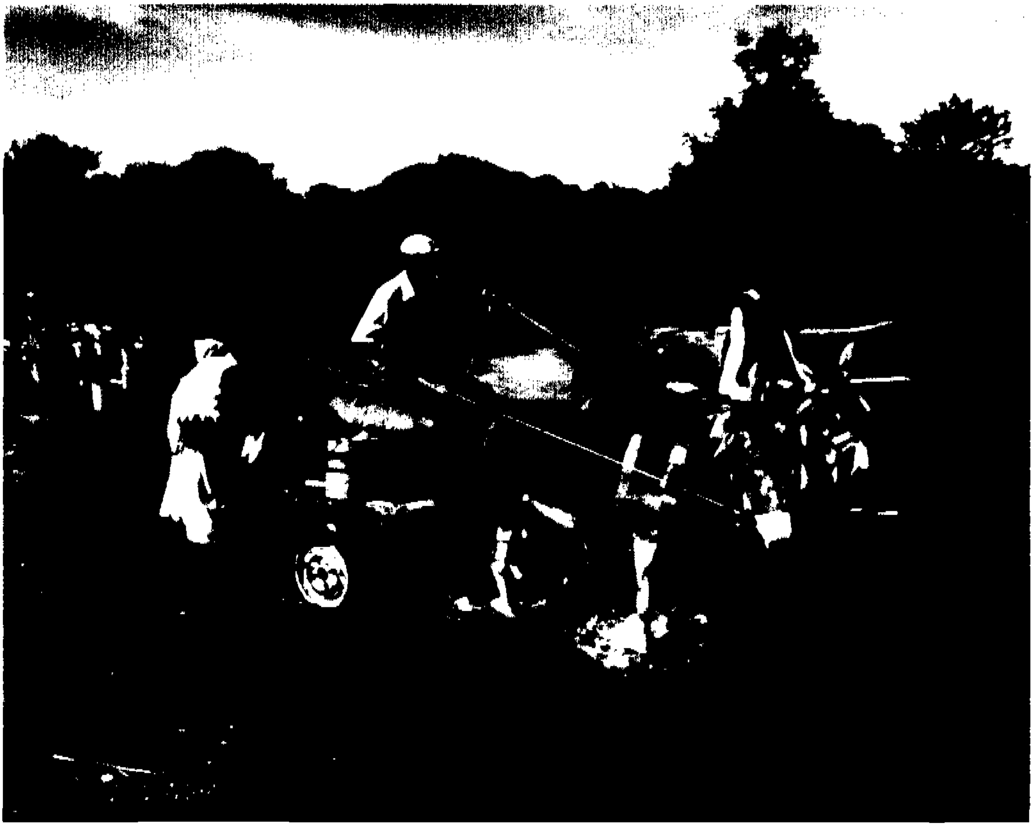
BMP 11 (WUA) Measure the volume of water delivered to each farm or user and maintain and calibrate monitoring equipment. The user should be encouraged to monitor the reading and records as both a management tool and a check on the WUA.

BMP 12 (Government/WUA) Train and accredit local designers and contractors for the planning, design and installation of on-farm storage and conveyance systems. The provision of incentives when farmers make use of accredited service

providers will strengthen the training programme

BMP 13 (WUA) Train farmers and their operators in the proper operation and maintenance of storage, conveyance and application systems. As irrigation is very diverse, the training should be focused on the specific needs of the farmers/users. Training of farmers in the use of proper planning and design should be facilitated through the concept of 'train the trainers'. The provision of incentives for farmers who attended the training will increase the popularity of such training significantly.

BMP 14 (User/Farmer) Compile an Irrigation Water Management Plan for the on-farm storage, conveyance and application system for your



specific farm. The plan should focus on the situation of the specific farm being planned for while fitting in with the overall WMP of the relevant WUA in the area.

BMP 15 (User/Farmer) Monitor the general conditions, seepage and leaks in the storage and conveyance system, and report regularly to the WUA.

BMP 16 (WUA) Provide an incentive system for users who identify and repair defects in their on-farm storage and conveyance system.

BMP 17 (User/Farmer) Make use of accredited service providers for the planning, design and construction of on-farm storage and conveyance systems.

BMP 18 (WUA) Implement an incentive system for irrigators who conduct a natural resource audit and report properly. The incentive system could encompass a point system where farmers earn points for BMPs achieved and lose points for negligence and unlawful water use. This point system could be linked to possible financing opportunities.

4.3 On-field application

BMP 19 (Government/WUA) Train and accredit local designers and contractors for the planning, design and installation of on-farm application systems and provide incentives for users/

farmers when they make use of these service providers.

BMP 20 (User/Farmer) Use accredited service providers for the planning, design and construction of on-farm application systems.

BMP 21 (WUA) Train farmers and their managers in the proper management of an irrigation farming enterprise. As irrigation is very diverse, the training should focus on the specific needs of the farmers/users. The training should include irrigation practices, scheduling techniques, water balancing, and management and business skills. An incentive for farmers who attend the training is likely to increase the popularity of the training programme significantly.

BMP 22 (User/Farmer) Select and use water- and energy-efficient irrigation systems in an appropriate manner. These can be flood-, sprinkler-, micro- or centre pivot irrigation systems.

BMP 23 (User/Farmer) Use an approved irrigation scheduling system for irrigating the crops. The scheduling should be accompanied by appropriate tools and techniques, including monitoring and recording water use; crop yields per block and other relevant information.

BMP 24 (WUA) Develop an incentive system for users/farmers that uses an appropriate scheduling method, provides regular maintenance of irrigation systems and does not degrade their natural resources.

BMP 25 (WUA) Develop an effective two-way communication system between farmers and relevant institutions or groups to ensure that farmers are informed of new technology and trends relevant to irrigation farming. This should be linked to the WUA's database.

BMP 26 (User/Farmer) Carry out regular maintenance of equipment and infrastructure.

BMP 27 (User/Farmer) Avoid negative impacts on the environment as a result of irrigation practices. For example, prevent salination by installing a sub-surface drainage system.

Box 8: Water efficient technology in the sugar industry

The Simunye estate of the Royal Swazi Sugar Corporation has been converting their irrigation system on the farm for the production of sugarcane over the last six years. By April 2004, they had successfully converted 7000 hectare from sprinkle to subsurface drip, at a current cost of US$4 000 per hectare. The Israel-based company that supplied the drip lines for this development also made a professional advisor available full time to support and train estate employees, and to ensure that the system is managed correctly. A South African-based agency also supplied assistance in this regard.

The estate has developed a structure by grouping attendants together for a specific block of fields, to ensure effective monitoring and the provision of regular, preventative maintenance to the irrigation system. At the end of each production season, the dripper lines are checked and repaired when necessary to assure readiness for the next production season.

Results from the implementation of subsurface drip indicated that 30% less water was pumped than when the sprinkle system was used. Furthermore, a 20% increase in sugar production was recorded. This is an indication of the relative advantage that the estate experienced in terms of the saving of both water and energy. Although these savings in terms of water and energy is remarkable, it must be understood in the context of the relatively high establishment costs, the improved water management applied since the establishment of the new irrigation system, and the important role played by professional support.

From this discussion on the critical factors that need to be taken into account for the planning of a WDM strategy, it is clear that technologists do have many of the answers in terms of appropriate technology to ensure efficient water management. Yet, surveys show that few farmers make use of scientific tools to improve their management of water. Technologists then tend to assume the assumption that the core problem is a lack of awareness of the solutions on the part of the farmers. However, it is possible that marketing and extension programmes have been based on the world views of the problem solvers rather than their clients (Blacket 1996). For example, scientists take it for granted that irrigation farmers want to spend time and money on saving water, yet farmer surveys show that this aim is not near the top of their priority list.

When the technology transfer approach is faltering, Blacket (1996) recommends that we pursue a joint 'learning-based' approach. The joint learning-based approach means that we take, as our starting point, the farmer's current practice, implicitly valuing his/her existing skill level and then develop new practices together with the farmer. This is why the identification and application of appropriate BMPs for a specific country and situation is imperative for the development and adoption of WDM strategies by farmers.

Conclusion

Water institutions can and should also play a supportive role in SADC countries to enable users to improve and adopt effective water management principles through the following roles to play:

- The active participation of SADC water institutions will be crucial in the development of WDM guidelines and in the implementation of their recommendations. This should be seen as a process in which all stakeholders can *participate, and* become accountable to each other as the farmers are empowered to make their own informed choices.
- Participants need to be made aware of technological, economic, social and legal ideas in an appropriate manner. The challenge is to present ideas in a manner that is acceptable and understandable to practical farmers, who are mostly interested in being able to evaluate possible implementation options easily and with certainty.
- Lastly, guidelines must be rooted on practical application in the field. Many poor and inappropriate decisions are taken in city buildings because people are not well informed about the reality of the broader situation in which irrigation farmers manage *their farms.*

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