water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

CONTRACT NO. WP 10276

Development and Implementation of Irrigation Water Management Plans to Improve Water Use Efficiency in the Agricultural Sector

SAND-VET WATER USER ASSOCIATION MANAGEMENT PLAN

FINAL REPORT

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DEVELOPMENT AND IMPLEMENTATION OF IRRIGATION WATER MANAGEMENT PLANS TO IMPROVE WATER USE EFFICIENCY IN THE AGRICULTURAL SECTOR

SAND-VET IRRIGATION SCHEME WATER MANAGEMENT PLAN

FINAL

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EXECUTIVE SUMMARY

Background

The Department of Water Affairs (DWA) through the Directorate: Water Use Efficiency commissioned a study to develop pilot Water Management Plans (WMPs) for fourteen (14) selected irrigation schemes as part of its assistance to the agriculture sector as well as to initiate a process whereby all irrigation schemes develop their own WMPs for implementation as required by the National Water Act (36 of 1998).

The study was informed by the fact that no progress had been made by the agricultural sector with respect to the development and implementation of WMPs for that sector. Furthermore the study was initiated to address the increasing water scarcity[1] in a number of Water Management Areas (WMAs).

One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently.

Project Objectives and approach taken

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes to improve water use efficiency in the agricultural sector. However the focus of the study was at the irrigation scheme level with minimal work conducted to determine on-farm irrigation water use efficiency levels.

In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water balance assessment and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water balance assessments prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;

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[1] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers

- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the Government Water Schemes (GWS's), Irrigation Boards (IB's) and Water User Associations (WUAs) to implement the identified opportunities to improve irrigation water use efficiency.

Overview of the Sand-Vet Irrigation Scheme

The Sand-Vet Irrigation Scheme was established in the early 1960's with the construction of the Erfenis Dam in the Vet River (which has a storage capacity of 207.5 million m^3) and the Allemanskraal Dam in the Sand River (which has a storage capacity of 174.2 million m^3). **Figure 1** below provides a schematic layout of the Sand-Vet Irrigation Scheme.

Schedule of rateable area

The Sand-Vet Irrigation Scheme has a total schedule of rateable area of 11 835.4 hectares, comprising 5 489 ha which is supplied from the Vet canal system; 5 049.5 ha which is supplied by the Sand Canal system and the remainder of 1 297 ha which are river irrigators. The Sand-Vet Irrigation Scheme has a total scheduled quota of 75.9 million m^3/a at 7 200 m^3 per ha per annum scheduled allocation.

The main types of crops irrigated in the Sand-Vet Irrigation Scheme are mainly wheat, potatoes and maize which comprise 78% of the crops under irrigation. Pecan nut and peanuts are on the increase in the Scheme.

Conveyance and delivery infrastructure

Water to the water users in the Sand-Vet Irrigation Scheme is delivered through a system of canal infrastructure comprising two main canals namely the Vet canal as well as the Sand canal. There are branch canals from these two main canals which deliver water to the sluice gates at the irrigators' farms.

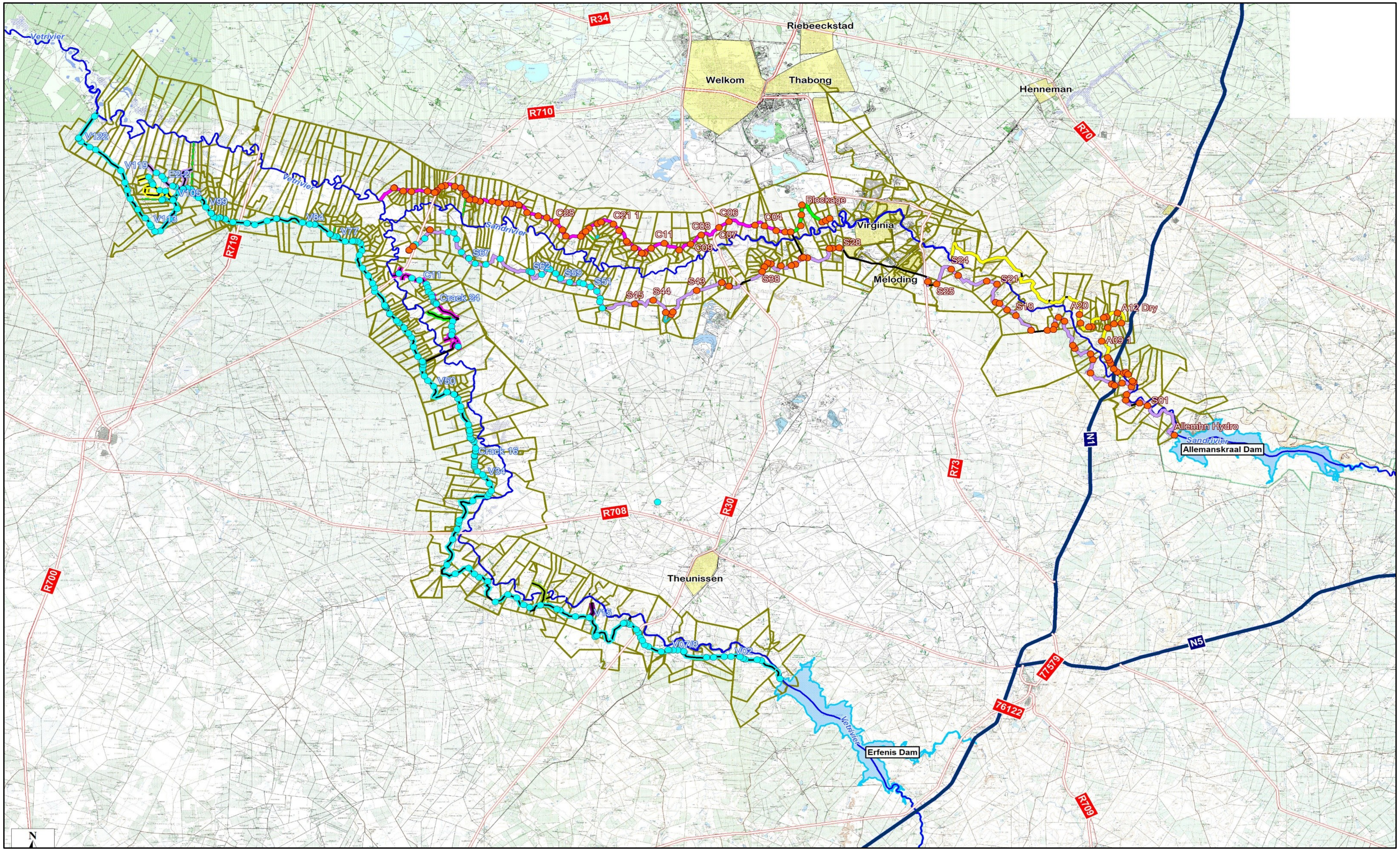

Figure 1: Sand-Vet Irrigation Scheme Layout

The total length of the canal infrastructure excluding drainage canals is 350.4 km with all the canals concrete lined. This comprises of 163.8 km of concrete lined canal for the Vet canal system and 186.6 km of concrete lined canals for the Sand canal system. The condition of the canals was found to be generally fair to very poor in some sections, particularly in the Vet canal were some panels had moved mainly due to flooding and drainage problems.

Besides the canal infrastructure there are sluice gates and Parshall Flumes to measure the volume of water taken by each water user in the canal. There are 244 sluice gates in the Vet canal system and 345 sluice gates in the Sand canal system.

Irrigation storage and regulation

There are two balancing dams, namely Klippunt and Palmietkuil in the Sand-Vet Irrigation Scheme which provide the balancing and regulation of flow to downstream water users. This is intended to reduce the time it takes to deliver water to downstream water users while balancing any irrigation spills from upstream water users. The capacity of the Klippunt is not known while the storage capacity of Palmietkuil Balancing Dam is provided as 0.713 million m^3 when it was last surveyed in 1995 and a live storage capacity of 0.441 million m^3.

Findings of the situation assessments

A situation assessment of the Sand-Vet Irrigation Scheme was conducted to determine the water management issues affecting the effective and efficient use of the available water to the scheme. The assessment was conducted at sub-scheme level, with the Sand-Vet Irrigation Scheme divided into two: the Vet Canal sub-scheme and the Sand canal sub-scheme.

Best Management Practice - Expected water losses

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is maintained was conducted for the Vet and Sand canal system. The analysis indicated that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals is 10.98 million m^3/a, which translates into 9% of the total volume of water diverted into the Sand-Vet canal system.

There are expected to be operational inefficiencies due to the canal filling required after the dry periods, the metering errors even after calibration as well as problems in matching supplies and demands when applicants make changes to their requirements during the week. This was determined to be 10% of the total releases into the Sand and Vet canals respectively.

Based on the evaluation of the unavoidable water losses and the expected operational inefficiencies for the Sand-Vet Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 19 % of the total inflow into the Vet irrigation canal and 18% of the total inflow into the Sand irrigation canal.

Water balance assessment

A water balance assessment that was conducted for the Vet and Sand irrigation sub-schemes indicated that the water losses in the two schemes exceeded the minimum expected seepage and evaporation losses. The average water losses based on the historic water use records was determined to be 34% of the total water released in the Sand canal system and 37% of the total released into the Vet canal system.

The equivalent depth of water released into the scheme per actual unit area irrigated was determined. The trend-line indicates an increase in the inflow into the scheme per unit of irrigated areas from 2000 to 2005 water years for the Vet canal system (see **Figure 2** below). The increasing inflows into the scheme per unit of irrigated land are a clear indication that there was a major decline in irrigation water use efficiency during the period when the records were available.

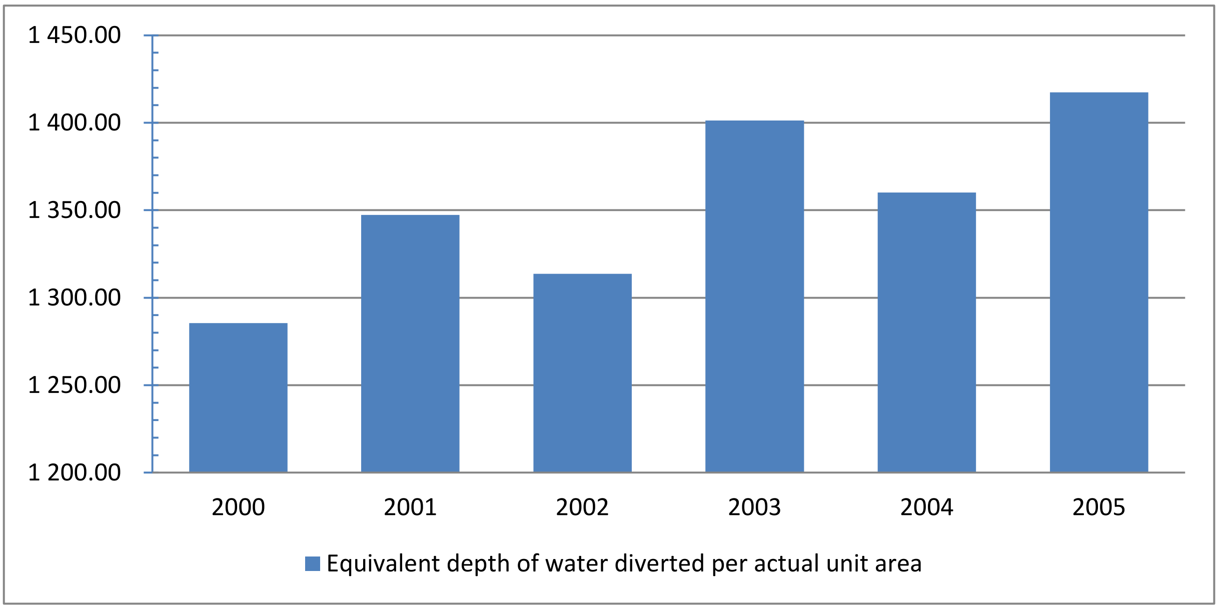

Figure 2: Irrigation water released into Scheme expressed as an equivalent depth of water released per actual unit area irrigated for the Vet canals (m^3*10^3)

However in the case of the Sand canal system the trend-line indicates a slight decrease in the diversion per unit of irrigated areas from 2000 to 2005 water years for the Vet canal system (see **Figure 3** below).

Any improvements in for example on-farm water use efficiency may be likely to be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

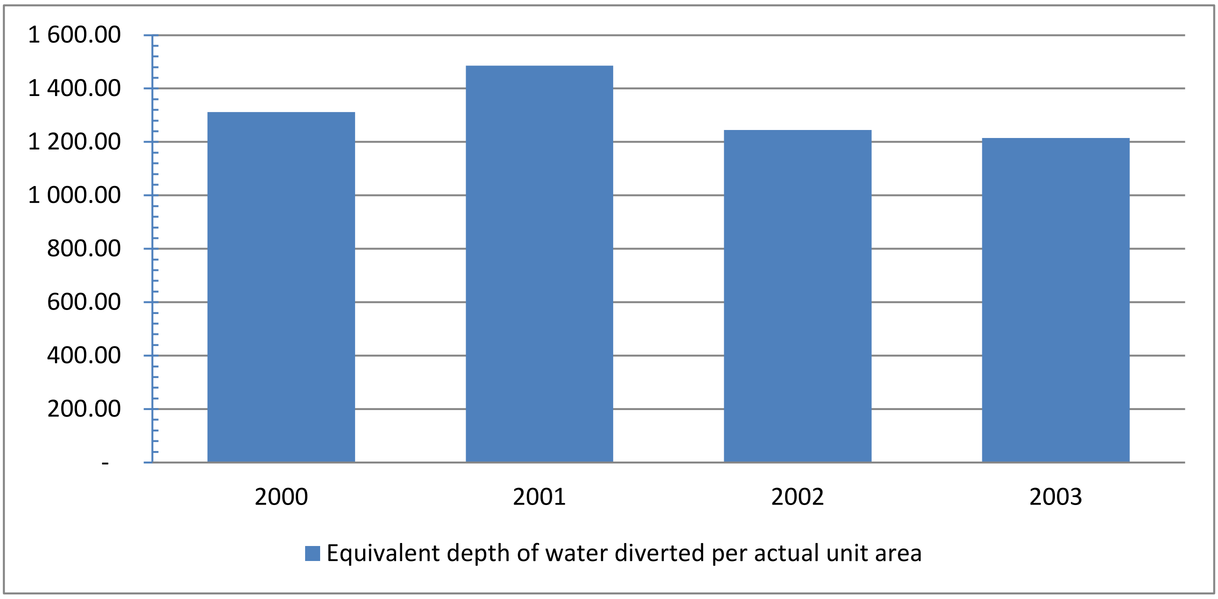

Figure 3: **Irrigation water released into Scheme expressed as an equivalent depth of water released per actual unit area irrigated for the Sand canals (m^3*10^3)**

Water Management Issues

A number of water management issues affecting the effective and efficient use of water in the Sand-Vet Irrigation Scheme were identified based on the water balance assessment, discussions with scheme managers and some field work that was conducted. The main water management issues identified include the following:

(i) There is a lack of measurement recording at some of the critical points in the scheme for a comprehensive water balance assessment to be conducted. These include the canal tail-ends as well as the balancing dams. The spills at the canal tail ends are considered losses and can be avoided if regular flow measurements were taken to allow real-time adjustments in canal flow. Therefore the current water balances are not accurate as they are based on estimates.

(ii) Although there is sufficient flow measurements, the accuracy of some of the measuring systems such as Parshall Flumes and lack of continuous flow monitoring to enable quick responses to operational problems have resulted in the low water use efficiency levels in the Sand-Vet Irrigation Scheme.

(iii) Not all modules of the water administration system to manage water use is being utilised for sub-scheme water balance assessments.

(iv) The conditions of the canal infrastructure, particularly in the Vet canal system were found to be poor. There are sections of the canal which will require complete refurbishment or rehabilitation as some of the concrete panel sections have moved. This is attributed to some flooding but mainly the drainage due to irrigation of lands above the canal system.

(v) The capacity of the Sand-Vet WUA to conduct full maintenance of the canal infrastructure including refurbishment or rehabilitation is limited. This is because the existing irrigation infrastructure was constructed in the early 1960s and as a result of the age there is major refurbishment required.

(vi) Although the current water rate structure does have some elements of incentive based pricing aspects, the fact that water users are charged a flat rate based on their scheduled quota does not provide an incentive to improve water use efficiency through managing demand.

Water Management Plan for the Sand-Vet Irrigation Scheme

Establishment of water saving targets at sub-scheme level

The implementation of a Water Management Plan for the Sand-Vet Irrigation Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the wheat, potatoes and maize crops being irrigated in the scheme area.

Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Sand-Vet Irrigation Scheme assuming the scheduled quota of 7 200 m^3/ha/a remains constant.

Table 1: Estimated water saving targets for the Vet Irrigation Scheme (Erfenis Dam) (million m^3/a)

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Seepages		6.06			6.06	8.55			0	0%	None
Evaporation		0.26			0.26	0.37			0	0%	None
Filling losses			7.09	9.90	16.98	23.96				0%	
Over delivery to users										0%	
Leakages									6.30	9%	Refurbishment & resealing
Infrastructure condition											
Operational Losses									1.35	2%	Flow measurement & monitoring Recalibration of Parshall flumes

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Canal end returns									2.30	3%	Canal tail ends Operational spills
Other					0.00					0%	
Total Loss		6.32	7.09	9.90	23.30	33	13.35	19%	9.95	14%	
Loss as a % of total losses		27%	30%	42%	100%					0%	
Loss as a % of total volume released into system		9%	10%	14%	33%					0%	
Total releases into Scheme	70.86										

Table 2: Estimated water saving targets for the Sand Irrigation Scheme (Allemanskraal dam) (million m^3/a)

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume released	Annual Volume	% of Total Volume Released	Potential water savings	% of inflow into Scheme	Intervention measure
Seepages		4.45			4.45	7.67			0	0%	None
Evaporation		0.21			0.21	0.36			0	0%	None
Filling losses			5.80	2.15	7.95	13.70				0%	
Over delivery to users										0%	
Leakages									1.65	3%	Refurbishment & resealing
Infrastructure condition											
Operational Losses									0.50	1%	Flow measurement & monitoring Recalibration

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume released	Annual Volume	% of Total Volume Released	Potential water savings	% of inflow into Scheme	Intervention measure
											of Parshall flumes
Canal end returns											Canal tail ends
Other					0.00					0%	
Total		4.66	5.80	2.15	12.61	21.74%	10.46	18%	2.15	4%	
Loss as % of total losses		37%	46%	17%	100%						
Loss as % of total volume released into system		8%	10%	4%	22%						
Total releases into Scheme	58.02										

Identified water management measures to improve water use efficiency in the Sand-Vet Irrigation Scheme

The priority water management measures to improve irrigation water use efficiency on the Sand-Vet Irrigation Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points which include the inflow and outflow at the balancing dams, the branch canals, as well as the canal tail ends, etc.

(2) Preparation of more detailed water balance assessments for the Sand-Vet irrigation scheme, as well as the sub-schemes which include the Vet canal and its branches and the Sand canal and the three main branch canals.

(3) Implementation of the release module of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertaken water balance assessment at scheme as well as sub-scheme level.

(4) Installation of telemetry infrastructure to enable real time monitoring of irrigation water in the long term.

(5) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand.

(6) Carry out the refurbishment and rehabilitation of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

Conclusions and Recommendations

A water management plan for the Sand-Vet Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 28% to 19% of the total inflow into the irrigation scheme include the following:

(i) *Conduct flow measurements and flow monitoring on all critical measurement points and calibration* - The evaluation of this measure has illustrated this to be the most beneficial to reducing water losses with the estimated water savings of 0.5 million m^3/a in the Sand canal system and 3.6 million m^3/a in the Vet canal system at an average incremental cost of R0.3 per m^3 of R164 per ha per year.

(ii) *Installation of telemetry system* - This measure is considered as the second most important intervention measure to do as it is critical to addressing the operational problems quickly and more effectively than the current manual monitoring of the scheme.

(iii) *Full implementation of WAS programme* - This measure is aligned to the first two measures and is considered to be important for implementation in the short term as well. It should be carried out at the same time as the first two intervention measures. There is potential to save approximately 0.5 million m^3/a in the Sand canal system and 3.6 million m^3/a in the Vet canal system as part of installing flow measurement and conducting real-time monitoring with the WAS programme and the telemetry system.

(iv) *Canal refurbishment and cleaning of siphons* - This measure although requiring significant capital investment will improve the condition of the infrastructure and reduce the high leakage losses. This will potentially save approximately 1.65 million m^3/a in the Sand canal system and 6.3 million m3/a in the Vet canal system at an average incremental cost of R1.01 per m^3.

(v) *Incentive based pricing* - This measure is considered a national issue which does not only affect the Sand-Vet irrigation scheme. It is dependent on whether the irrigators would require changes to the current water pricing which is area based and the implications to revenue management by the irrigation scheme which may not be stable.

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ABBREVIATIONS

AIC	Average Incremental Cost
BMP	Best Management Practice
DWA	Department: Water Affairs
ET	Evapo-Transpiration
EWR	Environmental Water Requirements
GIS	Geographic Information System
WUA	Irrigation Scheme
IB	Irrigation Board
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MISD	Matching Irrigation Supply and Demand
O&M	Operation and Maintenance
RAT	Remote Assessment Tool
RTU	Remote Telemetry Unit
SLA	Service Level Agreement
WARMS	Water Allocation Registration Management System
WAS	Water Administration System
WCA	Water Control Assistant
WCD	Water Control Department
WC/WDM	Water Conservation and Water Demand Management

WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plans
WUA	Water Use Association
WUEAR	Water Use Efficiency Accounting Report

GLOSSARY OF TERMS

Application efficiency	The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percentage
Applied water:	Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries
Conduit:	Any open or closed channel intended for the conveyance of water.
Conservation:	Increasing the efficiency of energy use, water use, production, or distribution.
Consumptive use (evapo-transpiration)	Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: Crop requirement, crop irrigation requirement, and consumptive use requirement.
Conveyance loss:	Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel.
Conveyance system efficiency:	The ratio of the volume of water delivered to irrigators in proportion to the volume of water introduced into the conveyance system.
Cropping pattern:	The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.
Crop water requirement:	Crop consumptive use plus the water required to provide the leaching requirements.
Crop irrigation	Quantity of water, exclusive of effective precipitation, that is needed

requirement:	for crop production.
Crop root zone:	The soil depth from which a mature crop extracts most of the water needed for evapo-transpiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in mm or m. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.
Deep percolation:	The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants.
Demand scheduling:	Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency, and duration. This is considered a flexible form of scheduling.
Distribution efficiency:	Measure of the uniformity of irrigation water distribution over a field.
Distribution loss:	See conveyance loss.
Distribution system:	System of ditches, or conduits and their appurtenances, which conveys irrigation water from the main canal to the farm units.
Diversion (water):	Removal of water from its natural channels for human use.
Diversion (structure):	Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.
Drainage:	Process of removing surface or subsurface water from a soil or area.
Drainage system:	Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or groundwater.
Drip (trickle) irrigation:	An irrigation method in which water is delivered to, or near, each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil

surface, be shallowly buried, or be supported above the surface (as on grape trellises).

Drought:	Climatic condition in which there is insufficient soil moisture available for normal vegetative growth.
Dry Period:-	A period during which there will be no water flowing in the canal system.
Evaporation:	Water vapour losses from water surfaces, sprinkler irrigation, and other related factors.
Evapo-transpiration:	The quantity of water transpired by plants or evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area.
Farm consumptive use:	Water consumptively used by an entire farm, excluding domestic use. See irrigation requirement, consumptive use, evapo-transpiration.
Farm distribution system:	Ditches, pipelines and appurtenant structures which constitute the means of conveying irrigation water from a farm turnout to the fields to be irrigated.
Farm loss (water):	Water delivered to a farm which is not made available to the crop to be irrigated.
Geographic Information System (GIS)	Spatial Information systems involving extensive satellite-guided mapping associated with computer database overlays
Incentive pricing	This involves setting water rates that provide motivation to use water efficiently
Irrigation schedule	This is the list prepared by the Board showing the sequence the Irrigators will lead and dependent on the scheduled area the time period that the Irrigator is entitled to receive water
Maintenance	This is the process of keeping the irrigation and drainage infrastructure assets in good repair and working order to fulfil the

functions for which they were created.

Modernisation This is the process of upgrading (replacing) an existing asset in order to meet enhanced technical capacity and level of service objectives.

On-farm: Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.

On-farm irrigation efficiency: The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).

Operational losses: Losses at the tail ends, sluices not opened or closed on time or opened to big and spills

Operational waste: Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.

Pan evaporation: Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapo-transpiration and assist in irrigation scheduling.

Parshall flume: A calibrated channel-like device, based on the principle of critical flow, used to measure the flow of water in open conduits. Formerly termed the Improved Venturi Flume.

Percolation: Downward movement of water through the soil profile or other porous media.

Rehabilitation This is the process of renovating an existing asset whose performance is failing to meet its original objective to its original design specifications. This may also be referred to as asset reproduction.

Reservoir: Body of water, such as a natural or constructed lake, in which water is collected and stored for use.

Return flow: That portion of the water diverted from a stream which finds its way back to the stream channel, either as surface or underground flow.

Return-flow system	A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a "reuse system or a “recovery system”.
Risk cost	This is usually expressed as the product of the cost of damage caused by the actual hazard occurrence and the probability of occurrence.
Run-off	This is the water produced when irrigation water is applied to fields at rates and in amounts greater than can be infiltrated into the soil profile.
Request Form	A form on which an Irrigator requests the quantity of water he requires.
Tail end water	This is water at the endpoint of a canal
Telemetry	Involving a wireless means of data transfer
Water Note	A form issued by the Control Officer informing the Irrigator of the quantity of water he will be receiving.

1 INTRODUCTION

1.1 Background

Irrigation agriculture is the biggest water user in the South Africa, using approximately 62% of the current water use nationally. With the increasing competition between existing user sectors, the available water cannot meet the demand under current water use practices and operating conditions in all water use sectors. It is therefore imperative to ensure that available water supplies are used efficiently and effectively to avoid supply shortages and intermittent water supplies, which would have a major impact on the socio-economic growth and development of the country.

The savings that can potentially be made from implementing WC/WDM measures will delay the need for the development of additional new water supplies, while ensuring that the natural environment is maintained or is not degraded further. The Department of Water Affairs (DWA) identified that, based on preliminary assessment of water losses in the agricultural sector, there was potential to implement measures to improve water use efficiency in the sector. The overall aim in reducing water losses and improving irrigation water use efficiency levels in the Water User Associations (WUAs)/Irrigation Boards (IBs)/Government Water Schemes (GWS) is that the limited available water can be optimally utilised to ensure the efficient use of water and a high economic return for the scheme area.

The study was commissioned because of the increasing water scarcity[2] in a number of Water Management Areas (WMAs). One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently. The Department of Water Affairs (DWA) Directorate: Water Use Efficiency, which has the mandate to ensure the efficient use of the water resources in the country by all water use sectors, identified that since the development of the pilot Water Management Plans (WMPs) for improving water use efficiency in irrigation agriculture, no progress had been made by the irrigation sector with respect to the development and implementation of WMPs for the sector.

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[2] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers and implementors.

In order to ensure the irrigation sector review their current water use efficiency levels and develop strategies to improve their water use efficiency, the DWA has identified a need to assist a number of irrigation schemes in developing their irrigation water management plans in order to primarily reduce their water losses. A secondary outcome can be seen as the enablement of irrigators to increase their on-farm irrigation efficiency.

Following the meetings with DWA Directorate: Water Use Efficiency, the Sand-Vet WUA and the DWA Regional Offices, this report provides the following:

- Overview of the water allocation and irrigation water use situation of the Sand-Vet WUA and related institutional arrangement for irrigation water management
- Identification and assessment of the water management issues and management goals expected to address the irrigation water management issues identified.

1.2 Study Objectives

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes (see **Figure 1.1** below) to improve water use efficiency in the agricultural sector. In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water balance assessment and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water balance assessments prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the GWS, IBs and WUAs to implement the identified opportunities to improve irrigation water use efficiency.

Figure 1.1 Location of the 14 irrigation schemes where WMPs have been developed

The development of the WMPs for the selected Irrigation Schemes will not only provide a plan for reducing water losses and improve system efficiencies, but if the management plan is implemented and water losses and water demand is reduced, the benefits to the agricultural sector, customers and the catchments in general will include:

- Improved system efficiencies;
- Reduction in irrigation water return flows;
- Reduction in system operation and maintenance expenses;
- Potential cost savings due to deferral or downsizing of capital works;
- Benefits which are important but difficult to quantify such as reduced environmental impact resulting from delays in or deferment of construction of water sources and the maintenance of higher water levels in rivers and reservoirs.

1.3 Structure of the report

This report has been structured to first provide a perspective of the Sand-Vet Irrigation Scheme as well as the potential for irrigated agriculture in the Sand and Vet River catchments.

Chapter 1 provides the overall objective of assessing water conservation and demand management measures in the context of increasing competition between existing water users and the need for water for the environment.

Chapter 2 describes the catchment characteristics of the Sand-Vet River catchment in which the Sand-Vet Irrigation Scheme is situated.

Chapter 3 describes the history of the Sand-Vet Irrigation Scheme and the scheduled quota. It also describes the catchment and the current land-use practices in the catchment. The chapter also describes the background to the scheme, the institutional arrangements.

Chapter 4 gives an overview of the inventory of the existing irrigation water management infrastructure which includes the size and capacity of the canals, the dams supplying the scheme; any balancing dams in the Sand-Vet Irrigation Scheme as well as the flow measurements available in the scheme.

Chapter 5 describes the condition of the conveyance infrastructure. A framework for determining the condition assessment of the infrastructure is described while the condition of the various sections of the main canals and the branch canals are discussed based on discussions with scheme operators; surveys conducted during the various site visits, and available information.

Chapter 6 of this report describes how the scheme is currently being operated to provide irrigation water to the irrigators. The scheme operating procedures including how the irrigators are supplied during drought periods is presented in this chapter.

Chapter 7 uses the information from the previous chapters to determine the irrigation water Best Management Practices for the irrigation schemes. This determines how much water losses would be expected if the scheme infrastructure is well maintained. Therefore the approach used to determine the expected seepage losses as well as the evaporation losses are described in the chapter of the management plan. It then describes the standards that can be adopted as appropriate for benchmarking of irrigation water use and management practices.

Chapter 8 describes the water balance assessment, as conducted, based on the water use and compared with expected irrigation efficiency levels for the different irrigation systems. This chapter also provides the performance benchmarking of the irrigation sector when compared with the expected standards.

Chapter 9 of this report describes the existing irrigation water management measures that the irrigation scheme is currently undertaking to improve irrigation water management efficiency and reduce the water losses taking place in the irrigation scheme. These include flow measurement, availability of balancing dams, flow monitoring to reduce operational losses if any, canal maintenance during the dry periods; etc.

Chapter 10 then discusses the water management issues identified from the previous chapters. It then sets the management goals required to ensure any identified water management issues can be addressed.

Chapter 11 of the report provides an assessment of the identified water management measures that can be implemented to achieve the goals and objectives set in chapter 9. This is the strategic WC/WDM business plan for the Scheme. The chapter also provides an estimate of the capital investment required to implement the strategy. It also provides the performance indicators for monitoring and controlling the implementation of the measures.

Chapter 12 presents the water management plan. This summarises all the water management issues, the irrigation water saving targets recommended to be achieved and the water management tasks to achieve the targets set to reduce water losses and improve irrigation water management efficiency of the scheme.

Chapter 13 provides a conclusion and recommendation for the irrigation scheme.

2 CATCHMENT CHARACTERISTICS OF SAND AND VET RIVER CATCHMENT

2.1 Overview

The Sand-Vet Irrigation Scheme is situated in the Lejweleputswa District Municipality, and traverses the local municipalities of Matjhabeng in the Sand River catchment, Masilonyana in the Vet River catchment and Tswelopele Local Municipality after the confluence of the two rivers to form the Vet River catchment. The nearest main towns to the Sand-Vet Irrigation Scheme is Welkom located to the north of the Sand River, Virginia which is in the Sand River catchment and Theunissen located in the Vet River catchment.

Figure 2.1 below presents the locality map of the Sand-Vet Irrigation Scheme area. The Sand River has its headwaters in the Witteberg Mountains area in the Dihlabeng Local Municipality while the Vet River has its headwaters in the Sherwood area in the Mantsopa Local Municipality. The confluence of the two river systems is within the irrigation scheme area before flowing into the Bloemhof Dam as the Vet River.

There are two major storage dams in the catchment, one in each of the two river systems. The Erfenis Dam is located in the Vet River near the town of Theunissen and has a storage capacity of 207.5 million m^3. It was constructed in 1960 to meet the irrigation water requirements of the Sand-Vet Irrigation Scheme. The Allemanskraal Dam is located in the Sand River near Ventersburg. The dam was built in 1960 to improve the security of supply to the irrigation as well as to meet the demands of Welkom and the surrounding towns including the mines.

2.1.1 Climate and rainfall distribution

The climate and temperature variations of the Sand and Vet River catchment are closely related to elevation. The study area experiences extreme conditions during the summer months (DWAF: 1999) with rainfall categorised into two climatic zones. The characteristics of the catchment indicate that there are two climatic zones with the following mean annual precipitation (see **Figure 2.2** below):

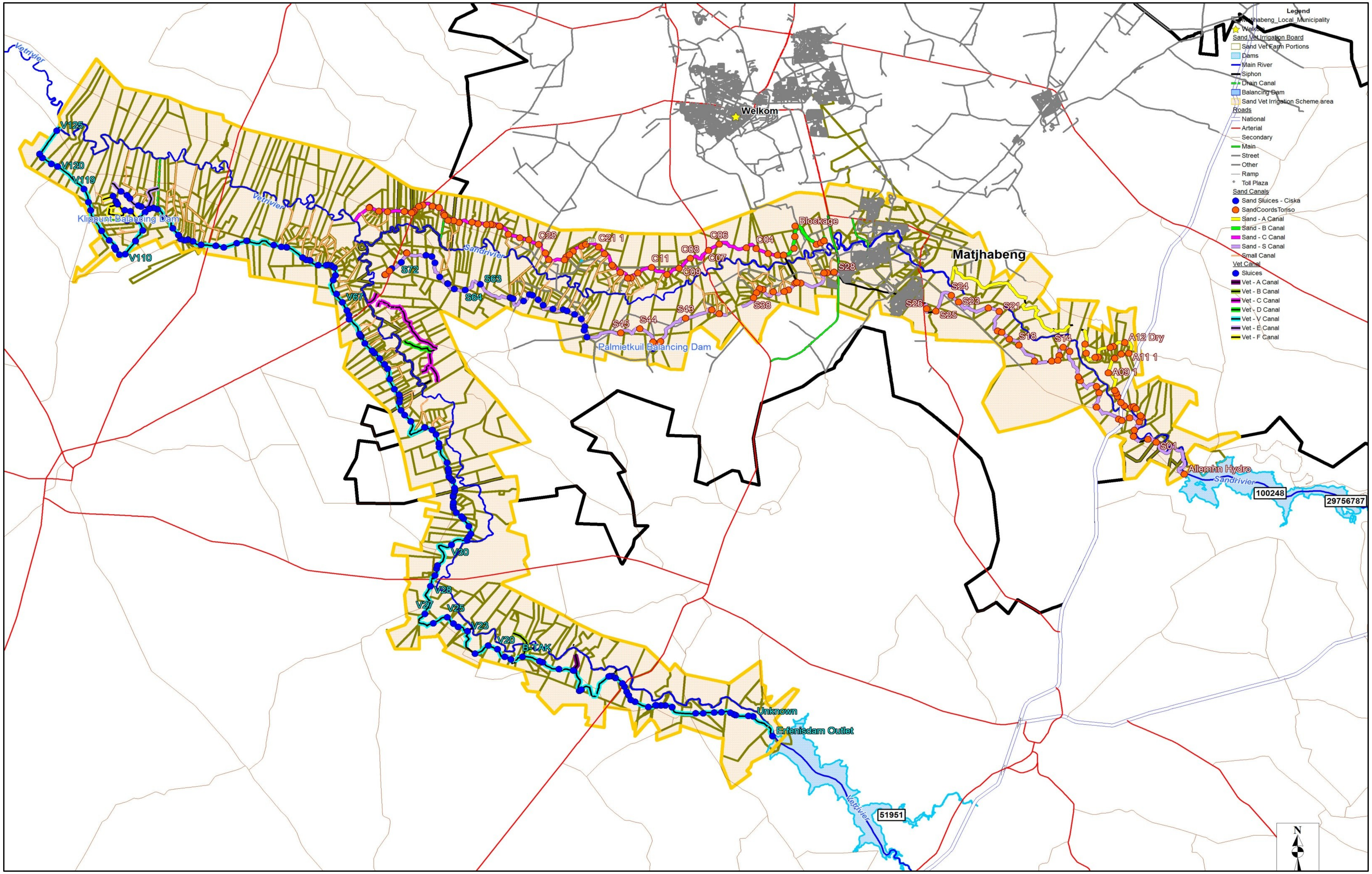

Figure 2.1: Sand-Vet Irrigation Scheme - Locality Map

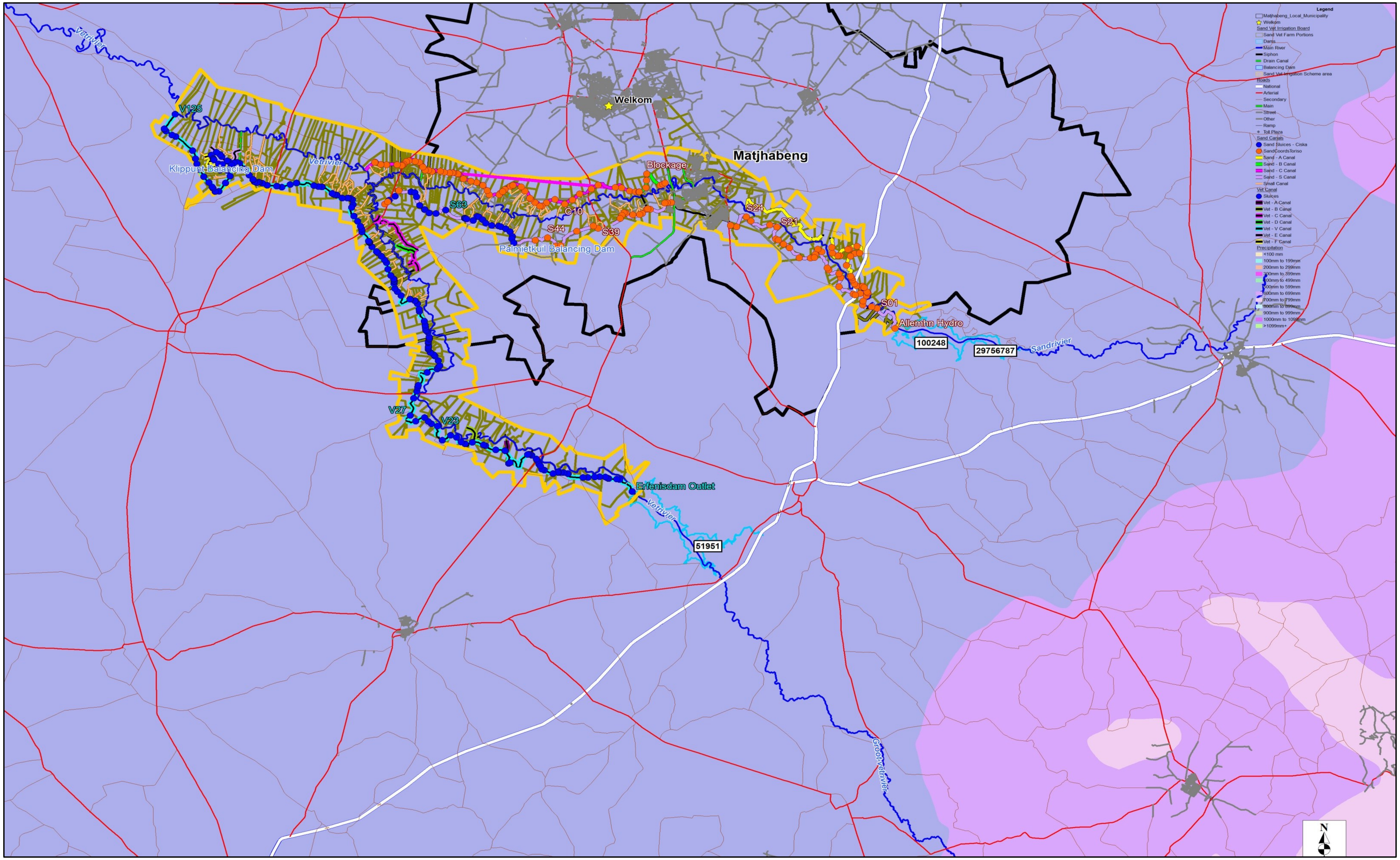

Figure 2.2: Precipitation of the Sand-Vet Irrigation scheme catchment area

- In the upper catchments where the catchment is characterised by rolling hills, upstream of the two dams, the precipitation is between 600 mm and 699 mm.
- In the middle portion of the catchment, where the Sand-Vet Irrigation Scheme is situated, and the lower part of the catchment, the precipitation ranges between 500 mm and 599 mm. The low MAP indicates the need for irrigating the lands because of low rainfall in the Sand-Vet Irrigation Scheme area.

The Sand and Vet River catchments are divided into two evaporation zones. The headwaters of the Sand and Vet catchment experience the lowest evaporation rate, estimated to range between 1400 mm to 1500 mm. From the Erfenis Dam downstream, up to the confluence of the Sand and Vet rivers, evaporation ranges between 1500 mm to 1700 mm. It is also important to note that this is the zone where the Sand-Vet Irrigation Scheme is situated. The high evaporation rate has a direct correlation with the irrigation water use requirements.

2.1.2 Geology and soils of the catchment

The geology of the area supplied by Sand-Vet Water User Association (WUA) has predominantly an assemblage of sedimentary extrusive and intrusive rocks (see **Figure 2.3** below).

Soil depths are generally moderate to deep with flat to undulating relief over the entire Middle Vaal WMA. There are four main soil types that are predominant in the Sand-Vet Irrigation Scheme area and are distributed across the scheme area as follows

(i) Upper catchment of the Sand River: The soil depth downstream of the Allemanskraal Dam is moderate to deep clayey loam soils in undulating terrain. The soils possess good balance between ability to convey water and the water holding capacity. The average soil depth is approximately 497.5 mm.

(ii) Upper catchment of the Vet River. This soil depth downstream of Erfenis Dam is moderate to deep sandy soils in generally flat terrain. The soils have a low water holding capacity compared to the rest of the scheme area. The average soil depth is approximately 1150 mm which makes it difficult to determine seepages as there is likely to be deep percolation.

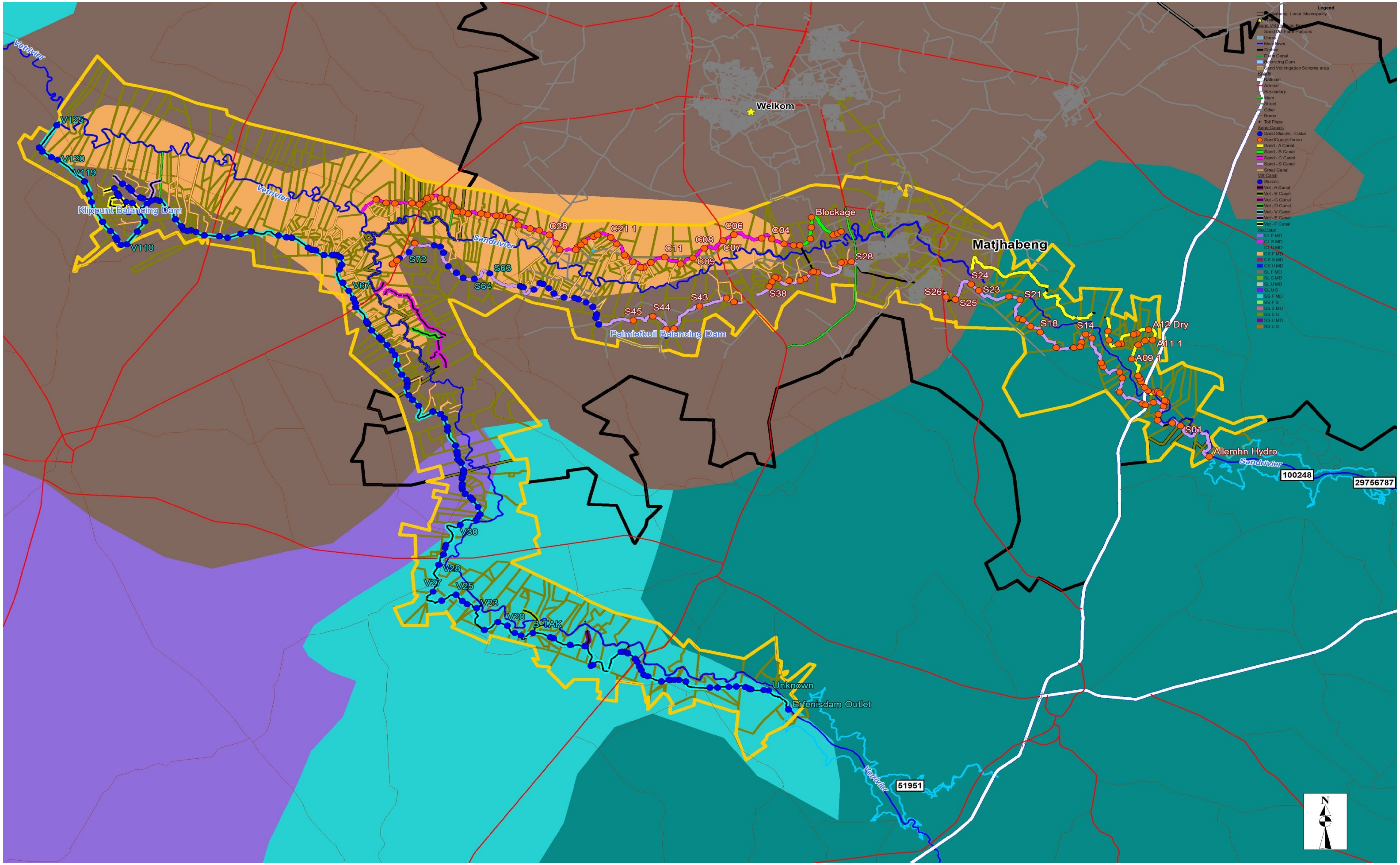

Figure 2.3: Soils Map of Sand-Vet Irrigation Scheme

(iii) Middle scheme area from Sand River downstream after the confluence with the Vet River. The soil depth in this area is moderate to deep clayey soils in generally flat terrain. The soils do possess a good balance between ability to convey water and the water holding capacity. The average soil depth is approximately 1150 mm deep.

(iv) Outer middle scheme area - lower portions of the Sand and Vet Rivers and after confluence with the Vet River, on the outer portions of the scheme area. This soil depth can be categorised as predominately moderately deep sandy loam soils on the generally flat plains downstream of the Erfenis and Allemanskraal Dams. It is important to note that the sandy soils are not very ideal for irrigation because the balance between ability to convey water and the water holding capacity is generally high, estimated to range between 32 mm and 40 mm (J.L. Schoeman and M. van der Walt). The average soil depth is approximately 852.5 mm.

3 OVERVIEW OF THE SAND-VET IRRIGATION SCHEME

3.1 History of the scheme

The Sand-Vet Irrigation Scheme is situated to the south of Welkom, downstream of the Allemanskraal Dam in the Sand River and Erfenis Dam in the Vet River. The irrigation scheme was first established in the 1960s. The Sand-Vet Irrigation Scheme includes the Vet Irrigation Scheme and the Sand Irrigation Scheme, currently supplied with water from the Erfenis Dam and Allemanskraal Dam, respectively. The scheme comprises a total of 145 farms. The total scheduled area for irrigation including the river irrigators is 11 835.4 ha.

The Erfenis Dam supplies water for irrigation of 5 489 ha of the scheduled area. Irrigation is taking place mainly along the left bank of the Vet River until the confluence of the Vet and Sand Rivers. There are approximately 72 irrigators in the Erfenis Irrigation Scheme area with the average farm irrigation area of 72.6 ha. Downstream of the confluence of the Sand and the Vet Rivers, another 1 297 ha of irrigation is mainly supplied directly from the Vet River.

The Allemanskraal scheme supplies water for irrigation to 5 049.5 ha of the scheduled area. For the Allemanskraal Irrigation Scheme, water is diverted from Allemanskraal Dam into the main canal. This canal then bifurcates into two separate canals downstream of the dam, supplying water for irrigation on the left and the right banks of the Sand River. There are approximately 349.2 ha which are irrigated directly from the Sand River and is not supplied by the existing canal infrastructure.

3.2 Organisational arrangements

The Sand-Vet Irrigation Scheme was established in the 1960s. The DWA was responsible for the operation and maintenance of the scheme until the DWA initiated the establishment of a Water User Association in 2002.

The Sand-Vet WUA was established in terms of section 92 of the National Water Act (No. 36 of 1998). Its powers and functions are based on schedule 4 of the Act. The membership of the Sand-Vet WUA includes representatives of the irrigators, other major consumers such as industries and mines, the WSAs which include Tswelopele and Masilonyana Local Municipalities as well as the bulk WSP, Sedibeng Water. All these stakeholders benefit from the conveyance infrastructure of the Sand-Vet Irrigation Scheme.

The Sand-Vet WUA is managed by a Chief Executive Officer (CEO) who is responsible for the strategic oversight and day to day management of the scheme (see **Figure 3.1** below).

3.2.1 Water distribution Section

One of the key functions of the Sand-Vet WUA was that it was delegated the function for the distribution of the irrigation water as required and on time as well as civil and/or mechanical maintenance of the Sand-Vet Irrigation Scheme.

As part of the water distribution and/or operation of the irrigation scheme, the Sand-Vet WUA supplies not only the irrigators but also the water requirements of the domestic and industrial users through the canal infrastructure. **Figure 3.1** below provides an illustration of the organisational structure of the Sand-Vet WUA for the distribution of water in the Sand and Vet Irrigation scheme sections. There are three levels in the water distribution section which include, the Assistant Manager: Water Distribution, the Section Managers; as well as the Water Control Assistants. Their responsibilities are discussed in the following sections.

3.2.1.1 Assistant Manager

As indicated in **Figure 3.1** below, Sand-Vet Water User Association has an Assistant Manager: Water Distribution who is responsible for the operation of the whole irrigation scheme, under the CEO and Operations and Maintenance Manager. His main function is to collect the information provided by the Water Control Assistants, process it and issue the operational orders to be executed. These include the amount and timing of releases from Allemanskraal and Erfenis Dams, the setting of the sluice gates and structures to deliver the amount and timing of irrigation water requested by the irrigator on a weekly basis.

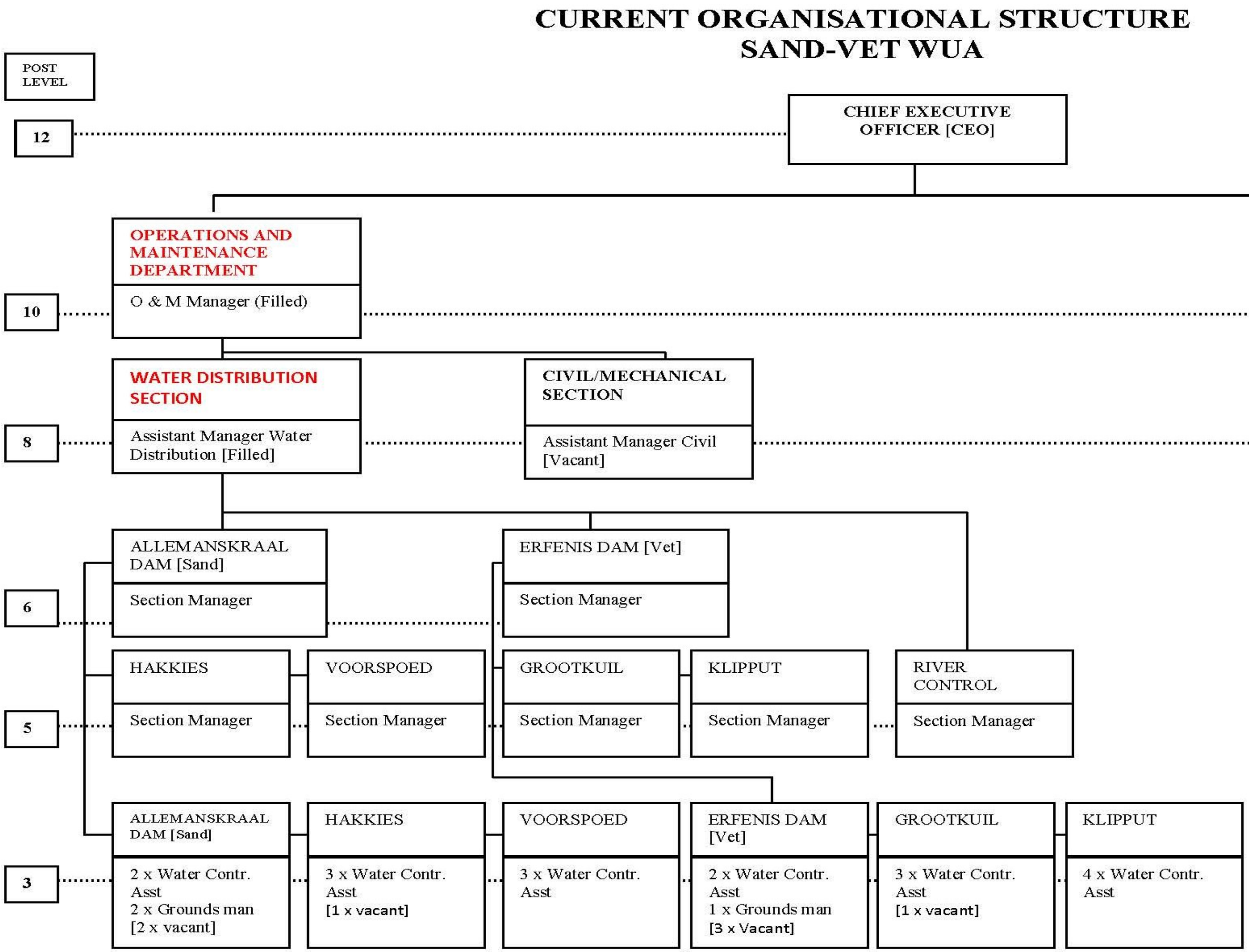

Figure 3.1: Current Organogram for water distribution in the Sand-Vet Water User Association

The job description of the Assistant Manager: Water Distribution ideally is mainly to carry out the following tasks:

(i) Receive the weekly water requests from the Water Control Assistants (see their job description below);
(ii) Planning the operation of the scheme in order to match the supply as closely as possible with the irrigation water applications (i.e. demand);
(iii) Transmit the operational orders to the Section Managers, Water Control assistants and Groundsman according to the instruction to set the sluice gates to prescribed levels to supply the water ordered;
(iv) Supervise that the orders provided to the Scheme Managers and WCAs are executed accurately;
(v) Coordinate with the Section Managers the operation of the main canal gates and the releases required including the timing of the releases;
(vi) Monitoring of the operation (i.e. collection of data related to water use and preparing accounting reports) and preparation of the annual irrigation plans and reports.

3.2.1.2 Section Manager

The Sand-Vet Irrigation Scheme is sub-divided into five (5) sections, each managed by a section manager. The job description of the section manager is mainly to carry out the following tasks:

(i) Read the water levels in the canal off takes, river and balancing dams in those sections they are available;
(ii) Transmit the data to the Water Control Assistants (WCAs) responsible for the different sections ;
(iii) Manipulate or set the sluice gates and structures as indicated by the Sand-Vet WUA main office;
(iv) Receive data from the WCAs as to the required amount of water, and transfer the data to the main office;
(v) Report to the Assistant Manager: Water Distribution any malfunctioning of sluice gates and structures and any water thefts;
(vi) Control and report on the state of maintenance of the stretch of canal for which they are responsible.

Manpower requirements

Data from several projects indicate that one section manager can cover 10 - 15km irrigation infrastructure, depending on the number of hydraulic structures in the canal. The main outlets which are Erfenis Dam and Allemanskraal Dam require one or two people depending on the complexity of operation. The operation of the dam gates requires one person.

In the Sand-Vet irrigation scheme, there are five (5) section managers with two of the managers responsible for operation of the two dams' outlet gates. Given the fact that the Sand canal has approximately 187 km of canal, each section manager is responsible for 94km of canal while the Vet canal has approximately 164 km of canal, and each section manager is responsible for 82 km of canal.

3.2.1.3 Water Control Assistants

The Water Control Assistants (WCAs) are the main communication channel between the scheme management and the farmer. Therefore the success of a smooth relationship between the two parties depends on their capabilities and honesty.

Although the job descriptions of the WCAs may vary slightly, the following are considered to be the usual expected tasks to be carried out:

(i) Distribute and control the flows that each sluice must deliver;
(ii) Open and close sluice gates and valves;
(iii) Collection of the water requests (if not placed into the box at the scheme);
(iv) Preparation of the forms for the water delivery;
(v) Communication to the Section Manager of the request for water;
(vi) Control of the canals and watercourses to avoid unauthorised use of water;
(vii) Compilation of the agricultural and water data as needed;
(viii) Delivery of water bills – if not posted to the user.

In the Sand-Vet irrigation scheme, the water control assistants not only perform functions related to the operation of the system, but also maintenance work during the off-season. The added duties during this period include the following:

- Cleaning of the irrigation canals;
- Small repairs in the small hydraulic works (sluices, siphons, joints, etc.);
- Supervision of repair works;
- Repairing and maintaining the sluice gates in their section

Manpower requirements

The Sand-Vet WUA has to distribute irrigation water to 11 835.4 ha with the 12 Water Control Assistants. Given the local circumstances such as transport facilities ease of access, the configuration of the irrigation canal scheme layout, there are approximately 5 WCA for each 5 000 ha of the scheduled area. This is considered more than sufficient when the size of the farms was determined as 72.6 ha.

As illustrated in the **Figure 3.1** above over 80% of the posts of water control assistants are filled. The Sand-Vet WUA has sufficient resources to carry out the water distribution to its constituents, the irrigators, in all the sections.

3.2.2 Civil / Mechanical Maintenance Section

The maintenance section is entrusted with the overall responsibility for keeping the irrigation and drainage infrastructure working in a satisfactory manner, within the limitations imposed by the design.

The main functions of the Civil/Mechanical Maintenance Section to be undertaken include the following:

(i) Planning the maintenance activities;

(ii) Implementing the maintenance activities planned and those unforeseen. Maintenance activities can be easily undertaken during the dry periods in the off-season;

(iii) Monitoring the abovementioned activities - a maintenance service requires data for good planning which can be obtained by regular monitoring. Without reliable data on costs for the different units of work and on productivity no realistic planning can be done.

The existing organisation structure for the Civil/Mechanical Maintenance section is provided in **Figure 3.2** below.

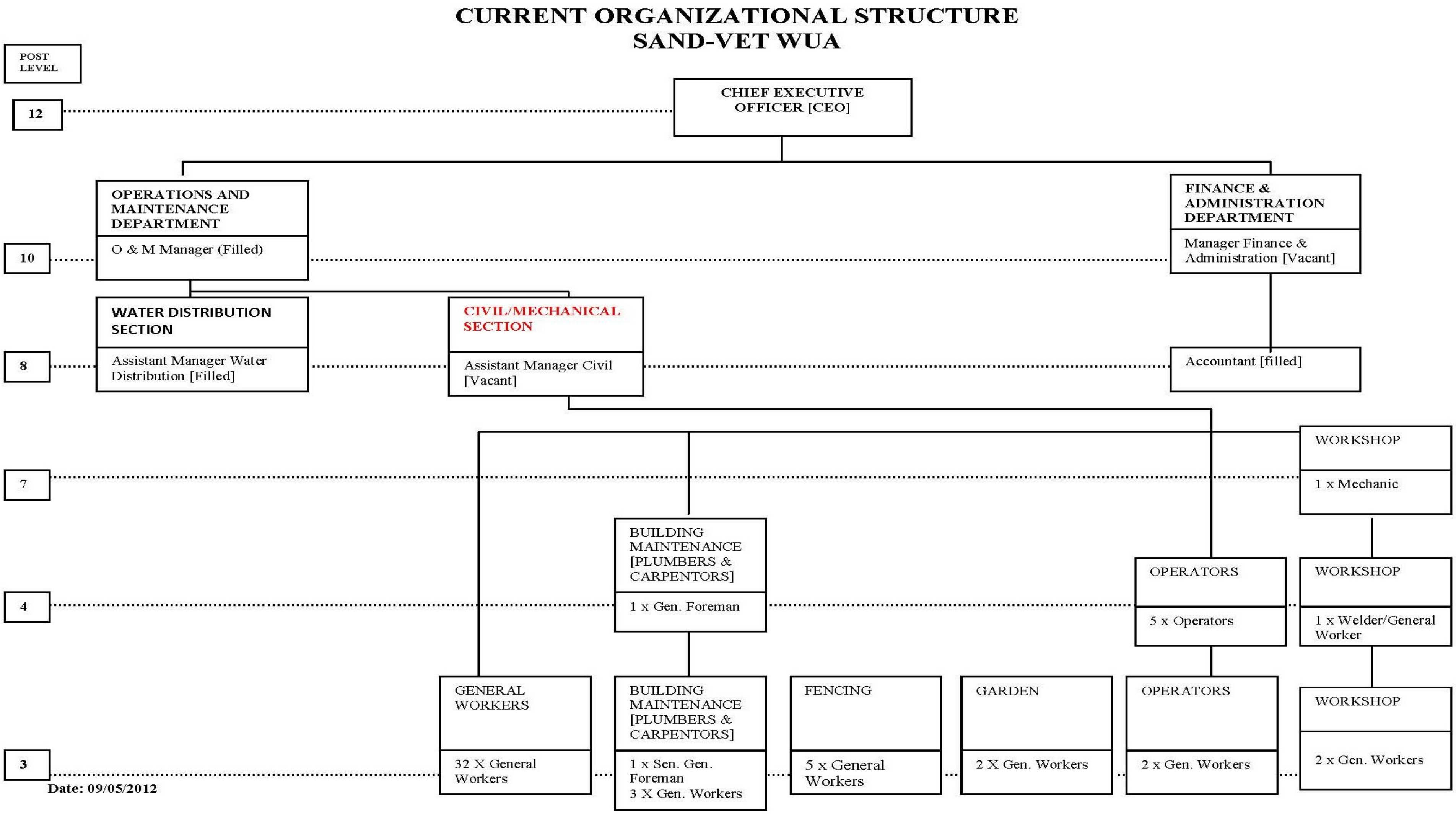

Figure 3.2: Current Organogram for civil/mechanical section in the Sand-Vet Water User Association

3.3 Irrigation water charges

3.3.1 Overview

The water users dependent on water from the Sand-Vet Irrigation Scheme pay water charges for different purposes. The water rates paid by the users include the contribution to the infrastructure investment paid to the government for the storage and distribution of water; the management of the resources of the catchments; as well as the water rates to cover the expenses related to the operation, maintenance and administration of the scheme. These water charges are indicated in **Table 3.1** below. Each is discussed in the following sections.

3.3.2 Water Charge for depreciation of the assets and return on assets

The first water charge paid by water users in the Sand-Vet Irrigation Scheme is the charge to cover for the depreciation of the infrastructure which includes the two dams, namely Erfenis and Allemanskraal Dams as well as the canal and related infrastructure.

The irrigators in the Sand-Vet Irrigation Scheme are charged a water use charge as part of the depreciation charge and return on assets (ROA) of R159.84 per hectare per annum for the current 2012/2013 financial. This is equivalent to 2.22 c/m^3 at the current schedule allocation of 7 200 m^3 per ha per annum.

The water use charge for the industrial users supplied from the canals is 38.16 c/m^3 while those supplied directly from the dam is 18.48 c/m^3. This clearly indicates that the water use charge to cover for the depreciation charge and ROA for irrigation agriculture is currently heavily subsidised when compared to the water use charged for domestic and industrial users. Although the gross replacement costs (GRC) of the existing assets is not known, it would appear that the current water use charge does not generate sufficient returns to exceed or cover the cost of funding the assets.

Each irrigator is responsible for the payment of the water use charge to the Department of Water Affairs (DWA). However the collection is carried out by the Sand-Vet WUA on behalf of the Department of Water Affairs (DWA).

It is important to note that the DWA does not recover the costs for operation and maintenance as well as for the refurbishment and renewal of the assets. This is supposed to be recovered by the Sand-Vet WUA to cover for the O&M costs of the assets.

Table 3:1: Schedule of tariffs for the Sand-Vet Irrigation Scheme

SCHEDULE OF TARIFFS		2008/2009	2009/2010		2010/2011		2011/2012		2012/2013	
SAND-VET OPERATION & MAINTENANCE				%	R	%	R	%	R	%
Irrigation Farmers' - Rate - R/ha/annum				%	R	%	R	%	R	%
Dam		99.36	120.24	21.01%	118.80	-1.20%	125.28	5.45%	118.80	-5.28%
River		741.60	891.36	20.19%	915.12	2.67%	902.88	-1.34%	751.68	-16.75%
Canals		1 102.32	1 308.24	18.68%	1 308.96	0.06%	1 300.32	-0.66%	1 254.24	-3.54%
Industrial Users - Rate :- c/m^3										
Canals		15.37	18.17	18.22%	18.18	0.06%	18.06	-0.66%	17.42	-3.54%
Dam		1.49	1.67	12.08%	1.65	-1.20%	1.74	5.45%	1.65	-5.28%
DWA Charges - Estimated Depreciation & ROA										
Irrigation Farmers' - Rate - R/ha/annum										
Dam		126.00	162.72	29.14%	146.88	-9.73%	151.20	-9.73%	159.84	5.71%

SCHEDULE OF TARIFFS		2008/2009	2009/2010		2010/2011		2011/2012		2012/2013	
River		126.00	162.72	29.14%	146.88	-9.73%	151.20	-9.73%	159.84	5.71%
Canals		126.00	162.72	29.14%	146.88	-9.73%	151.20	-9.73%	159.84	5.71%
Industrial Users - Rate :- c/m^3										
Canals		21.38	25.10	17.40%	28.34	12.91%	32.73	12.91%	38.16	16.59%
Dam		11.02	12.94	17.42%	13.72	6.03%	15.85	6.03%	18.48	16.59%
WRMC	-									
Irrigation R/ha		96	108	12.50%	139.68	29.33%	139.68	29.33%	139.68	0.00%
Industrial Users c/m^3		2	2	12.28%	2.50	30.21%	2.50	30.21%	2.61	4.40%
WRF	-									
Irrigation R/ha		4	4	6.67%	4.50	12.50%	5.00	12.50%	5.40	8.00%
Industrial Users c/m^3		3	3	4.53%	4.06	35.33%	4.50	4.00%	4.86	8.00%

3.3.3 Water Charge for the operation, maintenance and administration costs

Besides the payment of water charges by water users in the Sand-Vet Irrigation Scheme to pay for the return on assets (ROA), the water users are also responsible for the payment of water charge for the operation and maintenance of the canal infrastructure as well as the administration costs to cover the costs in managing the scheme by the Sand-Vet Water User Association (WUA).

Currently the water charge for O&M and administration costs ranges from R118.8 per ha per annum (or 1.65 c/m^3) for irrigators supplied from the dam alone, R751.68 per ha per annum (or 10.44 c/m^3) for river irrigators to R 1254.24 per ha per annum (17.42 c/m^3) for the irrigators using the canals to be supplied with their irrigation water. It is important to note that although the river irrigators or some of them are charged at less than the canal irrigators, discussions with the Sand-Vet WUA indicate that some of the irrigators are supplied through the irrigation canal tail ends.

This water charge is intended to ensure operation of the scheme and maintenance of the irrigation infrastructure. Whether the water charge is sufficient to meet the maintenance requirements of the infrastructure including the refurbishment and renewal of the infrastructure has not been evaluated as the depreciation charge of the assets is not known.

3.3.4 Water Resource Management Charge

Besides paying for the use of the water released from the Erfenis Dam and Allemanskraal Dam, the irrigators in the Sand-Vet Irrigation Scheme also pay for the water resource management charge which is to manage the water management area. The current WRM charge for the Middle Vaal Water Management Area is 1.94 c/m^3 or R135.68 per ha/a for the irrigators and 2.61 c/m^3 for the industrial users.

The WRM charge is not the same for all water users in the Middle Vaal Water Management Area (WMA) in which the Sand-Vet Irrigation Scheme is situated. The purpose is to cover all management activities that are undertaken by a Catchment Management Agency (CMA) or a proto-CMA where one has not been established and to ensure the sustainable water resource management to ensure all users in the WMA have fair and equitable share of the available water. The activities that are covered by the WRM include the following:

(i) water abstraction control to ensure that all get their fair share of water,
(ii) monitoring and pollution control to keep the rivers healthy,
(iii) planning for development of new schemes and to extend existing schemes,

(iv) clearing of invasive alien plants which consume water that should be available for use.

3.3.5 Total Water charge

The total water charge for users in the Sand-Vet Irrigation Scheme is different for different categories of users. This is dependent on the different assurances of supply provided to the users. The level of assurance of supply of irrigators in the Sand-Vet Irrigation Scheme is the lowest compared to industrial and domestic water users. This therefore means that irrigators will be the first to be curtailed when there are water shortages in the scheme area.

The total water charge to the canal irrigators including the water resource management charge (WRMC) amounts to R1 559.16 per ha per annum (or 21.66 c/m^3) while the total water charge for industrial users is the highest at an amount of 63.05 c/m^3 which is three times more than canal irrigators.

3.4 Water use permits / licenses and contracts

3.4.1 Registered irrigation water use

The authorisation for the water use, within the Sand-Vet Water User Association's (WUA) area of jurisdiction, lies in the Schedule, for 11 835 ha, drawn up in terms of section 88 of the 1956 Water Act, and approved by the Department in 1999. This Schedule forms an Annexure to the Sand-Vet's WUA Constitution. This scheduled use is deemed to be an Existing Lawful Water Use under section 32 of the National Water Act, 1998 and as such, does not require a Licence, but does need to be registered. In the case of the Sand-Vet, the scheduled water use has been registered. The irrigators have permission to continue irrigating this scheduled area until Compulsory Licensing takes place, provided they pay all charges due to Sand-Vet Water User Association and the DWA.

Each irrigator in the Sand-Vet irrigation scheme has a registration certificate for the scheduled area. The current scheduled area which has a registered water use is 11 835 hectares, comprising 5 489 ha in the Erfenis canal system, 5 049 ha supplied from the Allemanskraal canal system and 1 297.4 ha which is dependent on direct abstraction from the Vet River system. Each of the irrigators in the Sand-Vet Irrigation Scheme area is registered individually and the Registration certificates reflect the scheduled as well as the non-scheduled areas.

3.4.2 Domestic water use allocation

The water use authorisation for domestic water use in Sand-Vet irrigation scheme to supply the towns and surrounding communities is held by the Water Services Authorities (WSAs) such as Tswelopele and Masilonyana and bulk Water Services Providers which include Sedibeng Water who also hold the permit for the industrial water use. It is not known whether there is a service level agreement (SLA) between the domestic users and the Sand-Vet WUA for the delivery of water for domestic purposes through the irrigation canal infrastructure.

Besides the registered water use and licences held by the irrigators, the Sand-Vet WUA has a contract with the Sedibeng Water as the bulk water service provider of Tswelopele and Masilonyana Local Municipalities to supply the towns of Virginia, Welkom, the smaller towns within the catchment and the surrounding areas with water through its conveyance infrastructure. The domestic water is registered with Sedibeng Water and is 15.2 million m^3/a. This is supplied through the Sand main canal.

The total allocations for the Sand-Vet Irrigation Scheme is 75.9 million m^3/a, at 7 200 m^3/ha/a. A review of the Water Allocation Registration Management System (WARMS) database indicates that the total registered water use in the scheme area is 75.9 million m^3/a, which is supplied from the canal infrastructure.

It is important to note that over the period from 1999/2000 to 2005/06 water years, the annual diversions from the two sub-schemes making up the Sand-Vet Irrigation Scheme including the allowance for water losses have ranged between 37 million m^3/a and 71 million m^3/a (after patching for missing data) which ranges between approximately 30%- 40% of the scheduled area according to the records of releases into the main irrigation canals supplying the Sand-Vet Irrigation Scheme.

3.5 Irrigated areas and types of crops

3.5.1 Overview

The Sand-Vet WUA area comprises 319 950 hectares with the irrigation area estimated to be 11 835.4 hectares. In terms of the National Water Act (Act 36 of 1998), irrigation boards were required to be transformed into Water User Associations (WUA). The Sand-Vet Irrigation Scheme was transformed into a WUA on 29 November 2002. The scheme has a total scheduled area of 11 835.4, at a scheduled quota of 7 200 m^3/ha/a.

The typical crop mix across the Sand-Vet Irrigation Scheme is indicated in **Table 3.2** below. The irrigators in the scheme are growing diverse crops which include maize, wheat, sunflower and vegetables. In recent years the extent of maize grown has increased, as well as the inclusion of peanuts and pecan trees. Oats is no longer growing in the area. The water quota (water allocation) of 7200 m^3 per ha per year is too small to allow double cropping and therefore it is found that farmers tend to specialize in one crop per year.

The main crops that are under irrigation, include wheat (7 154 ha), potatoes (2 201 ha.) and maize (2 201 ha), with the other annual crops as indicated in the figure below. The table below illustrates the importance of crop mix on a per hectare basis in the Sand-Vet Irrigation Scheme, the first three crops comprising 77.6% of the total. Therefore there is significant crop mix taking place in the scheme area. The average yields of some of the crops grown in the scheme are: wheat = 5-7 t. per ha, maize ranges between 8-12 t per ha.

Table 3:2: Typical irrigated area in Sand-Vet Irrigation Scheme [a]

Crop Type	Total Crop Area	Percentage of total area (%)	Production	
			Average Farmer (t per ha)	Top Farmer (t per ha)
Wheat	7 154.00	48.0%	5	7
Potatoes	2 201.00	14.8%	22	27
Maize	2 201.00	14.8%	8	12
Oats (Grazing)	759.00	5.1%	3LSU	3LSU
Lucerne (grazing)	664.00	4.5%	3LSU	3LSU
Soya Beans	551.00	3.7%	2	3
Cabbage	414.00	2.8%	25	30
Rye Grass	285.00	1.9%	3 LSU	4LSU
Sorghum	190.00	1.3%	3 LSU	4LSU
Pumpkins	172.00	1.2%	25	30
Carrots	86.00	0.6%	40	45

Crop Type	Total Crop Area	Percentage of total area (%)	Production	
			Average Farmer (t per ha)	Top Farmer (t per ha)
Sweet Melons	86.00	0.6%	25	30
Water Melons	86.00	0.6%	25	35
Wine Grapes	34.00	0.2%	25	30
Tomatoes	17.00	0.1%	40	45
Total	**14 900.00**	**100%**		

[a] *Source:. WRC (2008)*

3.5.2 Wheat

Approximately 48% (i.e. 7 154 ha) of the total area under irrigation is wheat, which is irrigated.

The planting season for wheat starts in May - June with harvesting taking place in September -October. The average production yield for wheat is 5 tonnes per hectare.

3.5.3 Potatoes

Approximately 14.8% (2 201 ha) of the irrigated area in the Sand-Vet Irrigation scheme is under potatoes annually. The average production of potatoes is 22 tonnes per ha with the highest production of 27 tonnes per ha.

3.5.4 Maize

Approximately 14.8% (2 201 ha) of the irrigated area in the Sand-Vet Irrigation scheme is under maize annually. The average production of maize in the Sand-Vet Irrigation Scheme is 8 tonnes per ha with the highest production of 12 tonnes per ha. This is considered to be low. The average maize production is estimated to be 30 tonnes per ha.

The planting season for Maize starts in September / October, with harvesting taking place in April.

3.5.5 Other crops

There are a wide variety of other crops that are irrigated in the Sand-Vet Scheme area as illustrated in **Table 3.2** above which illustrates the significant crop mix in the irrigation scheme.

3.6 Historic water use

In order to evaluate the water use of the Sand-Vet Irrigation Scheme, the scheme was treated as having two sub-schemes namely the Erfenis Irrigation Scheme and the Allemanskraal Irrigation Scheme. The historic water use of each scheme is provided in the **Table 3.3** and **Table 3.4** below.

3.6.1 Historic water use - Erfenis Irrigation Scheme (Vet River)

The most recent six water years of continuous available data (1999/2000 to 2004/05) demonstrate a range of water use in the Erfenis Irrigation Scheme. Irrigation agriculture water demand has ranged from 24.34 million m^3/a in 2001/02 up to 32.64 million m^3/a in 2003/04, with a six-year average of 28.86 million m^3/a.

Over the 6 years approximately 73% of the water allocation was used by the irrigators in the Vet River canal system. The other major water use is the municipal use. Domestic water use has increased from 2.9 million m^3/a in 2001/02 to 5.4 million m^3/a in 2004/05 at a growth rate of approximately 6.1% per year.

The scheme also provides household domestic consumption for the farming communities. The household consumption has been constant over the 6 year period.

Table 3:3: Historic water use levels (million m^3/a) for Erfenis Irrigation Scheme area

User	1999/2000	2000/01	2001/02	2002/03	2003/04	2004/05	6 year average
Irrigation	32.20	30.31	24.34	36.44	32.64	17.22	28.86
Household	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Industry	-						
Municipal use	4.025	5.34	2.86	4.79	5.64	5.44	4.68

User	1999/2000	2000/01	2001/02	2002/03	2003/04	2004/05	6 year average
Total	36.61	36.04	27.59	41.63	38.68	23.06	33.94
Release into Vet Scheme	57.48	56.71	44.41	70.93	61.66	33.90	54.18
Gross Water Losses	20.87	20.67	16.81	29.30	22.98	10.84	20.24
Percentage Water Losses	36%	36%	38%	41%	37%	32%	37%

The historical records indicate that an average of 2.8 million m^3/a, was returned back to the river system at the tailwater ends and canal discharge points from branch canals.

The average volume of water diverted into the Erfenis irrigation canal system to match the irrigation and domestic water demands as well as the water losses was 54.18 million m^3/a. When compared to the demands from the canal infrastructure the average additional water to meet the water losses and operational spills is 37% of the total demand.

3.6.2 Historic water use - Allemanskraal Irrigation Scheme

The historic water use for Allemanskraal irrigation scheme area is provided in **Table 3.4** below. There were no historical records available for the water years of 2003/04 and 2004/05. Therefore the assessment has been undertaken for the first four years of available records. The average total water diverted into the Sand Canal system during the first four year period, was 59.76 million m^3/a.

Irrigation water requirements from Allemanskraal Dam has averaged of 32.78 million m^3/a, from 2000 to 2003. This is approximately 90% of the irrigation water allocation from the Allemanskraal Dam.

The other major water use is for municipal use. The data obtained is very erratic. There seems to have been a steady decrease in domestic consumption for the last three years of the assessment. The abstraction for domestic water use from Allemanskraal Dam has not been consistent with a significant abstraction in 1999/2000.

The gross water losses in the Allemanskraal irrigation canal system, taking into consideration evaporation and seepage losses as well as operational spills at the canal tail ends have averaged 20.46 million m^3/a. Therefore the average additional water to meet the water losses and operational spills is 34% of the total demand.

Table 3:4: Historic water use levels (million m^3/a) for Allemanskraal Irrigation Scheme area

User	1999/2000	2000/01	2001/02	2002/03	4 year average
Irrigation	32.49	32.38	30.57	35.66	32.78
Household	0.64	0.64	0.64	0.64	0.64
Industry	-				-
Municipal use	18.17	0.24	4.79	0.35	5.89
Total	51.30	33.26	36.00	36.65	39.30
Released into the Sand Scheme	59.20	66.83	52.85	60.16	59.76
Gross water losses	7.90	33.57	16.86	23.51	20.46
Percentage Water Losses (% of total demand)	13%	50%	32%	39%	34%

4 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

4.1 Overview

The Sand-Vet Irrigation Scheme comprises two storage dams, primary and secondary irrigation canal infrastructure; two balancing dams which regulate flows and reduce the time to delivery to irrigators as well as the canal distribution system which delivers the water ordered to the irrigators at their farm turnouts through a number of sluice gates and Parshall flumes.

4.2 Storage Dams

4.2.1 Erfenis Dam

Construction of the Erfenis Dam commenced in 1960 and it was commissioned in 1962. Its purpose was to address the water shortages and restrictions that the farmers were experiencing during the low flow periods because of dependency on the run-of-river abstraction from the Sand and Vet River.

The Erfenis Dam has a capacity of 207.5 million m^3 (see **Photo 4.1** below). Water is released from the Dam to supply the Vet River Irrigation Canal system. The volume of water released is dependent on the requests from irrigators and domestic consumers in the Vet River canal system, which is measured at the hydrological station downstream of the dam wall.

Photo 4.1: View of the Erfenis Dam

The dam also supplies river irrigators downstream after the confluence with the Sand River. At present the river irrigators are supplied through the canal tail ends which are currently not being electronically measured and therefore cannot be used to determine the irrigation water requirements/use by the river irrigators.

Besides releases for the Sand-Vet Irrigation Scheme, the Erfenis Dam is also intended to release water to meet the downstream environmental water requirements (EWR) of the Vet River System. At present this is not being released because the Reserve for the Vet has not yet been implemented.

4.2.2 Allemanskraal Dam

The Allemanskraal Dam is the second dam supplying irrigation water to the Sand-Vet Irrigation Scheme (see **Photograph 4.2** below). The Allemanskraal Dam has a capacity of 174.2 million m^3. The dam supplies irrigators with scheduled allocation situated in the Sand River catchment through the Sand River irrigation canal system. The irrigation water is released from the dam into the irrigation canal based on the demands of the irrigators who provide their weekly orders to the Sand-Vet Water User Association (WUA).

Photo 4.2: View of the Allemanskraal Dam wall

The volume of water released into the Sand River main canal is measured at the hydrological station as indicated in **Photo 4.3** below.

Photo 4.3: Photo of the flow gauging station into Sand River main canal downstream of Allemanskraal Dam

4.3 Irrigation conveyance infrastructure

Figure 4.1 below illustrates the conveyance and distribution infrastructure of the Sand-Vet Irrigation canal system. As discussed above, irrigation water is released from the two dams into the two main canals, namely the Sand and Vet River irrigation main canals to supply the respective irrigators in each sub-scheme of the Sand-Vet Irrigation Scheme.

The canal infrastructure comprises primary and secondary canal systems, as well as siphons at river crossings and road crossings in the towns. The total length of the two irrigation canal systems amounts to approximately 336.09 km, all of which is concrete lined.

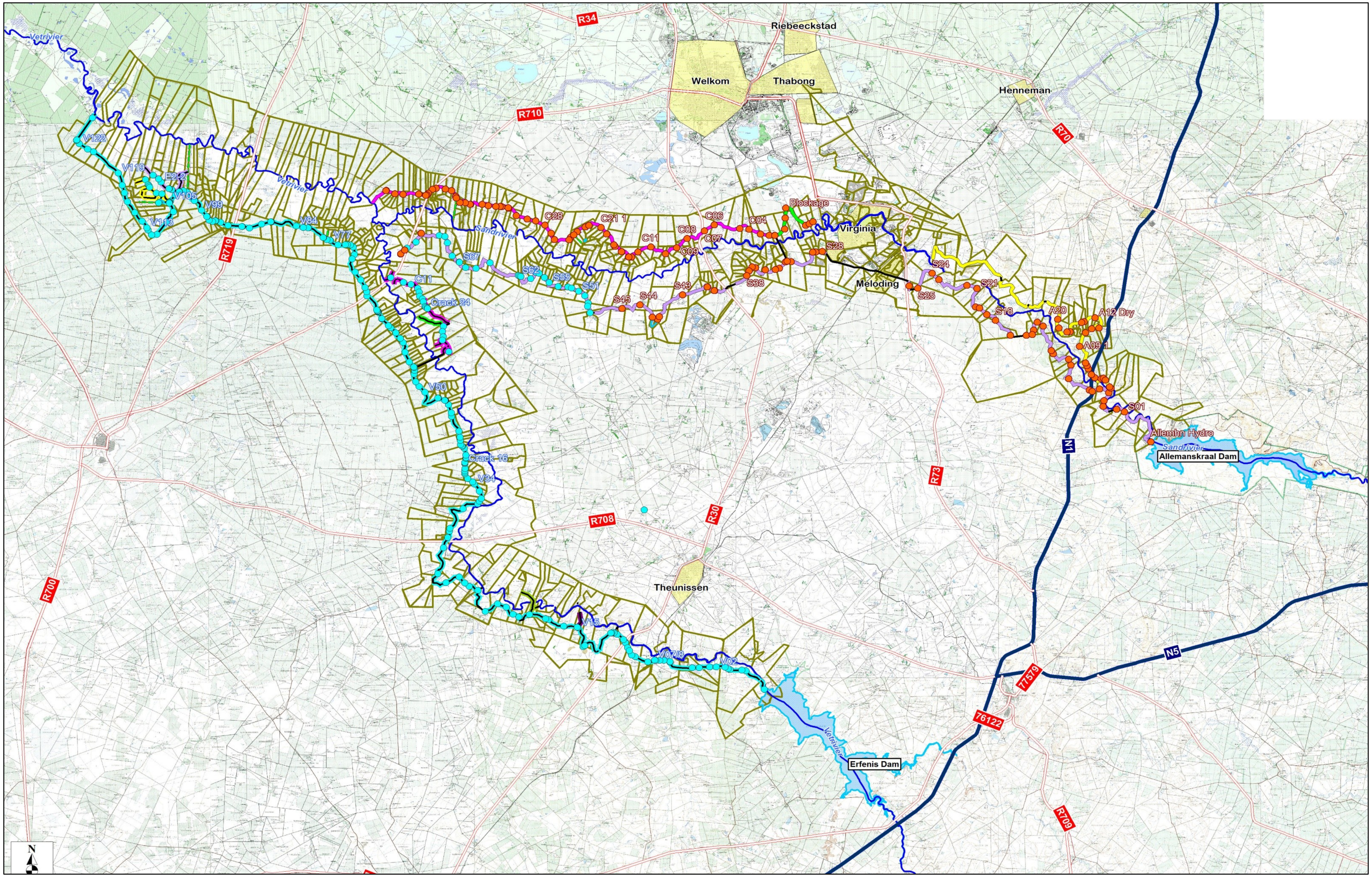

Figure 4.1: Sand-Vet Irrigation Scheme -Infrastructure

4.3.1 The Vet Irrigation Canal system

Table 4.1 below, lists the canal infrastructure on the Vet River canal system. The Vet River irrigation canal system comprises 126 km of main canal system known as the V canal as well as branch canals which make up approximately 37.6 km of concrete lined canals of varying sizes.

Table 4:1: Sand-Vet Irrigation Scheme – Vet River Irrigation Canal system

Item No	Canal Name	Type of canal	Total Length of canal (km)	Max. Hydraulic Capacity (m^3/hr)
1	Vet V Canal	Primary canal, concrete lined	251.43	17 000 - 250
2	Branch Canals			
2.1	A Canal	Branch Canal, concrete lined	1.7	1 000
2.2	B Canal	Branch Canal, concrete lined	8.75	1 800 -600
2.3	C Canal	Branch Canal, concrete lined	15.82	1 800 - 450
2.4	D Canal	Branch Canal, concrete lined	0.96	450
2.5	E Canal	Branch Canal, concrete lined	4.42	900 - 400
2.6	F Canal	Branch Canal, concrete lined	2.8	900
3	Drainage canals	Various		
Total length of Vet canal system (km)			285.86	

The Vet River irrigation canal system includes the following:

(i) *The Vet (V) main canal*: This is the main canal, which conveys the irrigation water from the Erfenis Dam. The irrigation water is released into the V canal from the Dam. The hydraulic capacity of the canal is 17 000 m^3/hr at the inlet. Because of changes in the canal geometry, the hydraulic capacity of the V canal reduces from 17 000 m^3/hr to 250 m^3/hr at the canal tail end downstream of the confluence with the Sand River.

(ii) *Branch canals:* There is approximately 37.6 km of branch canals in the whole of the Vet River canal system. There are six branch canals which are named in alphabetical order from the upstream branch canal as illustrated in **Table 4.1** above. The hydraulic capacity of the branch canals vary from the B and C canals which have a maximum hydraulic capacity of 1 800 m^3/hr to the D branch canal which has a maximum hydraulic capacity of 450 m^3/hr.

(iii) *Drainage canals*: There are a number of drainage canals from the above main canal and branch canals back to the Vet River system. These are to protect the Vet River canal system from damage due to the water draining from the farms.

4.3.2 Sand River irrigation canal system

Table 4.2 below, lists the canal infrastructure on the Sand River sub-scheme of the Sand-Vet Irrigation Scheme. The Sand River main canal starts downstream of the Allemanskraal Dam before it bifurcates into the A canal which is on the right bank of the Sand River.

The Sand River irrigation canal system comprises a total of 186.6 km of canal infrastructure which is mainly parabolic in shape although there are some trapezoidal canals, particularly on the branch canals.

The Sand River irrigation canal system includes the following:

(iv) *The Sand (S) main canal*: This is the main canal, which conveys the irrigation water from the Allemanskraal Dam. The irrigation water is released into the S canal from the Dam. The hydraulic capacity of the S canal is 15 292 m^3/hr at the inlet. Because of changes in the canal geometry, the hydraulic capacity of the S canal reduces from 15 292 m^3/hr to 300 m^3/hr at the canal tail end before the confluence with the Vet River on the left bank of the Sand River.

(v) *Branch canals:* There is approximately 91.2 km of branch canals in the whole of the Sand River canal system. There are three branch canals which are named in alphabetical order from the upstream branch canal as illustrated in **Table 4.2** below. The hydraulic capacity of the branch canals vary from the A canal which has a maximum hydraulic capacity of 765 m^3/hr to the C branch canal which has a maximum hydraulic capacity of 500 m^3/hr.

(vi) *Drainage canals*: There are a number of drainage canals from the above main canal and branch canals back to the Sand River system. These are to protect the Sand River canal system from damage due to the water draining from the farms.

(vii) *Siphons:* There are major siphons on the S canal as well as the branch canals. These are mainly to cross the rivers and roads in the irrigation scheme area (see **Figure 4.1** above).

(viii) *Canal tail ends*: There are three canal tail ends, one on the main S canal and two on the A and C branch canals. The tail end of the B canal ends at an irrigator's dam. The C canal tail end is also intended to supply the river irrigators downstream after the confluence of the Sand and Vet Rivers. The volume discharged at the canal tail ends reflects the amount of water that is diverted into the canal system and returned back to the Sand River having not been used.

Table 4:2: Sand-Vet Irrigation Scheme – Sand River Irrigation Canal system

Item No	Canal Name	Type of canal	Total Length of canal (km)	Max. Hydraulic Capacity m^3/hr
1	Sand S Canal	Primary canal, concrete lined	105.8	15292 - 300
2	Branch Canals			
	A Canal	Branch Canal, concrete lined	36.88	765 - 306
	B Canal	Branch Canal, concrete lined	7.15	750
	C Canal	Branch Canal, concrete lined	49.78	500
3	Drainage canals	Various		
Total length of Sand River canal system (km)			199.61	

4.4 Irrigation storage and regulation system

4.4.1 General

Besides the main dams and the canal system for conveyance of the irrigation water to the irrigators' farms, the Sand-Vet Irrigation Scheme also has two balancing dams, one in each of the two sub-schemes to reduce the time of delivery to downstream irrigators. The two balancing dams are indicated in **Figure 4.2** below and are discussed in the following sections.

4.4.2 Klipput Balancing Dam - Vet River sub-scheme area

The Klipput Dam is the balancing dam in the Vet River sub-scheme area of the Sand-Vet Irrigation Scheme. It provides the water requirements of the downstream irrigators supplied from the F canal as well as supplements the V canal by reducing the time of delivery to the downstream irrigators. The balancing dam also supplies domestic water supplies in the Tswelopele Local Municipality which include Bultfontein and Hoopstad.

The Klipput balancing dam is intended to provide significant operational flexibilities to the Sand-Vet River WUA depending on the distribution of users requesting water for the week downstream of the balancing dam. It is also likely to reduce the delivery time for the downstream irrigators supplied from the balancing dam.

However the storage capacity of Klipput Balancing Dam is not known which makes it difficult to determine the extent of its benefit to irrigation water management. Furthermore during the dry periods when the irrigation canals are emptied to carry out maintenance, it can provide water to the downstream irrigators thereby providing sufficient downtime for the canals to be properly maintained.

4.4.3 Palmietkuil Balancing Dam - Sand River sub-scheme area

The Palmietkuil Dam is the balancing dam in the Sand River sub-scheme area of the Sand-Vet Irrigation Scheme. It provides the water requirements of the downstream irrigators supplied from the S canal after the balancing dam by reducing the time of delivery to the downstream irrigators.

The Palmietkuil balancing dam is intended to provide significant operational flexibilities to the Sand-Vet River WUA depending on the distribution of users requesting water for the week downstream of the balancing dam. It is also likely to be reducing the delivery time for the downstream irrigators supplied from the balancing dam.

The storage capacity of Palmietkuil Balancing Dam is provided as 0.713 million m^3 when it was last surveyed in 1995 and a live storage capacity of 0.441 million m^3. Furthermore during the dry periods when the irrigation canals are emptied to carry out maintenance, it can provide water to the downstream irrigators thereby providing sufficient downtime for the canals to be properly maintained.

4.5 Irrigation infrastructure distribution system

As illustrated in **Figure 4.1** and **Tables 4.1** and **4.2** above, there are approximately 128.8 km of branch canals in both the Erfenis and Allemanskraal schemes which distribute the irrigation water to approximately 589 sluices and Parshall flumes.

The number of sluices supplying irrigators in the Vet River canal system amounts to approximately 244. On the Sand River irrigation canal system there are approximately 345 sluices supplying irrigators in the scheme area. The entire distribution canal infrastructure is concrete lined. The hydraulic capacity of the different distribution canal infrastructure was available; which can be used to compare with the maximum and average demands expected in the different irrigation sections.

4.5.1 Farm Dams

The irrigation water supplied by the Sand-Vet WUA is delivered mainly to the irrigator's farm dams. The actual water use is therefore dependent on the irrigation scheduling requirements of the individual farmer from the farm dam based on the crop water requirements and the timing of irrigation as required from the soil-water requirements.

4.6 Flow Measurement and telemetry system

4.6.1 Measurement of flow into the scheme area

Figure 4.2 below provides the existing location of the flow measurement system to manage the irrigation water requirements in the Sand-Vet irrigation scheme.

As illustrated, the first measurement of the water diverted from the Allemanskraal Dam into the Sand River canal system is located immediately downstream of the dam. This comprises a flow recorder as well as the 10 ft Parshall flume. There is no telemetry system linked to the flow measurement at the Sand River main canal inlet.

A 10 ft Parshall flume was installed by the hydrological branch of DWA at the inlet of the Vet River main canal downstream of the Erfenis Dam.

4.6.2 Measurement into the various canal systems

The Sand-Vet Irrigation Scheme has two main irrigation canals, namely the Vet River canal supplying the water users on the Vet River and the Sand River canal system supplying the water users on the Sand River. There are flow measuring weirs constructed at the inlets of these canals.

4.6.2.1 Flow measurement in the Sand River canal system

In the Sand River canal system there are some flow measurements which include Parshall Flumes as well as flow meters besides the Parshall flume at the inlet into the main canal. The following flow measurements exist on the Sand River canal system:

(i) There is a 6 ft Parshall flume which measures flows at the inlet of the A canal (see **Photo 4.4** below).

(ii) There is a flow measurement where the S canal bifurcates into a siphon that carries irrigation water to the right bank of the Sand River to supply the B and C canals. Therefore a water balance for the B-C canal sub-scheme can be prepared based on the measurement at the Parshall flume.

Photo 4.4: Flow measurement at the inlet to the A canal siphon on the Sand River canal system

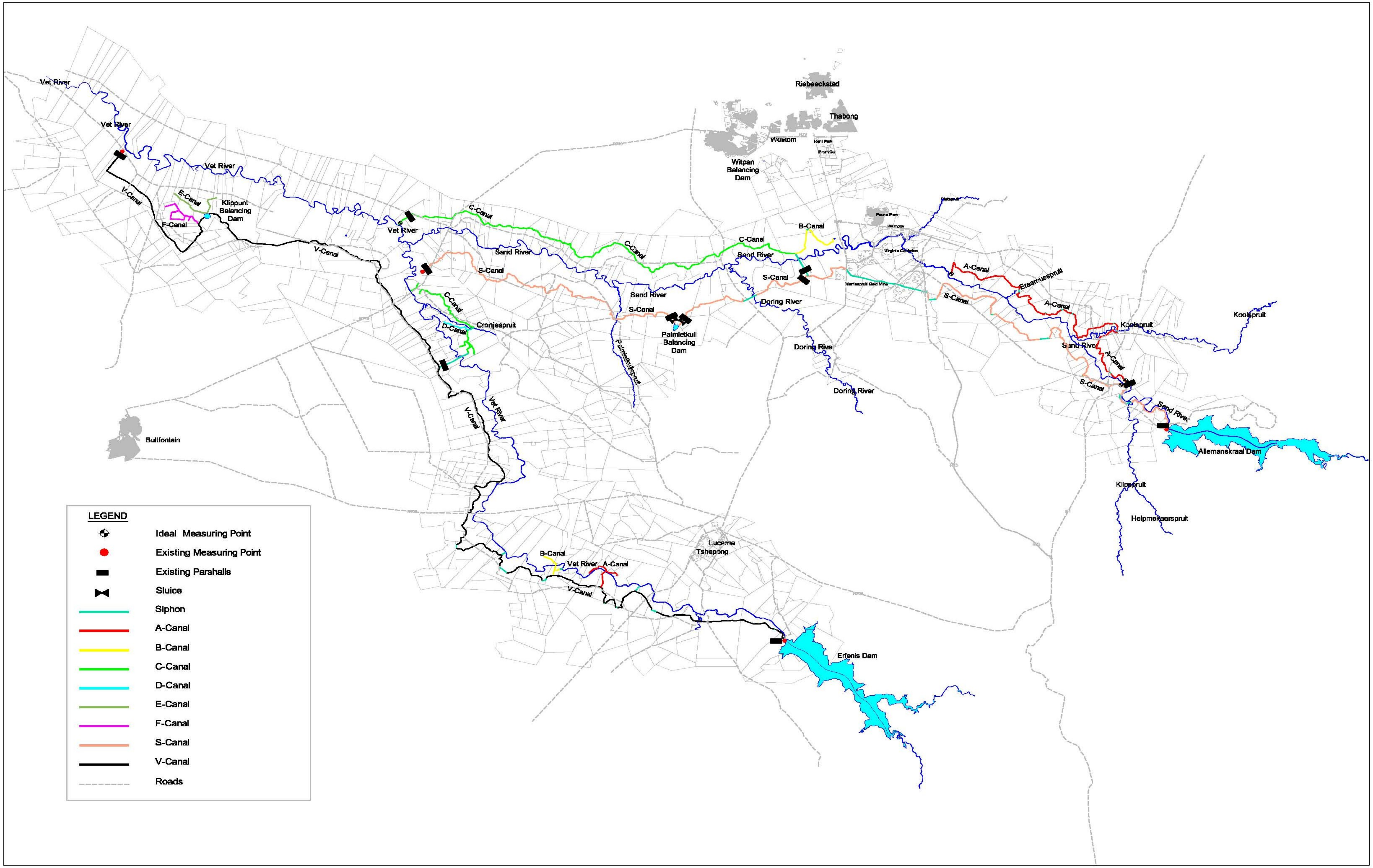

Figure 4.2: Schematic layout of the Sand-Vet Scheme with the existing water measurement system

(iii) There is a measuring structure on the S canal where a flow meter used to be. However there is no flow measurement to determine the flows in the S canal downstream of the siphon to the B and C canal system.

(iv) There is a flow meter to measure the inflow into the Palmietkuil Balancing Dam as well as a flow measurement or Parshall Flume at the outlet of the balancing dam.

(v) There are Parshall flumes measuring the canal tail ends at the S canal as well as the C canal system.

4.6.2.2 Flow measurement in the Vet River canal system

As is the case with the Sand River canal system, there are flow measurements along the V canal as well as flow measurements on the branch canals as discussed below:

(i) There is a 2ft Parshall flume flow measurement structure on the A canal off take.

(ii) There is a 1ft Parshall flume flow measurement structure on the B canal offtake.

(iii) There is a Parshall Flume which measure and monitors the flows into the C canal just before the siphon which takes irrigation water to the right bank of the Vet River.

(iv) There is a flow measurement structure and a 1 ft Parshall flume to the measure the flows into the D canal.

(v) There is a flow measurement structure on the E canal offtake. The 2ft Parshall can be used to measure and monitor the flows into the E canal and compare with the irrigation water applications

(vi) There is a 2ft Parshall flume flow measurement at the F canal off take.

(vii) There is an 8 ft Parshall flume at the canal tail end of the V canal.

4.6.3 Measurement at irrigators take off point

The Sand-Vet Water User Association (WUA) measures the weekly volume of water delivered to the water users at the farm gate using sluice gates and Parshall flumes. There are approximately 589 sluice gates in the irrigation scheme area.

4.6.4 Telemetry system

The Sand-Vet Irrigation Scheme has no telemetry system and relies on manual flow measurements by water control officers to monitor the flow at various sites of the scheme. OTT recorders/digitisers are installed at some points, but these are not operational.

5 INFRASTRUCTURE CONDITION ASSESSMENT

5.1 Overview

In order to determine the condition of the canal infrastructure, a methodology has been developed known as the Rapid Assessment Tool (RAT). This is a combination of methodologies designed to provide a quick and cost-effective analysis of condition within an irrigation scheme.

The main objective of undertaking condition assessment is to define the extent and seriousness of problems contributing to poor conveyance efficiency.

RAT methodologies include surveys, rating of infrastructure, flow measurement, seepage loss tests, and GIS-based mapping and analysis, among other activities. These methodologies are still evolving. Two visual rating procedures have been developed:

- water supply conditions (“head conditions”)
- canal conditions

The overall goal of this effort is to provide information which will allow decision makers involved in irrigation resource management to assess and compare the rehabilitation needs of irrigation networks.

Already a condition assessment survey was conducted by Aurecon on behalf of the Sand-Vet Water User Association (WUA) which has followed a more or less similar framework for assessing the condition of the canal infrastructure. The findings of the Aurecon field survey and our fieldwork have been combined to determine the condition of the canal infrastructure in the Sand-Vet irrigation scheme.

5.2 Canal Condition Evaluation

Although it was not possible to undertake condition assessment of the irrigation canals of the Sand-Vet Irrigation Scheme, because at the time of developing the WMP, there were no dry periods to inspect the canals, the results of the Aurecon comprehensive investigations and our preliminary investigations have been used to provide a situation assessment of the condition of the infrastructure.

Before discussing the condition of the Sand-Vet irrigation canal system, a list of criteria for undertaking canal condition assessment was developed for use in the implementation phase. The Canal Condition Evaluation component of RAT includes visual rating methodologies on:

- the general condition of the canal
- conditions which indicate seepage or structural problems

There are service factors that are used in this procedure which may be grouped as follows:

- general condition of the canals
- presence of cracks (hairline, pencil-size, and large)
- amount of patchwork
- vegetation in canal and along embankment

Tables 5.1 - 5.5 provide details on the rating factors and definition of numerical values that are recommended to be used during the dry periods.

Table 5:1: General Condition rating

Rating	Definition
1	Excellent – no visible cracks or vegetation
2	Good – having cracks greater than 3.0 m and some weeds
3	Fair – cracks 1.5-3.0 m apart, with moderate vegetation in canal and drainage ditch
4	Poor – cracks 1.0-1.5 m apart, with dense vegetation in canal and drainage ditch
5	Serious Problems – visible large cracks less than 1.0m apart with lush vegetation

Table 5:2: Criteria for hairline, pencil size and large cracks

Rating	Definition
1	None to Sparse
2	Greater than 3.0 m apart

Rating	Definition
3	1.5 – 3.0 m apart
4	1.0 – 1.5 apart
5	Less than 1.0 m apart

Table 5:3: Noticeable amounts of maintenance and repair (patchwork

Rating	Definition
1	None to a few areas
2	A few areas
3	Sparse
4	Moderate
5	Severe

Table 5:4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

Table 5:5: Vegetation in drainage canals and along the outer embankment of the levee

Rating	Definition
1	Normal; rain-fed weeds only
2	Canal fed grass or small weeds only
3	Moderate; bushes & some small to no trees with no water near levee or drain
4	Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
5	Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

5.3 Results and analysis of canal infrastructure condition assessment

5.3.1 Overview

The condition assessment of the canal infrastructure of the Sand-Vet irrigation scheme was done for the two sub-schemes, namely the Sand River canal system from the Allemanskraal Dam and the Vet River canal system from the Erfenis Dam up to the canal tail ends. These are discussed below. The findings of the condition of the infrastructure are discussed in the following sections.

5.3.2 Condition assessment of the Sand River canal infrastructure

5.3.2.1 Condition assessment of the Sand River main canal

An assessment of the condition of the Sand River main canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that can be observed.

There are cracks and vegetation growth that was identified in the Sand River main canal from the Aurecon site survey. This is illustrated in **Photo 5.1 and Photo 5.2** below. The condition of the main S canal section between the S 32 and the Palmietkuil Balancing Dam is considered to be poor and was given a condition rating of 4. This will require urgent attention because the scheme is losing significant volumes of water through leakage.

Photo 5.1: Open joints between the concrete panels as well as growth in the canal

Photo 5.2: Major Cracks on the S canal as well as vegetation growth in the joints of the concrete panels

5.3.2.2 Condition assessment of the siphons in the Sand River main canals

Although the assessment was conducted when the Sand River canal system was operational, the condition of the siphons could be determined by visual inspection of any blockage of the siphons.

Three siphons, namely the one on the S canal before Virginia, the siphon on the A canal as well as the siphon on the B canal were found to be blocked and leaking as a result. This is illustrated in **Photo 5.3** to **Photo 5.5** respectively. It is understood that the siphon on the S canal has been constantly getting blockages with the last major blockage taking place in 2009 whereafter it was cleaned.

The condition of the pipes on the S canal siphon was identified by Aurecon to be in a poor state. This may mean that there is a need to replace some of the pipes besides flashing and cleaning of the siphon.

Photo 5.3: Leakage due to blockage on the S canal

The impact of the blockage on the A canal section resulted in the canal overflowing resulting water losses in the A canal section (see **Photo 5.5** below).

Photo 5.4: Leakage on the A canal siphon as a result of the blockage

Photo 5.5: Overflow of the A canal due to siphon blockage

Photo 5.6: B canal spilling as a result of siphon blockage

5.3.3 Condition assessment of the Vet River canal infrastructure

5.3.3.1 Condition assessment of the Vet River man canal

An assessment of the condition of the Vet River main canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that can be observed.

There are major breaks in the V canal where sections or whole sections of the concrete panels have been washed away either due to drainage problems or the age of the concrete panels. Furthermore there was vegetation growth identified in the Vet River main canal from the Aurecon site survey. This is illustrated in **Photo 5.7 and Photo 5.8** below.

The condition of the main V canal section between the V36 and V42 is considered to be poor and was given a condition rating of 5. This will require urgent attention because the scheme is losing significant volumes of water through leakage.

Photo 5.7: Concrete panels in the V canal eroded due to drainage problems

As illustrated in **Photo 5.8** below, besides the sections of concrete lining missing, there has been major maintenance and repairs that have been done on this segment of the canal.

Photo 5.8: Concrete panels missing on the V canal including extent of repairs

Figure 5.1 below indicates the general condition rating of the different segments of the Sand-Vet Irrigation Scheme canal system. This will form the basis for prioritisation of the canal segments for maintenance including any canal section renewals that will be required.

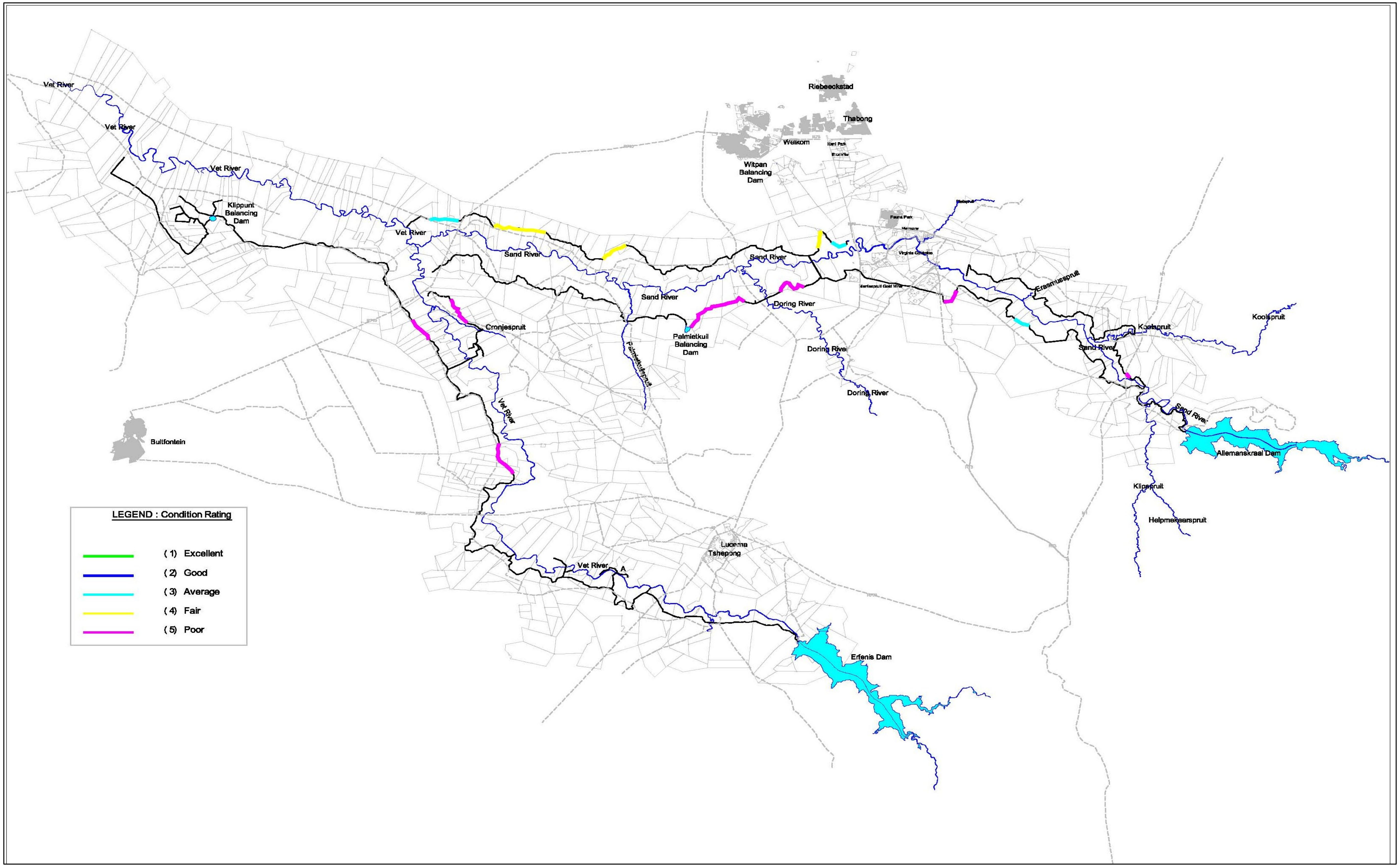

Figure 5.1: General Condition Rating of the surveyed canal segments

6 SCHEME OPERATIONS AND OPERATING PROCEDURES

6.1 General scheme options

The Erfenis Dam and Allemanskraal Dam were constructed in order to develop the Sand-Vet irrigation scheme by providing irrigation water and improving the assurance of supply to the irrigators. There was limited water available for the scheme before the dams were constructed as it would have experienced irrigation water shortages on an annual basis, during the low flow periods.

Since the two dams became operational, the irrigation scheme has still experienced some water restrictions, where the scheduled quotas have not been delivered to the farmers. Since the 1999/2000 water year, the average amount of water released into the Scheme has been 71% of the scheduled allocation. There have been periods such as in 2004/05 when only 45% of the scheduled allocation was diverted while in 2001/02 only 59% of the scheduled allocation was diverted. The management of irrigation water requirements during periods of water shortages are discussed in this chapter.

The two dams are owned and operated by the Department of Water Affairs (DWA). Water is only released for the Sand-Vet Irrigation Scheme to meet the irrigation water requirements as well as industrial and domestic water users, based on the weekly requested demands from users in the scheme area. The water ordering and delivery procedures are discussed in the following section.

6.2 Water ordering and delivery procedures

6.2.1 Overview

The Sand-Vet WUA has formalised and documented scheme regulations that describe the procedures for application and delivery of water to users in the scheme. The irrigation water year runs from 1 April to 31 March of the following year.

In order to ensure that the irrigators receive their scheduled quota or a portion of their scheduled quota, if the available water is not sufficient to meet the full allocation as and when required, the Sand-Vet WUA operates the irrigation scheme based on "delivery on request" where each water user (irrigator) must submit a written request on a weekly basis and the water is delivered to some 589 abstraction points along the canal systems.

6.2.2 Operation of matching irrigation supply and demand

The procedures followed by the irrigators in ordering their water requirements are as follows:

(1) Each irrigator determines how much water they require to order for the following week from the scheme, based on their irrigation scheduling which is dependent on the type of crops being irrigated as well as their available scheduled quota.

(2) The irrigators submit their requests to the Sand-Vet WUA on the appropriate application form, before Thursday, for their irrigation water requirements to be delivered the following week. Irrigators must specify their needs clearly on the request form and the WUA will endeavour to supply the water, as requested.

(3) The scheme operators at the Sand-Vet WUA then reconcile the total requested volume from the beginning of the water year with each irrigator’s scheduled quota. The total volume of water required in each branch canal, is then calculated to determine how much water should be supplied within the maximum of 132 hours in each of the different sections of canal systems based on the request. This is compared with the hydraulic capacity of the canal section to ensure that either the volume of water ordered is above the threshold for delivery into the canal section or the volume of water ordered including the expected canal losses does not exceed the maximum hydraulic capacity of the canal system.

(4) The above process is repeated from the branch canals up to the Sand River main canal or the Vet River main canal to determine how much water needs to be released from the Allemanskraal Dam or the Erfenis Dam respectively. This includes the total transmission (compensation) losses required to deliver the requested water.

(5) The requested water, including the transmission losses for the different canal sections are then reconciled with the available water in the balancing dam in order to determine the volume of water required to be released from the dams over the 132 hours of the week.

(6) Water is then requested by the scheme operators to DWA from Erfenis Dam and Allemanskraal Dam in time to meet the requested water for the following week starting on Monday 05h00 when the irrigation reaches the first irrigators till Saturday 17h00 when the sluice gates are closed.

(7) In the event that the requested volume exceeds the maximum hydraulic capacity of the canal systems, the requested volumes will be reduced proportionally to the determined hydraulic capacity of the canal infrastructure, taking into account the estimated water losses.

(8) In order to reduce the water losses, the Sand-Vet WUA also determines the minimum volume of water that can be delivered in each canal system without significant water losses. If the requests amount to less than the minimum threshold for release, then the irrigators in that particular section will not receive their requests. This procedure has not been document in the existing scheme regulations.

(9) The Water Control Department (WCD) of Sand-Vet WUA sets up a flow chart of levels of the sluice gates and Parshall flumes based on the water requests of the week. These are given to the Water Control Assistants (WCAs) to set the sluices at levels provided on the chart.

(10) The information regarding the volume of water allocated to each user is then communicated back by the Section Managers to the consumers including their remaining scheduled quota.

The above water ordering and delivery procedures have not been formally documented. It is important that the procedures are formally documented to enable all irrigators as well as the Section Managers to be aware of the procedures. This will be useful particularly for new irrigators and Section Managers to understand the procedures for ordering and processes for delivering the irrigation water requirements.

It is important to note that, in the Sand-Vet Irrigation Scheme, the water is supplied through sluice gates with the Parshall Flumes measuring the flow and volume delivered by the scheme to the irrigator, which are adjusted according to the water level (i.e. pressure) provided by the long weirs in the canal system. Due to the pressure variance in the canal system there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%.

The stop and start nature of the operation of the canals and laterals increases the extent of evaporation as well as losses due to seepage as a result of changes in the capillary forces and gravity as well as changes in the water table.

6.3 Procedures during water supply shortages

There have been water shortages even with the construction of the two dams. Therefore there is a need to have some procedures in place on how the irrigators will be supplied during water supply shortages. There appear to be some procedures that are followed, although not formalised to address any water supply shortages. These include the following:

(i) At the start of the water year, the available water from Erfenis Dam and Allemanskraal Dam that can be supplied to irrigators is reconciled with the scheduled quota. Where it is envisaged that less water is available, the allocations to irrigators are curtailed equitably.

(ii) Priority is given to supply domestic water users in the event of water shortages. This is supplemented by transfers from the Vaal River System.

(iii) The available water allocation to each irrigator is then supplied based on the delivery on request basis.

(iv) The available water is reviewed during the course of the water year depending on whether rainfall and any changes are then made to the annual water allocation

6.4 Water Transfers

6.4.1 Temporary water transfers

There may be periods when existing irrigators exhaust their scheduled quota before the end of the water year and may require additional irrigation water. The scheme regulations allow for applications to be made for temporary transfer of water from one property to another depending on the following conditions:

(i) Irrigators cannot make a temporary transfer to lands that do not have any water rights. This is because the canals were designed to supply the existing water entitlements and are not likely to meet the additional demand.

(ii) Irrigators can however transfer water temporarily to another land which has a water use entitlement if there are shortages. However the transfer is subject to the canal having sufficient capacity for the additional stream.

(iii) Furthermore the temporary transfer can only be supplied during those periods that the canal feeding existing irrigators is not being required by other irrigators. This should however be arranged with the Scheme Manager prior to delivery.

The irrigators then approach the Sand-Vet River WUA to facilitate the temporary transfer with the Department of Water Affairs (DWA) Free State Regional office. The approval will only be granted based on whether there is sufficient hydraulic capacity of the irrigation canal system for the transfer to be delivered to the temporary user.

Currently the WUA is not involved in any of the negotiations as the water use entitlements are held by the individual water user.

6.5 Water pricing structure

6.5.1 Structure of irrigation water charges

The Sand-Vet WUA scheme regulations have structured the water rates to be a two part tariff structure. The first part is the basic charge or fixed charge which has been set at 60% of the scheduled allocation. Therefore water users such as canal irrigators are required to pay 60% of their R1 559.16 per ha per annum or R935.5 per ha per annum regardless of whether they use the water or not.

In the case that less than 60% of the scheduled allocation is provided by the Sand-Vet WUA, rebates will be payable to the water users. The rationale for setting the basic charge is to minimise volatility in revenue to operate and maintain the Sand-Vet Irrigation Scheme.

The remaining 40% of the scheduled quota is paid to the scheme based on the actual volume of water the water user takes up during the irrigation water year. This is being done to encourage water users of the Sand-Vet Irrigation Scheme to use water efficiently in that water users do not necessarily have to take up their full scheduled allocation as they will not have to pay for the portion they do not use. This reduces their costs of farming.

The current water pricing structure for the Sand-Vet Irrigation Scheme provides some means of providing incentives for water users to improve their efficiency. However the fact that the water rate for the 40% of the scheduled quota is still charged at the same water rate, which in the case of canal irrigators is 21.66 c/m^3 of water taken above the 60% of the scheduled quota, negates the incentive. The incentive will be beneficial with an incremental water rate system.

6.5.2 Collection of the irrigation water use charges

The Sand-Vet River WUA is responsible for collection of the water use charges on behalf of the Department of Water Affairs (DWA). The WUA collects the money for the O&M charge, which it uses to pay for the operation and maintenance of the irrigation scheme.

Irrigators, domestic and industrial users are billed directly by DWA for the WRM charges.

7 DETERMINATION OF UNAVOIDABLE WATER LOSSES IN SAND-VET IRRIGATION SCHEME

7.1 OVERVIEW

Before determining the irrigation water use efficiency of the Sand-Vet Irrigation Scheme, it was important to assess the expected seepage and evaporation losses based on the premise that the irrigation scheme infrastructure is being maintained as well as taking into account the useful life of the canal system infrastructure.

This is discussed in the following sections of this chapter.

7.2 Overview of the water losses

7.2.1 Overview

According to Howell (2001), there are four basic losses that can result when water is diverted for irrigation. This can be described as follows:

1) Part of the water is consumed in evaporation (e.g. from channels) and transpiration (e.g. vegetation growing next to the channel).
2) Some water percolates to surface or subsurface areas (e.g. canal seepage or deep percolation) and cannot be recaptured (e.g. in the vadose zone, the ocean, or a salt sink) or can be recaptured (e.g. interceptor drains into a drainage canal or a drainage well) and used as an additional supply.

Quantifying these losses is the first step in determining the level of efficiency of conveyance and distribution systems and to compare with the Best Management Practices (BMP) for each of the identified water losses.

In order to establish the generally accepted practice that results in more efficient use, conservation or management of water, the estimate of the level of acceptable water losses due to seepage, evaporation and leakage was determined as part of setting the Best Management Practices (BMP) for the Sand-Vet Irrigation Water Scheme.

7.2.2 Unavoidable water losses due to canal seepage

Canals continue to be the major conveyance systems for delivering water for irrigation agriculture. The seepage losses from irrigation canals constitute a substantial percentage of usable irrigation water. Therefore computation of the canal seepage losses is an important aspect of determining the best management practices for sustainable irrigation water management practices for the scheme.

Canals are often lined to reduce the seepage losses as is the case in the Sand-Vet Irrigation Scheme. A perfect canal lining which is well maintained significantly reduces the amount of seepage although the canal lining deteriorates with time and becomes ineffective in controlling the seepage.

Seepage losses from concrete lined, and unlined canals are normally expressed in l/s per 1 000 m^2 of wetted area and appear to fluctuate between approximately 0.35 l/s per 1 000 m^2 wetted area and 1.9 l/s per 1 000 m^2 (Reid, Davidson and Kotze (1986). For design purposes Butler (1980) suggested a value of 1.9 l/s per 1 000 m^2 wetted area. Therefore depending on the wetted area, this could result in an unavoidable loss rate of up to 15% of the inflow into an irrigation canal.

The seepage losses from a concrete lined canal system depend on a number of driving factors among which the following can be said to have a marked influence:

(i) The hydraulic conductivity of the canal lining which is the concrete;

(ii) Subsurface condition in so far as they affect drainage and the groundwater table;

(iii) The age of the canal and the amount and fineness of the material carried in suspension;

(iv) The flow of water in the canal and its depth and velocity;

(v) The relation between the wetted perimeter and other hydraulic elements of the canal, particularly the discharge;

(vi) The temperature of the water.

In order to determine the seepage losses of the Sand River canal as well as the Vet River canal system, the geometry of two canals were collected and used to determine the wetted perimeter and flow area of each segment of the canal. The formula used to calculate the seepage losses for curvilinear canal systems (i.e. parabolic canal geometry) is expressed as follows:

$$q_s = k*y*F \quad (1)$$

where q_s = seepage discharge per unit length of canal (m_2/s); k = hydraulic conductivity of the lining (m/s); y = depth of water in the canal (m); F = function of channel geometry (dimensionless); and yF = width of seepage flow at the infinity. The seepage function, F for parabolic canals was taken as

$$F = (T/y) + Pi^{\wedge 2}/4G \quad (2)$$

Where

T =top width of the channel at the water surface (m); y= flow depth of water (m); and G = 0.915965594, known as Catalan's Constant.

The seepage loss per unit length was then calculated using the hydraulic conductivity of the concrete lining; the canal geometry and the seepage rate based on the wetted perimeter. The expected seepage losses for the different canal sections in the Sand River and Vet River canal system are indicated in **Table 7.1** and **Table 7.2** below.

As illustrated in **Table 7.1** below, the minimum seepage losses expected in the Sand River canal system is 4.45 million m^3/a in order to supply the scheduled allocation of 36.4 million m^3/a. As a percentage of the scheduled allocation, the minimum seepage losses that should be provided as additional to the scheduled allocation are 12% of the scheduled allocation.

Table 7:1: Expected seepage losses in the Sand River canal system

Canal Name	Max Hydraulic Capacity (m^3/hr)	Seepage Rate ($m^3/s/m^2$)	Canal Length (km)	Expected Seepage losses (million m^3/a)
S Canal	12 642.00	0.0815	106.33	2.39
A Canal	15 292.00	0.3671	36.88	1.01
B Canal	4 890.00	0.2115	7.27	0.26
C Canal	3 670.00	0.0722	49.78	0.79
Total Seepage Losses Sand River Canal			200.25	4.45

In the case of the Vet River canal system, the minimum expected seepage losses is 6.06 million m^3/a. The expected seepage losses are therefore approximately 15% of the scheduled allocation. This has been determined taking into account the age of the canal infrastructure but assuming the canal system is well maintained and the renewal and refurbishment requirements are carried on time in order for the canal system to deliver the expected level of service to the irrigators.

Table 7:2: Expected seepage losses in the Vet River canal system

Canal Name	Max Hydraulic Capacity (m^3/hr)	Seepage Rate ($m^3/s/m^2$)	Canal Length (km)	Expected Seepage losses (million m^3/a)
V Canal	17 000.00	0.2346	251.43	5.71
A Canal	1 000.00	0.0074	1.70	0.01
B Canal	600.00	0.0076	8.75	0.07
C Canal	1 800.00	0.0187	15.82	0.18
D Canal	450.00	0.0087	0.96	0.01
E Canal	900.00	0.0306	4.42	0.05
F Canal	900.00	0.0135	2.80	0.03
Total Seepage Losses Vet River Canal			285.87	6.06

When the above percentage seepage losses are compared with the best management practices and taking into account the water table levels in the Sand Vet irrigation scheme, canal seepage would range between 12% and 15% of the input volume (Streutker, 1981 and Muller, 1984). Other factors that have an effect on seepage losses are, *inter alia*, soil characteristics, water depth in the canal, flow speed and hydraulic profile of the canal, soil capillary tension, amount of sediment, algae, etc.

The minimum seepage losses as calculated above have been compared with the water losses of each canal system in the Sand Vet Irrigation Scheme based on the water balance assessment which is discussed in the following chapter. The difference in the water losses and the minimum seepage losses were taken as avoidable water losses.

7.2.3 Unavoidable losses due to surface evaporation

The evaporation loss, expressed as a percentage of total inflow was determined based on the total surface area of the irrigation canals, the mean annual evaporation (MAE) based on the A-pan evaporation figure for the 1957 - 1979 hydrological record.

The total annual evaporation from the irrigation canal surface area was determined to be 0.26 million m^3/a. This was taken as the average over the seven years records. Based on the calculated evaporation losses, the evaporation losses as a percentage of the total inflows was determined to be 0.35%. This is within the margin of error for the estimated evaporation losses at approximately 0.3% of total released volume (Reid, Davidson and Kotze; 1986).

Therefore the BMP evaporation loss in the Sand-Vet Irrigation Scheme area that was used was 0.35% of the total inflows which was taken as the unavoidable evaporation losses for the scheme area. This amount has been taken out of the gross water losses.

8 SAND-VET IRRIGATION SCHEME WATER BALANCE ASSESSMENT

8.1 Overview

The key aspects in developing and implementing water management plans (WMP) in the agricultural sector, is to understand:

- how much water is released into the irrigation scheme area;
- how much water is delivered to the various sub-schemes or sections of the irrigation scheme;
- how much water is delivered to the irrigators in the various sub-schemes, and
- how much water is returned to the river/water resource.

This approach provides the irrigation water balance assessment to account for any inefficiency in irrigation water management in the scheme.

The Sand-Vet Irrigation Scheme uses the Water Administration System (WAS) to account for the water used by the scheme and the water use efficiency accounting report (WUEAR) for reporting on matching irrigation supply and demand (MISD).

The purpose of calculating the water balance and water balance assessment is to help Sand-Vet Irrigation Scheme to answer three questions:

1) Is the water being distributed equitably among the irrigators and domestic and industrial consumers in the scheme?
2) How efficiently is water being used within the scheme area?
3) Is the scheme receiving its target allocation of water from the sources of supply?

The irrigation water balance assessment for the Sand-Vet Irrigation Scheme was undertaken at two levels. The first level was to determine the overall water balance assessment, with a view to determining the extent of water losses at an irrigation scheme level. The second level was a water balance assessments for the Vet canal system and the Sand Canal system.

8.2 Quality and integrity of the available information

8.2.1 Sources of information

It is however important to note the available records from the WUEARs that were used to conduct the water balance assessment for the two schemes in the Sand-Vet irrigation scheme are for the period 1999/00 to 2004/05. Another source of information for the volume of water released from the Erfenis and Allemanskraal Dams was from the DWA, hydrological branch. This was used to compare the inflows into the irrigation scheme.

There was initially no information from the recent water years. However the last year of records (i.e. water year starting June 2011 to May 2012) are now available and have been used to determine the water balance of the Sand River and Vet River canal systems. This has been used to update the water balance assessment as discussed later in this section.

8.2.2 Integrity of the available data and information

The data and information used to date to carry out the water balance assessments for the Sand-Vet irrigation scheme was from the available WUEARs prepared by the Water User Association (WUA). The data used to prepare the WUEARs were based on measured data of the inflows into the canal irrigation; measured data on the balancing dam at the beginning of the irrigation cycle; measured data of the irrigation water requested as well as measured data on canal spills at the tail ends.

Not all canal tail ends are measured as some of the canal tail ends end at the irrigators dams and any spills may have been accounted for in the amount of water delivered to the irrigator.

The water balance assessment has not included the precipitation during delivery of water to irrigators. The assumption made is that the amount of precipitation during delivery of irrigation water is negligible. This may not be the case during the rainy season and consideration of incorporating information regarding precipitation should be made in future irrigation water use accounting.

There were gaps in monthly records from the WUEARs in some of the years. In order to evaluate the full year a process of patching, using average monthly records for the year was conducted This has resulted in patching some of the records to determine the total annual inflow and outflow records in some of the years.

8.3 Evaluation of the operational losses

8.3.1 Overview

The determination of operational losses (and mechanisms to minimise it) is one of the most important tools for improving irrigation water use efficiency levels. Higher accuracy in determining these losses, can underpin the efforts to decrease losses over the extent of the whole canal distribution system. Decreasing “avoidable losses” from irrigation canals is often the only “relatively” inexpensive method available when contemplating water management measures.

Avoidable losses occur as a result of inefficient management in the operation of the canal system and can mainly be attributed to poor canal maintenance (leaks), incorrect headwork and inefficient runtime release determination, inaccurate water measuring structures and other restricting factors such as algae growth, etc.

Unavoidable losses from canal systems can be attributed to seepage and evaporation and is related to the surface area of water in the canal, wetted perimeter area of the canal and to the structural condition of the canal network.

8.3.2 Determination of the water losses

Because the historical records had many gaps and were mainly estimates, these have not been used in the water balance assessment. Instead the water balance assessment for the Sand-Vet Irrigation Scheme has been based on the 2011/12 water year of records for the current irrigation water year (2011/2012). The water balance was based on information from the primary data on applications and releases provided by the scheme operators.

The records of inflows or releases into the canals which consist of all the sources of water supply to the Sand-Vet Irrigation Scheme as well as the irrigation and industrial water use demand were provided on a weekly basis. These flows (weekly inflows and irrigation water demands) were used to determine the water losses for the Sand River and Vet River canal systems.

8.4 Water balance assessment - Vet River canal system

8.4.1 Overview

The Sand-Vet irrigation scheme was analysed on the basis that it comprises two irrigation schemes namely the Vet River canal system which is supplied from Erfenis Dam up to including the irrigators downstream after the confluence of the Vet River and Sand Rivers. The other irrigation scheme within the Sand-Vet irrigation scheme is the Sand River canal system which is supplied from the Allemanskraal Dam in the Sand River catchment.

Two water balance assessments have been prepared to assess the extent and magnitude of irrigation water use efficiency in each irrigation scheme. This is discussed in the following sections.

8.4.2 Inflows into Vet River canal system

8.4.2.1 Releases from Erfenis Dam

The first measurement of water takes place at the Erfenis Dam, where water is released from the dam into the main irrigation canal on the left bank of the Vet River. The weekly records of inflows into the main canal, from June 2011, the beginning of the water year were used to generate the inflows into the Vet River canal system as illustrated in **Table 8.1** below. Based on the monthly records for the full water year, the total inflow into the Vet River canal system for the 2011/12 water year of available records was 70.86 million m^3/a.

The allocation for irrigation agriculture water use is 51.84 millionm^3/a including river irrigators. It is important to note that the irrigation water supply at the beginning of the water year is not significant. The lowest irrigation water applications by farmers has occurred between June to August for the current water year when between 0.06 million m^3/a and 1.3 million m^3/a, was applied for by irrigators from the Vet irrigation canal system. This period coincides with the harvesting of the main crops before land preparation begins in September. Therefore there is a low demand for irrigation water during this period.

The peak irrigation demand occurred between September and November when irrigators prepare lands for planting of the annual crops (see **Table 8.1** below).

8.4.2.2 Precipitation

No data was available on the monthly rainfall in the Sand-Vet Irrigation Scheme area for the same period. Therefore the precipitation was not included as an input into the water balance assessment.

8.4.2.3 Changes of volume in storage of Klippunt Balancing Dam

The impact of a regulatory storage such as Klippunt Dam and the potential benefit in management flexibility and improved water use efficiency associated with balancing dams in irrigation schemes is illustrated in **Figure 8.1** below. The storage capacity of Klippunt Dam is currently not known.

The Klippunt balancing dam is currently not being included in the water inflow into the canal system. This is because of lack of proper flow measurements at the inlet and outlet of the balancing dam to determine the additional water either supplied to downstream irrigators or stored but not used during the week. Therefore the current inflow data is not adequate and does not reflect the complete picture of the inflows into the Vet River canal system. There is currently a Parshall flume at the inlet to the Dam.

Table 8:1: Water Balance Assessment for the Vet River canal system for the 2011/12 water year

Scheduled Area	
Canal Irrigators -area	5 489.00
River irrigators - area	1 262.00
Total scheduled area	**6 751.00**
Scheduled qouta	7 200.00

WRM Charge	1.49

Scheduled allocation	
Scheduled Qouta	7 200.00
Canal Irrigators	39 520 800.00
River Irrigators	9 086 400.00
Total scheduled allocation	**48 607 200.00**

Unavoidable Losses			
Expected Seepage Loss	6 063 159.28	8.56%	15%
Evaporation Losses		0.4%	

Month & Year	INFLOWS					OUTFLOWS						GROSS WATER LOSSES		NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES				UTILISATION
	Vet Canal	Storage release	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households / Stock Consumption	Industrial	Municipality	Downstream demands	Total Outflows	Total water losses	% of inflow	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Leakage & spills	Total avoidable losses	% avoidable water losses	% of scheduled volume
June 2011	1 437 000.00	-	-	-	1 437 000.00	57 000.00	27 000.00	-	531 000.00	-	615 000.00	822 000.00	57.2%	5 173.20	122 952.17	128 125.37	-	693 874.63	693 874.63	48.3%	
July 2011	3 005 000.00				3 005 000.00	1 127 000.00	34 000.00	-	624 000.00	-	1 785 000.00	1 220 000.00	40.6%	10 818.00	257 112.93	267 930.93	-	952 069.07	952 069.07	31.7%	
August 2011	3 033 000.00				3 033 000.00	1 300 000.00	27 000.00	-	420 000.00	-	1 747 000.00	1 286 000.00	42.4%	10 918.80	259 508.66	270 427.46	-	1 015 572.54	1 015 572.54	33.5%	
September 2011	6 838 000.00				6 838 000.00	4 619 000.00	27 000.00	-	574 000.00	-	5 220 000.00	1 618 000.00	23.7%	24 616.80	585 070.96	609 687.76	-	1 008 312.24	1 008 312.24	14.7%	
October 2011	12 505 000.00				12 505 000.00	9 056 000.00	34 000.00	-	732 000.00	-	9 822 000.00	2 683 000.00	21.5%	45 018.00	1 069 949.15	1 114 967.15	-	1 568 032.85	1 568 032.85	12.5%	
November 2011	10 068 000.00				10 068 000.00	6 845 000.00	27 000.00	-	416 000.00	-	7 288 000.00	2 780 000.00	27.6%	36 244.80	861 435.27	897 680.07	-	1 882 319.93	1 882 319.93	18.7%	
December 2011	3 410 000.00				3 410 000.00	1 137 000.00	27 000.00	-	828 000.00	-	1 992 000.00	1 418 000.00	41.6%	12 276.00	291 765.42	304 041.42	-	1 113 958.58	1 113 958.58	32.7%	
January 2012	5 865 000.00				5 865 000.00	2 993 000.00	34 000.00	-	920 000.00	-	3 947 000.00	1 918 000.00	32.7%	21 114.00	501 819.41	522 933.41	-	1 395 066.59	1 395 066.59	23.8%	
February 2012	8 538 000.00				8 538 000.00	5 138 000.00	27 000.00	-	472 000.00	-	5 637 000.00	2 901 000.00	34.0%	30 736.80	730 525.86	761 262.66	-	2 139 737.34	2 139 737.34	25.1%	
March 2012	8 091 000.00				8 091 000.00	4 697 000.00	27 000.00	-	635 000.00	-	5 359 000.00	2 732 000.00	33.8%	29 127.60	692 279.78	721 407.38	-	2 010 592.62	2 010 592.62	24.8%	
April 2012	5 822 000.00				5 822 000.00	2 256 000.00	34 000.00	-	857 000.00	-	3 147 000.00	2 675 000.00	45.9%	20 959.20	498 140.26	519 099.46	-	2 155 900.54	2 155 900.54	37.0%	
May 2012	2 251 000.00				2 251 000.00	484 000.00	27 000.00	-	491 000.00	-	1 002 000.00	1 249 000.00	55.5%	8 103.60	192 599.40	200 703.00	-	1 048 297.00	1 048 297.00	46.6%	
2011/12 Water Year	**70 863 000.00**	**-**	**-**	**-**	**70 863 000.00**	**39 709 000.00**	**352 000.00**	**-**	**7 500 000.00**	**-**	**47 561 000.00**	**23 302 000.00**	**32.9%**	**255 106.80**	**6 063 159.28**	**6 318 266.08**	**-**	**16 983 733.92**	**16 983 733.92**	**24.0%**	**#REF!**
June 2012	2 222 000.00				2 222 000.00	628 000.00	20 000.00	-	260 000.00	-	908 000.00	1 314 000.00	59.1%	7 999.20	190 118.11	198 117.31	-	1 115 882.69	1 115 882.69	50.2%	
July 2012	3 194 000.00				3 194 000.00	879 000.00	34 000.00	-	851 000.00	-	1 764 000.00	1 430 000.00	44.8%	11 498.40	273 284.09	284 782.49	-	1 145 217.51	1 145 217.51	35.9%	
August 2012	4 275 000.00				4 275 000.00	1 794 000.00	27 000.00	-	452 000.00	-	2 273 000.00	2 002 000.00	46.8%	15 390.00	365 776.30	381 166.30	-	1 620 833.70	1 620 833.70	37.9%	
September 2012	9 542 000.00				9 542 000.00	4 578 000.00	34 000.00	-	896 000.00	-	5 508 000.00	4 034 000.00	42.3%	34 351.20	816 429.81	850 781.01	-	3 183 218.99	3 183 218.99	33.4%	
October 2012	9 528 000.00				9 528 000.00	6 468 000.00	27 000.00	-	487 000.00	-	6 982 000.00	2 546 000.00	26.7%	34 300.80	815 231.95	849 532.75	-	1 696 467.25	1 696 467.25	17.8%	
November 2012																					
December 2013																					
January 2013																					
February 2013																					
March 2013					-						-	-		-	-	-	-	-	-		
April 2013																					
May 2013																					
2012/13 Water Year	**28 761 000.00**	**-**	**-**	**-**	**28 761 000.00**	**14 347 000.00**	**142 000.00**	**-**	**2 946 000.00**	**-**	**17 435 000.00**	**11 326 000.00**	**39.4%**	**103 539.60**	**2 460 840.27**	**2 564 379.87**	**-**	**8 761 620.13**	**8 761 620.13**	**30.5%**	**#REF!**
											-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	

As illustrated in **Figure 8.1** below, the available storage capacity in Klippunt Dam is supposed to reduce the releases from the Erfenis Dam depending on how much storage is available in the next irrigation schedule.

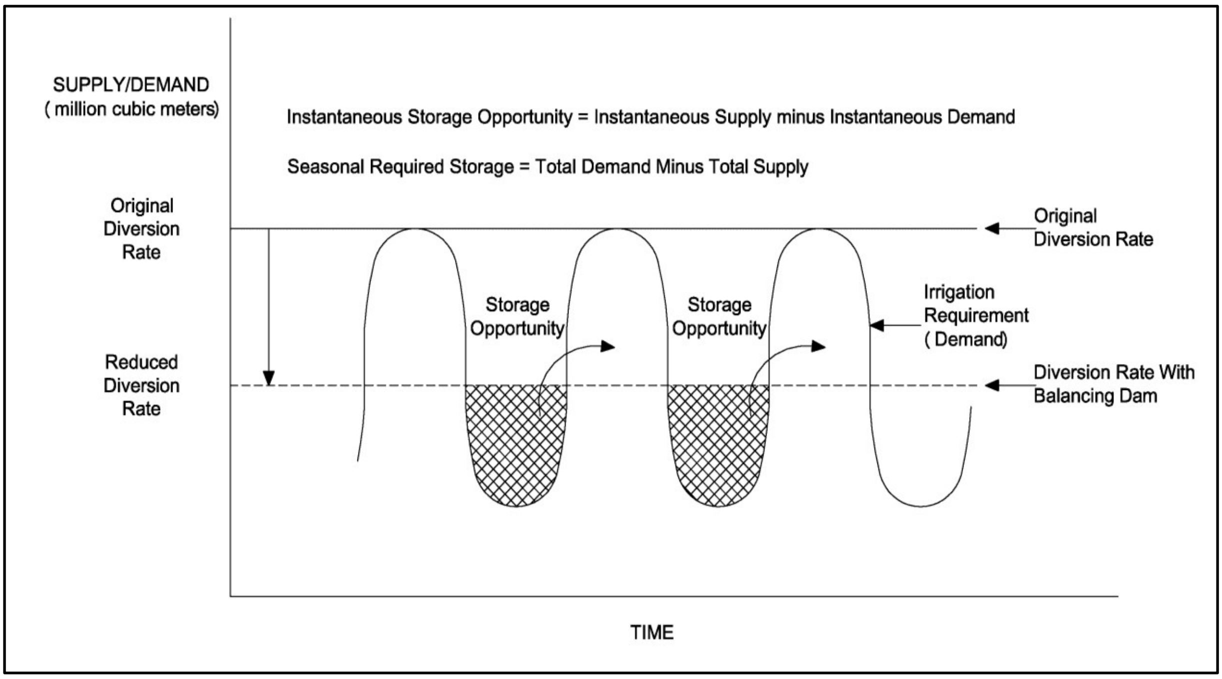

Figure 8.1: Possible demand and supply relationship and potential benefit in flexibility from a balancing dam

8.4.3 Demands

The supply to individual water users is measured (or rather administered) through the Parshall Flumes below the sluice gates. The adjustment to the flow measurement is done in increments of 25 m^3/hr. The sluice gates are adjusted by hand in increments every 24 hours to supply irrigators' demands for the week at an average of 120 hours or 5 days before the sluices are closed. During peak periods irrigators are supplied up to 168 hours in a week.

Due to the water level and hence pressure variance in the canal system, there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%. The weekly data on releases at the individual sluices and Parshall Flumes were aggregated in the WUEARs to provide monthly records of water requested and used by the irrigators.

This was taken as the crop evapo-transpiration (ET). Records of monthly deliveries to other water users, namely Masilonyana and Tswelopele Local Municipalities for domestic supply was included in the water use.

8.4.3.1 Irrigation water demands

The volume of water that is requested by the irrigators in the Vet River canal system varies from week to week, and from month to month, as does the cropping pattern for each year. For the past 2011/12 water year, the irrigation water application has ranged from 0.06 million m^3/a in June to 9.1 million m^3/a in October and November when the irrigators prepare the lands for planting.

The total irrigation water application for the 2011/12 water year was 39.7 million m^3/a. When compared with the scheduled quota for canal irrigators including the river irrigators who are supplied by diverting water through drain 47, this represents approximately 98% of the scheduled allocation was utilised in the year. It would appear that the scheme is diverting much more water for the water losses required to deliver the irrigation water application to the irrigators.

8.4.3.2 Other demands

Besides irrigation water demands, the Vet River canal system is supposed to supply two major water users namely the Tswelopele and Masilonyana Local Municipalities for domestic water use mainly in Theunissen and Bultfontein towns and the surrounding communities.

8.4.4 Comparison of monthly releases into the canal system with monthly water requirements

There is a correlation between the monthly releases from the Erfenis Dam into the Erfenis irrigation primary canal with the monthly water requirements as illustrated in **Figure 8.2** below. The irrigation water supplied is more than the water used by irrigators and other water users in the scheme as the scheme has tried to match the irrigation supplies with the irrigation demands. The difference in matching supply to the irrigation demand was to take into account the losses needed to deliver the water required by the irrigators.

As illustrated in **Figure 8.2** below, there is a major difference in trying to match the irrigation supply to the irrigation water demands, particularly during the August to November when the irrigation application is high. The difference in the supply and demand is to account for water losses which include seepage losses, operational losses particularly through return flows, evaporation losses and leakage.

The average percentage of additional water required to meet the water requirements from the Vet canal was determined to be 33% of the total water released into the canal. This does not take into account the effect of the Klippunt balancing dam. Therefore it is likely that the percentage water loss for the Vet River canal system is higher than the 33%. There may be irrigators who do not take up the full amount of water they have requested which ends up in the Klippunt balancing dam, which would have been accounted as a demand.

The above average percentage has been benchmarked against best management practice (BMP) in order to determine the extent required to meet the BMP for irrigation operation of the Erfenis Irrigation Scheme.

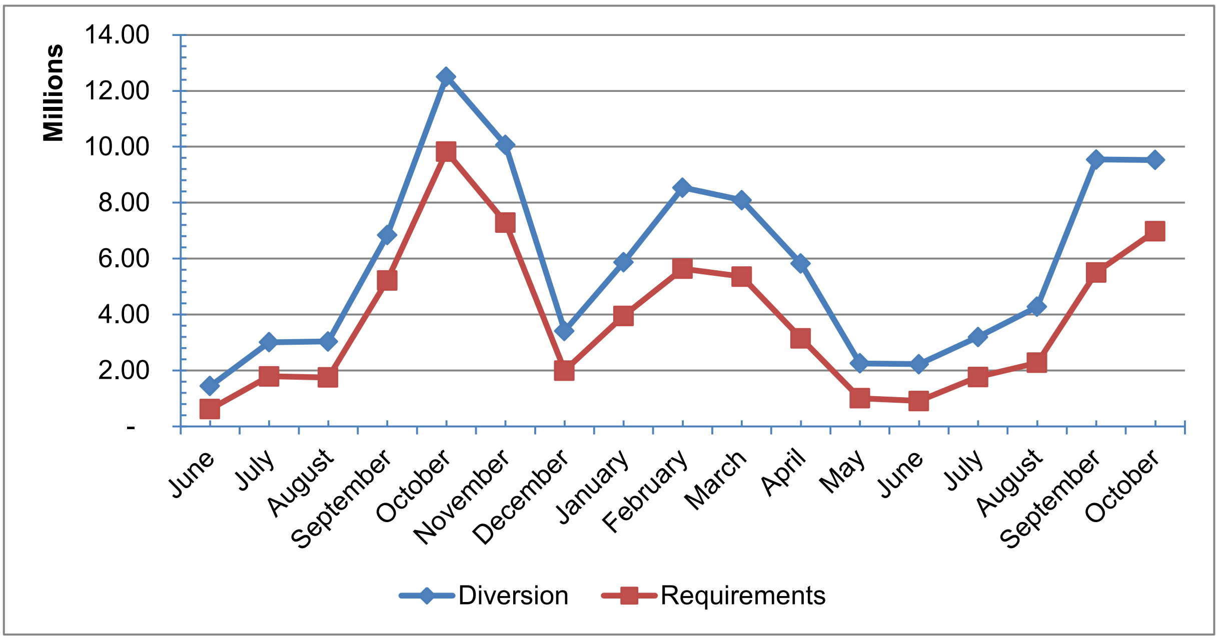

Figure 8.2: Comparison of deliveries and the demands in the Erfenis scheme (million m^3)

8.5 Gross Water losses

An analysis of the percentage of inflow to the Vet main canal indicates that since the start of the current water year, the WUA diverted on average 33% more water from the Erfenis Dam than the water applications of 47.56 million m^3/a from all the water users for the same period.

Figure 8.2 indicates that the average gross water losses including the return flow, has been 33% of the total flow released into the Vet canal system. This translates to approximately 23.3 million m^3/a of gross water losses in the Vet River canal system. This amount includes both minimum expected seepage and evaporation losses (i.e. unavoidable water losses) and avoidable water losses such as operational losses, leakage and canal spills which may be beneficial to downstream water users.

Figure 8.3 below provides a trend analysis of the total water losses and the estimated gross water losses. It is important to note that during the period between August and November the amount of water losses as a percentage of volume released from the Dam is consistently higher than normal. This may be attributed to the fact that there are leaks due to the water depth in the canal infrastructure which is an important factor.

The high water depth due to the high demand during this period, results in higher leakages as the canal is running close to or at full capacity. This is because of small breakages, chips, etc. at the top portion of the irrigation canals which are more exposed to the elements and general wear and tear than the lower sections.

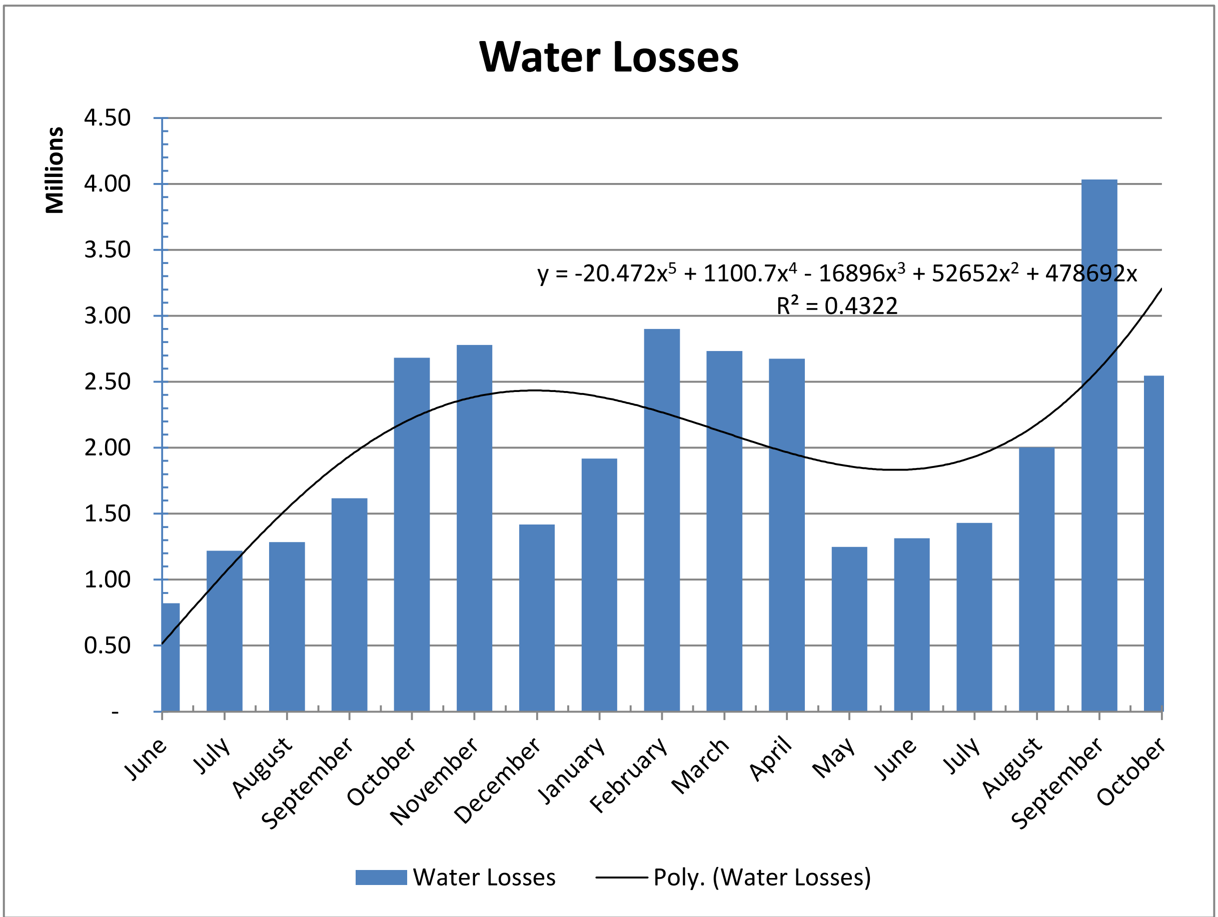

Figure 8.3: Water losses in Erfenis Irrigation Scheme

8.5.1 Unavoidable water losses in the Vet River canal system

There was no data to disaggregate further the water losses into evaporation, seepage, leakage, filling losses and operational spills. There were also no records being taken at the canal tail ends to determine the operational spills. Direct measurement of operational spills at the canal tail end returns can be conducted as there are Parshall flumes at most canal tail ends which can be measured.

Table 8.2 below provides a summary of the water losses in the Vet River canal system. As illustrated in the table, the minimum seepage losses as calculated in the previous chapter for the Vet River canal system is 6.06 million m^3/a while the evaporation losses was calculated based on the canal surface area and the MAE as 0.26 million m^3/a. The total minimum unavoidable losses that has to be added to the irrigation water requirements or the schedule allocation is 6.32 million m^3/a, or 9% of the total diverted into the Vet River canal system.

Table 8:2: Summary of the water losses for the Vet River Irrigation Canals

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>6.06</td><td></td><td>6.06</td></tr>
<tr><td>Evaporation</td><td>0.26</td><td></td><td>0.26</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="6">16.98</td><td rowspan="6">16.98</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
<tr><td>Canal end returns</td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td>0.00</td></tr>
<tr><td>Total</td><td>6.32</td><td>16.98</td><td>23.30</td></tr>
<tr><td>% of total volume released into Vet canals</td><td>9%</td><td>24%</td><td>33%</td></tr>
<tr><td>% of total losses</td><td>27%</td><td>73%</td><td>100%</td></tr>
</table>

8.5.2 Avoidable water losses

8.5.2.1 Total avoidable water losses

The unavoidable losses calculated in the previous chapter were based on the assumption that the condition of the Vet canals are being well maintained and are refurbished in time to maintain the level of service from the canals. This was considered to be the economic level of seepage (ELS) for the Vet canal system.

Having determined the unavoidable water losses which are required to deliver the irrigation water requirements, the remainder of the gross water losses are considered avoidable water losses to the scheme, although they are beneficial to downstream water users. This is because these losses can be prevented by implementing appropriate water management intervention measures. The total avoidable water losses for the Vet River canal system was determined to be 17 million m^3/a, or 73% of the gross water losses. The avoidable water losses include leakage, filling losses, over delivery to users, as well as operational spills particularly at canal tail ends.

8.5.2.2 Operational losses and canal end returns:

There are water losses on the canal system which can be classified as operational losses due to the way the scheme is operated. Such losses include start-up and shut-down losses, operational wastage due to the lack of quick response to changes in demand, water not used (outflows) due to unexpected drops in demand and losses due to incorrect metering. These losses are estimated to fluctuate between 9% and 28% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

Because of lack of sufficient flow measurement data, particularly at canal tail ends, it was not possible to disaggregate the avoidable losses into operational losses and leakage losses. However the preliminary estimates of the operational losses at the canal tail end, that were taken during the site visit, was estimated to be 1.35 million m^3/a. This is approximately 15% of the avoidable irrigation water losses, which is much higher than the norm, a clear indication that there are operational problems in the Sand-Vet irrigation scheme. This excludes the losses due to metering errors.

The operational losses at canal tail ends represent that more water is being diverted into the canal system than is required which could either have been left in the river or in the Erfenis Dam, to meet demands during low flow periods. On the Vet River irrigation canal system where the scheme is manually operated these losses are likely to be high as the time to react to any changes in demands are likely to take longer.

8.5.2.3 Water Losses due to calibration and metering error

Besides the operational spills at various points in the Vet canal including the canal tail end, there are metering errors on the Parshall Flumes due to calibration problems because of submergence conditions at some of the sluices.

Based on the literature review on the Parshall Flumes the percentage error due to calibration problems are around +/- 3% of the water losses increasing to as high as 10% of the irrigation water losses ((Kulin 1984), if submergence conditions are experienced. Therefore it was determined that the water losses due to meter errors as well as lack of real time flow monitoring to be 2.33 million m^3/a in the 2011/12 water year.

8.5.2.4 Leakage losses:

The determination of the volume of water that is wasted as a result of leakages is very difficult to calculate and can only really be determined through accurate measuring or undertaking tests such as ponding tests on the irrigation canals. Leaks normally occur in broken sections of the canals and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal network due to its age (see **Photo 8.1** below).

An important factor that has a marked effect on leakages is the water depth in a canal system. The leakage losses which can be avoided is due to the constant movement of water through the bottom and sides of the canal system due to small cracks including abnormally large cracks in the canal infrastructure which can be reduced through canal maintenance. The top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

As expected because of the age of the canal infrastructure and the condition of some sections of the canals as discussed in the previous chapter 4, the leaks due to the poor condition of the canal infrastructure are high. The leakage losses were determined based on the difference between the total avoidable losses and the water losses from operational losses, and flow measurement and monitoring as discussed above. Therefore the estimated leakage losses in the 2011/12 water year for the Vet canal system was determined to be 12.15 million m^3/a based on the difference between the total avoidable losses and the estimated operational losses.

The leakage losses were estimated to be more than the operational losses which is an indication that there are abnormally large cracks in the canal system due to a lack of renewal and refurbishment of the Vet River irrigation canals. A review of the condition of the infrastructure (see **Photo 8.1** below) does seem to confirm that there are significant leakage losses due to the major cracks and vegetation growth in the Vet canal system. Furthermore there are hairline cracks resulting in seepage losses particularly with the changes in the capillary rise and fall due to the start and stop procedure of operating the scheme.

Photo 8.1: Broken section of concrete panels of canal system

8.5.2.5 Aquatic weeds and algae:

Aquatic weed and algae growth in irrigation canal systems is fast becoming one of the major operational problems in scheme management, especially on those schemes where water is becoming progressively eutrophic. Du Plessis and Davidson (1996) list the following impacts of excessive aquatic weed growth on irrigation canal systems:

(i) A negative influence on hydraulic capacity and flow speeds in the canals. This decrease in canal capacity occurs particularly when the water demand is at its highest.
(ii) Overestimation of the amount of water supplied, because of the artificially increased water levels that are measured at calibrated weirs.
(iii) Water loss because of the flooding of canals.
(iv) Impediment of floodgate and sluices at dividing structures.
(v) Water logging of long-weirs.
(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.

(vii) Aquatic weed fragments block irrigation systems and filters at water purification plants.

(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

The aquatic weeds and algae is not a major issue in the Sand-Vet Irrigation Scheme and have not been considered as such.

8.5.2.6 Total avoidable water losses - Vet River irrigation canal irrigation system

The estimated avoidable water losses for the current water year are 16.98 million m^3/a (see **Table 8.2** above). The largest component of the avoidable water losses in the Vet Irrigation is the leakage due to the age and condition of the infrastructure at 6.3 million m^3/a, while the operational losses due to calibration were estimated to be 1.35 million m^3/a and the water losses due to spills was determined to be as high as 2.3 million m^3/a.

8.6 Water balance assessment - Sand River canal system

8.6.1 Overview

The Sand-Vet irrigation scheme was analysed on the basis that it comprises two irrigation schemes namely the Vet River canal system which is supplied from Erfenis Dam up to including the irrigators downstream after the confluence of the Vet and Sand Rivers. The other irrigation scheme within the Sand-Vet irrigation scheme is the Sand River canal system which is supplied from the Allemanskraal Dam in the Sand River catchment.

Two water balance assessments have been prepared to assess the extent and magnitude of irrigation water use efficiency in each irrigation scheme. This section addresses the Sand River canal system.

8.6.2 Inflows into Sand River canal system

8.6.2.1 Releases from Allemanskraal Dam

The first measurement of water takes place at the Allemanskraal Dam, where water is released from the dam into the main irrigation canal on the left bank of the Sand River before it bifurcates into the A canal which is on the right bank of the Sand River. The main canal further bifurcates later into the B and C canals on the right bank of the Sand River.

Weekly records of the releases into the main canal at the dam were evaluated. The weekly records from June 2011, the beginning of the water year were used to generate the total inflows into the Sand River canal system as illustrated in **Table 8.3** below. This was done based on the full water year. The total inflow into the Sand River canal system for the 2011/12 water year of available records was 58 million m^3/a.

It is important to note that the irrigation water supply is fairly consistent for the nine months of record for the current water year. The water allocation for irrigation agriculture water use is 36.4 million m^3/a excluding river irrigators.

The lowest irrigation water release occurred in June and August based on the current water year when only the industrial application was 1.0 million m^3, which was diverted from the Sand River main irrigation canal to the industries. This may be due to the low demand for irrigation water during this period as this is the period for harvesting of the maize crop.

8.6.2.2 Precipitation

No data was available on the monthly rainfall in the Sand-Vet Irrigation Scheme area for the same period. Therefore the precipitation was not included as an input into the water balance assessment.

Table 8:3: Weekly Water Balance Assessment for the Sand River canal system

Scheduled Area	
Canal Irrigators -area	5 049.50
River irrigators - area	349.20
Total scheduled area	**5 398.70**
Scheduled qouta	7 200.00

WRM Charge	1.49

Scheduled allocation	
Scheduled Qouta	7 200.00
Canal Irrigators	36 356 400.00
River Irrigators	2 514 240.00
Total scheduled allocation	**38 870 640.00**

Unavoidable Losses			
Expected Seepage Loss	4 453 768.37	7.68%	12%
Evaporation Losses		0.4%	

Month & Year	INFLOWS					OUTFLOWS						GROSS WATER LOSSES		NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES				UTILISATION
	Sand Canal	Storage release	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Downstream demands	Total Outflows	Total water losses	% of inflow	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Leakage & spills	Total avoidable losses	% avoidable water losses	% of scheduled volume
June 2011	1 897 000.00	-	-	-	1 897 000.00	-	48 000.00	1 001 000.00	-	-	1 049 000.00	848 000.00	44.7%	6 829.20	145 626.26	152 455.46	-	695 544.54	695 544.54	36.7%	
July 2011	3 728 000.00	-	-	-	3 728 000.00	559 000.00	60 000.00	2 227 000.00	-	-	2 846 000.00	882 000.00	23.7%	13 420.80	286 185.92	299 606.72	-	582 393.28	582 393.28	15.6%	
August 2011	2 855 000.00	-	-	-	2 855 000.00	691 000.00	48 000.00	1 590 000.00	-	-	2 329 000.00	526 000.00	18.4%	10 278.00	219 168.67	229 446.67	-	296 553.33	296 553.33	10.4%	
September 2011	4 904 000.00	-	-	-	4 904 000.00	1 661 000.00	48 000.00	1 714 000.00	-	-	3 423 000.00	1 481 000.00	30.2%	17 654.40	376 463.45	394 117.85	-	1 086 882.15	1 086 882.15	22.2%	
October 2011	8 813 000.00	-	-	-	8 813 000.00	4 177 000.00	60 000.00	2 005 000.00	-	-	6 242 000.00	2 571 000.00	29.2%	31 726.80	676 544.13	708 270.93	-	1 862 729.07	1 862 729.07	21.1%	
November 2011	7 769 000.00	-	-	-	7 769 000.00	3 616 000.00	48 000.00	1 920 000.00	-	-	5 584 000.00	2 185 000.00	28.1%	27 968.40	596 399.79	624 368.19	-	1 560 631.81	1 560 631.81	20.1%	
December 2011	4 018 000.00	-	-	-	4 018 000.00	915 000.00	48 000.00	2 050 000.00	-	-	3 013 000.00	1 005 000.00	25.0%	14 464.80	308 448.24	322 913.04	-	682 086.96	682 086.96	17.0%	
January 2012	4 958 000.00	-	-	-	4 958 000.00	2 040 000.00	60 000.00	2 343 000.00	-	-	4 443 000.00	515 000.00	10.4%	17 848.80	380 608.85	398 457.65	-	116 542.35	116 542.35	2.4%	
February 2012	5 686 000.00	-	-	-	5 686 000.00	3 050 000.00	48 000.00	1 908 000.00	-	-	5 006 000.00	680 000.00	12.0%	20 469.60	436 494.94	456 964.54	-	223 035.46	223 035.46	3.9%	
March 2012	6 133 000.00	-	-	-	6 133 000.00	3 251 000.00	48 000.00	1 820 000.00	-	-	5 119 000.00	1 014 000.00	16.5%	22 078.80	470 809.61	492 888.41	-	521 111.59	521 111.59	8.5%	
April 2012	4 881 000.00	-	-	-	4 881 000.00	1 684 000.00	60 000.00	2 463 000.00	-	-	4 207 000.00	674 000.00	13.8%	17 571.60	374 697.82	392 269.42	-	281 730.58	281 730.58	5.8%	
May 2012	2 375 000.00	-	-	-	2 375 000.00	99 000.00	48 000.00	1 997 000.00	-	-	2 144 000.00	231 000.00	9.7%	8 550.00	182 320.70	190 870.70	-	40 129.30	40 129.30	1.7%	
2011/12 Water Year	**58 017 000.00**	**-**	**-**	**-**	**58 017 000.00**	**21 743 000.00**	**624 000.00**	**23 038 000.00**	**-**	**-**	**45 405 000.00**	**12 612 000.00**	**21.7%**	**208 861.20**	**4 453 768.37**	**4 662 629.57**	**-**	**7 949 370.43**	**7 949 370.43**	**14%**	**117%**
June 2012	1 441 000.00	-	-	-	1 441 000.00	173 000.00	36 000.00	876 000.00	-	-	1 085 000.00	356 000.00	24.7%	5 187.60	110 620.68	115 808.28	-	240 191.72	240 191.72	16.7%	
July 2012	2 608 000.00	-	-	-	2 608 000.00	254 000.00	60 000.00	1 990 000.00	-	-	2 304 000.00	304 000.00	11.7%	9 388.80	200 207.32	209 596.12	-	94 403.88	94 403.88	3.6%	
August 2012	2 164 000.00	-	-	-	2 164 000.00	588 000.00	48 000.00	1 284 000.00	-	-	1 920 000.00	244 000.00	11.3%	7 790.40	166 122.94	173 913.34	-	70 086.66	70 086.66	3.2%	
September 2012	4 253 000.00	-	-	-	4 253 000.00	1 512 000.00	60 000.00	2 012 000.00	-	-	3 584 000.00	669 000.00	15.7%	15 310.80	326 488.39	341 799.19	-	327 200.81	327 200.81	7.7%	
October 2012	4 519 000.00	-	-	-	4 519 000.00	2 330 000.00	48 000.00	1 585 000.00	-	-	3 963 000.00	556 000.00	12.3%	16 268.40	346 908.31	363 176.71	-	192 823.29	192 823.29	4.3%	
November 2012		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
December 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
January 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
February 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
March 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
April 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
May 2013		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
		-	-	-	-		-		-	-	-	-	#DIV/0!	-	-	-	-	-	-	#DIV/0!	
2011/12 Water Year	**14 985 000.00**	**-**	**-**	**-**	**14 985 000.00**	**4 857 000.00**	**252 000.00**	**7 747 000.00**	**-**	**-**	**12 856 000.00**	**2 129 000.00**	**14.2%**	**53 946.00**	**1 150 347.64**	**1 204 293.64**	**-**	**924 706.36**	**924 706.36**	**6%**	**33%**
		-	-	-	-	-					-	-						-	-		

8.6.2.3 Changes of volume in storage of Palmietkuil Balancing Dam

The impact of a regulatory storage such as Palmietkuil Dam and the potential benefit in management flexibility and improved water use efficiency associated with balancing dam in irrigation schemes is illustrated in **Figure 8.4** below.

The storage capacity of Palmietkuil Dam is estimated to be 0.713 million m^3 with a live storage capacity of 0.44 million m^3. This however may have changed with siltation of the balancing dam.

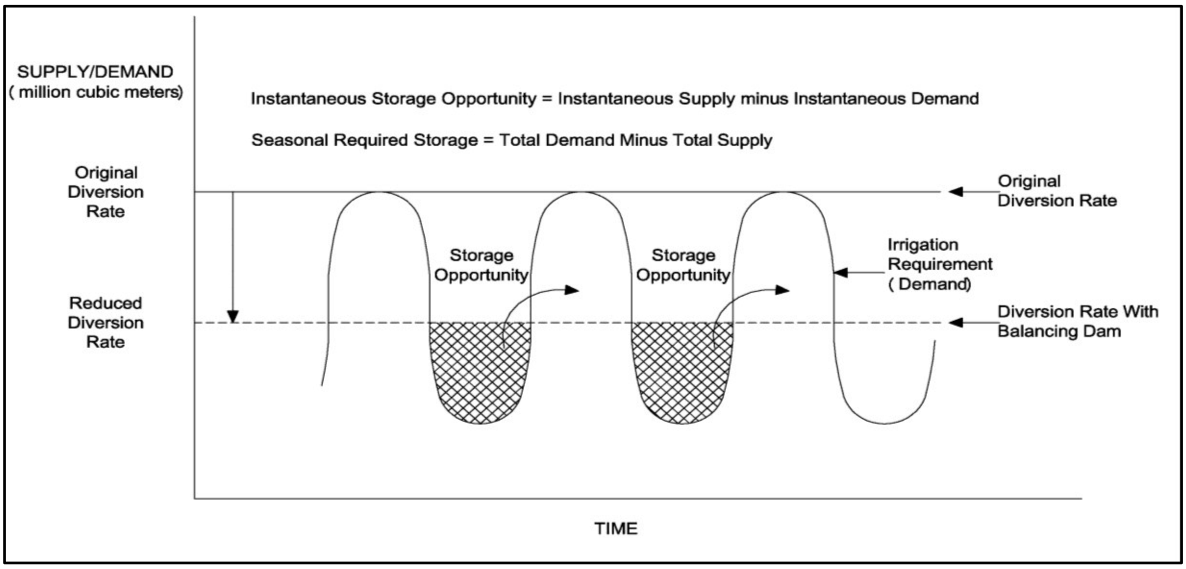

Figure 8.4: Possible demand and supply relationship and potential benefit in flexibility from a balancing dam

The Palmietkuil balancing dam is currently not being included in the water inflow into the water balance although there are flow measurements into the balancing dam as well as the flow measurements out of the balancing dam. These flow measurements can be used to determine the additional water either supplied to downstream irrigators or stored but not used during the week. Therefore the current inflow data is not adequate and does not reflect the complete picture of the inflows into the Sand River canal system.

As illustrated in **Figure 8.4** above, the available storage capacity in Palmietkuil Dam is supposed to reduce the releases from the Allemanskraal Dam depending on how much storage is available before the next irrigation schedule.

8.6.3 Demands

The supply to individual water users is measured (or rather administered) through the pressure head generated by the long weir and hence the variable water pressure at different adjustable sluice gates.

8.6.3.1 Irrigation water demands

The volume of water that is requested by the irrigators in the Sand River canal system varies from week to week, as well as from month to month, as does the cropping pattern for each year. For the past 2011/12 water year, the irrigation water application has ranged from nil in June to 4.2 million m^3/a in October when the irrigators prepare the lands for planting.

The total irrigation water application in the last water year of 2011 /2012 was 21.74 million m3. When compared with the scheduled quota for canal irrigators this represents approximately 58% of the scheduled allocation. Therefore either the irrigators are not using their full water entitlements or they may have transferred some of these entitlements to other water user such as the industries in the scheme area.

8.6.3.2 Other demands

Besides irrigation water demands, the Sand River canal system also supplies major water users namely Sedibeng Water and the mines and industries in the areas. Sedibeng Water in turn supplies treated water for domestic water use mainly to Virginia and the surrounding communities.

The water requirements from the irrigation canal infrastructure in the 2011/12 water year was 23 million m^3/a which is significant particularly given the fact that it is considered a high priority water use compared to agriculture.

8.6.4 Comparison of monthly diversions with monthly demands

There is a correlation between the monthly releases from the Allemanskraal Dam into the Sand River irrigation primary canal with the monthly demands as illustrated in **Figure 8.5** below.

The total water diverted into the Sand River canal system is more than the water used by irrigators and other water users in the scheme as the scheme has tried to match the irrigation supplies with the irrigation demands. The difference in matching supply from Allemanskraal Dam to the irrigation water applications and any domestic water requirements supplied from the canals was to take into account the unavoidable and avoidable water losses needed to deliver the water applied for by the irrigators.

As illustrated in **Figure 8.5** below, there is a difference in trying to match the irrigation supply to the irrigation water demands, which appears to be fairly constant throughout the water year. The difference in the supply and demand has taken into account the water losses which include seepage losses, filling losses, operational losses particularly through canal tail ends, evaporation losses and leakage.

The average percentage of additional water required to meet the irrigation demands was determined to be 21.7% of the total water released. This does not take into account the effect of the Palmietkuil balancing dam. Therefore it is likely that a percentage water loss for the Sand River canal system is much higher than the 21.7%. There may be irrigators who do not take up the full amount of water they have requested which ends up in the Palmietkuil balancing dam.

The above average percentage has been benchmarked against best management practice (BMP) in order to determine the extent required to meet the BMP for irrigation operation of the Sand River Irrigation Scheme.

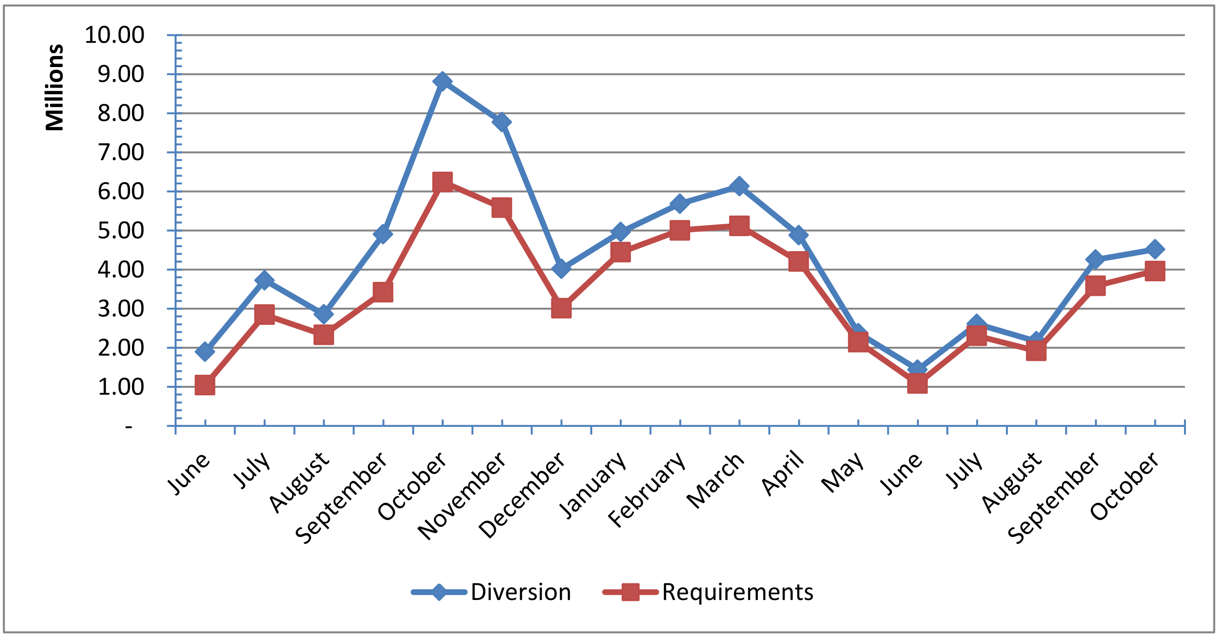

Figure 8.5: Comparison of deliveries and the demands in the Sand River scheme (million m^3)

8.7 Gross Water losses in the Sand canal system

An analysis of the percentage of inflow to the water allocation indicates that since the start of the current water year, the WUA diverted on average 21.7% more water at the Allemanskraal Dam than the water applications of 45.4 million m^3/a for canal irrigators for the same period.

Figure 8.5 indicates that the average gross water losses including the return flow, has been 21.7% of the total flow released from Allemanskraal Dam. This translates to approximately 12.6 million m^3/a of water losses in the Sand River canal system. This amount includes both minimum expected seepage and evaporation losses (i.e. unavoidable water losses) and avoidable water losses such as operational losses, leakage, canal spills which may be beneficial to downstream water users.

Figure 8.6 below provides a trend analysis of the total water losses and the estimated gross water losses. It is important to note that during the period between September and November the amount of water losses as a percentage of volume released from the Dam is consistently higher than normal. This may be attributed to the fact that there are leaks due to the low groundwater table at this time of the year, and the high water depth in the canal infrastructure. The top section of the canal is more exposed to the elements and general wear and tear, resulting in small breakages, chips, etc., than the lower section, resulting in higher leakages when the canal is running close to or at full capacity.

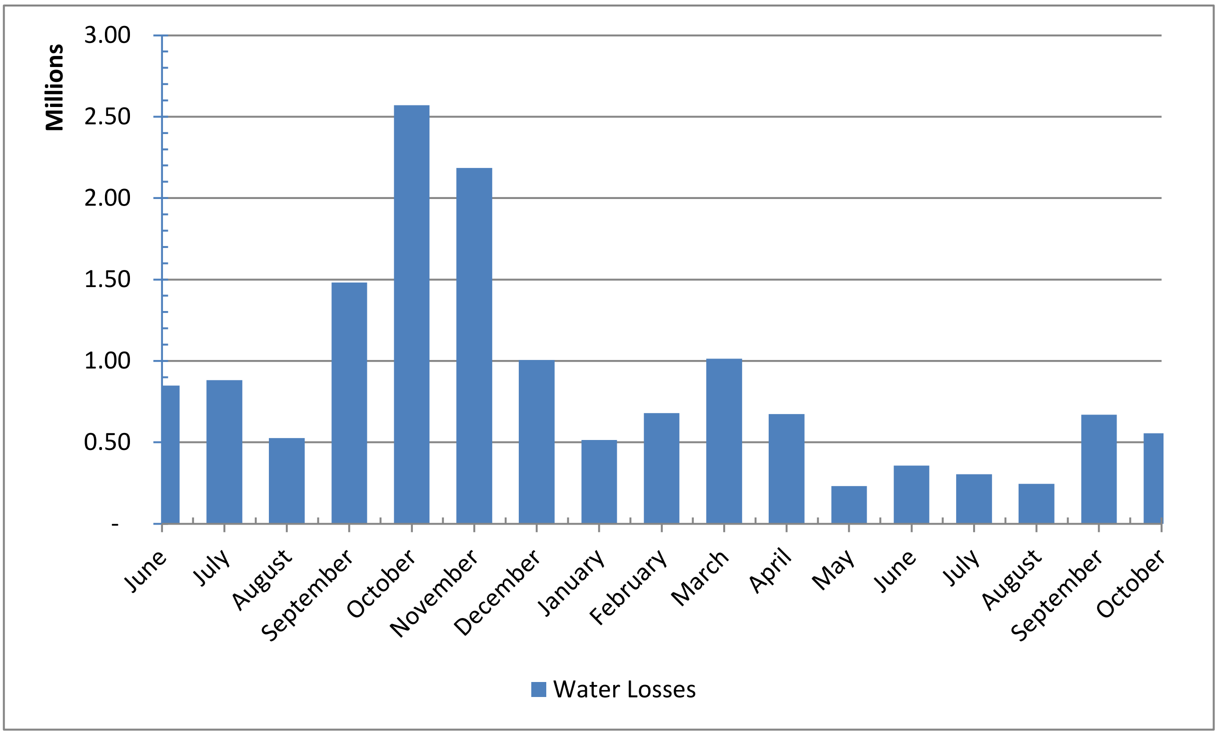

Figure 8.6: Water losses in Sand Irrigation Scheme (million m^3)

8.7.1 Unavoidable water losses in the Sand River canal system

There was no data to disaggregate further the water losses into evaporation, seepage, leakage and operational spills. There were also no records being taken at the canal tail ends to determine the operational spills. Direct measurement of operational spills at the canal end returns can be conducted as there are Parshall flumes at most canal tail ends which can be measured.

Table 8.4 below provides a summary of the water losses in the Sand River canal system. As illustrated in the table, the minimum seepage losses as calculated in the previous chapter for the Sand River canal system is 4.45 million m^3/a while the evaporation losses was calculated based on the canal surface area and the MAE as 0.21 million m^3/a. The total minimum unavoidable losses that has to be added to the irrigation water requirements or the schedule allocation is 4.66 million m^3/a, or 8% of the total diverted into the Sand River canal system.

Based on the above Best Management Practice (BMP) for evaporation losses, and expected seepage losses from lined canal infrastructure, the estimated seepage and evaporation losses for the Sand River irrigation canal is 8% of the net inflow.

Table 8:4: Summary of the water losses for the Sand River Irrigation Canals for the 2011/12 water year (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>4.45</td><td></td><td>4.45</td></tr>
<tr><td>Evaporation</td><td>0.21</td><td></td><td>0.21</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="7">7.95</td><td rowspan="7">7.95</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
<tr><td>Canal end returns</td><td></td></tr>
</table>

Description	Unavoidable losses	Avoidable losses	Total losses
Other			0.00
Total	4.66	7.95	12.61
Loss as a % of total volume released into system	8.0%	13.7%	21.7%
Loss as a % of total losses	37%	63%	100%

8.7.2 Avoidable water losses

8.7.2.1 Total avoidable water losses

Having determined the unavoidable water losses which are required to deliver the irrigation water requirements, the remainder of the gross water losses are considered avoidable water losses to the scheme, although they are beneficial to downstream water users. This is because these losses can be prevented by implementing appropriate water management intervention measures. The total avoidable water losses for the Sand River canal system was determined to be 7.95 million m^3/a, or 63% of the gross water losses. The avoidable water losses include leakage and operational spills, particularly at canal tail ends as well as calibration problems on the Parshall Flumes.

8.7.2.2 Operational losses and canal end returns:

Apart from the two losses described above, there are also other losses on the canal system which can be classified as operational losses due to the way the scheme is operated. Such losses include start-up and shut-down losses, operational wastage due to the lack of quick response to changes in demand, water not used (outflows) due to unexpected drops in demand and losses due to incorrect metering. These losses are estimated to fluctuate between 9% and 28% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

Because of lack of flow measurement particularly at canal tail ends, it was not possible to disaggregate the avoidable losses into operational losses and leakage losses for the long term data. However the preliminary estimates that were taken during the site visit of the operational losses at the canal tail end was estimated to be 0.5 million m^3/a.

The operational losses at canal tail ends represent that more water is being diverted into the canal system than is required which could either have been left in the river or in the case the Allemanskraal Dam, could have been left in the dam to meet demands during low flow periods. On the Sand River irrigation canal system where the scheme is manually operated these losses are likely to be high as the time to react to any changes in demands are likely to take longer.

8.7.2.3 Water Losses due to calibration and metering error

Besides the operational spills at various points in the Vet canal including the canal tail end, there are metering errors on the Parshall Flumes due to calibration problems because of submergence conditions at some of the sluices.

Based on the literature review on the Parshall Flumes the percentage error due to calibration problems are around +/- 3% of the water losses increasing to as high as 10% of the irrigation water losses ((Kulin 1984), if submergence conditions are experienced.

8.7.2.4 Leakage losses:

The determination of the volume of water that is wasted as a result of leakages is very difficult to calculate and can only really be determined through accurate measuring or undertaking tests such as ponding tests on the irrigation canals. Leaks normally occur in broken sections of the canals and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal network due to its age and/or lack of maintenance (see **Photo 8.2** below).

An important factor that has a marked effect on leakages is the water depth in a canal system. The leakage losses which can be avoided is due to the constant movement of water through the bottom and sides of the canal system due to small cracks including abnormally large cracks in the canal infrastructure which can be reduced through canal maintenance. The top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

As expected because of the age of the canal infrastructure and the condition of some sections of the canals as discussed in the previous chapter 4, the leaks due to the condition of the canal infrastructure are relatively high. The water losses due to leakages were determined to be 1.65 million m^3/a. This was calculated based on the operational losses as discussed in the following section, that were determined based on the measured data at canal tail ends that was conducted during the site visits.

This is more than the operational losses which is an indication that there are leakages in the canal system as illustrated by the leaking siphons in the Sand River irrigation canals (see **Photo 8.2** below). Furthermore there are hairline cracks resulting in leakage losses particularly with the changes in the capillary rise and fall due to the start and stop procedure of operating the scheme.

Photo 8.2: Leakage on siphons in the Sand River canal system

8.7.2.5 Aquatic weeds and algae:

Aquatic weed and algae growth in irrigation canal systems is fast becoming one of the major operational problems in scheme management, especially on those schemes where water is becoming progressively eutrophic. Du Plessis and Davidson (1996) list the following impacts of excessive aquatic weed growth on irrigation canal systems:

(i) A negative influence on hydraulic capacity and flow speeds in the canals. This decrease in canal capacity occurs particularly when the water demand is at its highest.

(ii) Overestimation of the amount of water supplied, because of the artificially increased water levels that are measured at calibrated weirs.

(iii) Water loss because of the flooding of canals.

(iv) Impediment of floodgate and sluices at dividing structures.

(v) Water logging of long-weirs.

(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.

(vii) Aquatic weed fragments block irrigation systems and filters at water purification plants.

(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

The aquatic weeds and algae is not a major issue in the Sand-Vet Irrigation Scheme and therefore have not been considered.

8.7.2.6 Total avoidable water losses - Sand River irrigation canal irrigation system

The estimated avoidable water losses for the nine months of the current water year are 7.95 million m^3/a (see **Table 8.4** above). The largest component of the avoidable water losses in the Sand River Irrigation canal is the leakage due to the age and condition of the infrastructure.

8.8 Overall water losses in the Sand-Vet Irrigation Scheme

Table 8.5 below provides an overall summary of the water losses in the whole of the Sand-Vet Irrigation Scheme area.

Table 8:5: Summary of the overall water losses in the Sand-Vet Irrigation Scheme based on 2011/12 water year (million m^3/a)

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Seepages	10.52		10.52	29.3%
Evaporation	0.46		0.46	1.3%
Filling losses			0.00	0.0%
Over delivery to users			0.00	0.0%
Leakages		24.93	24.93	69.4%
Spills				
Operational Losses				
Canal end returns				
Other			0.00	0.0%
Total	10.98	24.93	35.91	
Loss as % of total volume released into system	9%	19%	28%	
Loss as % of total losses	31%	69%	100%	

The total unavoidable water losses comprising of expected seepage losses in concrete lined canals and evaporation losses was determined to be 10.98 million m^3/a which is 9% of the irrigation water diversion for the same period.

However there are still significant avoidable water losses determined to be 24.93 million m^3/a, which is 19% of the irrigation water diverted into the Sand-Vet canal system. The focus of this water management plan is to determine the measures that can be implemented to reduce the avoidable water losses in the short, medium and long term.

8.9 Factors affecting high irrigation water losses

8.9.1 Matching of supply and irrigation water deliveries

One of the main issues that may be contributing to the high avoidable water losses could be that, although there is weekly scheduling of deliveries and water is delivered only when needed, it is a very complicated challenge to match the deliveries with the water orders.

There may be periods when, although irrigators have requested particular volumes of water for the week, irrigators determine that they may not require the full amount applied for. This then creates a time lag in adjusting the volume required, not only at the sluice, but through the canal system to the Erfenis Dam and Allemanskraal Dam. Given the fact that the sluices are adjusted after 24 hours, there is potential for operational spills to take place which may account for the high flows at the canal tail ends as illustrated in the irrigation water balances.

Furthermore, with the Sand-Vet irrigation scheme being manually operated, it is difficult to reduce the response time to such changes in demands and have the flexibility to respond by reducing the release rate.

8.9.2 Age and condition of the canal infrastructure

As indicated earlier on the condition of the infrastructure, there are significant canal leakages, because of the age and condition of the canal infrastructure. Leaks normally occur in broken sections of the canals, at canal joints and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal network owing to its age.

Based on the preliminary assessment that was conducted during the site visits as well as the information provided by Aurecon on the survey done on the canals it was possible to determine which sections or canal reaches have significant leakages. This information can assist the Sand-Vet WUA to determine which sections of the canals require refurbishment and /or rehabilitation. This work can provide the basis for prioritising the refurbishment and rehabilitation of the infrastructure and provide the Sand-Vet WUA with the motivation necessary to access the R40 million which is to the account of the DWA on the refurbishment and rehabilitation of the water infrastructure on the canal sections or reaches with the highest seepage in accordance with clause 6.7 of the Memorandum of Agreement between the DWA and the Sand-Vet WUA which came into effect from 1st of September 2007. This would provide a programme for canal maintenance during the dry periods.

8.9.3 Flow measurement errors and accuracy of Parshall Flumes:

8.9.3.1 Meter reading

With the current method of manual reading of the depth of flows by the Scheme Managers, there is a likelihood of meter reading errors due to human error. The lack of availability of an electronic automated system to use in flow monitoring may be contributing to the high avoidable losses because these are not identified earlier and addressed.

8.9.3.2 Accuracy of the Parshall Flumes

One of the problems with the current water use records is the accuracy of the existing Parshall Flumes which are used to record the actual irrigation water taken by the irrigators at each sluice gate.

The Parshall Flumes were designed for free-flow depth discharge conditions. As a result these flumes were constructed without the downstream measurement required for flumes with submergence flow conditions. Over time the errors of the free flow Parshall flumes have increased due to the increasing condition of submergence in a number of the flumes (see **Photo 8.3** below).

Photo 8.3: Potential for submergence increases inaccuracy in Parshall flumes

9 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

9.1 Overview

The Sand-Vet WUA has been implementing measures to improve the management of delivery to the irrigators since it was established. They have used some aspects of the WAS programme, which reduces the amount of canal seepage; annual maintenance of the irrigation canals to reduce avoidable water losses, as well as having flow measurements in place to audit the water delivery. These existing water management measures are discussed in more detail below.

9.2 Flow metering

The Sand-Vet WUA has most of the flow measurement structures and systems at the critical diversion points to measure how much water is diverted at different points of the irrigation scheme. The existing infrastructure is sufficient to ensure that detailed water balance assessments can be conducted at scheme level as well as at sub-scheme level.

The problem currently experienced is that, although the measurement structures and systems are in place, the Sand-Vet WUA is not reading all the flow measurements, particularly the Parshall Flumes at the canal tail ends. Therefore detailed water balance assessments cannot be prepared even at scheme level let alone at sub-scheme level.

9.3 Use of WAS

The Sand-Vet WUA is one of a number of schemes where the Water Administration System (WAS) has been installed to allow for water use efficiency and accounting reporting to be done.

There are 7 modules of the WAS programme. However, the Sand-Vet WUA is currently not utilising all modules the WAS particularly the release module, which assists in releasing the correct amount of water at the correct time, making it difficult to account for the level of water losses at scheme or sub-scheme level.

9.4 Flexibility in the Balancing Dam

The Sand-Vet WUA uses the Klippunt Balancing Dam on the Vet canals as well as the Palmietkuil Balancing Dam on the Sand canals to reduce the time of delivery to irrigators and match the supply to the irrigation applications.

Klipput and Palmietkuil Balancing Dams play an important role in helping the WUA match water deliveries to irrigation water requirements. Together with the farm dams that are in the scheme the reservoirs allow farmers to use their allocations at their convenience, both in terms of time of irrigation and the amount of water used. In addition to increasing water delivery flexibility, the storage reservoirs are used to:

(i) Reduce overall system spills as well as capture spills from upstream users to the benefit of the scheme;

(ii) Capture rainfall and storm water runoff which provides an additional source of supply.

9.5 Irrigators responsibilities

Although the Sand-Vet Irrigation Scheme has the ability to check or shut down canals and branch canals to avoid spills, this can only be done after 24 hours because the system is not automated.

Therefore in order to ensure that irrigators only apply for the water they require, the Sand-Vet WUA has put the onus on irrigators to apply for any reduction in the water application in time. If there is any amount of the water that the irrigator does not take up for whatever reason such as the farm dam being full or rainfall during the week, the loss is taken to the account of the farmer who requested the water.

The problem with this principle, however is that there is a likelihood of reducing the level water losses if the reduction is not factored in the water balance assessment. Therefore the water not taken up may result as flow at canal tail ends, which will be a loss to the scheme.

9.6 Operation and maintenance of the canal infrastructure

The ownership of the canal infrastructure at the Sand-Vet River WUA is with the DWA. However the Sand-Vet WUA is responsible for the operation and maintenance of the canal infrastructure.

During dry periods, significant maintenance is carried out on the primary canal and secondary canals. The availability of Klipput and Palmietkuil balancing dams provides the flexibility during the dry period to provide some of the irrigators from the balancing dam.

9.7 Refurbishment and Rehabilitation of water infrastructure

9.7.1 Capital funding for refurbishment and rehabilitation

The Memorandum of Agreement (MOA) between the Department of Water Affairs (DWA) and the Sand-Vet WUA which came into effect on the 20th January 2009 recognises that the age and condition of the water infrastructure in the Sand-Vet irrigation scheme was in a bad state and requires significant refurbishment and rehabilitation.

Clause 6.7 of the MOA clearly indicates that the initial refurbishment and rehabilitation to bring the infrastructure to the level of service it was designed for will be to the account of the DWA. Clause 6.11 provides an 8 year refurbishment programme with the completion date envisaged to be the end of 2016. Therefore there is in place an initiative to refurbish and rehabilitate the existing water infrastructure in the Sand-Vet irrigation scheme to ensure that the WUA can take over the operation and maintenance of the canal infrastructure including the refurbishment and rehabilitation once the initial capital investment by DWA on refurbishment is completed by 2016.

9.8 Water Pricing Structure

The existing water pricing structure is not a fully incentive based system where there is the increasing block or step tariff system to discourage overuse and encourage water use efficiency.

10 WATER MANAGEMENT ISSUES AND GOALS

10.1 Overview the management issues

The water use performance benchmarking and water balance analysis of the Sand-Vet Irrigation Scheme which was presented in the previous chapter 7 as well as chapter 8 together with discussions held with Sand-Vet WUA, has helped to identify several key water management issues.

The comparison between the expected water losses according to the best management practice (BMP) for irrigation water conveyance and the water balance analysis has identified that there are substantial losses taking place in the Sand-Vet Irrigation Scheme. There is insufficient data to clearly determine where and how losses are occurring. Currently there are no long term records as to how much water spills due to operational issues at the canal tail ends.

The water balance analysis did reveal, however, that on an annual basis, there is sufficient water to meet the Sand-Vet Irrigation Scheme's irrigation demands. It also highlighted that irrigators are currently not utilising their full water allocation.

Table 10.1 below provides the key issues identified and these are discussed in more detail in the following sections of this chapter.

Table 10:1: Sand-Vet Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	There is a lack of measurement of flows at balancing dams, branch canals and canal tail ends (i) Although there are adequate flow measurement structures which can be used to measure flows at the canal tail ends, this is not being carried out; (ii) Measurements at the branch canals are not being measured to conduct detailed water balances.	Encourage the scheme managers to ensure consistent reading of flow measurements at branch canals and canal tail ends or install electronic flow recording equipment
2	Current water balances being conducted at Sand-Vet are not accurate & comprehensive. (i) There are no sub-scheme water balances being conducted to assist in determining where the focus should be in repairs and maintenance of the irrigation canals during the dry periods; (ii) Water balances contain estimates of water losses - there are no measurements being undertaken; (iii) Water balance assessment does not include precipitation.	Implement a detailed water balance including measurement at canal tail ends and balancing dams in order to disaggregate the water losses by sub-scheme as well as whether operational or leakage losses.
3	There is a lack of continuous flow monitoring in the scheme: (i) The flow recorders at the canal tail ends are currently not operational (ii) No manual flow monitoring is taking place at the critical points.	Encourage flow monitoring either through installation of telemetry system or electronic means in order to make an improvement in

Item No.	Issue description	Comments
		irrigation water management
4	No all modules of the water administration system to manage water use is being fully utilised for sub-scheme water balance assessments: (i) The water release module is currently not being utilised to improve water management; (ii) It is difficult to pinpoint the exact scheme area experiencing water losses.	Implement use of WAS to conduct detailed sub-scheme irrigation water balance assessment
5	Gross water losses are substantially higher than the expected BMP for a lined canal irrigation scheme: (i) Condition of sections of the canal infrastructure is in a very poor condition; (ii) Some of the major siphons are blocked resulting in the overtopping of the canal.	Implement refurbishment of canals
6	There is no electronic measurements or telemetry infrastructure to improve management of water delivery system operations: (i) The manual reading of flow records, is cumbersome and has high risk of errors; (ii) There is no flow measurement at some of the canal end points; (iii) There are no automated controls.	Install electronic measurement systems or telemetry infrastructure for realtime monitoring
7	Irrigators are paying the Sand-Vet WUA based on a 2 step tariff but which is based on the area	Financial incentives are necessary

Item No.	Issue description	Comments
	irrigated and not actual water use (i) The effectiveness of the current structure needs to be evaluated (ii) Irrigators are losing on the benefits of the use of their full water use entitlements (iii) Area based assessment encourage water waste and produce inequitable water costs between efficient and inefficient users.	to encourage efficient water use
8	With the conveyance infrastructure owned by the DWA, there are concerns around the following: (i) There are service level agreements between the DWA and Sand-Vet WUA regarding the roles and responsibilities. However all the refurbishment requirements have not been completed at this stage. Assets are owned by DWA while the O&M is carried out by Sand-Vet WUA. There is a likelihood of a disjuncture in ensuring the assets are maintained until such time that the asset are refurbished according to the MOA, resulting in deterioration of the infrastructure and increase in water losses (ii) The lack of clarity may result in some of the issues such as refurbishment of the infrastructure not being carried out in time to reduce water losses from the canal infrastructure (iii) The priorities between the two entities may differ in terms of when to undertake rehabilitation of the infrastructure	Service Level Agreement between the DWA and Sand-Vet WUA

10.2 Flow measurement data and assessments

10.2.1 Adequacy of flow measurement data

Good information is fundamental to making decisions on managing irrigation water at any irrigation scheme. **Figure 10.1** below provides the extent of flow measurement that is ideal for conducting an irrigation scheme water balance assessment. The availability of flow measurements helps inform both the water user and the WUA about the quantity, timing, and location of water use and therefore enables the WUA to conduct a water balance analysis not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated **in Figure 10.1** below, it would be ideal to have flow measurements at the inlet to the primary canals, at the main branch canals, at balancing dams as well as at the canal tail water ends. This would assist in determining the water losses in each section of the canal system, as well as the operational spills if there are any.

As indicated in **Figure 3.2**, the Sand-Vet Irrigation Scheme appears to have adequate flow measurement structures in place at the ideal places to measure the flows. The WUA is currently only taking flow measurements at the canal headwork's as well as adjusting sluice gates according to the irrigator's weekly water application. These include weirs and Parshall flumes on the canals, and flumes and rated sluice gates on the laterals to the individual farmers.

However, currently the existing Parshall flumes at the branch canals as well as the canal tail ends are not being measured. At the canal tail ends the flow recorders which would provide continuous flow measurement for monitoring are not functional. Therefore the Sand-Vet WUA cannot conduct detailed water balances at scheme and sub-scheme level to determine the extent of water losses, including operational losses which are measured at canal tail ends.

As an example, it would be useful to measure the flows into the A and B/C canals of the Sand canal system in order to determine whether there is excess water being diverted which could be adjusted in time to potentially save water into these branch canals. The extent of water losses in the branch canal could be used to address any operational issues or prioritise the branch canals for maintenance.

Losses from outfalls can be reduced by improving water control in channels through the use of channel control technology and/or changing management practices. Examples of measures to control outfalls include the automation of flow-control structures and measurement devices and the optimisation of channel operations, using computer software.

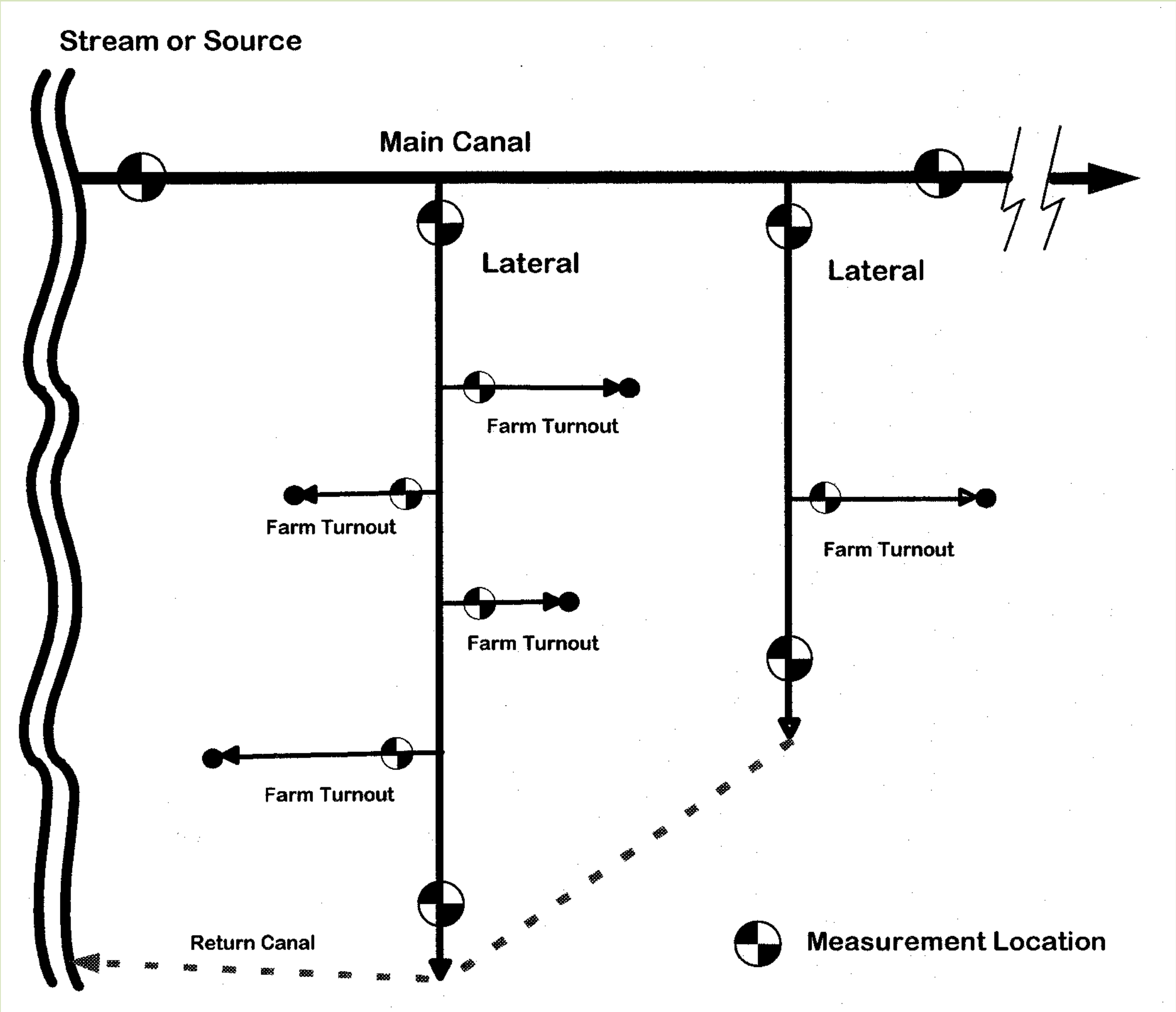

Figure 10.1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

10.2.2 Lack of continuous monitoring

The Sand-Vet Irrigation Scheme is a manually operated system with no electronic flow recording. There is no telemetry infrastructure linked to any of the existing flow measurements within the scheme area to carry out real time or near real time flow monitoring and control of deliveries. The only real time flow monitoring is being done at the canal head works were the Department of Water Affairs (DWA) Hydrological Branch has remote control flow measurements at the Parshall Flumes.

The ideal system for improving irrigation water use efficiency would be to provide data on a real-time basis through the use of automatic and data transmission devices such as a telemetry system used by some irrigation schemes in the country.

The lack of real time reduces the scheme operators' capacity to respond to changes in demand by water users and allowing for improving the efficiency of irrigation water management.

However, with the installation of the Water Administration System (WAS) to undertake water accounting reports, it would be ideal to install a telemetry system that is compatible with the WAS programme to enable real-time or near real-time measurement and changes to be made. This will significantly improve the water use efficiency of the Sand-Vet Irrigation Scheme.

Although manual flow measurements are being undertaken, these are not taken at all critical points and therefore the determination of a detailed water balance assessment cannot be done

10.2.3 Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Sand-Vet WUA:

(i) Regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system to enable detailed water balance assessments to be carried out;

(ii) Ensuring that all measuring devices in the scheme are in good operating condition and regularly calibrated.

(iii) Planning for the installation of telemetry system infrastructure, so that the flow measurement data is sent via the telemetry to the Sand-Vet WUA office for direct input into the WAS programme. This should be with a view to have real time flow monitoring in order to reduce the time required to adjust flows, identify where losses are occurring and allow the Sand-Vet WUA to operate the scheme more efficiently.

10.3 Irrigation water balance assessment

10.3.1 Irrigation water balance is not conducted in detail

Although a lot of measurement structures are available including the Parshall flumes at branch canals, at the balancing dams as well as at canal tail ends in the Sand-Vet Irrigation

Scheme, there are some components of the water balance that are not being measured, estimated or included in the water balance assessment. These include the following:

(i) Measurement of evaporation using pan evaporation, to determine local evaporation losses, is currently not being conducted. Therefore the losses calculated at present from the water balance assessment are unreliable or inaccurate.
(ii) Measurement at the canal branch to enable sub-scheme water balance assessments to be conducted.
(iii) Measurement of changes in the balancing dams to include in the water balance assessment.
(iv) Measurement of operational losses at the tail ends, as well as at the rejects.
(v) Measurement of precipitation records is currently not being included in the water balance assessment, which may indirectly result in higher operational spills if irrigators do not take up their full water demands.

10.3.2 Irrigation outfalls and operational spills are not included in the irrigation water balance assessment

The irrigation water balance at scheme level for the Sand-Vet Irrigation Scheme, indicated that the scheme "water losses", comprising seepage losses, evaporative losses, operational spills, as well as the flows at the canal tail ends, was averaging approximately 35.9 million m^3/a. Not all of this volume can be considered avoidable water losses, as some is unavoidable losses, such as evaporation due to the exposed canal surface area and the seepage losses due to the hydraulic conductivity of the concrete lining as well as the water table in which the canal system was built.

It is currently difficult to disaggregate the avoidable losses into the different components of water losses. This is because no measurement is being taken at the canal tail ends although there are measuring structures. This would provide the operational losses at canal tail ends assuming there are no other river demands downstream that are supplied by the scheme. At this stage, it is difficult to determine how much water is returned back to the Sand and Vet River and the tributaries. Therefore the available flow measurements can provide a more accurate water balance if the measurements are included in the WAS programme.

As a result of the lack of sufficient flow measurement, the actual water losses are estimated, which complicate the setting of water saving targets for different interventions.

Although there are Parshall Flumes to measure the inflows into most of the canals as well as the canal end points in the Sand-Vet Irrigation Scheme, the measurements from these points are currently not being included in the determination of a comprehensive irrigation water balance assessment at both scheme and sub-scheme level. If conducted, this would assist the Sand-Vet WUA to determine which of the sub-schemes has the highest seepage losses and where to focus on reducing the losses, instead of refurbishing the whole irrigation canal infrastructure system.

10.3.3 Management Goal 2

The goal to address the above issue is as follows:

(i) Ensure that flows measurements at the canal tail ends, measurements into and out of the balancing dams and branch canals are taken on a continuous basis in the Sand-Vet Irrigation Scheme;

(ii) Ensure that all measured data forms the basis for conducting water balance assessments and calculating water losses at scheme as well as sub-scheme level.

10.4 Full utilisation of the Water Administration System

10.4.1 The installed WAS is currently not being fully utilised

The Water Administration System (WAS) was developed as a tool to be used by Irrigation Boards/Schemes and Water User Associations (WUAs) to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. The WAS consists of seven modules, integrated into a single programme and these modules can be implemented partially or as a whole. The system includes the following seven modules:

10.4.1.1 Administration module

This module provides the details of all water users on an irrigation scheme. Information managed by this module includes addresses, notes, cut-off list, list of rateable areas, scheduled areas, household and livestock pipes installed on canals, industrial water quotas, crops and areas planted and crop yields. This module was installed and is currently operational.

10.4.1.2 Water order module

This module captures all the weekly and monthly water requested by each farmer in the scheme. It also includes any additional water requests or any cancellations of water orders.

This module is very useful to determine the extent of additional requests, as well as the cancellations, as this will provide a clear indication of the extent of operational spills on rejects and tail ends in the case of cancellations that were not made on time. It will also highlight the flexibility that the Sand-Vet Irrigation Scheme has in responding to cancellations.

10.4.1.3 Water release module

This module takes information from the water order module and calculates the volume of water to be released from the Erfenis Dam and Allemanskraal Dam into the main canal and all its branches allowing for lag times and any water losses and accruals to supply the request for the week.

A schematic layout of the total canal network or river system, is captured with detail such as the cross sectional properties, positioning of sluices or pumps, canal or river slope, structures and canal or river capacities. Discharges are converted to the corresponding measuring plate readings where needed, so that the sluice gates can be set to deliver the volume of water requested.

10.4.1.4 Measured data module

This module provides the field data that is measured from the rates and volume of water delivered to each user and the rate and volume of water released at the Erfenis Dam and Allemanskraal Dam, as well as the rate and flow at different points in the canal system. This data is very useful in conducting water balance assessment not only at scheme level but also at sub-scheme level.

Currently the data is measured manually because there is no telemetry system. The existing flow recorders are not functioning and therefore the scheme relies on water control assistants and the Scheme Managers to manual take flow measurements.

10.4.1.5 Other modules

The above four modules together with the Reporting module are the key modules in accounting for water use in an irrigation scheme. However there are other modules which include the following:

(i) *Water accounts module*- this module administers all water accounts for an irrigation scheme or water management office. The water accounts module is a full debit system, from which monthly reports can be printed, including invoices on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

(ii) *Crop water use module* is used to calculate the water usage per crop between two specified dates for all the planted crops on a scheme, based on the plant date, the area planted and the crop water use curve.

(iii) *Reporting Module* – includes an extensive range of water and financial reports. Water balance sheets, distributions sheets, WUEAR and various other operator defined reports can be generated. This module is currently in use at the scheme.

However, at present not all the modules of the WAS is being fully utilised by the scheme as the full extent of the release module is not being utilised. There will be substantial benefit in utilising the WAS system to undertake Water Use Efficiency Accounting Reporting (WUEAR), with a view to determining which of the irrigation sub-schemes are experiencing significant water losses. This can provide priority areas, where issues need to be addressed in irrigation water management in the Sand-Vet Irrigation Scheme.

It has been estimated that field measurements indicated water savings of between 10% and 20% on fully implementing the water release module of the WAS program alone. In the case of Sand-Vet Irrigation Scheme, the WAS programme has been installed for about 10 years but the records indicate that these savings have not been achieved because the WAS programme has not been fully implemented.

10.4.2 Management Goal 3

The management objective to address the above issue, is to ensure that all the modules of the WAS programme are implemented and that weekly and monthly reports from the modules are generated.

Furthermore, the measured data module should be linked to a telemetry system, to enable direct reading of the measured data in the WAS programme. This can be used to undertake automatic reporting on water losses, not only at scheme level, but also at sub-scheme levels.

10.5 Capacity of Balancing Dams and availability of farm dams

10.5.1 Overview

There are balancing dams in the Sand-Vet Irrigation Scheme. There is the Klippunt balancing dam which regulates flows to downstream irrigators in the Vet canal system, while the Palmietkuil balancing dam regulates flows to downstream irrigators in the Sand canal system.

One of the benefits of having regulating structures such as balancing dams, is that balancing dams will reduce the time it takes to deliver water to the irrigators, thereby reducing the seepage losses and leakages in the conveyance system. However in order to determine the benefits of having balancing dams, it is important to know the capacity of these balancing dams. This is a problem in the Sand-Vet irrigation scheme as discussed below.

10.5.2 Capacity of Klippunt Balancing

The capacity of the Klippunt Balancing Dam is not known. As a result it is not known whether the capacity of the balancing dam is sufficient to supply the downstream irrigators.

Besides the fact that the capacity of Klippunt balancing dam is not known, the scheme operators are not utilising the existing measurements upstream and downstream of the dam to determine the changes in the storage volume of the balancing dam. These changes will contribute to the water diverted into the scheme.

10.5.3 Palmietkuil balancing dam capacity

The total capacity of the Palmietkuil is provided as 0.713 million m^3/a with a net full capacity of 0.441 million m^3/a. This was when it was constructed. However, with the siltation, the current net full supply capacity may have decreased.

There is a gauge plate which can be used to determine the changes in the storage for input into the water balance assessment. This is currently not being used.

10.5.4 Management Goal 4

The management goal to address this operational problem is undertake the following:

(i) Determine the capacity of the balancing dams and start measuring the inflow and outflow of the balancing dams in order to determine the impact of the dams on supplying the downstream irrigators.

(ii) Ensure that the capacity of the balancing dam at the end of the week is incorporated in the calculation of water balance assessments. This effect is currently not being factored in the water balance assessments and therefore the impact of balancing dams is not being felt.

10.6 Condition of the conveyance and measurement facilities

10.6.1 General

In order to properly develop the Sand-Vet Irrigation scheme water management plan, it was essential that an assessment of the overall condition of the facilities to identify potential issues was carried out. As indicated in Chapter 4, a high level condition assessment together with discussions with the Sand-Vet WUA was undertaken. This was supplemented with the work conducted by Aurecon on the canal infrastructure. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

10.6.2 Condition of canal infrastructure

Although there are no measurements to determine the actual avoidable water losses in the Sand-Vet Irrigation Scheme, the assessment carried out in the previous chapter has highlighted that there are likely to be very high water losses due to the condition of the canal infrastructure.

The condition of the Vet canal was found to be in very poor condition. Sections of the canals had the concrete panels washed away due to the problem with the drainage from the farms. Irrigators are pumping water to the farms above the Vet canal. However because of lack of a sufficient drainage canal system, the irrigation water drains on to the canal weakening the bearing capacity of the soils.

10.6.3 Condition of the siphons

On the Sand canal system, it was found that the major problems related to the blockage of the canal siphons particularly on the S canal as well as the A and B canals. The blockages are resulting in some sections of the canal, particularly the A canal as well as the B canal overtopping. This will likely damage the canals with a significant cost required to refurbish in the future if this is not addressed as a matter of urgency.

Besides the siphon blockages, it would appear that the canals, particularly the main Sand canal siphon is leaking badly. Discussions with the scheme operators indicated that the same siphon had given problems before and was repaired in 2009. Therefore there may be a need to replace the pipes making the siphon.

10.6.4 Management Goal 5

The management objective to address the above issues is to develop and implement a refurbishment programme to reduce irrigation canal losses within 5 years, so the amount of water losses are reduced towards the BMP and the water saved stored in the Erfenis Dam and Allemanskraal Dam to provide security of water supply during drought periods.

10.7 Lack of sufficient maintenance of the existing canal infrastructure

10.7.1 Limited resources available to undertake maintenance

Due to the limited resources both financial and management, the Sand-Vet Irrigation Scheme cannot undertake all the maintenance requirements needed during the dry periods. As a result there is a significant backlog in the maintenance of the canal infrastructure as well as the canal siphons.

Furthermore there are sections of the canals where complete renewal of these sections is required. This requires significant financial resources which the Sand-Vet WUA does not have. Given the fact that ownership of the canal infrastructure belongs to the Department of Water Affairs (DWA) the responsibility for ensuring that the irrigation water infrastructure handed to the Sand-Vet WUA is in good condition to provide the level of service provision of effective and efficient conveyance of canal infrastructure still lies with the DWA. The DWA has committed 40 million over the 8 year period to refurbish the canals according to the MOA between DWA and the Sand-Vet WUA.

The lack of maintenance of the canals may be resulting in a rapid deterioration of the canal infrastructure. This may therefore be one of the major reasons contributing to the high irrigation water leakages in the Sand-Vet Irrigation Scheme.

10.7.2 Refurbishment and rehabilitation of water infrastructure

The current water charge recovered by the DWA only appears to cover for the return on assets (ROA) but does not cater for the refurbishment and renewal of the infrastructure. The Sand-Vet WUA charges the water users of the irrigation scheme for the operation, maintenance and administration costs of the WUA. The fact that the DWA is not recovering for the O&M costs means that the Sand-Vet WUA is responsible for the maintenance of the canal infrastructure from the water charge for O&M, while the refurbishment of the canals is done with the funds provided by DWA according to the MOA.

However the rationale of how the water charge for O&M and whether it takes into account the refurbishment and canal replacement costs as well as depreciation of assets is not known.

It is likely that the current water charge for O&M and for the administration costs is not sufficient to cover for the refurbishment and renewal of the canal infrastructure. The matter is further complicated by the fact that ownership of the infrastructure is still with the DWA.

The condition of the infrastructure when it was handed over to the Sand-Vet WUA by the DWA may be major issue affecting how the scheme is operated and the responsibilities (both financial and managerial) of the parties in the maintenance of the infrastructure including refurbishment and renewal of the infrastructure..

10.7.3 Management Goal 6

The management goal to address this issue is for the Sand-Vet Irrigation Scheme and the DWA to address the following:

(i) Develop a strategy for maintenance, rehabilitation and modernisation of the irrigation infrastructure;

(ii) Develop a financial model to determine the actual system cost and investment strategy to ensure sustainability of the hydraulic infrastructure and the Sand-Vet Irrigation Scheme. This model can be used as a basis for establishing the water rate charges to the water users in the Sand-Vet Irrigation Scheme.

10.8 Ownership of irrigation infrastructure

10.8.1 Roles and responsibilities in infrastructure maintenance have not been clearly described

The irrigation boards and Water User Associations (WUAs) have two main elements that dictate their operations – water and infrastructure. The ownership of irrigation infrastructure can prove to be one of the main barriers to improvement in irrigation efficiency if it is not well managed. More specifically, it is the management of the infrastructure, more than the ownership of the irrigation infrastructure that can create problems with the ensuring the quality of the infrastructure is maintained.

In the Sand-Vet Irrigation Scheme, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the Erfenis Dam and Allemanskraal Dam, the main, primary and branch canals. However, the WUA operates the irrigation infrastructure as an agent of the DWA and undertakes the normal maintenance of the irrigation infrastructure as part of the draft service level agreement.

The problems in the Sand-Vet irrigation scheme arise, when the major infrastructure needs replacement/total refurbishment, as is the case with the sections of the Vet canals. It is unlikely that the WUA has the financial capacity to undertake the refurbishment of the assets which are owned by government. It is also difficult to borrow against the assets as they are owned by government. The responsibility for replacement of major assets lies with government, whose priorities may be different to those of the WUAs.

10.8.2 Management Goal 7

The broad objective to address this issue around ownership of the irrigation infrastructure is to ensure that the levels of responsibility between the DWA and the Sand-Vet WUA are further refined and the draft agreements signed in order to enable the responsible party to refurbish the canals particularly the identified Vet canal as a matter of urgency. This is assuming that the DWA does not want to transfer the infrastructure to the WUA in the short to medium term.

11 IDENTIFICATION AND EVALUATION OF WATER MANAGEMENT MEASURES

11.1 Overview

There are numerous water management measures that accomplish a wide range of the goals identified in the previous section. However, only a few of the measures have the capacity to accomplish the goals to improve irrigation water use efficiency in the Sand-Vet Irrigation Scheme.

The priority water management measures to improve irrigation water use efficiency on the Sand-Vet Irrigation Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points which include the inflow and outflow at the balancing dams, the branch canals, as well as the canal tail ends, etc.

(2) Preparation of more detailed water balance assessments for the Sand-Vet irrigation scheme, as well as the sub-schemes which include the Vet canal and its branches and the Sand canal and the three main branch canals.

(3) Implementation of all modules of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail end spills to be carried out as well as undertake water balance assessment at scheme as well as sub-scheme level.

(4) Installation of electronic measurements or telemetry infrastructure to enable real time monitoring of irrigation water in the long term.

(5) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand.

(6) Maintenance and refurbishment of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

11.2 Best Management Practices for irrigation water management in Sandvet Irrigation Water Scheme

11.2.1 Overview

In order to evaluate the candidate water management measures it was important to first of all determine the water loss target by incorporating not only the unavoidable water losses but also determining the attainable level of water losses based on the Best Management Practices (BMP) envisaged in the Sand Vet Irrigation that takes account of the technical and managerial capacity of the Water User Association. This is discussed in the following sections.

11.2.2 Gross/Total water losses

The water losses in the Sand-Vet Irrigation Scheme are considered to be very high at 33% of the total release into the Vet canal and 22% of the total release into the Sand canal system giving an overall 28% of the total volume water released into the Scheme from the Erfenis and Allemanskraal Dams. The total water losses were determined to be 35.9 million m^3/a (i.e. 23.3 million m^3/a losses in the Vet and 12.61 million m^3/a in the Sand) based on the 2011/12 water year and the available records.

In order to determine the potential water that can be saved from the two sub-schemes, the unavoidable water losses as well as the BMP for operational and distribution efficiency were determined.

11.2.3 Unavoidable water losses

It was determined in Chapter 7 that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals in the Vet canal system was 6.32 million m^3/a based on the total releases into the canal system in the 2011/12 water year, which translates into 9% of the total volume of water diverted into the Vet canal system.

For the Sand canal system, the unavoidable water losses due to evaporation losses and seepage losses were calculated as 4.7 million m^3/a or 8% of the total releases into the canal system in the 2011/12 water year.

11.2.4 Best Management Practice for operational and distribution efficiency

Besides the seepage and evaporation losses which are unavoidable because of the type of conveyance infrastructure which are open channels and are liable to leak because of the hydraulic conductivity of the concrete lining, there are operational losses which are unlikely to be recovered at a scheme level due to a number of factors. These factors include the following:

(i) Canal filling – The Sand-Vet allows for a minimum of 2 weeks scheduled dry period to allow for the maintenance of the canal infrastructure and repairs necessary at measuring structuring, etc. During this period the canal is emptied to allow for the maintenance to be carried out. A significant volume of water is then required to fill the canals before they can deliver the irrigation applications to the users in the scheme. This canal filling is included as part of the operational losses which cannot be recovered through any major intervention measures.

(ii) Operational performance losses – The existing sluices and Parshall flumes have in inherent error that needs to be included in the operational performance of the scheme even after improving the calibration of the flow measurements. These metering errors have to be taken into account when determining the Best Management Practice (BMP) for in the Sand-Vet Irrigation Scheme distribution efficiency

(iii) Untimely deliveries of water that cannot be used as a result of cancellations which will take a minimum of 12 hours to make adjustments to the releases. These losses can result in either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme.

A Water Research Commission (WRC, TT466/10) which was conducted in 2010, has provided guidelines of the desired range of operational losses due to metering errors, canal filling losses after each dry period that have to be included in order to determine the BMP for operational and distribution efficiency (WRC 2010). This is additional to the unavoidable losses determined in the previous sections. This desired range is expressed as a percentage of inflow into the irrigation scheme. The desired range for operational losses (i.e. metering errors, canal fillings, etc.) is 10% of the inflow into the irrigation scheme.

Therefore on the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the Sand and Vet irrigation canal systems. This has been used in setting the water savings and the acceptable water losses of each of the two canal systems.

11.2.5 Acceptable water losses in the Sand-Vet Irrigation Scheme

The unavoidable water losses in the Sand-Vet irrigation scheme were determined to range between 8% for the Sand canal and 9% for the Vet canal. This water is additional to the irrigation water use required at the farm edge.

Furthermore there are operational performance inefficiencies in operating the Sand-Vet scheme including trying to match the delivery to the irrigation applications as mentioned in the previous section. Based on the WRC study the attainable range of operational losses which are not likely to the recovered through water management intervention measures is 10% of the total releases into the Sand and Vet canal systems. **Table 11.1** and **Table 11.2** below provide the water loss target for the Vet and Sand canal system respectively.

As illustrated in **Table 11.1** below, the expected average water losses taking into account the unavoidable water losses and the expected inefficiencies in the distribution of irrigation water due to problems of matching supply and delivery as well as metering errors and canal filling losses will be 19% of the total releases into the Vet canal system.

Therefore based on the 2011/12 water year, the expected water losses 13.40 million m^3/a. When compared with the total losses of 23.3 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 33% to the acceptable water losses of 19% of the total releases into the Vet canal system.

Table 11:1: Acceptable water losses in the Vet canal system (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>BMP Distribution Efficiency</th><th>Acceptable water losses</th><th>Potential water savings</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>6.06</td><td></td><td>6.06</td><td></td><td>6.06</td></tr>
<tr><td>Evaporation</td><td>0.26</td><td></td><td>0.26</td><td></td><td>0.26</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="3">7.09</td><td rowspan="3">7.09</td><td rowspan="3">9.90</td><td rowspan="3">16.98</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Leakages</td><td></td></tr>
</table>

Description	Unavoidable losses	BMP Distribution Efficiency	Acceptable water losses	Potential water savings	Total losses
Spills					
Operational Losses					
Canal end returns					
Other					-
Total	6.32	7.09	13.40	9.90	23.30
% of total volume released into system	9%	10%	19%	14%	33%
% of total losses	27%	30%	58%	42%	100%
Total releases					70.86

In the case of the Sand canal system the acceptable water losses are provided in **Table 11.2**. As illustrated in **Table 11.2** below, the expected average water losses taking into account the unavoidable water losses and the expected inefficiencies in the distribution of irrigation water due to problems of matching supply and delivery as well as metering errors and canal filling losses will be 18% of the total releases into the Sand canal system.

Therefore based on the 2011/12 water year, the expected water losses are 10.46 million m^3/a. When compared with the total losses of 12.61 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 22% to the acceptable water losses of 18% of the total releases into the Sand canal system.

Table 11:2: Acceptable water losses in the Sand canal system (million m^3/a)

Description	Unavoidable losses	BMP Distribution Efficiency	Acceptable water losses	Potential water savings	Total losses
Seepages	4.45		4.45		4.45
Evaporation	0.21		0.21		0.21
Filling losses		5.80	5.80	2.15	7.95
Over delivery to users					
Leakages					
Spills					
Operational Losses					
Canal end returns					
Other					-
Total	4.66	5.80	10.46	2.15	12.61
% of total volume released into system	8%	10%	18%	4%	22%
% of total losses	37%	46%	83%	17%	100%
Total releases					58.02

The overall acceptable water losses for the Sand-Vet irrigation scheme is 19% of the total releases into the Sand and Vet canal system (see **Table 11.3** below). However the Sand-Vet WUA intends to report on the performance of the two sub-schemes separately and therefore have been treated separately.

Table 11:3: Acceptable water losses for the whole of the Sand-Vet irrigation scheme (million m^3/a)

Description	Unavoidable losses	BMP Distribution Efficiency	Acceptable water losses	Potential water savings	Total losses
Seepages	10.52		10.52		10.52
Evaporation	0.46		0.46		0.46
Filling losses		12.89	12.89		24.93
Over delivery to users				12.05	
Leakages					
Spills					
Operational Losses					
Canal end returns					
Other					-
Total	10.98	12.89	23.87	12.05	35.91
% of total volume released into system	9%	10%	19%	9%	28%
% of total losses	31%	36%	66%	34%	100%
Total releases					128.88

11.3 Task 1: Flow measurements at critical points of the irrigation scheme, calibration of the flow measurements and detailed water balance assessment

11.3.1 Frequent measurement of flows at headworks, branch canals and canal tail ends

As indicated in the previous chapter, the Sand-Vet irrigation scheme has all the necessary flow measurement structures at the critical points in the scheme. There are Parshall Flumes which can be measured to determine the flow rate, and the volume of water diverted into the headworks and branch canals or returning to the river system at canal tail ends.

Therefore with the existing measurement infrastructure, the Sand-Vet irrigation scheme should be taking continuous flow measurement at all the branch canals as well as the canal tail ends. As a matter of priority the Sand-Vet WUA should commence with measurements at the canal tail ends. This will improve the information provided in the water use accounting reports submitted to the Department of Water Affairs (DWA).

This can be followed by taking flow measurements at the branch canals so that water balance assessments at sub-scheme level can be carried out.

11.3.2 Initial capital and operation and maintenance costs

There will be capital cost required for the Sand-Vet WUA install electronic flow measurement system in order to start taking electronic flow measurements at the canal tail ends or at the branch canals. However the functions and responsibilities of the existing scheme operators will need to be updated to include taking of flow measurements on a regular basis.

11.3.3 Calibration of the Parshall Flumes

There is an urgent need to carry out an inventory of the accuracy of the existing Parshall Flumes in order to calibrate those that are found to be inaccurate. Furthermore the existing Flumes may be operating in submergence conditions resulting in inaccurate measurement of actual water delivered to the farmers.

11.3.4 Impact of the identified water management

Although it is difficult to determine exactly how much water will be saved by taking flow measurements electronically and calibrating the Parshall Flumes or replacing them with more robust measurement system such as Crump weirs, it was determined that the potential water that will be saved will be 3.25 million m^3/a based on the 2011/12 water year. The installation of accurate flow measurement will provide the Sand-Vet WUA with appropriate and relevant information on where the water losses are taking place and much better information on actual water delivered to its customers. For example by taking flow measurements at the canal tail ends, the Sand-Vet WUA will be able to determine by how much they can reduce the flow rate at the canal headwork's.

However there will be some cost related to the calibration of the Flumes to improve the accuracy of the measurement structures.

11.4 Task 2: Installation of flow monitoring system

11.4.1 Installation of a telemetry system

The existing flow recorders are not operational. Therefore there is limited monitoring through manual operation of the irrigation scheme. The need for continuous monitoring of water supply delivery to the irrigators and irrigation water management is considered to be critical in reducing operational losses such as operational spills at rejects and at the canal tail ends.

The gross water losses in the Sand-Vet Irrigation Scheme over the 2011/12 water year has averaged 35.91 million m^3/a, which is considered to be very high. The likelihood of a significant portion of the gross water loss being due to operational losses is high. Therefore by improving the monitoring of irrigation water in the scheme through the telemetry system will see significant water savings for both the scheme as well as the downstream water users.

The Sand-Vet Irrigation Scheme is planning on installing a telemetry system to monitor the flows in the canal conveyance system. The first urgent action to be undertaken by the Sand-Vet WUA is to ensure that the proposed telemetry system is compatible with the WAS programme so that the flow measurements from the 20 diversion points can be monitored on a real-time basis and the reading can be entered directly into the Water Administration System (WAS) for use by the release module.

In order to get the telemetry system operational, the Sand-Vet WUA needs to appoint a specialist telemetry expert to assess and carry out the installation of the telemetry system. This will also include ensuring that the software is compatible with the WAS programme. The telemetry system should be to display current, last 24 hours flow rates and monthly water and flow level data of all the Remote Telemetry Units (RTU). It will also store all engineering and conversion data necessary for converting flow levels into flow rates and volumes. This will be done to ensure compatibility with the WAS so that all flow records can be read directly into the WAS programme. This will provide data on a real time basis and provide the tracking and accounting of water use in the irrigation scheme.

The installation of the telemetry system and ensuring compatibility is envisaged to take 2 years with an ensuing expected useful life of 15 years.

11.4.2 Initial and O&M Costs

Table 11.4 below indicates that initial capital costs and related operation and maintenance costs. The estimated initial capital investment is the cost of the telemetry expert and software requirements related to the compatibility issues. This has been estimated to be R498 000, comprising the supply and installation of the telemetry infrastructure, estimated at R348 000, which includes the time for the telemetry expert and the software link with the WAS estimated to cost about R150 000.

As indicated further in **Table 11.4** below, the expected water savings due to the flow monitoring as a result of installation of the telemetry that is aligned to the WAS programme including training of the Scheme Managers/WCOs, is estimated to be approximately 3% of the avoidable water losses as determined in the irrigation water balance assessment. This has been estimated to be 1.85 million m^3/a allowing for an 90% success rate.

Based on the preliminary work that was done during the site visit when flow measurements were taken at the Sand canal tail end and the C canal tail end of the Sand Canal system, the water that can potentially be saved by changing the current operational procedures would be 0.5 million m^3/a. In the Vet river canal this would be 2.34 million m^3/a.

The water saved will be available in the Erfenis and Allemanskraal Dams for distribution as required. This will improve the yield of the two dams with the scheme benefiting during the low flow periods or drought periods as there will be more water available to mitigate any drought.

The average incremental cost (AIC) of installing the telemetry system for real-time monitoring will be 3 c/m^3 which when compared with the current heavily subsidised water use charge of 2.28 c/m^3, would appear to be high. However as the subsidies on irrigation agriculture are removed to reflect the scarcity value of irrigation water in future, the implementation of the real-time monitoring will be beneficial in the long term.

Table 11:4: Summary of the costs and potential savings - Telemetry system update and alignment with WAS

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Telemetry	Install telemetry system which is compatible with WAS programme				
Installation period					12 months
Productive period					20 years
Initial Capital Investment Costs	Software			150 000.00	
	Telemetry infrastructure			348 000.00	498 000.00
Annual O&M Expenses	Software licence, replacement of parts, and batteries, etc.			37 350.00	
Water Losses					
Estimated reduction in water losses due to flow monitoring	Flow monitoring	1.85	1 068 340.53		
Average Incremental Cost (AIC)					0.06

11.5 Task 3: Management Systems

11.5.1 Overview

One of the critical aspects of improving water use efficiency in the Sand-Vet Water User Association is to ensure that all the relevant technical, managerial, information system is available.

11.5.2 Task 3.1: Asset Management System including development of canal infrastructure management plan

Millions have already been invested in developing the Sand Vet Irrigation Scheme with significant investment in canal infrastructure and related infrastructure. Therefore the performance and return on investment of their infrastructure needs to be managed having understanding (i) What infrastructure is being managed by the WUA; (ii) Where is it located?; (iii) What condition the infrastructure is in?; (iv) What on-going work is required?, as well as (v) What is the value of the assets?

The current environment generally requires better management of assets, more flexible operations, faster rectification of failures and more effective customer service. Being able to predict problems, develop proactive strategies (such as not waiting for failures to occur) and take the necessary action, are critical tasks of advanced asset management. In addition, it is important to fully understand the cost of maintenance services. Too often these services have been contracted out without fully understanding the costs. This can result in the contractor having all the knowledge of the costs associated with the network, and more importantly, the ability to be able to dictate terms to the WUA

In order for the Sand-Vet Water User Association (SWUA) to manage the existing canal infrastructure it is important that the WUA establish an infrastructure management system. This means that the SWUA should have an information management system such as GIS to enable the linking of the spatial information with the data on the location, capacity and performance as well as the condition of the assets.

11.5.3 Task 3.2: Full implementation of WAS and alignment with the telemetry systems

11.5.3.1 Implementation of WAS release module

The importance of relevant and opportune information in decision making cannot be overemphasized. Managing irrigation systems is no exception to the rule. On the contrary, information is vital since daily decisions with regard to water deliveries and other aspects may affect the well-being of many farmers. Traditionally, managers of irrigation systems have tried to cope with this problem through the compilation of field information that was manually processed.

Unfortunately, the number of users in the Sand-Vet irrigation system runs in the order of hundreds and manual processing of information becomes a lengthy and costly exercise. As a consequence, relevant information is often not available on time or is incomplete and many *ad hoc* decisions have to be made.

11.5.3.2 Review the current use of WAS

As mentioned earlier, the Sand-Vet Scheme does not have a comprehensive water accounting system to not only track water deliveries but also determine the areas of improving irrigation water management. The scheme is not using all the modules of the WAS programme to manage and reduce water losses.

Therefore, the Sand-Vet Irrigation Scheme (WUA) needs to ensure that they implement, particularly the release module of WAS together with the telemetry system.

11.5.4 Initial Capital Expenditure and O&M Costs

The Sand-Vet WUA already has the WAS programme installed at their offices. However, in order to ensure that all WAS modules are operational, will require the training of the water control personnel. The programme should also be set up to enable water balance assessments at sub-scheme levels (i.e. for each of the six canals in the irrigation scheme).

The estimated operation and maintenance costs for operating the WAS programme includes an annual fee of R24 000 to obtain the latest updates of the programme and maintenance of the programme.

The estimated water savings has been included together with the installation of water measurements discussed above. It is estimated that 1.85 million m^3/a, could be saved, by undertaking the installation of telemetry system and implementation of a water accounting system such as the full WAS programme.

The capital investment required to carry out these two tasks is minimal, compared to the significant benefit in reducing water losses in the Sand-Vet Irrigation Scheme. This should be considered priority by the Sand-Vet Water User Association.

11.6 Task 4: Conveyance infrastructure maintenance and refurbishment programme

11.6.1 General

The conveyance infrastructure rehabilitation programme is to carry out the refurbishment of the infrastructure in the conveyance system that was found to have significant leaks and seepage. The discussion with Sand-Vet WUA indicated that the major problem currently is the Vet canal where whole sections of the concrete panels have been removed as well as siphon blockage on the Sand main canal. This is discussed in the following section.

11.6.2 Conveyance infrastructure refurbishment and canal relining

The preliminary assessment conducted as well as the information supplied by Aurecon on the infrastructure survey they conducted indicates that the condition of sections of the Vet and Sand canal system is very poor (see **Figure 4.1** in chapter 4).

Given the high water losses, due to structural failure of concrete lined irrigation canals due to flooding and drainage problems, there is significant scope for refurbishment of the existing canal infrastructure, in order to reduce the current water losses. This will provide the WUA with the baseline to ensure efficient utilisation of the assets. These sections will require complete refurbishment at significant capital costs while other sections will require sealing of the wetted perimeter of the canal with polyfelt and bitumen emulsion that is sprayed.

It was estimated that approximately 8.5 km of the canal mainly in the Vet with some in the Sand will require total reconstruction and/or relining of the canal with concrete. Approximately 50 km of the canal will require sealing of the wetted perimeter with polyfelt and bitumen emulsion. This was based on the assessment of the Aurecon report and preliminary assessment of the canal.

The refurbishment of the canal infrastructure is likely to save approximately 7.95 million m^3/a. However this will come at a significant cost. The total cost estimate for relining of the canal sections with concrete and sealing of the wetted perimeter was determined to be R53 million while the operation and maintenance costs to maintain the infrastructure in good condition from thereon was calculated as R0.18 million per year.

A condition assessment of the canal system has already been conducted and the results of the assessment should be used to develop a canal refurbishment and renewal programme for the Sand-Vet Irrigation Scheme.

Table 11:5: Summary of capital investment requirement & benefits - Rehabilitation of the canal infrastructure

Item	Description	Water Savings Million m3/a	Cost Savings R per year	Sub-Total	Total
Refurbishment of canal sections	*Construction of canal sections with concrete, relining and sealing of the wetted perimeter of the canal with bitumen emulsion*				
Installation period					Five years
Productive period					20 years
Initial Capital Investment Costs	Total construction & relining of canal sections			39 178 091.59	
	Sealing of canal with bitumen emulsion			14 298 800.81	53 476 892.40
Annual O&M Expenses	Repair & sealing of joints			184 454.60	
Water Losses					
Reduction in water losses due to canal refurbishment	Leakage reduction	7.95	11 707 841.43		
Average Incremental Cost (AIC)					1.01

The capital cost requirements to enable the Sand-Vet irrigation scheme to carry out the refurbishment of the infrastructure is beyond the normal maintenance costs for which the Sand-Vet WUA is responsible. The total construction and relining of canals requires significant capital investment which the DWA will need to provide, since they own the assets. This should be carried out to the poor canal sections once a detailed condition assessment has been finalised taking into account the surveys of the canals recently conducted by Aurecon.

Currently the refurbishment balance assessment is with the DWA, who still own the infrastructure. In terms of the Service Level Agreement (SLA) between the Department and the Water User Association, provision was made in terms of clause 6.7 that refurbishment cost in the order of R40 million spread over five to eight years in equal amounts will be provided by the Department on the refurbishment and rehabilitation of the infrastructure. This figure could increase if found necessary considering the age of the infrastructure.Therefore the DWA should carry out the rehabilitation of the deteriorating conveyance infrastructure, where this is identified.

11.7 Task 5: Incentive based water pricing

11.7.1 General

To achieve an incentive for efficient water use, the price of irrigation water must be directly related to the volume delivered.

In order to encourage irrigators to use water efficiently, it is recommended that the existing pricing of water is reviewed to determine whether it provides the incentives for users to use water more efficiently. An incentive based water pricing structure for Sand-Vet Irrigation Scheme based on the current initiative should be considered. The implementation of incentive water pricing in irrigation agriculture, requires that comprehensive regulatory and operational criteria to be met before considering the economic criteria for incentive based pricing of irrigation water.

11.7.2 Regulatory aspects for incentive pricing

An orderly system of distributing water is already in place in the Sand-Vet Irrigation Scheme, based on the regulatory framework for distributing water among the farmers. The rules and procedures defining the water ordering and water releases are in place. These include responsibilities of the WUA and those of the irrigators, priorities in case of shortage or excess supplies; penalties for breach of rules, and so on. Based on this, there is immediate scope for improving water distribution through pricing. Furthermore, there are already flow measurement devices (i.e. sluice gates and Parshall flumes), for measurement of the quantity delivered.

From a regulatory perspective, the water pricing strategy can be used to in determining incentive pricing structure with two or three levels of pricing, to encourage efficient use of irrigation.

11.7.3 Operational aspects for incentive pricing

Measurement and charging at the farm level will require substantial investment in equipment, and an associated administrative bureaucracy, to collect and collate data on farm-level deliveries, and undertake the billing process.

The Sand-Vet Irrigation Scheme already has the operational systems in place such as weekly ordering, as well as the sluice gates (however not very accurate) to measure each irrigator's use. Furthermore, the scheme has the administrative system to carry out billing based on actual use, rather than on a scheduled basis.

With the above operational aspects in place, the direct link between service and payment are achieved, and the efficiency incentive that pricing is designed to produce, can be met.

11.7.4 Economic aspects for incentive pricing

Although the current pricing provides some incentives it is still based on the scheduled quota and not the actual water use. The current pricing, based on the scheduled quota does not provide the economic incentives for improving water use efficiency at farm level, as irrigators feel that they are entitled to the full use of their scheduled quota, even when they can achieve higher levels of production with less water.

If the charging system is to have an impact on consumption, then the system of payment must be such as to induce the desired economic response. In the case of Sand-Vet, the benefit of incentive pricing means irrigators can expect to pay less for their irrigation compared to the current scheduled quota which provides an economic incentive to the irrigators.

Because the Sand-Vet WUA needs to undertake fixed operation and maintenance activities, the incentive based pricing should consider the potential effects on revenue generated through water sales. However any savings made from reduction in water use at field edge, can be sold to other users such as the domestic sector whose demand is growing. This will provide supplemental revenue that could be used to develop more improvements to the scheme.

The potential savings are on the on-farm water use efficiency. The estimate is that there is likely to be savings of approximately 3% of the current irrigation water requirement, which translates to approximately 1.84 million m^3/a.

12 SAND-VET WATER MANAGEMENT PLAN

12.1 General

12.1.1 Legal provision for developing and implementing a WMP

The development and implementation of a Business Plan is a legal requirement to be undertaken by a WUA in terms of section 21 of Schedule 4 of the National Water Act (Act 36 of 1998). The constitution of a WUA - referred to schedule 5 for model constitution - outlines the principle functions to be performed by the WUA and will include the following:

(i) Prevent water from any water resource being wasted;
(ii) Exercise general supervision over water resources;
(iii) Regulate the flow of water course;
(iv) Investigate and record quantities of water;
(v) Supervise and regulate the distribution and use of water from a water resource.

The Business Plan for a WUA will thus incorporate a Management Plan setting out standards and Best Management Practices. Another 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 -*

b) 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;

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

Although the above section of the act is not prescriptive, there is a business case in light of the above legal requirements for the Sand-Vet WUA to develop a WMP in terms of the provisions of the act to enable it to manage the irrigation water in the scheme effectively and efficiently.

12.2 Establishment of water saving targets for Sand-Vet Irrigation Scheme

12.2.1 Use of equivalent depth per actual unit area

The implementation of a Water Management Plan for the Sand-Vet Irrigation Scheme to reduce water losses will imply reducing the water diverted/released per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the wheat, maize and potatoes that are being irrigated in the scheme area. Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Sand-Vet Irrigation Scheme assuming the scheduled quota of 7 200 m^3/ha/a remains constant.

In the Sand-Vet Irrigation Scheme, the trend-line indicates an increase in the diversion per unit of irrigated areas from 2000 to 2005 water years for the Vet canal system (see **Figure 12.1** below). The increasing diversions per unit of irrigated land are a clear indication that there was a major decline in irrigation water use efficiency during the period when the records were available. This may be due to the poor condition of the canal infrastructure as discussed previously as well as operational losses during the period.

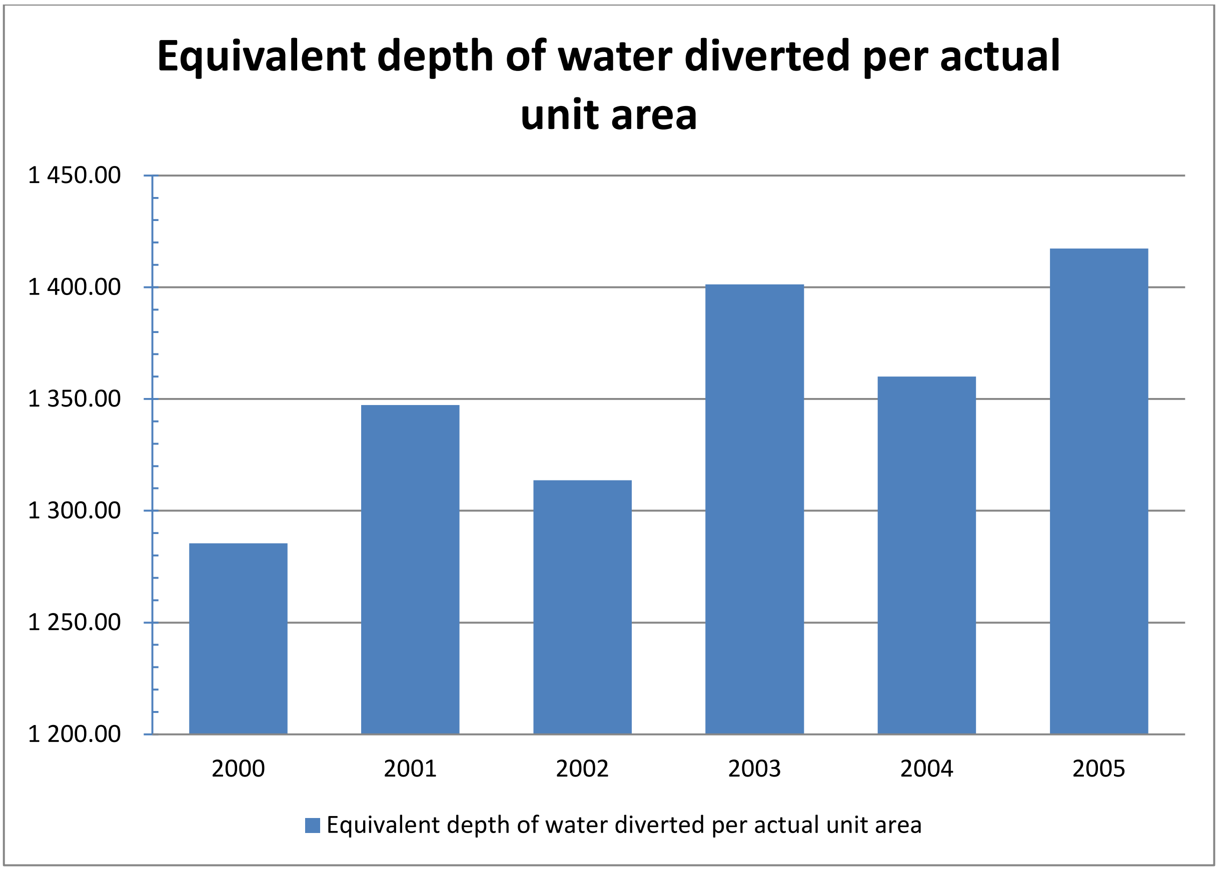

Figure 12.1: Trend line of increasing irrigation water diversion/released from Erfenis Dam expressed as an equivalent depth of water diverted per actual unit area irrigated for the Vet canals (m^3*10^3)

However in the case of the Sand canal system the trend-line indicates a slight decrease in the diversion per unit of irrigated areas from 2000 to 2005 water years (see **Figure 12.2** below). Hardly much has changed in irrigation water use efficiency over the last 2 years of records.

As the irrigation area has been constant over the period from 2000 to 2005, the allocated water per unit has increased in the case of the Vet while it has remained nearly the same in the case of the Sand canal over the same period.

Any improvements for example in on-farm water use efficiency may be likely to be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

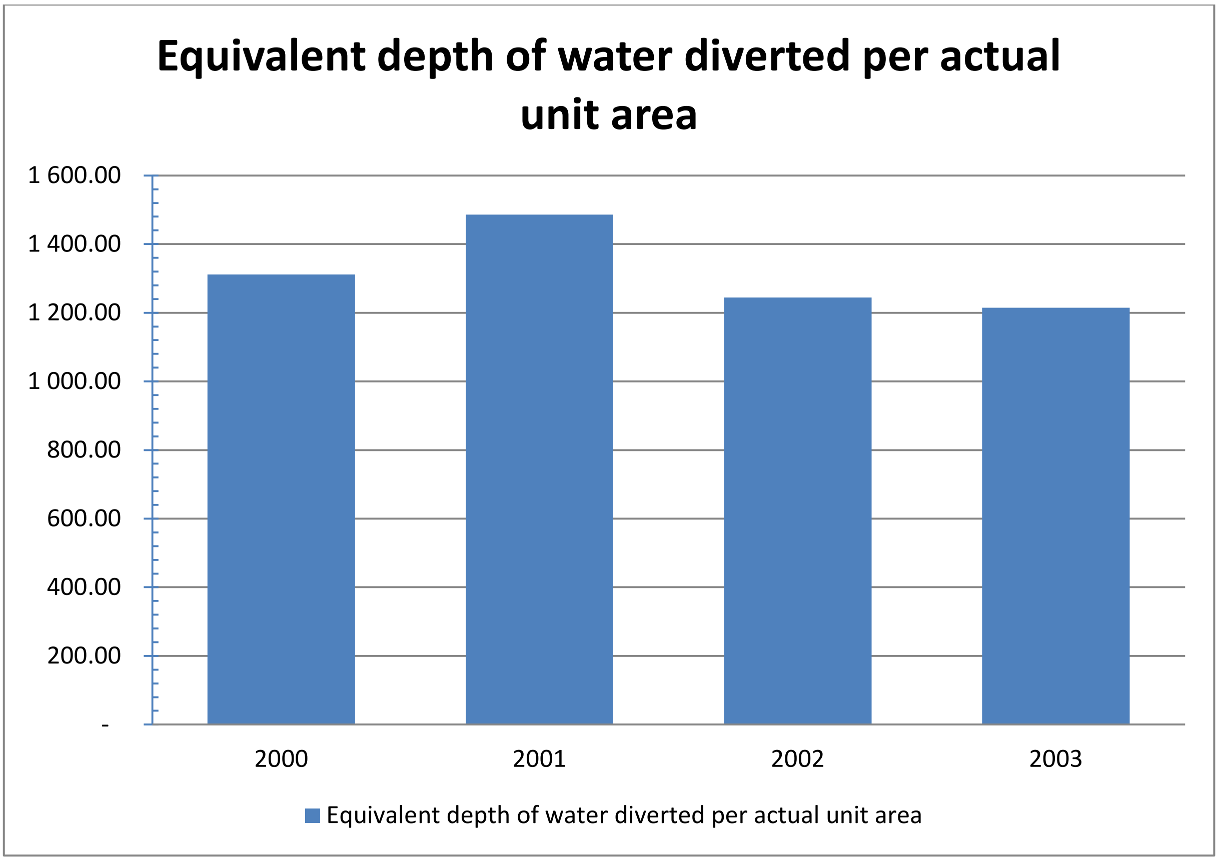

Figure 12.2: Trend line of slightly decreasing irrigation water diversion/released from Allemanskraal Dam expressed as an equivalent depth of water diverted per actual unit area irrigated for the Sand canals (m^3*10^3)

Therefore in setting water saving targets for the Sand-Vet Irrigation Scheme, the use of the equivalent depth per unit area irrigated as a performance indicator is proposed. Any decrease per unit of actual irrigated area will indicate progress being made by the scheme towards greater irrigation water use efficiency. This performance indicator can be used at scheme as well as at sub-scheme level. Currently this measure is not being used when the irrigation schemes submit their WUEARs.

12.2.2 Recommended water saving targets

12.2.2.1 Water savings from the Sand canal system

Because there has not been a decline in the trend-line of the diversions per unit area irrigated over the observed period for the Sand canal, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water that can be saved from implementing the identified water management measures for the Sand-canal system is provided in **Table 12.1** below.

Table 12:1: Projected water saving targets for the Sand-Canal system (million m^3/a)

Irrigation Component	Intervention	Estimated water savings	Percentage of inflow into Scheme	Implementation time line
Conveyance Infrastructure	Refurbishment of canal including renewal	1.65	3%	5 to 8 years
	Resealing of canals	0.43	0%	5 years
Distribution infrastructure	Flow measurement & monitoring	0.50	1%	2 years
	Recalibration of Parshall Flumes		0%	2 years
Operational	Canal tail ends /	0.5	0%	1 year
	Operational spills		0%	
Sub-Total Scheme target		2.15	4%	
On Farm irrigation	Incentive pricing	0.83	1%	
	Irrigation systems			

12.2.2.2 Water savings from the Vet canal system

The trend-line of the diversions per unit area irrigated over the observed period for the Vet canal indicated that more water is being diverted per unit area irrigated from the canals, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water that can be saved from implementing the identified water management measures for Vet canal system is provided in **Table 12.2** below.

Table 12:2: Projected water saving targets for the Vet Canal system (million m^3/a)

Irrigation Component	Intervention	Estimated water savings	Percentage of inflow into Scheme	Implementation time line
Conveyance Infrastructure	Refurbishment of canal including renewal	4.8	6%	5 to 8 years
	Resealing of canals	1.50	3%	5 years
Distribution infrastructure	Flow measurement & monitoring	1.35	2%	2 years
	Recalibration of Parshall Flumes		0%	2 years
Operational	Canal tail ends /	2.34	3%	1 year
	Operational spills		0%	
Sub-Total Scheme target		9.95	14%	
On Farm irrigation	Incentive pricing	1.01	1%	
	Irrigation systems			

Based on the projected water saving targets, the Sand-Vet Irrigation Scheme can achieve a 4% reduction in irrigation distribution water losses relative to 2012 levels in the Sand and 14% reduction in irrigation distribution water losses relative to 2012 levels in the Vet, by the end 2022 based on the components provided in **Table 12.1** and **Table 12.2** above.

12.2.2.3 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings from implementing the flow measurements; recalibration of Parshall Flumes and flow monitoring of 0.5 million m^3/a Sand canal and 1.35 million m^3/a in the Vet canal can be achieved. This is the water savings that have been targeted to be saved over a period of 3 years for the Sand-Vet Irrigation scheme until 2016.

12.2.2.4 Long term water saving targets

For the long term a further 6.3 million m^3/a, is envisaged to be saved by refurbishment of the Vet canal infrastructure where it was identified that the condition of the infrastructure has deteriorated badly compared with the Sand canal infrastructure. The potential water saved from refurbishment of the Sand canals particularly the siphons which are blocked was determined to be 1.65 million m^3/a (see **Tables 12.1** and **Table 12.2** above)

A total of 1.84 million m^3/a comprising of 0.83 million m^3/a in the Sand and 1.01 million m^3/a in the Vet, could potentially be saved through implementing incentive based pricing. This will require amendments to the current water pricing strategy which is currently being reviewed. It is unlikely that these water savings can be realised in the next three years. They are considered for the medium to long term in this water management plan. Therefore because of the complexities in implementing incentive based pricing and the timeline, it is recommended that this measure be implemented last.

The long term target is however to reduce the water losses to approximately 19% of the total inflow into the whole of the Sand-Vet Scheme. The annual water savings targets are discussed together with the action plans for implementation of the identified measures.

12.3 Implementation plan to achieve the water saving targets

12.3.1 General

The evaluation of the potential measures for implementation in the Sand-Vet Irrigation Scheme area, to improve water use efficiency and reduce water losses, indicates that there are some financial and socio-economic imperatives to implement the identified water management based on the envisaged water savings. There is potential in the Sand-Vet Irrigation Scheme to expand irrigation areas based on the gross margins from growing citrus and grape fruit.

12.3.2 Target 1: Conduct flow measurement at all critical measurement points in the scheme

Table 12.3 below provides the plan of activities required to ensure all flow measurements are taken by the Sand-Vet WUA and detailed water balance assessments are conducted on a quarterly basis and a management report presented to DWA on the status of water losses, water saving targets as well as the actions taken to reduce water losses.

As discussed in the previous chapters, the Sand-Vet irrigation scheme has all the measurement structures to enable the WUA to taken flow measurements at all critical points albeit by manually reading the flow levels and converting these levels to flow rates.

It is therefore considered a priority that the Sand-Vet WUA initiates the electronic reading of flow measurements at the following critical points:

(i) All the three main canal tail ends of the Vet canal, the Sand canal and the C canal which is a major branch canal of the Sand canal system.
(ii) Incorporate the balancing dam information by taking flow measurements at the inflow and outflow of the two dams, particularly the Palmietkuil so that changes in storage capacity is included in the water balance assessment.
(iii) At the main branch canals particularly the A, B and C canals in the Sand canal system.

12.3.3 Target 2: Conduct detailed water balance assessment at sub-scheme level

In order for the Sand-Vet WUA to benefit from taking the flow measurements, detailed water balances should be prepared to incorporate actual flow measurements. Currently the WUA relies on estimates, particularly of the water losses. As a first step, two water balance assessments, one for the Sand and the other for the Vet sub-schemes should be conducted including the measurements at the balancing dams as well as the canal tail ends.

12.3.4 Target 3: Installation of the telemetry system for real time flow and level monitoring

Telemetry basically refers to accessing the data and controlling the system by remote means. With a telemetry setup, the Sand-Vet WUA can program the system to run automatically and the WUA can assess the system at any time to find out the status of a canal system. If something goes wrong with the system, it can be set up to alarm the WUA.

Table 12:3: Sand-Vet Irrigation Scheme: Water Management Measures and action plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	To measure all critical points in the Sand-Vet irrigation scheme	(i) Install and Commission Orpheus Mini Meters at the 3 main canal tail ends.	June 2013	Sand-Vet WUA
		(ii) Measure the inflow and outflow at the balancing dams to determine weekly changes in storage by installing and Commissioning Orpheus Mini Meters.	June 2013	
		(iii) Calibrate measurement structures as required	June 2013	
2	Undertake detailed water balance assessments of the scheme	(i) Split the Sand-Vet scheme into the Sand and Vet sub-schemes and prepare a water balance assessment and WUEAR for each sub-scheme to DWA	June 2013	Sand-Vet WUA
		(ii) For the Sand canal system split the scheme into the Sand and the 3 main branch canals	June 2013	
		(iii) Prepare detailed water balance assessment for the sub-schemes and split the losses to reflect operational losses from canal tail ends	June 2013	
		(iv) Set water saving targets based on update information to reduce operational losses at canal tail ends	June 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
3	To enable real or near real time flow monitoring	(i) Detailed design of the flow measurement and remote telemetry units (RTU) required for flow measurement (ii) Install new telemetry system infrastructure including software to ensure compatibility with WAS (iii) Calibrate the flow measurements such as flumes and sluices to improve the accuracy in flow measurement (iv) Prioritise areas of significant water losses	Oct. 2013 June . 2014 May 2014 June 2014	Sand-Vet WUA
4	To fully implement the WAS programme	(i) Review current use of WAS programme modules (ii) Implement the full use of the WAS ordering and release modules (iii) Set up WAS programme to carry out water balances at scheme and sub-scheme level (iv) Implement full use of the WAS programme including the release module	May 2013 June. 2013 June. 2013 June 2013	Sand-Vet WUA

Priority	Goal	Action Plan	Timeline	Responsible Authority
5	To conduct the refurbishment of the canals	(i) Classify the condition of all canal segments based on the condition of the canals. In cooperation with scheme personnel, conduct field reconnaissance to obtain attribute data and rate the condition of segments;	June 2013	Sand-Vet WUA
		(ii) Prepare a motivation to DWA for refurbishment of the poor sections of the canals requiring total construction as well as relining;	Oct. 2013	
		(iii) Engage with the DWA Infrastructure branch to motivate for refurbishment of the identified canal sections;	November 2013	DWA / Sand-Vet WUA
		(iv) If applicable prepare tender documents & specifications for total re-construction of canal sections and relining of the canals. n	March 2014	DWA
		(v) Assess water savings made from total construction of sections of the Vet canal and relining of canal sections	May 2019	DWA
		(vi) Hand over the refurbished canals to Sand-Vet WUA for on- going maintenance in accordance with the formal service level agreement between the two parties	June 2020	

Priority	Goal	Action Plan	Timeline	Responsible Authority
6	To implement incentive pricing structure for the WMA in 3 years	(i) Review current irrigation water pricing strategy and update administration systems (ii) Provide inputs in updating the DWA water pricing strategy (iii) Engage with irrigators on incentive pricing structure (iv) Install accurate flow measurement & implement water billing based on incentive pricing rate (v) Update the operating rules of Erfenis Dam and Allemanskraal Dam to supply irrigators based on incentive pricing rate	June 2013 July 2013 August 2013 March 2014 June 2014	DWA / Sand-Vet WUA
7	To implement management systems to assist in water savings	(i) Install an Asset Management system including Geographic Information System (ii) Update the WAS programme to enable sub-scheme water balances (iii) Financial systems – Review current pricing structure and update for future sustainable maintenance	June 2013 June 2013 May 2014	Sand-Vet WUA

Priority	Goal	Action Plan	Timeline	Responsible Authority
		(iv) Administration systems – Review the roles & responsibilities of current personnel (v) Assess and revise additional administration requirements to enable implementation of the plan	October 2013 June 2014	
8	To align the WMP to the catchment management plan	(i) Engage with the catchment forum to present the WMP (ii) Align activities between the catchment process and the WMP (iii) Update the WMP including the tasks and related activities from the catchment process	June 2013 July 2013 August 2013	Sand-Vet WUA/ Catchment Forum
9	Undertake water quality monitoring of the river upstream and downstream of the Sand and Vet canals.	(i) Identify water sampling points. (ii) Taking water samples for analyses (i.e. Microbiological and Chemical) from identified points. (iii) Feedback Analyses reports to users.	March 2013 May 2013 June 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority

Figure 12.3 below provides a layout plan of where the installation of the telemetry base station and the location of the remote terminal units are required to provide access to the flow and level data which can be sent to the base station at the Sand-Vet WUA offices. A number of activities and tasks for implementation of installation of telemetry infrastructure is presented in **Table 12.2** above.

As illustrated in the Table, the first priority action plans focuses on designing the telemetry infrastructure and network in the scheme. It is important that the telemetry system first focuses on installing the infrastructure at the two primary canals of Sand and Vet where the releases from the Dams into the canals takes place; the main branch canals; the balancing dams as well as the canal tail ends.

With the installation of telemetry system, the Sand-Vet WUA will be in a position to conduct the real time flow measurements at all critical points of the Sand-Vet irrigation scheme, including the spills at the canal tail ends as well as the flow into the different branch canals. This will assist the scheme in determining where any critical changes to the expected flows such as at canal tail ends can be done thereby allowing the scheme operators to react to any operational losses or even theft of irrigation water.

Besides the monitoring of flows, the Sand-Vet WUA will now be in a position to conduct detailed irrigation water balances for the scheme as well as at sub-scheme level. This will enable the scheme operators to determine which of the sub-schemes has the highest water losses and therefore develop specific intervention measure to reduce water losses. Furthermore, the scheme operators will be able to determine the different types of water losses.

The updating and calibration of the existing flumes should also be conducted to enable accurate flow measurements to be taken.

12.3.5 Target 4: Full implementation of WAS programme

The benefits of the rehabilitation of the telemetry system cannot be fully realised without the full implementation of all the modules of the WAS programme, which needs to be linked with the data and records from the telemetry system. The WAS programme can then use the information and flow records to match the water releases and the water requested, to minimise operational spills, as well as to reduce any current flows at the tail ends.

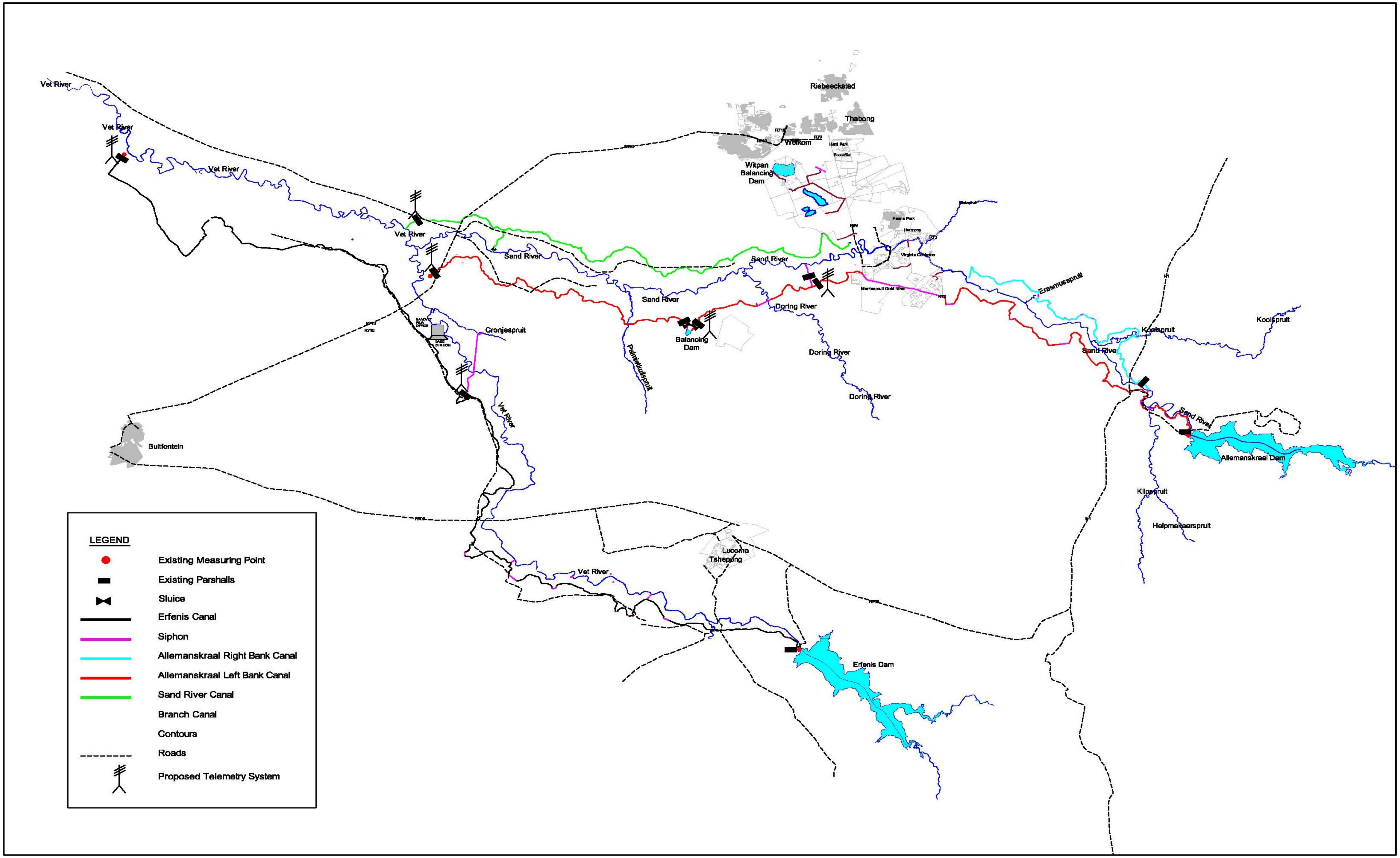

Figure 12.3: Proposed telemetry system for the Sand-Vet Irrigation Scheme

The flow at the tail ends is considered as a loss, although it may have a beneficial use downstream. The downstream demands can however be supplied by direct flows in the Sand and Vet River and/or releases from Erfenis Dam without releases made from Erfenis Dam and Allemanskraal Dam into the canal infrastructure.

The full implementation of the WAS programme, together with the telemetry system, will substantially improve the operation of the Sand-Vet Irrigation Scheme and reduce current operational losses in particular, which are considered to be high. The target reduction in operational losses, estimated to be 4.1 million m^3/a, can be achieved within the current water year, by implementing these two priority measures.

12.3.6 Target 5: The refurbishment of concrete panels on the Vet Main canal

Besides the need to reduce operational spills and losses through improving irrigation water management using the flow measurement and the WAS programme, the seepage losses and leakages were also determined to be high. Therefore priority in rehabilitation of the conveyance infrastructure is an imperative.

The losses due to the deteriorating condition of the concrete canal can be reduced by rehabilitating the canal. This requires first engaging with the DWA to inform them of the major leaks due to the canal breakage which requires significant capital to replace and leaks from the siphon resulting in deterioration of the canal infrastructure. As they own the asset, it is envisaged that the DWA can utilise the refurbishment balance assessment to replace the canal and siphon.

The actions to be undertaken are indicated in **Table 12.3** above. It is important to note that because the actual amount of leakage has not yet been fully established, a pond test is recommended to determine how much water is lost before a final decision is made on replacing the siphon. Once the pond test indicates that the amount of leakage justifies replacing the pipe, this can be implemented within the time frame as illustrated in **Table 12.3** above.

12.3.7 Updating and implementation of the Water Management Plan

The Scheme Manager will be responsible for amongst others the implementation and updating of the Water Management Plan (WMP) for the scheme.

The roles and responsibilities of the applicable Scheme Manager for the updating and implementation of the WMP will be the following:

(i) Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level

(ii) Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office and SAAWUA

(iii) Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues

(iv) Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes

(v) Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme

(vi) Maintenance and modernisation of the irrigation infrastructure

(vii) Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme

(viii) Monitor the plan and schedule for implementing water conservation program components

(ix) Report quarterly to DWA on the implementation status of the WMP, i.e. actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives

(x) Annually review and update the WMP with a water conservation program for the scheme with goals, objectives, improved water saving targets, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

12.3.8 Implement incentive pricing

This requires a review and updating of any regulatory and operational criteria required to enable the Sand-Vet WUA to implement incentive based pricing. The action plans and time frame including the responsible authority are indicated in **Table 12.2** above. Although the Sand-Vet WUA is indicated as the responsible authority, the DWA will need to play a significant role to ensure that the structuring of the incentive based pricing is done within the framework of the water pricing strategy. The focus is in trying to reduce any over-irrigation and the current volume of on-farm irrigation water by implementing incentive based pricing.

Implementation of incentive based pricing requires a review and updating of any regulatory and operational criteria required to enable the Sand-Vet WUA to implement incentive based pricing. The action plans and time frame including the following:

(i) Review and update the regulatory aspects of incentive based water pricing structure by proving inputs into the updating of the water pricing strategy;
(ii) Evaluate the average actual water use by irrigators as a percentage of their scheduled allocation. This can be done through a questionnaire and reviewing the historical records of irrigation demands;
(iii) Determine the fixed operation and maintenance costs of the Sand-Vet Irrigation Scheme and assess the revenue requirements for sustainable operation of the scheme;
(iv) Establish the base price of irrigation water per unit of water based on the revenue requirements of the scheme to meet the O&M costs;
(v) Determine the marginal costs per unit of water in excess of the base price and design one or more pricing levels above the base price;
(vi) Establish that the operational and accounting aspects of water pricing are in place;
(vii) Implement the incentive based water pricing structure for Sand-Vet Irrigation Scheme.

Besides the additional revenue that the Sand-Vet Irrigation Scheme may benefit from implementing incentive based pricing, the reduction in on-farm irrigation will help the scheme to:

(i) Reduce erosion;
(ii) Improve the crop yield and quality;
(iii) Reduce fertiliser leaching; and
(iv) Reduce drainage problems and downstream water quality problems.

As the DWA's water pricing strategy is currently under review and update, where amendments may be required to encourage incentive based pricing in the strategy, this should be considered.

12.4 Funding of the Sand-Vet Irrigation Scheme WMP

12.4.1 General

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. This is followed by on-going operations and maintenance which is required to ensure the installed infrastructure assets can provide the required performance for its intended use.

It has been proven in the analysis of the identified water management measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Sand-Vet Irrigation Scheme. This was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures. This is discussed in the following section.

12.4.2 Financing by Sand-Vet WUA

The benefits in taking flow measurement and implementing real time monitoring of the flows at critical points in the irrigation scheme will directly benefit the Sand-Vet WUA. Therefore based on the fact that the beneficiaries are the irrigators in the Sand-Vet Irrigation Scheme, the financing of the following aspects should be borne by Sand-Vet;

(i) Conducting measurement of flows at the identified critical points to enable detailed water balance assessments to be done at scheme and sub-scheme level;

(ii) Installation of the telemetry system infrastructure to enable real or near real time flow monitoring with a view to enabling quick response to water management and therefore reduce operational losses currently taking place in the scheme;

(iii) Providing the operation of all modules of the WAS programme to enable water accounting to be conducted as well as to fulfil the legal requirements in terms of the Act to provide annual reporting to the DWA on the irrigation water management for the scheme;

(iv) Carry out the removal of blockage on the canal siphons in order to reduce operational losses.

12.4.3 Financing by the DWA

The canal infrastructure in the Sand-Vet Irrigation Scheme is owned by the Department of Water Affairs (DWA) who has a draft service level agreement with the Sand-Vet WUA to operate and carry out annual maintenance of the infrastructure.

However as the condition of some of the infrastructure has deteriorated to the extent that there are a number of sections which require total construction of lined canals and relining of some of the canal sections, the cost of refurbishment is prohibitive and requires the DWA to provide the necessary financing necessary to reduce the high leakage losses due to the poor condition of the infrastructure.

It is therefore recommended that the DWA provide the funding for the refurbishment and rehabilitation of the canal infrastructure in terms of clause 6.7 of the MOA which amounts to approximately R40 million over an 8 year period or as required and motivated by the WUA. This funding is necessary to reduce water losses for the following:

(i) Refurbishment of the Vet canal sections requiring total reconstruction and other sections of the canal that are identified to require refurbishment.

(ii) Refurbishment of the sections of irrigation canals which are in a bad condition which are identified through a ponding test.

(iii) Implementation of the incentive based pricing by Sand-Vet WUA

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

The following can be concluded from the assessment of the water supply/requirements conducted for the Sand-Vet Irrigation Scheme area and can be summarised as follows:

- The Sand-Vet Irrigation Scheme is situated in the Lejweleputswa District Municipality, and traverses the local municipalities of Matjhabeng in the Sand River catchment, Masilonyana in the Vet River catchment and Tswelopele Local Municipality after the confluence of the two rivers to form the Vet River catchment. The scheme has a scheduled quota of 5 488 ha at an allocation of 7 200 ha/a in Erfenis sub-scheme and 5 049 ha at an allocation of 7 200 m^3/ha/a in the Allemanskraal sub-scheme. The total water allocation for Sand-Vet WUA is 75.88 million m^3/a.
- The main crops that are under irrigation include wheat, potatoes, maize, pecan nuts, peanuts and other cash crops.
- The Sand-Vet Irrigation Scheme receives its raw water supplies from the storage dam in the Sand and Vet Rivers namely Allemanskraal Dam and Erfenis Dam respectively from where irrigation water is released into the main canals delivering water to the scheme.
- The Erfenis Dam has a total storage capacity of 207.5 million m^3 while the Allemanskraal Dam has a storage capacity of 174.5 million m^3/a. Water is released from the dames to supply Sand-Vet Irrigation Scheme, based on the weekly orders.
- The Sand-Vet Irrigation Scheme has a total length of approximately 350.4 km of irrigation canal which supplies the irrigators as well as household consumption. There are two measurement gauge stations to measure the water diverted into the Sand and Vet canals respectively. The canals distribute irrigation and domestic water to approximately 589 sluice gates and Parshall flumes.
- Although no detailed condition assessment could be undertaken on the Sand-Vet Irrigation Scheme, a preliminary assessment and discussion with scheme operators and the condition assessment report by Aurecon, indicated that the Sand-Vet canals are in a very poor condition because of the age and lack of sufficient maintenance of the canals.
- In order to ensure that the irrigators receive their scheduled quota as and when required, the Sand-Vet WUA operates the irrigation scheme based on “delivery on

request" where each water user (irrigator) must submit a written request on a weekly basis and the water is delivered to some 589 abstraction points along the canal systems. These procedures are not all formerly documented.

- The total irrigation water use in the Sand-Vet for the past 10 months of records was 37.7 million m^3/a, for the Vet canal and 30.25 million m^3/a for the Sand canal system.
- The average total water diverted within the Sand-Vet Irrigation Scheme for the same period was 47.3 million m^3/a in the Vet canal and 58 million m^3/a for the Sand canal system which is a total of 81.8 million m^3/a for a period of 10 months of the irrigation water year.
- An irrigation water balance assessment conducted for Sand-Vet Irrigation Scheme indicated that the water losses averaged 28% of the total water diverted. This amount to total gross water losses of 35.9 million m^3/a, made up of 23.3 million m^3/a, the Vet canal and 12.6 million m^3/a in Sand canal system.
- The total water losses were disaggregated to determine the unavoidable and avoidable water losses with a view to establishing the irrigation water delivery BMP for Sand-Vet Irrigation Scheme. The total unavoidable water losses comprising evaporation losses and unavoidable seepage due to the age and condition of the infrastructure was determined to be 6.06 million m^3/a of the total water diverted from Erfenis Dam and 4.45 million m^3/a of the total water diverted from Allemanskraal Dam. These figures are only for 10 months of records and do not reflect the total water losses for the whole water year which is going to be higher.
- Based on the unavoidable water losses as well as the expected operational performance inefficiencies, the avoidable water losses was calculated as of 9.9 million m^3/a in the Vet canal and 2.15 million m^3/a for the Sand canal system making a total of 12.05 million m^3/a for the 2011/12 water year. These avoidable losses are considered to be due to operational wastage and leakage and spills at canal tail ends which can potentially be avoided.
- The irrigation water balance assessment together with discussions with Sand-Vet WUA operators highlighted that there were number of management issues which included the following:
  - (i) Although there are flow measurements, there are a number of measurements which are currently not being read. The most critical points to measure and monitor flows which are not being done include the canal tail ends as well as measurement of changes in the storage capacity of the balancing dams. Because these critical points are currently not being measured, the integrity and validity of the WUEARs currently being submitted are questionable.

(ii) Because of lack of sufficient flow measurements, the Sand-Vet WUA is not conducting detailed water balance assessment. The current water balance assessments include estimation of flows at some of the points where measurement structures exist. These include the canal tail ends. There is a need to address this in order to clearly determine where and how much water can be considered as water losses.

(iii) There is no flow monitoring system in place besides the manual monitoring taking place. This is because the flow recorders which were used to monitor the flows and levels at different critical points such as canal tail ends are not operational.

(iv) Not all the modules of the WAS programme which was installed are being utilised to undertake water use accounting reports. The main one which is the water release module is currently not being used.

(v) The condition of the canal infrastructure is in a very poor state resulting in significant water leakages. This is due to the canal breakages particularly in the Vet canal while there are cracks in the canals and there are problems with the canal joints in most of the canals. Furthermore the canal siphons are blocked and some may be damaged. This has resulted in significant water leakages particularly in the Vet canal as indicated in the water balance assessment.

- Based on the above water management issues, a number of measures were identified to address the issues with the main management goal being to reduce the high water losses and improve irrigation water use efficiency in Sand-Vet WUA. These measures were evaluated and prioritised based on the water savings and the average incremental cost (AIC) of implementing the measures.

13.2 Recommendations

13.2.1 Sand-Vet Water Management Plan

A water management plan for the Sand-Vet Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 28% to 19% of the total inflow into the irrigation scheme include the following:

(vi) *Conduct flow measurements and flow monitoring on all critical measurement points and calibration* - The evaluation of this measure has illustrated this to be the most beneficial to reducing water losses with the estimated water savings of 0.5 million m^3/a in the Sand canal system and 3.6 million m^3/a in the Vet canal system at an average incremental cost of R0.3 per m^3 of R164 per ha per year.

(vii) *Installation of telemetry system* - This measure is considered as the second most important intervention measure to do as it is critical to addressing the operational problems quickly and more effectively than the current manual monitoring of the scheme.

(viii) *Full implementation of WAS programme* - This measure is aligned to the first two measures and is considered to be important for implementation in the short term as well. It should be carried out at the same time as the first two intervention measures. There is potential to save approximately 0.5 million m^3/a in the Sand canal system and 3.6 million m^3/a in the Vet canal system as part of installing flow measurement and conducting real-time monitoring with the WAS programme and the telemetry system.

(ix) *Canal refurbishment and cleaning of siphons* - This measure although requiring significant capital investment will improve the condition of the infrastructure and reduce the high leakage losses. This will potentially save approximately 1.65 million m^3/a in the Sand canal system and 6.3 million m3/a in the Vet canal system at an average incremental cost of R1.01 per m^3.

(x) *Incentive based pricing* - This measure is considered a national issue which does not only affect the Sand-Vet irrigation scheme. It is dependent on whether the irrigators would require changes to the current water pricing which is area based and the implications to revenue management by the irrigation scheme which may not be stable.

13.2.2 Financing options for the WMP

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures.

Two sources of funding were identified and is recommended based on the beneficiaries of the intervention measures. The recommendation is that

(i) Sand-Vet WUA should look at financing the measures which will benefit and improve the operation and monitoring of irrigation water in the scheme. These measures will also allow Sand-Vet to fulfil it legal requirements in terms of the National Water Act on reporting and efficient management of irrigation water. These include updating the flow measurements, installation of the telemetry system and to fully implement the WAS programme.

(ii) The DWA owns the infrastructure in Sand-Vet Irrigation Scheme. The refurbishment of the canal infrastructure requires significant funding which cannot be met with the maintenance balance assessment of Sand-Vet. Therefore the capital investment required for the total construction of sections of the Vet canal and the relining of sections of the canals should be provided by the DWA. This also includes the implementation of incentive based pricing which will improve the on-farm irrigation efficiency while the savings will benefit downstream users unless Sand-Vet WUA can use the water to expand.

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