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

HARTBEESPOORT IRRIGATION SCHEME WATER MANAGEMENT PLAN

FINAL REPORT

February 2013

Prepared by

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Contract Title:	Development and Implementation of Water Management Plans to improve water use efficiency in the agricultural sector
Report Title	Lower Olifants River WUA - Water Management Plan
Authors	Francois Joubert Toriso Tlou, Pr. Eng

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Chief Executive Officer: N Fourie	Chairman: HBPIB

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EXECUTIVE SUMMARY

The Hartbeespoort Irrigation Board is one of the oldest irrigation schemes in South Africa. The dam has a catchment of 4 112 km², which is drained by the Crocodile River and its tributaries, the most important of which are the Jukskei, Hennops and the Magalies Rivers.

With a mean annual rainfall of 685mm, the initial runoff to the dam was estimated at 163 million m³. Since 2000, this volume has already doubled due to urban development in the catchment, which resulted in increased run-off and return-flows from wastewater treatment plants.

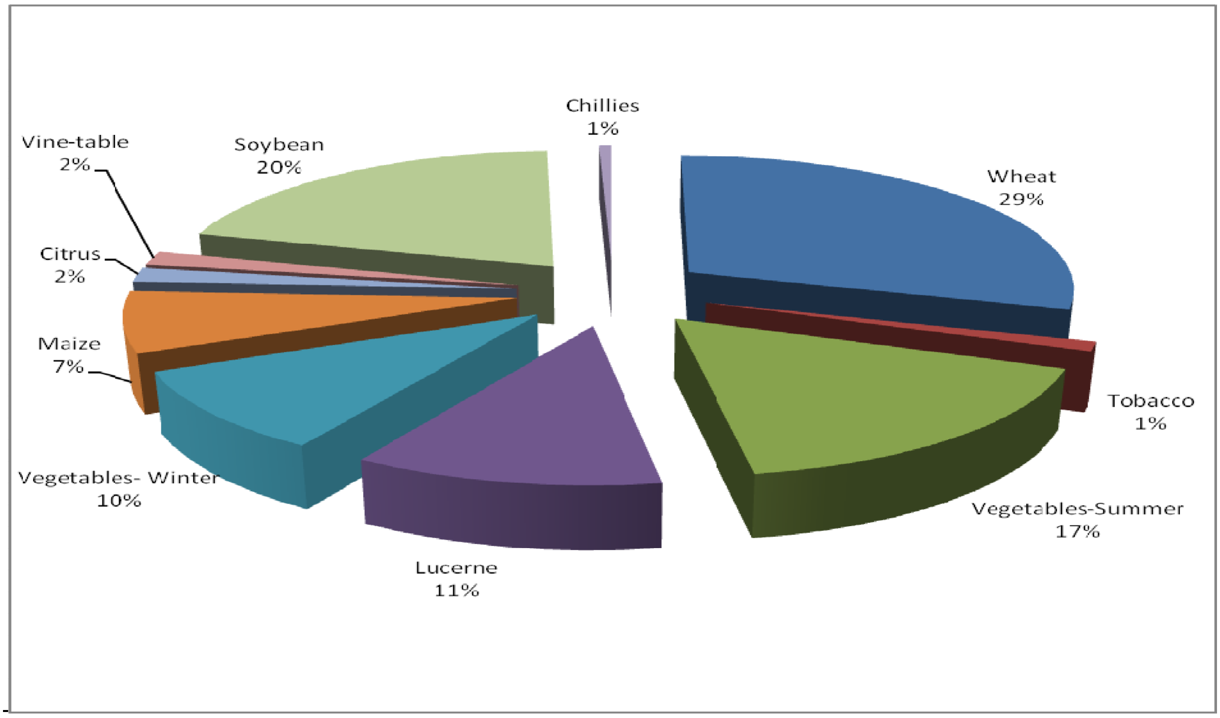
The scheme consists of the Hartbeespoort Dam (205 million m^3) on the Crocodile River and approximately 134 km main canals and 405 km branch canals. The Eastern canal comprises a 72 km long, wide parabolic concrete lined canal which has a capacity of 6.8 m³/s and serves irrigators on the eastern side of the Crocodile River. There are three siphons of approximately 700 meters in length on the Eastern canal. The Western canal is a 56 km long wide concrete lined canal structure which has a capacity of 6.8 m³/s and serves irrigators on the western side of the Crocodile River. There is a tunnel of 600 m conveying the water through granite outcrops and a 3 km siphon located on the Western canal.

There are six wards in the scheme, three for the East canal and three for the West canal and water is delivered to farmers through sluices. Depending on the size of the sluice gate opening, water can be delivered at 50 m³/hour, 70 m³/hour or 100 m³/hour. The sluices are adjusted by hand every 12 hours.

The Irrigation Board has a total scheduled area of 13 911 (hectares, at a scheduled quota of 6 200 m3/ha/a which translates to a total allocation of 86 248 200 m^3/annum. The various categories of water users and the annual allocations are shown in the following table.

Water Use category	***Annual allocation m³***
Commercial Farmers (13 911 ha)	*86 248 200*
Industrial users	*9 316 290*
TOTAL	***95 796 490***

Economic activity is based on commercial irrigated agriculture and the types of crops cultivated within the area of operation of the Hartbeespoort Irrigation Board are presented in the following figure.



<u>*Water balance assessment*</u>

Using the information obtained from the Water Use Efficiency Accounting Reports (WUEARs) for Oct 2004 to Aug 2011, previous studies and consultation with the management of the IB, a water budget for the Hartbeespoort IB was prepared. The water budget is an important tool for analysing the water management issues provided adequate and reliable data is available. At a scheme level there was sufficient data to determine a water budget based on the Water Administration System (WAS).

The average water losses have been 47% (17% unavoidable and 30% avoidable) of the released water from the dam into the canal system. This translates to an average of approximately 63.5 million m^3/a water losses in the Hartbeespoort IB area of operation. In terms of volume, approximately 40.6 million m^3/a are avoidable losses.

<u>*Existing water conservation measures*</u>

The Hartbeespoort IB has been implementing measures to improve the management of delivery to the irrigators and to minimise water losses. These measures include (a) annual maintenance of the irrigation canals to reduce avoidable water losses, (b) installation and maintenance of a telemetric flow measurement system to monitor the flow in the canal system, (c) replacing some 21 km of canal on the eastern canal section from own funds, (d) automating releases from the Kleinfontein balancing dam, (e) introducing the use of MAGNACIDE H Herbicide for the control of submerged aquatic weeds and algae, (f) ongoing *risk analysis where the potential risks involving the scheme are tabled and possible methods for resolving them identified.*

Best Management Practice - water losses

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is sufficiently maintained was conducted for the Hartbeespoort IB canal system. The analysis indicated that the unavoidable water losses due to evaporation losses and seepage is 22.9 million m^3/a, which translates to 17% of the total volume of water released into the IB canal system.

A Water Research Commission (WRC) study conducted in 2010 (Report TT465/10) provided guidelines on the desired range of operational losses that have to be included in order to determine the BMP for operational and distribution efficiency (Reinders 2010). On the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the scheme. This amounts to 13.6 million m^3/a based on the average inflow into the canals. 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 was set at 27% of the total releases into the canal system or 36.5 million m^3/a.

Water management issues

The compilation of a water budget and subsequent analysis has helped to identify key water management issues. The water budget analysis showed that on an annual basis, there is sufficient water to meet the irrigation demands. In addition to the water budget analysis, discussions were held with the management and other parties who are knowledgeable about the IB. This was done to determine the key issues the scheme is facing. The main water management issues identified include the following;

a) *The Hartbeespoort IB has six Android Telemetry Systems (not measuring accurately) installed of which two are located at the Dam outlet works where water is released into the two main canals. However, the telemetry system and WAS are not compatible. Flows and levels are therefore manually captured on the WAS system. The compatibility between the existing telemetry system and WAS should be addressed together with the automatic importation of telemetry data into WAS.*

b) *Four of the seven WAS models are used by the Hartbeespoort IB. They are the administration module, the water order module, the water accounts module and the report module. It would be ideal if the water release module is implemented fully and that weekly and monthly reports from the modules are generated. The WAS water release module is currently not being utilised due to the huge differences in canal characteristics as a result of the blooming of aquatic weeds over a very short period.*

c) *It is currently difficult to disaggregate the losses as there is no differentiation in the water balance assessment between the losses. Loss quantities are all based on* *estimates and no accurate measurements are taken. Tail water returns are not measured and the remaining avoidable losses such as leakage, spills and over delivery to users have not been disaggregated. Currently it is not possible to easily conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention.*

d) There is very little scheme balancing capacity and the goal is to investigate the possibility of creating additional storage capacity which will assist in operating the system as effectively as possible.

e) The quality of the water in the Hartbeespoort Irrigation Scheme has deteriorated over the last couple of years. This is not only due to the poor quality water flowing into the Hartbeespoort Dam but also due to informal settlements along the canal structure.

f) Aquatic weeds are an ever growing and major concern and are causing serious problems. The canal structure is under a lot of stress when the banks are flooded due to the effect that the aquatic weeds have on the water level. Algae and water grass also cause blockages in the system (from the main canal to the irrigation system) and contribute to operational losses including over delivery to irrigators.

Water Management Plan

Water saving targets

During the assessment it was possible to undertake sub-scheme assessments for the East and West canals.

The set targets for the East Canal are presented in the table below.

Description	***System inflow*** *(x 10^6m^3)*	***Present situation - Losses***				**Acceptable water losses**		**Target water saving**	
		Unavoidable losses *(x 10^6m^3)*	***Avoidable losses*** *(x 10^6m^3)*	***Total Losses*** *(x 10^6m^3)*	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**
Seepages		*12.0*		*12.0*	16.57%	12.0	16.57%	0	0.00%
Evaporation		*1.1*		*1.1*	1.52%	1.1	1.52%	0	0.00%
Filling losses		*0*	*11.8*	*11.8*	16.31%	7.24	10.00%	16.705	23.07%
Leakages									
Spills									
Over delivery									
Canal end returns			*12.1*	*12.1*	16.77%				
Other		*0*	*0*	*0*	0.00%	0	0.00%	0	0.00%
Total	***72.4***	***13.1***	***23.945***	***37.045***	***51.17%***	***20.34***	***28.09%***	***16.705***	***23.07%***
% of total volume released into system		***18.09%***	***33.07%***	***51.17%***					

The targets for the West Canal are presented in the table below.

Description	System inflow ($x\ 10^6 m^3$)	Present situation - Losses				Acceptable water losses		Target water saving	
		Unavoidable losses ($x\ 10^6 m^3$)	Avoidable losses ($x\ 10^6 m^3$)	Total Losses ($x\ 10^6 m^3$)	% of total volume released	Annual volume ($x\ 10^6 m^3$)	% of total volume released	Annual volume ($x\ 10^6 m^3$)	% of total volume released
Seepages		*9.011*		*9.011*	14.44%	9.011	14.44%	0	0.00%
Evaporation		*0.799*		*0.799*	1.28%	0.799	1.28%	0	0.00%
Filling losses		*0*	*7.59*	*7.59*	13.43%	6.24	10.00%	10.464	16.77%
Leakages									
Spills									
Over delivery									
Canal end returns			*9.114*	*9.114*	14.61%				
Other		*0*	*0*	*0*	0.00%	0	0.00%	0	0.00%
Total	***62.4***	***9.81***	***16.704***	***26.514***	42.49%	***16.05***	***25.72%***	***10.464***	***16.77%***
% of total volume released into system		***15.72%***	***26.77%***	***42.49%***					

The total losses on the Eastern Canal are roughly 9% more than the losses on the Western canal. This can mainly be attributed to three factors, namely; (a) the distance that the water has to travel in the Eastern canal is further than that of the Western canal. The Western canal also has the 3km long siphon and 600m tunnel, resulting in lower transmission losses, (b) large sections of the Eastern canal runs through "norite based" soils while the Western canal runs through heavy clay soils and (c) differences in the types of crops under irrigation between water users situated at the upper sections and those at the lower and end sections of the canal.

The targets for the Hartbeespoort IB as a whole are shown in the table below.

Description	System inflow ($x\ 10^6 m^3$)	Present situation - Losses				Acceptable water losses		Target water saving	
		Unavoidable losses ($x\ 10^6 m^3$)	Avoidable losses ($x\ 10^6 m^3$)	Total Losses ($x\ 10^6 m^3$)	% of total volume released	Annual volume ($x\ 10^6 m^3$)	% of total volume released	Annual volume ($x\ 10^6 m^3$)	% of total volume released
Seepages		*21.011*	*0*	*21.011*	15.59%	21.011	15.59%	0	0.00%
Evaporation		*1.899*	*0*	*1.899*	1.41%	1.899	1.41%	0	0.00%
Filling losses			*19.395*	*19.395*	14.39%	13.48	10.00%	27.169	20.16%
Leakages									
Spills									
Over delivery									
Canal end returns		*0*	*21.254*	*21.254*	15.77%				
Other		*0*	*0*	*0*	0.00%	0	0.00%	0	0.00%
Total	***134.80***	***22.91***	***40.649***	***63.559***	**47.15%**	**36.39**	**27.00%**	**27.169**	**20.16%**
% of total volume released into system		***17.00%***	***30.16%***	***47.15%***					

Based on the projected water saving targets, the Hartbeespoort IB can achieve a 6% reduction in irrigation water losses relative to the 2011 levels in a relative short period.

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans and aquatic weed control is some 8 million m^3/a.

For the long term a further 19 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 27% of the total diversion.

The priority water management measures to improve irrigation water use efficiency on the Hartbeespoort Irrigation Board include the following:

- *(i) Linking the existing telemetry system with WAS.*
- *(ii) Measure and record return-flows of the two main canals and major branch canals.*
- *(iii) Expand WUEAR to enable water budget analysis at both scheme and sub-scheme level.*
- *(iv) Fully implement the Release Module of WAS.*
- *(v) Investigate possibility to increase balancing capacity.*
- *(vi) Address pollution problems.*
- *(vii) Formalise Service Level Agreement.*
- *(viii) Develop and implement a comprehensive Management Information System.*
- *(ix) Implement incentive based pricing*

Conclusions and recommendations

The Water Management Plan forms the backbone of actions that have to be taken in increasing the efficient use of water within the Hartbeespoort Irrigation Board.

The intention of the Water Management Plan not to burden the IB and its officials with administrative tasks, but rather to promote a culture of using water as effectively and efficiently as possible. The plan will allow the IB to improve on current water management practices and to profit from their efforts.

The Water Management Plan is living document and close and ongoing co-operation between the IB and DWA is essential to the ultimate success of the WMP and also the goals and strategic objectives of the DWA Directorate: Water Use Efficiency.

The Goals for the WMP have been set and the IB believes that the targets and objectives set in the WMP are achievable through proper oversight by the CEO and support from the DWA.

This WMP must be seen as a first generation plan and has to be reviewed and updated on an annual basis. The identified measures for implementation (short term) should reduce the water losses from the current 47.15% to 41.15% of the total inflow into the irrigation scheme. The long term target is to reduce the water losses to approximately 27% of the total inflow into the scheme.

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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
GWS	Government Water Scheme
HBPIB	Hartbeespoort Irrigation Board
IB	Irrigation Board
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
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
WCC	Water Conservation Coordinator
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 percent.

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 quantity 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 requirement: — Quantity of water, exclusive of effective precipitation, that is needed 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. 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
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
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.

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.

Run-off: This is the water produced when irrigation water is applied to fields at rates and in quantities 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 in 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 is 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 Schemes is that the limited available water can be optimally utilised to ensure a high economic return for the scheme area.

The study was commissioned because of the increasing water scarcity 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 that sector.

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.

1.2 Study Objectives

The primary objective of the study is the development and implementation of an irrigation WMP for the Hartbeespoort IB to improve water use efficiency in the scheme. 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 scheme.
- Determination of the irrigation water budget and establishing water use baseline for the scheme.
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for the scheme.
- Identification of opportunities to improve water use efficiency in the scheme.
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for the scheme.
- Preparation of an irrigation water management plan for the scheme.
- Capacity building of officials to implement the identified opportunities to improve water use efficiency.

The development of a WMP for the Hartbeespoort IB 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 Hartbeespoort Irrigation Scheme as well as the potential for irrigated agriculture in the Crocodile River catchment. The chapter then 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. This is the focus of **Chapter 1**.

Chapter 2 describes the characteristics of the Crocodile River catchment in which the Hartbeespoort Irrigation Scheme is situated. The chapter describes the history of the Hartbeespoort Irrigation Scheme, the scheduled quotas and current land-use practices in the catchment.

Chapter 3 provides an overview of water distribution infrastructure found in the Hartbeespoort Irrigation Scheme. The chapter also describes the measurement of flow into and out of the scheme.

Chapter 4 provides a condition assessment of the infrastructure of the Hartbeespoort Irrigation Scheme.

Chapter 5 describes the scheme operations and operating procedures. Procedures relating to the ordering and delivery of irrigation water are *inter alia* discussed. The procedures for trading and transfers of water are handled as well as the present water pricing structure.

Chapter 6 describes the water balance assessment undertaken for the Hartbeespoort IB. The various losses identified on the scheme are also handled in detail.

Chapter 7 of this report describes the existing water conservation and demand management measures that the irrigation sector is currently undertaking.

Chapter 8 describes the key issues that the Hartbeespoort IB is facing and also includes the goals of the IB when WCWDM is contemplated.

Chapter 9 provides the Water Management Plan for the Hartbeespoort IB.

Chapter 10 includes the conclusion and recommendations.

2 CATCHMENT CHARACTERISTICS OF CROCODILE RIVER

2.1 Overview

The Hartbeespoort Irrigation Board is situated within the Madibeng Local Municipality, surrounding the town of Brits. **Figure 2.1** presents the locality map of the Hartbeespoort Irrigation Board area of operation which is provided with water from the Hartbeespoort Dam, fed mainly by the Crocodile River. The Crocodile River has its headwaters near Roodepoort in the City of Johannesburg Metropolitan Municipality. The major tributaries of the Crocodile River are the Rietspruit, Magalies and Jukskei Rivers flowing through areas where development is taking place to such an extent that it contributes to the increasing load of pollution that reaches the Hartbeespoort Dam. The total catchment area of the Hartbeespoort Dam is estimated to be some 4 112 km^2.

The Crocodile River and some of its main tributaries rise in the south of the catchment in the Witwatersrand topographical feature at an altitude close to 2000 meters above sea level (masl). This feature in the southern part of the catchment may be described as gently rolling hills on the Highveld plateau. The rivers wind their way through the Daspoort Ridge to the Magaliesberg mountain range at the Hartbeespoort Dam where the altitude is around 1200 masl. The Crocodile River then meanders through a reasonably flat weathered volcanic landscape, past the extinct Pilanesberg volcano, and through the Thabazimbi Mountains down to its confluence with the Groot Marico where it becomes the Limpopo River (altitude approximately 900 masl).

2.1.1 Climate and rainfall distribution

The upper higher lying areas of the catchment experience cold winters (daily average minima and maxima of 1ºC and 15ºC respectively) and reasonably hot summers (10ºC and 30ºC). Frost is prevalent in winter. North of the Magaliesberg Mountain Range less frost occurs and winters are more moderate. Summer midday temperatures can reach maxima of 35ºC to 40ºC in the shade. Summer (October to April) rainfall patterns predominate with the traditional heavy downpours in the afternoon (cumulonimbus induced thundershowers being the norm). December and January are the peak rainfall months with hail being prevalent. Frontal climatic systems bring soft soaking rains on occasion.

Mean Annual Precipitation (MAP) is generally higher in the southern and eastern parts of the catchment where this value averages out at around 800mm per annum. The northern and western lower lying areas tend to have a MAP of between 500-600mm. MAPs fluctuate in dry/wet cycles of between 7 and 10 years (variations from 300mm in dry years to 1000mm in good rainfall years). During certain years large-scale flooding occurs in this catchment which results in tremendous damage on irrigation farming operations (mainly north of Magaliesberg).

This irrigation farming tends to be located on the broad floodplains associated with the middle and lower Crocodile River System.

The generalised Mean Annual Evaporation (MAE - Gross Symon's Pan) varies from about 1 600 mm in the south to around 2 000 mm at the Crocodile River's confluence with the Limpopo River in the north. The coefficient of variation ranges from 25% to 35% on these values. The mean annual gross irrigation requirement (based on rainfall and evaporation) ranges from 1 400mm in the south east to around 2 000mm in the drier north western parts. The minimum mean monthly requirement usually occurs in June (+100mm) and the maximum mean monthly requirement occurs in September (140 - 240 mm for perennial crops). This phenomenon needs to be factored into the managerial approach adopted by water resource managers.

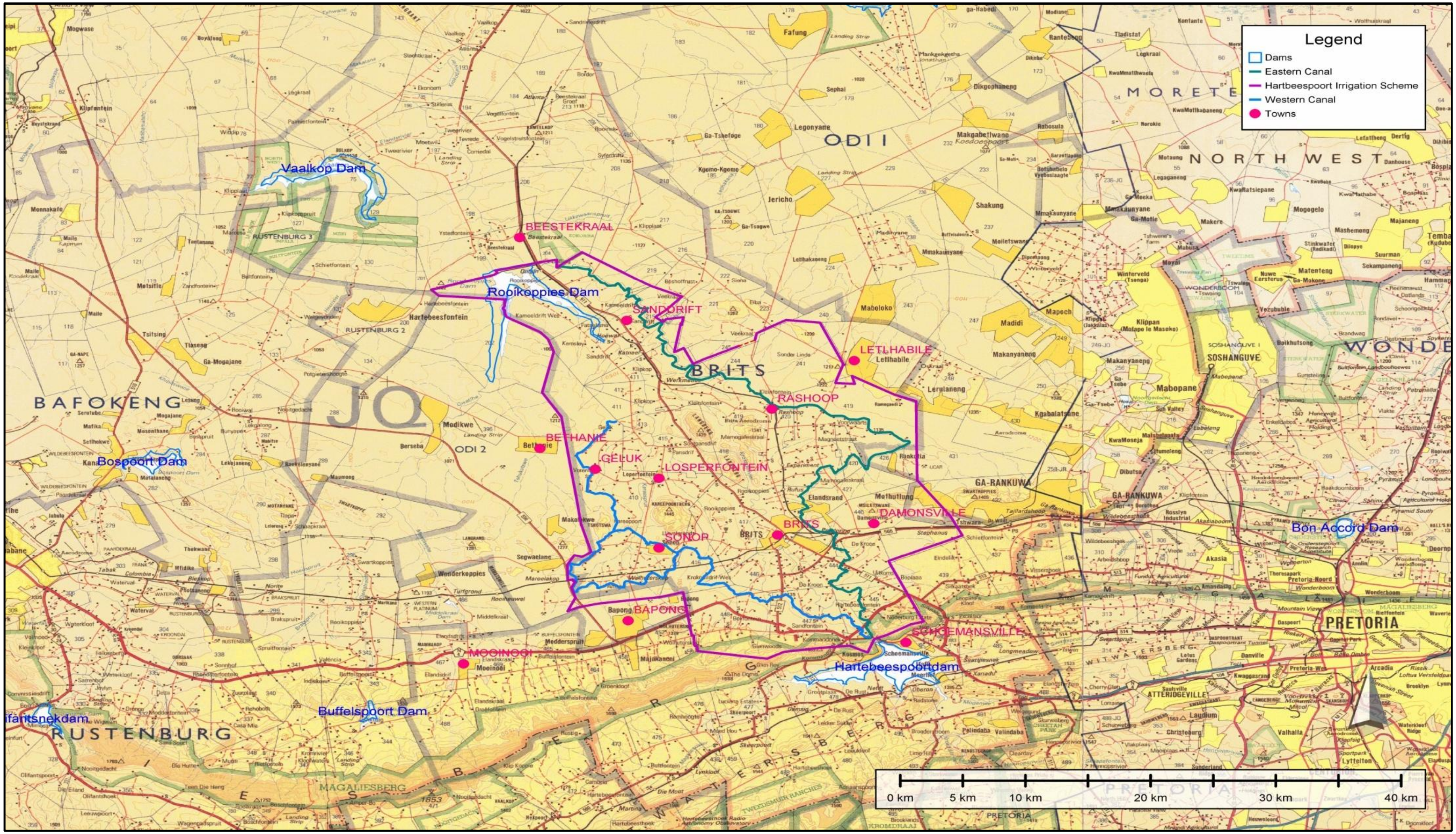

Figure 2-1: Location Map of Hartbeespoort Irrigation Scheme

2.1.2 Geology and soils of the catchment

The major geological feature of this catchment is the large area of volcanic intrusive rock (north of the Magaliesburg to Thabazimbi) referred to as the Bushveld Igneous Complex. Formations in this complex are extremely rich in minerals, which has led to large-scale exploitation of the platinum group of metals in this area. Soil types in this area may be broadly classified as moderate to deep clayey loams which are well utilised for agricultural crops and which also allow a relatively high percentage of runoff of water.

Dolomitic rock is found in a band running east-west between Rietvlei Dam and Mogale City (formerly Krugersdorp). These dolomitic compartments tend to be chert-rich, with consequent high water storage capacity. Dewatering of these compartments has led to sinkholes in the past. Some of the gold-bearing seams of the Witwatersrand Ridge in the south fall within the upper catchment but only a few goldmines still operate here. Soils in this higher and undulating southern part of the catchment are broadly classified as sandy loam, which are easily susceptible to erosion. The balance of catchment consists of sedimentary rock, with the quartsitic Magaliesberg Mountain Range being the prominent feature. Soils in the northern part of the catchment are classified as sandy loams.

2.2 History of the Hartbeespoort Irrigation scheme

During the period 1905 – 1910 the scheme was investigated by the then Transvaal Irrigation Department. A provisional scheme entailing a dam and irrigation of some 13 000 ha was planned but it was recommended that further and more detailed investigations of the dam site and irrigation areas be made. After many disputes regarding the expropriation of land for building the Hartbeespoort Dam the river was finally diverted on 24 May 1921 and by 29 July 1921 the first foundation concrete was placed. By 7 September 1921 the wall was 2m above riverbed. The floods of 1922/23 were impounded. In April 1923 the wall proper was completed and all that remained was the finishing off of the parapets and the crest road. In September 1923 the road across the wall was officially opened. The Hartbeespoort Dam was completed in 1925 and has a trough spillway situated on its western flank, which was fitted with radial crest gates in 1971 to increase the storage capacity of the dam.

The scheme receives an allocation of 86 million m^3/ annum of water from the Hartbeespoort dam. This allocation amounts to 69% of the total average water supply available from Hartbeespoort Dam. However this allocation excludes losses – it is a productive allocation. Generally in years in which there was sufficient water in the dam, the irrigators could count on some 120 million m^3/a, thus compensating for the water losses in the system. Historically this surplus allocation acted as a hidden subsidy to the irrigators: they paid for 86 million m^3 but received 120 million m^3. One of the uncertainties the Hartbeespoort Irrigation Board currently faces is the way in which the new water tariffs and water use charges will be calculated, because if the board is charged for system losses it will substantially reduce their income. The income of the board currently stands at an average of R11,5 million per annum from water sales. However, this income literally fluctuates as much as the seasonal rainfall, because the board pays for full allocation of water even if it does not use it, i.e. if farmers do not require water because of good rains. This then leads to 'under consumption' and a lack of income in 'good' years.

Photo 1: Hartbeespoort dam wall 1923

The allocation of water from the dam is adjusted twice a day by the dam manager who releases the water into the canals or into the river. The annual allocation starts on the 1 st of October, when the Department considers the water availability in the dam. The allocation is then determined on the basis of water availability. In dry years the irrigation board may only receive a small percentage of their allocation. Thus in the drought of 1992 for instance, only 20% of the water entitlement was released into the irrigation system. In dry years the canals only flow for 24 to 36 hours a week and because of low levels of pressure, the losses are very high. Losses in the system average 45% but at low pressure they show a strong increase. Also, the system is in need of major refurbishment but the cost of doing this has been estimated at around R200 million. There are insufficient funds for even minor upgrades and thus the system has entered into a long term decline.

Lack of funds also means improper monitoring of the quantities of water utilised. The distribution of water is administered through variable water pressure at different sluice gates. The board measures the pressure and a certain pressure is deemed to correspond with a specific quantity of water - 50 m³/hour, 70 m³/hour and 100 m³/hour. The sluices are adjusted by hand, in increments of 12 hours.

In 1998, following a reorientation of priorities within the Department of Water Affairs away from further expenditure towards the overheads of irrigation schemes such as Hartbeespoort, the farmers on the water scheme were encouraged to form an irrigation board so that the responsibility for the infrastructure could be transferred to them.

Initially this idea of irrigation management transfer reportedly met with a lot of resistance amongst the farmers because they felt that the department had allowed the canals to fall into disrepair and now they were being saddled with the responsibility for a decrepit system. Whereas other irrigation schemes that were being transferred to farmers were fairly new, this one was very old and dilapidated and Government should repair the scheme before handing it over.

The resistance led to delays in the formal transfer of infrastructure to the board, but ultimately the opportunity of creating a farmer managed irrigation system that could begin to cut back on overheads and thus reduce the per hectare cost for water supply, was an attractive option to the farmers. In 1998 the responsibility for the maintenance for the system was transferred to the irrigation board, although the formal ownerships of the system remained in DWA.

In terms of the policy of irrigation management transfer, the new irrigation board was given three years to adjust to its new economic realities. The existing subsidy on the water tariff was removed over a period of three years. 1999/2000 the farmers paid between R600-00 and R700-00 per hectare in water tariffs. This cost represented a situation in which the board received only 66,7% of the subsidy. Over the next two years, the subsidy was further reduced until, on the 1st of October 2002, the board was financially on its own. In this period, the irrigation board managed to bring irrigation water tariffs back to the 1999 level of R700-00 per hectare where DWA had predicted they would lie at around R1000-00, i.e. they managed to cut costs substantially relative to the period as a government water scheme. However, it must be borne in mind in this context that the tariffs only cover operation and maintenance costs (i.e. small repairs) and cannot hope to build up the kind of capital needed to refurbish the scheme.

The Hartbeespoort Government Water Scheme had just transformed into an irrigation board when the 1998 Water Act was promulgated. In terms of the Act, as mentioned above, they were required to transform again into a Water User Association and to this end were obliged to submit a proposal for transformation with six months of the promulgation of the Act. Having created this legal vehicle for transformation, a crucial issue was how this was to be carried out in practice.

2.3 Water use permits / licenses and contracts

When the National Water Act, 1998 (Act No 36 of 1998) came into effect in 1998, irrigation boards were required to submit applications for the transformation into Water User Associations (WUA).

Policy proposals regarding the treatment of scheduled irrigation allocations on Government and Irrigation Board schemes as existing lawful water use in terms of section 33 of the NWA, 1998, were approved by the Minister on 10 May 1999. Under this policy, all lawful scheduling in terms of sections 63 and 88 of the Water Act (1956) on Government and Irrigation Board schemes, which has been annually paid for before 1 January 1999, was declared as existing lawful use in terms of section 33 of the NWA, 1998. The Policy also stated that all unexercised water uses must be exercised within three years after the promulgation of the Act to be considered as existing lawful water use

In Circular 18 of 2001 the Director General stated that "all lawful scheduling in terms of section 63 and 88 of the WA for which all due water use rates and charges were paid on 30 September 1998, should be treated as existing lawful water uses in terms of section 33 of the WA. As there is no authority for the Minister to attach conditions to a declaration of an existing lawful water use, the three-year period to develop unutilised water allocations as granted in terms of Circular 59 of 1999 is hereby withdrawn. These unutilised rights can be treated as existing lawful water use until compulsory licensing is required." The entitlement to use water on the scheme is therefore the continuation of existing lawful use. The Board therefore functions under the rules and regulations of the previous Water Act, 1956 (Act No 54 of 1956) until the Board is transformed and compulsory licensing is required.

The Irrigation Board has a total scheduled area of 13 915 hectares, at a scheduled quota of 6 200 m^3/ha/a which translates to a total allocation of 86.263 million m^3/a.

2.4 Irrigated areas and types of crops

The types of crops cultivated within the area of operation of the Hartbeespoort Irrigation Board are provided in Table 2-1.

Table 2-1: Crops under irrigation - Hartbeespoort Irrigation Board

Crop	% of Total crop area under irrigation
Wheat	29.49
Soybean	20.22
Vegetables-Summer	16.85
Lucerne	11.24
Vegetables-Winter	9.83
Maize	7.30
Citrus	1.69
Table grapes	1.69
Tobacco	1.12
Chillies	0.56

Figure 2-2 illustrates the composition of the crops irrigated within the area of operation of the Hartbeespoort Irrigation Board.

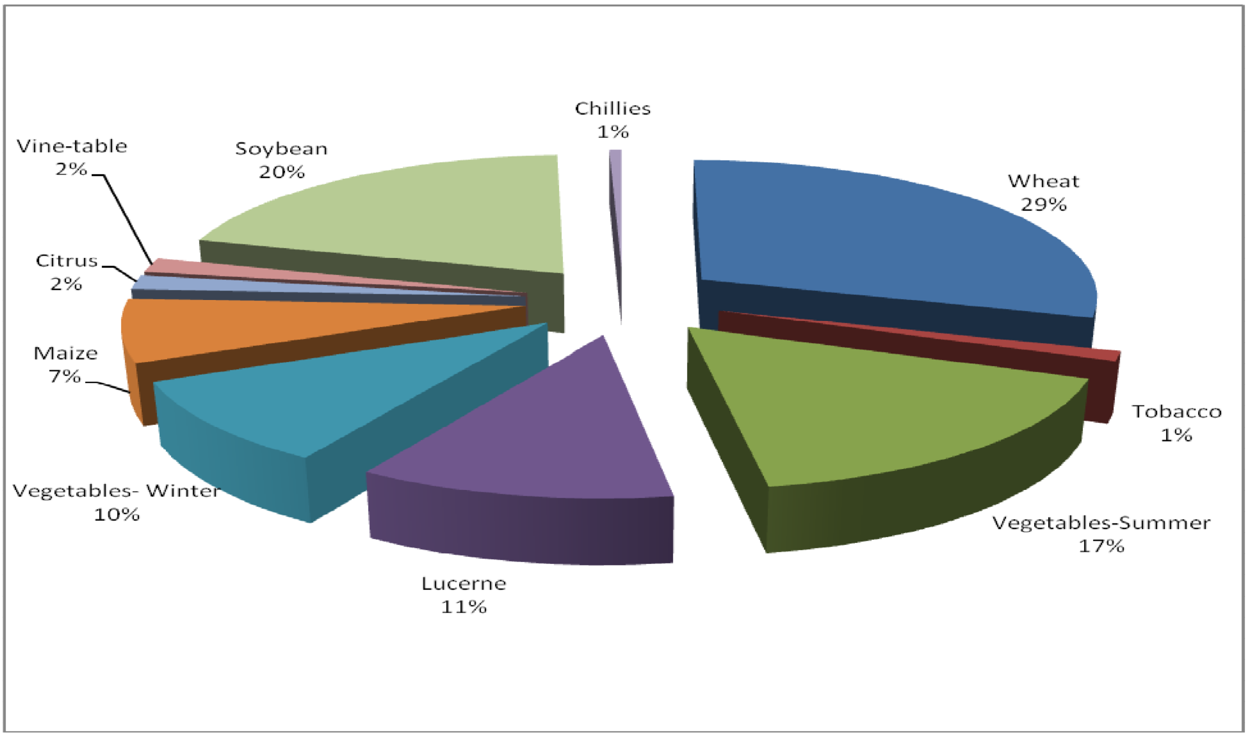

Figure 2-2: Crops under irrigation: Hartbeespoort Irrigation Board

2.5 Historic water use

The seven water years (2004/05 to 2010/11) demonstrate a range of water use in the Hartbeespoort Irrigation Scheme. Irrigation agriculture has ranged from 50.35 million m^3/a in 2007/08 up to 74.28 million m^3/a in 2004/05, with a seven year average of 62.36 million m^3/a. The industrial use, ranges from 3.3 million m^3/a in 2008/09 up to 5.75 million m^3/a, in 2004/05, while the seven year average, is 4.37 million m^3/a. The domestic water use ranges from 0.11 million m^3/a in 2008/09 up to 1.12 million m^3/a, in 2004/05.

Table 2-2: Historic water use levels (million m^3/a) for Hartbeespoort IB

User	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	7 year average
Irrigation	74.28	59.63	80.30	50.35	56.47	56.79	58.71	62.36
Industry	5.75	3.64	3.52	4.96	3.30	5.46	3.92	4.37
Domestic	1.12	0.42	0.31	0.21	0.11	0.17	0.18	0.36
Total	**81.14**	**63.70**	**84.14**	**55.52**	**59.87**	**62.43**	**62.81**	**67.09**

The average total water diverted within the Hartbeespoort Irrigation Scheme during the same seven year period, was 136.27 million m^3/a, with the range being 121.36 million m^3/a in 2007/08 up to 157.72 million m^3/a in 2004/05. According to the WUAERs an average of 21.25 million m^3/a water was estimated at the canal end points.

The scheduled quota for the Hartbeespoort Irrigation Scheme is provided as 6 200 m^3/ha/annum, with a total water use entitlement of approximately 86 million m^3/a, to irrigate more or less 13 900 hectares.

3 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

3.1 Overview

The Hartbeespoort Irrigation Scheme comprises of two main irrigation canal infrastructures, the East and the West canal, which originates at the Hartbeespoort Dam wall. The canal distribution system includes two balancing dams and secondary canals which deliver water to the irrigators at their farm turnouts through a number of sluice gates (1 721).

3.2 Hartbeespoort Dam

In the early 1900's the Transvaal Irrigation Department identified the need for a dam to provide water to an irrigation scheme in the Brits district. The dam wall was completed in 1923. The water is released at the bottom of the wall by two sluices from where it flows down the eastern and western canals. The eastern canal is 78km long and the western one is 56km. Each canal has a capacity of 8.5 m^3/s. The eastern canal runs along the rock face of the Magalies Mountain and contains a sluice from where the water can be released via a waterfall to feed the river and the "old furrows".

When the dam was full, the water used to run over the concrete overflow but in 1971, 10 steel radial crown sluices were placed on top of the overflow. Because of this the water level of the dam increased by 2.44 metres. The dam's volume increased from 160 million cubic metres to 205 million cubic metres.

3.3 Irrigation conveyance infrastructure

Figure 3.1 below provides the conveyance and distribution infrastructure of the Hartbeespoort Irrigation Scheme. The whole irrigation conveyance infrastructure is concrete lined. Water is released from the Hartbeespoort Dam into the two main canals being the East and West canals. Both canals are mainly parabolic structures ranging in widths from 6 m to 10.5 m in the East canal and 6 m to 12.5 m in the West canal.

The irrigation scheme also includes some unlined earthen furrows, referred to as the "old furrows". Some of these furrows had been concrete lined and formalised as government infrastructure and therefore included in the irrigation scheme currently managed by the Hartbeespoort Irrigation Board. However, some of these furrows have not been improved and still function independently from the Irrigation Board.

There are six wards in the scheme, three for the East canal and three for the West canal. Water users in ward seven as indicated on the map abstract water from the Eckhard old furrow. Each water ward has a ward manager who is responsible for the water distribution management of the specific ward. The canal infrastructure comprises of secondary canal systems, an active balancing dam on the East canal as well as an active balancing dam on the West canal. Water is delivered to the farmers through pressure regulating sluices which are set on a daily basis. The dam setting is changed on a twelve hourly interval. The aim of the water distribution is to make water available at a specific time for a predetermined period of time at a fixed flow rate to a certain point to the best advantage of the irrigators .

The total length of the main canals is 134 km and the branch canals is 532 km, serving a total scheduled area of 13 915 hectares with a full irrigation water quota of 86 273 000 m^3/annum. About 23 km of the system is piped which represents 3.4 % of the conveyance system. Water supply to water users is 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 1 721 abstraction points along the canal systems. Water released into the canals is not only used for irrigation purposes but mining and industrial activities are also supplied with water.

3.3.1 Eastern irrigation canal

The Eastern canal comprises a 78 km long, wide parabolic concrete lined canal which has a capacity of 8.5 m^3/s and serves irrigators on the eastern side of the Crocodile River. Sections vary in widths of 6 m to 10.5 m and shapes include parabolic and rectangular structures. There are three siphons of approximately 700 meters in length on the Eastern canal.

3.3.1 Western irrigation canal

The Western canal is a 56 km long wide concrete lined canal structure which has a capacity of 8.5 m^3/s and serves irrigators on the western side of the Crocodile River. Sections vary in widths of 6 m to 12.5 m and shapes include parabolic and rectangular structures. There is a tunnel of 600 m conveying the water through granite outcrops and a 3 km siphon located in the region of Sonop.

Photo 2: Western Main canal

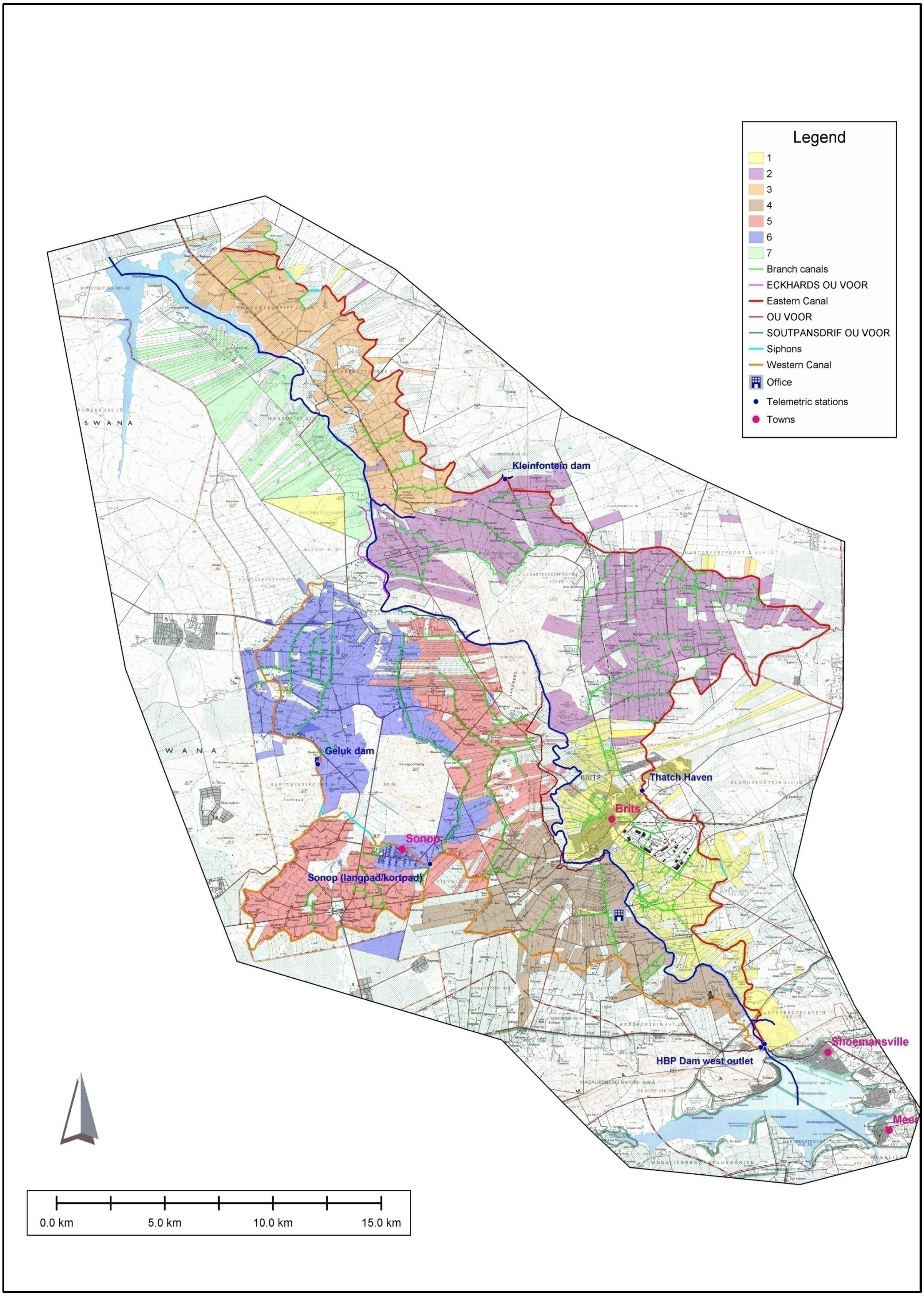

Figure 3-1: Hartbeespoort Irrigation Board Infrastructure

3.4 Irrigation storage and regulation system

Storage on the irrigation scheme consists of two balancing dams. The one in the eastern canal, Kleinfontein, covers an area of 3 ha, with a capacity of 48 000 m³ and an average depth of 3.5 m. The dam in the western canal, Geluk, has an area of 3.9 ha, a capacity of 42 000 m³ and an average depth of 2.5 m. Unfortunately the dams cannot operate at their full capacities due to algae growth, pollution and silt, limiting them to maximum capacities of 28 000 and 34 000 cubic meters respectively. It will be ideal to clean these dams to such a degree that optimum use is enabled or even enlarge them in order to increase the storage capacity.

Photo 3: Geluk balancing dam (Western canal)

3.5 Flow Measurement and telemetry system

3.5.1 Measurement of flow into and out of the Scheme

The first measurements are taken at the Hartbeespoort Dam wall where a telemetry system is used to measure the total volume of water released into the two main canals of the Hartbeespoort Irrigation Scheme. The telemetry system at the Eastern outlet however has according to the IB inaccurate readings and is not located at a suitable measuring point. The IB processes the weekly water orders, allows for losses and requests the DWA to release the volume water from the dam. There is no accurate reading of the volume of water being released into the Eastern canal. A Base System is located at the Hartbeespoort Irrigation Board Office and consists of a base computer, which holds the central database to store and convert all of the data received from the Remote Telemetry Units together with an antenna to receive from and transmit data to the remote telemetry system. There are six telemetry systems in the whole scheme from where data is sent the IB office. Only three of these systems (Hartbeespoort Picnic, Thatch Haven and Sonop) were sending data to the office during the field inspection in 2010. This data is used by the IB to monitor the flows in the canal system and to determine losses between the various measuring stations. None of this data however is included in WAS or the WUEARs. The ideal will be to have a telemetry system at each canal end point, but it is seen as too expensive at this point in time to install more telemetry systems in other parts of the scheme. Due to the problems with algae and water grass the measurements of the equipment is only accurate for a very short while after being cleaned of aquatic weeds.

Furthermore the Hartbeespoort Irrigation Board measures the weekly volume of water delivered to the water users using weirs and pressure regulating sluice gates. The quantity of water supplied to individual farmers is regulated by the degree to which the various sluice gates along the canal are opened. Depending on the size of the sluice gate opening, water can be delivered at rates of 50 m^3/hour, 70 m^3/hour or 100 m^3/hour. The sluices are operated by hand, in increments of 12 hours and because of varying pressure in the system, farmers are asked to accept a margin of error of 10%, i.e. the allocated water is between 90% and 110% of the allocation.

The volume of water that was actually delivered to farmers can be monitored by comparing the quantity of water ordered from the Hartbeespoort Dam with the water that is returned to the Crocodile River. The percentage of water lost can then be calculated and the scheme administrators will also know if any farmer has taken more than his or her allocation.

Photos 4 and **5** indicate the telemetry system at the Sonop diversion. Even though the readings received from these telemetric stations are only used for monitoring purposes and not included in WAS or the WUEARs, it is important that they be accurate. In **Photo 5** it is evident that algae, water grass and pollution can have a negative influence on the accuracy with which flows are measured at the Parshall flow gauges.

Photo 4: Telemetric station – Sonop (langpad/kortpad)

Photo 5: Parshall at telemetry station

4 INFRASTRUCTURE CONDITION ASSESSMENT

4.1 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 conditions 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.

4.2 Canal Condition Evaluation

A list of criteria for undertaking canal condition assessment was developed for use later during the implementation phase. The Canal Condition Evaluation component of RAT includes visual rating methodologies based on:

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

The factors that are used in this procedure are grouped as follows:

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

Tables 4.1 – 4.5 provide details on the rating factors and definition of numerical values used that are recommended to be used during the dry periods.

Table 4-1: General Condition rating

Rating	Definition
1	Excellent – no visible cracks or vegetation
2	Good – having cracks greater than 3.0 m apart 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 4-2: Criteria for hairline, pencil size and large cracks

Rating	Definition
1	None to Sparse
2	Greater than 3.0 m apart
3	1.5 – 3.0 m apart
4	1.0 – 1.5 apart
5	Less than 1.0 m apart

Table 4-3: Noticeable amounts of maintenance and repair (patchwork)

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

Table 4-4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

Table 4-5: 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

4.3 Results and analysis of preliminary assessment

In order to evaluate the current status of the canal infrastructure the Hartbeespoort Irrigation Board conducted a survey during which the two main canals were visually inspected and classified based on their current condition. A map was compiled from this data through the use of a GIS, which shows the various canal widths together with the relevant classification. This map is shown in **Figure 4-1**. A summary of the condition of the main canal infrastructure is provided in **Table 4-6**.

Photo 6 indicates section movement on the West canal. This may be contributed to the age of the structure, soil conditions or even blasting activities undertaken by mines in the area. The section has been filled with concrete at the back to prevent excessive leakage.

Table 4-6: Hartbeespoort IB - Canal infrastructure condition summary

Classification	Canal width (m)							Total
	12.5	10.5	9.5	9	8	7.5	6	
Max. 10 yrs. Repair cracks within 3 yrs.		12.2	5.3					17.5
Max. 5 yrs. Complete rebuild	9.4			8.4				17.8
Max. 15 yrs. Repair cracks within 5 - 7 yrs.			5.3		4.2	23.1	23.8	56.4
Rebuilt by Irrigation Board							22.1	22.1
Total	**9.4**	**12.2**	**10.6**	**8.4**	**4.2**	**23.1**	**45.9**	**113.8**

Photo 6: Slab movement on the West canal

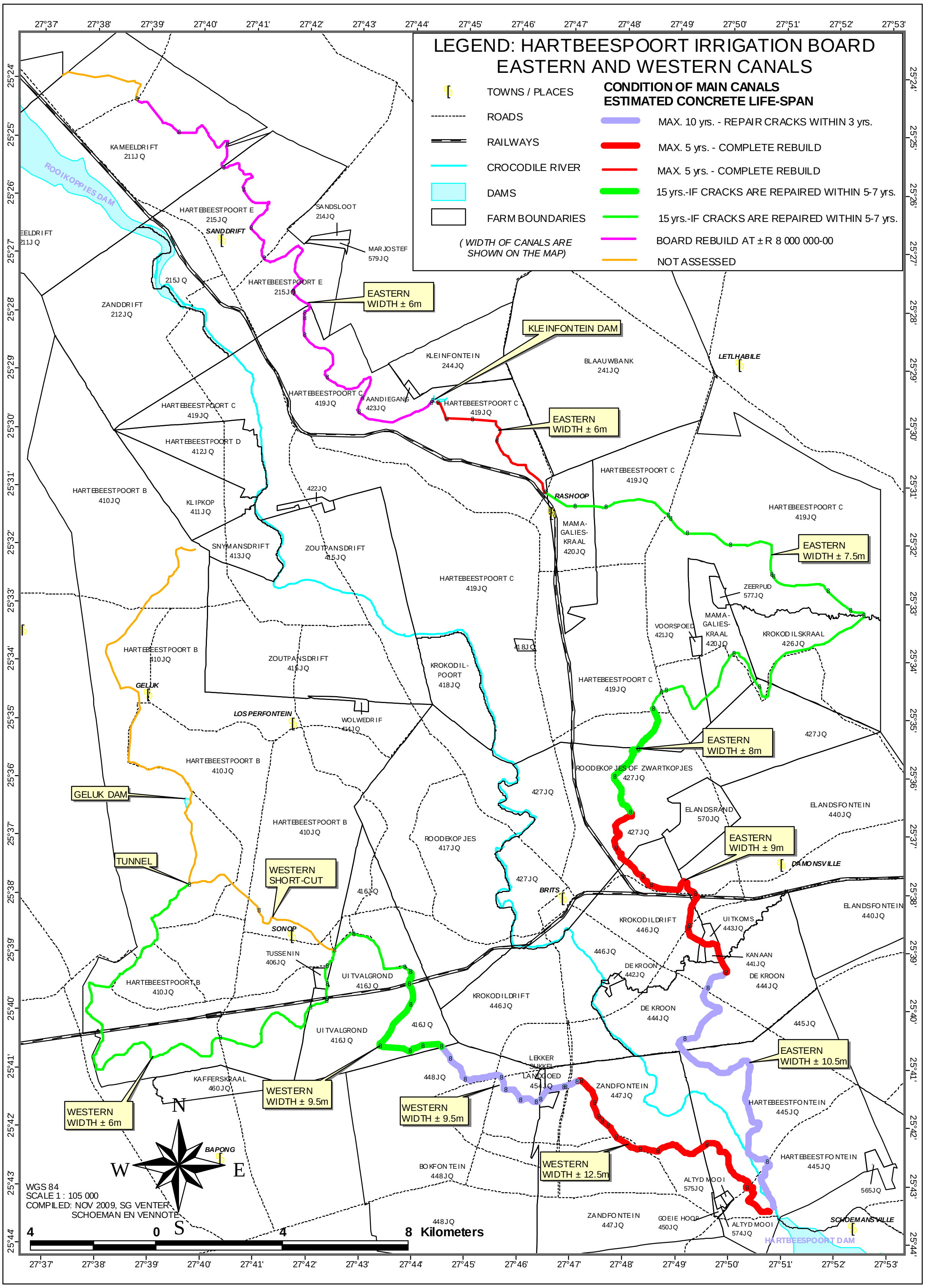

Figure 4-1: Hartbeespoort IB - Condition of main canals

5 SCHEME OPERATIONS AND OPERATING PROCEDURES

5.1 General scheme options

The Hartbeespoort Irrigation Board has a total of 82 employees (i.e. technicians, managers and unskilled labourers). Considering the age and extent of the scheme (1 721 sluices), almost 39 people of the 82 employed are directly involved with the water distribution. The allocation of water from the dam is ordered twice a day from the dam manager who releases the water into the canals. Water is released from the dam until Friday afternoon and only again on Sunday afternoon in order to reach the lowest abstraction points in time on Monday.

The Hartbeespoort Irrigation Scheme is scheduled for an area of 13 093 ha. All properties that fall within the Irrigation Scheme, title deed details and scheduling are shown on the Schedule of Rateable Areas (SRA).

The maximum quota that is annually granted to the irrigators is 6 200 m^3 per hectare. If there is not enough water available to grant the full 6 200 m^3 per hectare for a specific year, a lower quota is granted. It is also possible that, when surplus conditions occur, extra water can be bought, if so, water has to be paid for in advance.

A normal water year stretches from 1 October to 30 September of the next year. If the allocated water has not been fully used before the end of the water year, it can be used for a further one (1) month (October) in the next water year. If the allocated water is fully used before the end of that specific water year, the new water year's water allocation can already be used in the last month (September) of the previous year.

5.2 Water ordering and delivery procedures

Application forms (white) must be completed by the irrigator and placed in the application boxes before 10:00 on Thursdays, preceding the irrigation week water is applied for. Such an application is called a normal application.

The application boxes are opened and emptied directly after 10:00 on Thursdays and a late application will not be taken into consideration before the Monday of the following week.

If an application is not put into the box on the prescribed time and day, the irrigator can go to his Ward Manager for a late application. A late application (blue form) must be handed in at the Ward Manager's office. For a late application, the blue form must be handed in on Mondays before 10:00.

The local Ward Manager is only allowed to consider a late application in the following circumstances: If the late application can be fitted into the feeder/flow charts without any negative impact on other irrigators, like a decrease or cancellation of their water use.

An irrigator can cancel his/her entire demand or only a part of it by requesting for a cancellation on a cancellation form (pink form) at the local Ward Manager's office.

A cancellation can only be considered if there is enough time to bring about the necessary adjustments to the sluice. Water that is already on its way to the irrigator may not be cancelled and will be deducted from the irrigator's quota, whether or not the irrigator has received/taken the water.

If the Board is of the belief that it is in the best interest of all irrigators to cancel all the water, it can be done by request of the Board. In such an event, the individual irrigator does not have to hand in a pink form. Such a cancellation is known as an "automatic cancellation" and normally occurs after good rain on the scheme. The Board delegated the authority to the CEO make decisions regarding the cancellation of all water.

An irrigator can apply for an increase on his requested water by applying on a blue form at the Ward Manager's office. This application is called a special application (replenishment). The local Ward Manager will only be allowed to consider a special application under the following circumstances:

- If the replenishment can fit into the local Ward Manager's supply schedule without other irrigators' demands being decreased or cancelled.
- If the replenishment application is handed in on time, which is on Wednesdays before 10:00, so that necessary adjustments can be made.
- If a normal application was handed in. Replenishment on late applications will not be considered.

Late applications and replenishments can only be done at the Ward Manager's office on Mondays and Wednesdays before 10:00. Cancellations can be done every day, but must be done before 10:00.

Returned water (short delivery due to operational problems) is limited to the minimum due to management problems and only allowed in extreme cases. Where there are water shortages, the remaining water demands and/or the period of short running must be partially or fully cancelled and the irrigator must hand in a new application as soon as possible hereafter or when needed.

5.3 Water trading - Temporary water transfers

There are periods when existing irrigators exhaust their scheduled quota before the end of the water year and may require additional irrigation water. The current practice is that the irrigator sources additional water from other irrigators who are not using their full water allocation and negotiates for a temporary transfer subject to agreeing compensation for the transfers.

Application for temporary transfer of water must first be approved by the CEO of the Irrigation Board before the water can be supplied. If the properties concerned have the same owner, the CEO can favourably consider such an application for the transferring of water entitlements. If the properties concerned do not have the same owner where water entitlements must be transferred, the CEO may only consider the application in the following cases:

- If the applicant can provide proof that he/she is the owner of the one property and the legal tenant of the other. The lease contract must at least stretch to the end of the same water year.

- In the event where all the properties are rented, the irrigator must provide proof that he/she is legally renting all the properties for the same water year.

The transfer must however be feasible (sufficient capacity in canal). The water quota of the property where the water will be transferred to must be exhausted before transfer can take place. Both the properties that are involved in the transfer must be scheduled under the Hartbeespoort Irrigation Board. The charges of both the properties that are involved in the transfer must be paid up before transfer can take place and must remain that way

5.4 Water pricing structure

5.4.1 Setting of the irrigation pricing

The Department of Water Affairs currently sets the water use charge for irrigation water based on the pricing strategy. Therefore the water use charge for the scheme is set based on the total scheduled hectares in the irrigation scheme.

While the costs of supplying water from the Hartbeespoort Dam are high, irrigation farmers are not required to meet many of these costs. Most significantly, they are not required to meet any capital costs. The Hartbeespoort Irrigation Board incurs a number of expenses relating to the maintenance and refurbishment of the canal systems and the administration of the scheme. **Table 5-1** summarises the monthly tariffs which the irrigation farmers need to pay.

Table 5-1: Monthly tariffs as on 11/11/2011

Description	**Value**
VAT (%)	14
Quota (R/ha)	92.74
WRF (R/ha)	0.42
CMC (R/ha)	30.75
Total (R/ha)	**141.26**

Table 5-2 summarises the annual costs in c/m³ which the Hartbeespoort IB was responsible for from 1999 – 2010. **Figure 5-1** illustrates these costs graphically.

Table 5-2: Annual costs in c/m³

Year	Admin.	Maintenance	Staff	Operational	Total
1999	0.94	11.56	5.83	1.62	19.95
2000	0.87	11.47	6.06	1.05	19.45
2001	0.87	8.58	5.41	1.09	15.96
2002	0.89	7.9	4.79	0.85	14.43
2003	0.83	6.77	4.63	0.61	12.85
2004	1.06	9.65	5.64	0.81	17.17
2005	0.93	8.39	5.13	0.7	15.15
2006	1.17	11.18	7.32	0.89	20.57
2007	1.4	6.96	6.05	0.74	15.14
2008	1.42	10.87	9.12	1.23	22.64
2009	1.36	12.58	9.29	1.17	24.4
2010	1.2	8.39	10.71	1.54	21.85

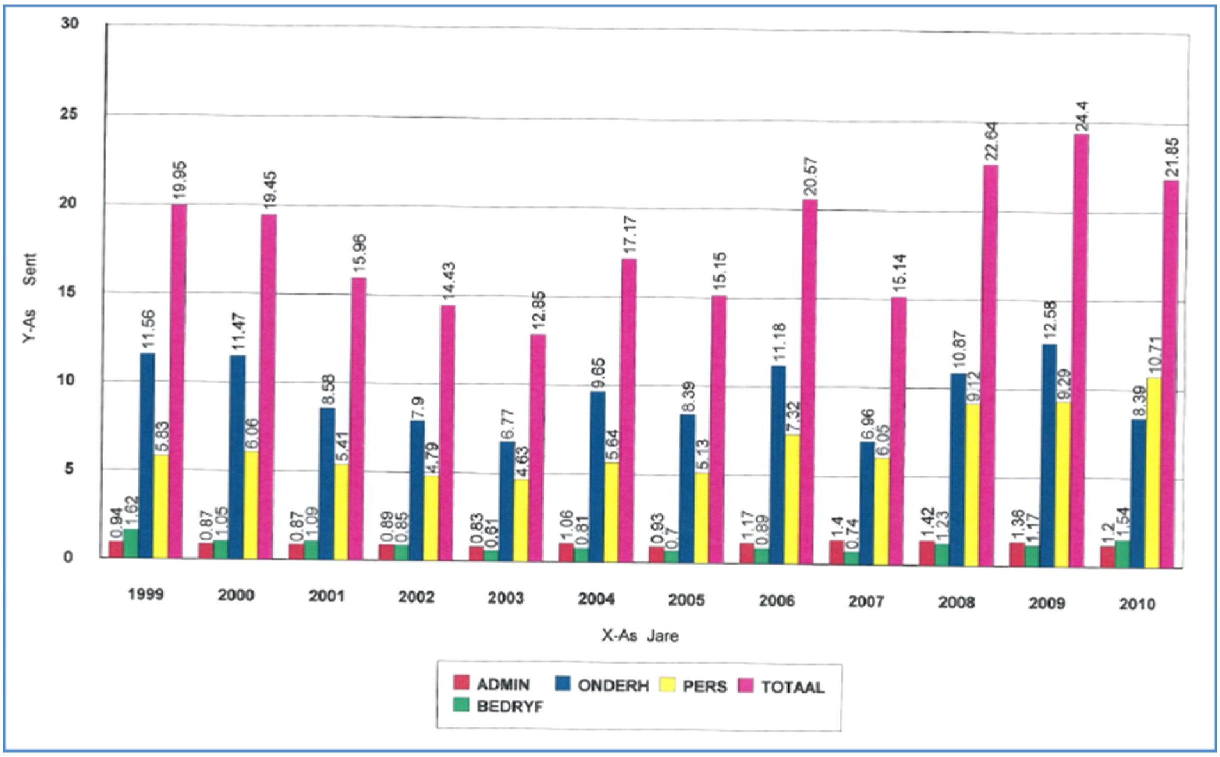

Figure 5-1: Breakdown of annual costs

6 HARTBEESPOORT IRRIGATION SCHEME WATER BALANCE

6.1 Introduction

The purpose of a water balance is to summarise the inflows, consumption and outflows from the area of operation of an Irrigation Board/Scheme. During the preparation of the water balance the beneficial and non-beneficial consumptive uses are determined which form the basis for the calculation of performance indications which are necessary in identifying water savings opportunities.

Every water use component in a Scheme/Board is represented in the water balance and the various categories for inflows, consumptive use and outflows are described and discussed below.

6.2 Inflows

The first measurement of water flow takes place at the Hartbeespoort Dam wall where water is released from the dam into the two main irrigation canals. Weekly records of the inflows into the main canals at the Hartbeespoort Dam wall were evaluated. The records of the water released from the dam are not automatically included in the WAS system and the records obtained from the DWA telemetry station at the Eastern outlet is faulty. Therefore the records of inflows of water into the scheme released from the dam are based on the total weekly request by all the scheme water users.

6.3 Consumptive use

Consumptive use can be classified as the use that removes the water from the scheme and renders it unavailable for further use. Consumptive use can be classified into two main categories;

Process consumption

Process consumption or productive use is that volume of water that is used to produce the crops and is therefore considered beneficial use.

Non-process consumption

Non-process consumption or non-productive use occurs when water is consumed (depleted), but not by the irrigation of crops. Non-process consumption can further be subdivided in two types of uses, namely;

- Beneficial use, such as water that is used by indigenous riverine vegetation, and
- Non-beneficial use, such as evaporation or deep percolation that cannot be retrieved for productive use.

The supply to individual water users is measured (or rather administered) through the variable water pressure at different adjustable sluice gates. Depending on the size of the sluice gate opening, water can be delivered at 50 m^3/hour, 70 m^3/hour and 100 m^3/hour. The sluices are operated by hand, in increments of 12 hours and because of varying pressure in the system, farmers are asked to accept a margin of error of 10%, i.e. the allocated water is between 90% and 110% of the allocation.

6.4 Outflows

As the name suggests, outflow is water flowing out of the system or area of operation of the scheme and can be classified as ether committed or non-committed outflow.

Committed outflow is that part of the outflow that is committed to other uses or users.

Uncommitted outflow is outflow that is available for other or downstream use. Uncommitted outflow is a loss and can occur as a result of a lack of storage or operational measures.

Actual outflows are not presently measured and the canal end point values are based on estimates from the WUEARs.

6.5 Overall scheme water balance

The water balance is based on information from the Water Administration System (WAS). Distribution sheets are then compiled using WAS and losses are added. The records of inflows which consist of all the sources of water supply to the Hartbeespoort Irrigation Board were provided on a monthly basis.

The outflows consist of all the ways that water is consumed within the scheme. This includes the canal seepage, operational spills, evaporation from the canals and percolation. Consumptive use is based on the delivery to irrigators and other users.

Figure 6-1 is a graphical illustration of the annual water distribution in the Hartbeespoort Irrigation Scheme from 1999 to 2012. The quantity of losses is similar to the water use by the irrigators while the industrial uses are the lowest.

Using the information obtained from the WUEARs, previous studies and consultation with the management of the Board, the water accounting report for the Hartbeespoort IB is provided in **Figure 6-2**. The volume of water that is requested by the Irrigation Board varies from year to year, as does the cropping pattern for each year. Following discussions with the CEO of the Board, Mr. Nick Fourie it was established that the actual volume of water requested for release rarely exceeds 70% of the total annual allocation. The data contained in **Figure 6-2** reflects the water use based on the information obtained from the WUEARs for the water year 1 October 2004 to 30 September 2009 as well as the reports from WAS for water years 2009/2010 and 2010/2011. The IB only started making use of the WAS reporting module from the 2009/2010 water year.

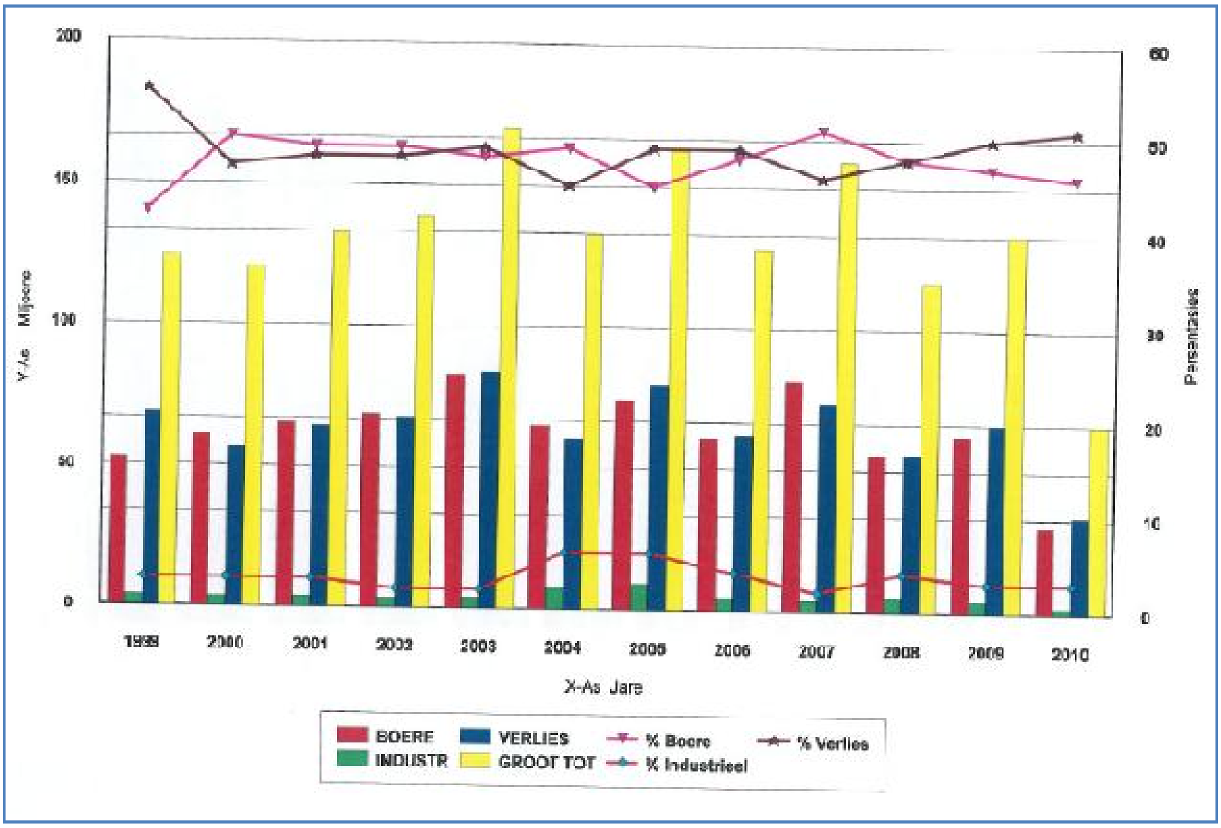

Figure 6-1: Annual water distribution

In Table 6-1 below the full quota includes both East and West canals as indicated in the WUEARs. The consumptive uses include agriculture, domestic (drinking water and stock watering) industrial and municipality, free water, government departments and old furrows. The average consumptive use for the seven years is 72.75 million m³/a which represents 92.4 % of the full quota. The total consumptive use as a percentage of the full quota is displayed in the last column of Table 6-1.

It is noticeable that for the 2009/10 and 2010/11 water years there are no volumes recorded for free water, government departments or old furrows since. These volumes area actually allocations included in the Schedule of Rateable Areas and are included in the agricultural releases.

Table 6-1: Hartbeespoort IB - Water Budget

		Inflow		Consumptive use							Unavoidable losses						Avoidable losses						Gross losses		Utilisation
Water Year	Month	Full quota	Inflow to Scheme	Agricultural use requested	Domestic	Industrial and municipality	Free Water	Government departments	Old furrows	Total use	Evaporation	% of total loss	% of inflow	Seepage	% of total loss	% of inflow	Canal end points	% of total loss	% of inflow	Operational losses & leakages	% of total loss	% of inflow	Total losses	% of inflow	% of full quota
2004/2005	Oct		18 269.7	9 537.5	159.5	768.1	32.0	88.2	679.2	11 264.5	196.1	2.8	1.1	1 977.4	28.2	10.8	2 512.3	35.9	13.8	2 319.3	33.1	12.7	7 005.2	38.3	
	Nov		13 362.0	5 232.0	127.6	278.8	25.6	81.6	808.4	6 554.0	204.2	3.0	1.5	1 972.4	29.0	14.8	2 373.1	34.9	17.8	2 258.3	33.2	16.9	6 808.0	51.0	
	Dec		12 739.3	4 857.2	153.1	251.6	30.8	51.0	880.0	6 223.7	189.0	2.9	1.5	1 858.9	28.5	14.6	2 319.4	35.6	18.2	2 148.3	33.0	16.9	6 515.6	51.1	
	Jan		11 089.8	4 666.9	122.5	223.7	24.7	0.0	585.0	5 622.8	147.6	2.7	1.3	1 568.7	28.7	14.1	1 909.9	34.9	17.2	1 840.8	33.7	16.6	5 467.0	49.3	
	Feb		12 279.5	6 457.3	98.0	309.6	19.8	122.5	628.8	7 636.0	134.7	2.9	1.1	1 344.9	29.0	11.0	1 571.8	33.8	12.8	1 592.2	34.3	13.0	4 643.5	37.8	
	Mar		14 092.5	7 462.7	117.6	705.2	23.7	88.2	779.4	9 176.8	139.7	2.8	1.0	1 818.1	37.0	12.9	1 570.2	31.9	11.1	1 387.7	28.2	9.8	4 915.7	34.9	
	Apr		5 961.1	1 731.7	94.1	333.7	18.9	1.2	468.0	2 647.6	92.8	2.8	1.6	957.6	28.9	16.1	1 097.9	33.1	18.4	1 171.2	35.3	19.6	3 313.5	55.6	
	May		10 745.7	4 186.0	111.9	612.9	23.2	54.0	641.0	5 629.0	133.0	2.6	1.2	1 469.9	28.7	13.7	1 715.6	33.5	16.0	1 798.2	35.1	16.7	5 116.7	47.6	
	Jun		11 796.2	5 827.5	90.0	455.3	19.0	124.8	514.0	7 030.6	114.4	2.4	1.0	1 390.7	29.2	11.8	1 617.4	33.9	13.7	1 643.1	34.5	13.9	4 765.6	40.4	
	Jul		10 383.7	4 924.8	72.2	173.6	15.5	42.0	524.8	5 752.9	115.8	2.5	1.1	1 495.4	32.3	14.4	1 572.0	33.9	15.1	1 447.6	31.3	13.9	4 630.8	44.6	
	Aug		17 729.2	8 723.3	86.7	875.3	18.6	136.2	625.0	10 465.1	188.9	2.6	1.1	2 322.7	32.0	13.1	2 481.5	34.2	14.0	2 271.1	31.3	12.8	7 264.1	41.0	
	Sep		19 275.5	10 672.9	69.3	704.8	14.9	126.0	683.0	12 270.9	203.1	2.9	1.1	2 300.5	32.8	11.9	2 435.6	34.8	12.6	2 065.4	29.5	10.7	7 004.6	36.3	
Subtotal		**80 521.1**	**157 724.2**	**74 279.8**	**1 302.5**	**5 692.6**	**266.7**	**915.7**	**7 816.6**	**90 273.9**	**1 859.3**	**2.8**	**1.2**	**20 477.2**	**30.4**	**13.0**	**23 176.7**	**34.4**	**14.7**	**21 943.0**	**32.5**	**13.9**	**67 450.3**	**42.8**	**112.1**
2005/2006	Oct		19 728.3	10 259.9	55.4	821.2	11.8	143.7	781.2	12 073.2	234.4	3.1	1.2	2 592.3	33.9	13.1	2 554.1	33.4	12.9	2 274.3	29.7	11.5	7 655.1	38.8	
	Nov		12 403.7	5 324.2	44.3	663.7	9.4	114.6	668.0	6 824.2	181.9	3.3	1.5	1 887.8	33.8	15.2	1 866.8	33.5	15.1	1 643.0	29.4	13.2	5 579.5	45.0	
	Dec		11 065.7	3 498.0	59.9	714.0	11.2	0.0	565.8	4 848.9	213.1	3.4	1.9	2 118.7	34.1	19.1	2 044.6	32.9	18.5	1 840.5	29.6	16.6	6 216.8	56.2	
	Jan		2 372.5	581.3	47.9	183.1	9.0	40.3	481.0	1 342.6	34.3	3.3	1.4	313.8	30.5	13.2	336.7	32.7	14.2	345.0	33.5	14.5	1 029.9	43.4	
	Feb		5 151.0	1 711.5	48.0	182.6	7.9	0.0	494.0	2 444.0	29.7	1.1	0.6	308.6	11.4	6.0	322.9	11.9	6.3	2 045.8	75.6	39.7	2 707.0	52.6	
	Mar		7 282.0	2 489.2	38.4	214.4	6.3	49.2	524.8	3 322.3	120.6	3.0	1.7	1 218.7	30.8	16.7	1 313.5	33.2	18.0	1 307.0	33.0	17.9	3 959.7	54.4	
	Apr		7 334.9	3 257.6	30.8	181.7	5.1	77.7	529.0	4 081.9	96.3	3.0	1.3	1 001.5	30.8	13.7	1 076.9	33.1	14.7	1 078.3	33.1	14.7	3 253.0	44.3	
	May		9 015.2	4 296.2	36.9	222.5	6.0	108.0	660.0	5 329.6	104.9	2.8	1.2	1 149.7	31.2	12.8	1 189.6	32.3	13.2	1 241.4	33.7	13.8	3 685.6	40.9	
	Jun		11 142.7	6 158.4	29.4	255.9	4.8	48.6	577.0	7 074.1	111.8	2.7	1.0	1 317.0	32.4	11.8	1 304.6	32.1	11.7	1 335.2	32.8	12.0	4 068.6	36.5	
	Jul		9 278.1	4 725.6	23.5	241.4	3.9	19.0	589.0	5 602.4	105.1	2.9	1.1	1 187.8	32.3	12.8	1 180.6	32.1	12.7	1 202.1	32.7	13.0	3 675.7	39.6	
	Aug		14 625.4	7 679.4	29.1	239.8	5.0	34.8	715.0	8 703.1	171.7	2.9	1.2	1 915.6	32.3	13.1	2 115.7	35.7	14.5	1 719.2	29.0	11.8	5 922.3	40.5	
	Sep		15 930.0	9 648.4	22.2	232.7	5.4	96.0	620.0	10 624.7	159.2	3.0	1.0	1 804.3	34.0	11.3	1 842.3	34.7	11.6	1 499.5	28.3	9.4	5 305.3	33.3	
Subtotal		**80 521.1**	**125 329.5**	**59 629.7**	**465.8**	**4 153.0**	**85.8**	**731.9**	**7 204.8**	**72 271.0**	**1 563.1**	**2.9**	**1.2**	**16 815.7**	**31.7**	**13.4**	**17 148.4**	**32.3**	**13.7**	**17 531.3**	**33.0**	**14.0**	**53 058.5**	**42.3**	**89.8**
2006/2007	Oct		18 755.6	12 059.0	26.7	311.0	6.1	125.4	664.0	13 192.2	169.6	3.0	0.9	1 913.6	34.4	10.2	1 938.7	34.8	10.3	1 541.5	27.7	8.2	5 563.4	29.7	
	Nov		8 065.7	4 191.0	32.0	577.2	7.2	72.3	698.0	5 577.7	83.3	3.3	1.0	858.3	34.5	10.6	851.0	34.2	10.6	695.4	28.0	8.6	2 488.0	30.8	
	Dec		12 864.9	6 948.1	25.6	150.0	5.8	46.2	589.6	7 765.3	176.3	3.5	1.4	1 768.2	34.7	13.7	1 748.4	34.3	13.6	1 406.7	27.6	10.9	5 099.6	39.6	
	Jan		13 522.7	6 080.1	30.7	259.6	6.9	27.6	742.0	7 146.9	227.0	3.6	1.7	2 220.1	34.8	16.4	2 170.3	34.0	16.0	1 758.4	27.6	13.0	6 375.8	47.1	
	Feb		15 319.2	7 286.8	30.3	268.1	6.6	110.4	599.4	8 301.6	264.1	3.8	1.7	2 492.7	35.5	16.3	2 438.5	34.7	15.9	1 822.3	26.0	11.9	7 017.6	45.8	
	Mar		16 659.1	8 318.3	30.4	269.2	6.8	144.0	615.0	9 383.7	281.3	3.9	1.7	2 592.3	35.6	15.6	2 517.0	34.6	15.1	1 884.8	25.9	11.3	7 275.4	43.7	
	Apr		10 365.1	4 627.0	24.4	294.3	5.4	25.8	521.0	5 497.9	178.3	3.7	1.7	1 738.4	35.7	16.8	1 671.6	34.3	16.1	1 278.9	26.3	12.3	4 867.2	47.0	
	May		11 186.0	4 927.5	29.3	254.5	6.5	90.0	680.0	5 987.8	179.4	3.5	1.6	1 832.1	35.2	16.4	1 783.3	34.3	15.9	1 403.4	27.0	12.5	5 198.2	46.5	
	Jun		8 820.7	4 624.1	23.4	295.0	5.2	0.0	495.0	5 442.7	106.3	3.1	1.2	1 175.6	34.8	13.3	1 148.6	34.0	13.0	947.5	28.0	10.7	3 378.0	38.3	
	Jul		8 693.5	4 568.5	18.7	284.0	4.1	1.8	504.0	5 381.1	101.4	3.1	1.2	1 128.8	34.1	13.0	1 139.0	34.4	13.1	943.2	28.5	10.8	3 312.4	38.1	
	Aug		12 817.1	6 901.8	13.8	517.1	2.7	24.0	432.0	7 891.4	139.9	2.8	1.1	1 714.3	34.8	13.4	1 663.9	33.8	13.0	1 407.7	28.6	11.0	4 925.7	38.4	
	Sep		18 896.2	9 768.0	17.9	173.7	3.7	95.4	528.0	10 586.7	287.5	3.5	1.5	2 847.4	34.3	15.1	2 829.8	34.1	15.0	2 344.9	28.2	12.4	8 309.5	44.0	
Subtotal		**80 521.1**	**155 965.8**	**80 300.2**	**303.2**	**3 653.7**	**67.0**	**762.9**	**7 068.0**	**92 155.0**	**2 194.4**	**3.4**	**1.4**	**22 281.7**	**34.9**	**14.3**	**21 900.0**	**34.3**	**14.0**	**17 434.7**	**27.3**	**11.2**	**63 810.8**	**40.9**	**114.4**
2007/2008	Oct		8 233.7	3 597.1	38.4	182.2	8.6	0.0	540.0	4 366.3	138.2	3.6	1.7	1 329.2	34.4	16.1	1 298.0	33.6	15.8	1 102.0	28.5	13.4	3 867.4	47.0	
	Nov		10 568.5	4 402.5	30.8	278.5	6.7	56.6	576.0	5 351.1	158.5	3.0	1.5	1 807.6	34.6	17.1	1 698.5	32.6	16.1	1 552.8	29.8	14.7	5 217.4	49.4	
	Dec		4 503.7	1 368.1	24.6	279.5	5.3	56.4	560.9	2 294.8	72.4	3.3	1.6	766.2	34.7	17.0	729.2	33.0	16.2	641.1	29.0	14.2	2 208.9	49.0	
	Jan		7 316.0	3 015.8	29.5	670.0	6.2	0.0	598.9	4 320.4	85.4	2.9	1.2	1 043.9	34.8	14.3	976.7	32.6	13.3	889.6	29.7	12.2	2 995.6	40.9	
	Feb		10 109.8	4 312.8	23.6	298.0	4.9	0.0	565.0	5 204.3	145.1	3.0	1.4	1 724.7	35.2	17.1	1 576.7	32.1	15.6	1 459.0	29.7	14.4	4 905.5	48.5	
	Mar		8 027.9	3 022.4	18.8	401.8	3.8	19.2	516.0	3 982.0	119.7	3.0	1.5	1 433.0	35.4	17.9	1 296.3	32.0	16.1	1 196.9	29.6	14.9	4 045.9	50.4	
	Apr		9 476.2	3 510.9	22.5	382.2	4.4	0.0	551.0	4 471.0	150.2	3.0	1.6	1 786.6	35.7	18.9	1 613.3	32.2	17.0	1 455.2	29.1	15.4	5 005.2	52.8	
	May		5 738.3	2 453.3	18.0	382.2	3.5	0.0	565.0	3 422.0	80.0	3.5	1.4	815.8	35.2	14.2	795.4	34.3	13.9	625.1	27.0	10.9	2 316.3	40.4	
	Jun		10 465.7	4 697.7	14.3	476.0	2.7	0.0	586.0	5 776.7	147.8	3.2	1.4	1 625.1	34.7	15.5	1 597.5	34.1	15.3	1 318.6	28.1	12.6	4 689.0	44.8	
	Jul		10 990.7	5 980.8	17.1	439.4	3.2	15.4	540.0	6 995.9	106.0	2.7	1.0	1 404.9	35.2	12.8	1 363.5	34.1	12.4	1 120.4	28.0	10.2	3 994.8	36.3	
	Aug		16 106.6	3 059.1	7.3	350.4	1.2	0.0	192.0	3 610.0	324.9	2.6	2.0	3 837.1	30.7	23.8	4 265.7	34.1	26.5	4 068.9	32.6	25.3	12 496.6	77.6	
	Sep		19 819.1	10 927.8	11.1	350.8	2.1	24.0	613.0	11 928.8	241.2	3.1	1.2	2 768.4	35.1	14.0	2 615.1	33.1	13.2	2 265.6	28.7	11.4	7 890.3	39.8	
Subtotal		**80 521.1**	**121 356.2**	**50 348.3**	**256.0**	**4 491.0**	**52.6**	**171.6**	**6 403.8**	**61 723.3**	**1 769.5**	**3.0**	**1.5**	**20 342.6**	**34.1**	**16.8**	**19 825.7**	**33.2**	**16.3**	**17 695.1**	**29.7**	**14.6**	**59 632.9**	**49.1**	**76.7**

Water Year	Month	Inflow		Consumptive use							Unavoidable losses						Avoidable losses						Gross losses		Utilisation
		Full quota	Inflow to Scheme	Agricultural use requested	Domestic	Industrial and municipality	Free Water	Government departments	Old furrows	Total use	Evaporation	% of total loss	% of inflow	Seepage	% of total loss	% of inflow	Canal end points	% of total loss	% of inflow	Operational losses & leakages	% of total loss	% of inflow	Total losses	% of inflow	% of full quota
2008/2009	Oct		25 926.5	13 042.5	13.8	653.9	2.5	88.0	854.0	14 654.7	361.5	3.2	1.4	3 944.3	35.0	15.2	3 804.6	33.8	14.7	3 161.3	28.0	12.2	11 271.8	43.5	
	Nov		3 174.6	1 571.6	11.0	379.0	1.9	26.0	432.0	2 421.5	24.2	3.2	0.8	265.0	35.2	8.3	251.6	33.4	7.9	212.3	28.2	6.7	753.1	23.7	
	Dec		15 590.2	6 352.0	13.1	301.4	2.2	1.2	540.0	7 209.9	285.8	3.4	1.8	2 940.6	35.1	18.9	2 799.9	33.4	18.0	2 354.0	28.1	15.1	8 380.3	53.8	
	Jan		6 881.4	2 279.3	10.4	75.9	2.1	0.0	540.0	2 907.7	113.6	2.9	1.7	1 384.5	34.8	20.1	1 296.1	32.6	18.8	1 179.5	29.7	17.1	3 973.7	57.7	
	Feb		4 131.9	1 047.3	8.2	110.2	1.7	0.0	528.0	1 695.4	72.1	3.0	1.7	899.5	36.9	21.8	781.1	32.1	18.9	683.7	28.1	16.5	2 436.5	59.0	
	Mar		8 722.0	2 982.1	9.8	293.0	1.9	0.0	661.0	3 947.8	136.5	2.9	1.6	1 767.3	37.0	20.3	1 525.8	32.0	17.5	1 344.7	28.2	15.4	4 774.2	54.7	
	Apr		7 677.0	3 376.3	7.8	334.2	1.6	0.0	594.0	4 313.9	89.4	2.7	1.2	1 252.0	37.2	16.3	1 071.4	31.9	14.0	950.4	28.3	12.4	3 363.1	43.8	
	May		7 821.9	3 079.5	6.2	428.7	1.3	128.2	527.0	4 170.9	89.0	2.4	1.1	1 356.2	37.1	17.3	1 152.9	31.6	14.7	1 052.9	28.8	13.5	3 651.0	46.7	
	Jun		9 134.4	4 532.0	4.9	452.1	1.5	120.0	491.0	5 601.5	79.7	2.3	0.9	1 346.9	38.1	14.7	1 120.3	31.7	12.3	986.1	27.9	10.8	3 532.9	38.7	
	Jul		12 365.3	5 657.2	5.8	346.0	1.7	0.0	652.0	6 662.7	123.7	2.2	1.0	2 159.5	37.9	17.5	1 805.9	31.7	14.6	1 613.5	28.3	13.0	5 702.6	46.1	
	Aug		12 551.7	2 583.7	6.9	227.7	1.9	15.6	600.5	3 436.3	258.5	2.8	2.1	3 173.8	34.8	25.3	3 078.5	33.8	24.5	2 604.5	28.6	20.8	9 115.4	72.6	
	Sep		18 582.9	9 965.3	5.4	349.2	1.5	0.0	591.0	10 912.4	234.2	3.1	1.3	2 691.9	35.1	14.5	2 542.5	33.1	13.7	2 201.9	28.7	11.8	7 670.5	41.3	
Subtotal		**80 521.1**	**132 559.8**	**56 468.8**	**103.3**	**3 951.3**	**21.8**	**379.0**	**7 010.5**	**67 934.7**	**1 868.1**	**2.9**	**1.4**	**23 181.5**	**35.9**	**17.5**	**21 230.7**	**32.9**	**16.0**	**18 344.8**	**28.4**	**13.8**	**64 625.1**	**48.8**	**84.4**
2009/2010	Oct		17 269.4	8 273.7	14.4	0.0	0.0	0.0	0.0	8 288.1	281.2	3.1	1.6	2 978.4	33.2	17.2	3 076.1	34.3	17.8	2 645.5	29.5	15.3	8 981.3	52.0	
	Nov		12 345.8	4 919.6	15.7	717.5	0.0	0.0	0.0	5 652.9	213.7	3.2	1.7	2 234.6	33.4	18.1	2 256.4	33.7	18.3	1 988.2	29.7	16.1	6 693.0	54.2	
	Dec		3 479.2	1 017.7	13.1	0.0	0.0	0.0	0.0	1 030.7	80.9	3.3	2.3	818.9	33.4	23.5	828.4	33.8	23.8	720.2	29.4	20.7	2 448.5	70.4	
	Jan		4 732.9	1 100.5	18.0	292.2	0.0	0.0	0.0	1 410.8	106.1	3.2	2.2	1 026.5	30.9	21.7	1 077.0	32.4	22.8	1 112.6	33.5	23.5	3 322.2	70.2	
	Feb		12 294.6	5 380.2	13.8	410.8	0.0	0.0	0.0	5 804.8	186.8	2.9	1.5	1 920.5	29.6	15.6	1 873.6	28.9	15.2	2 508.8	38.7	20.4	6 489.8	52.8	
	Mar		14 117.5	6 598.6	13.8	0.0	0.0	0.0	0.0	6 612.4	228.0	3.0	1.6	2 425.5	32.3	17.2	2 493.8	33.2	17.7	2 357.7	31.4	16.7	7 505.1	53.2	
	Apr		4 547.5	1 231.6	13.8	571.6	0.0	0.0	0.0	1 817.0	79.5	2.9	1.7	877.6	32.1	19.3	898.6	32.9	19.8	874.8	32.0	19.2	2 730.5	60.0	
	May		3 390.0	1 076.4	17.3	1 111.9	0.0	0.0	0.0	2 205.6	34.8	2.9	1.0	368.8	31.1	10.9	399.9	33.8	11.8	380.8	32.2	11.2	1 184.4	34.9	
	Jun		9 715.1	4 384.1	13.8	0.0	0.0	0.0	0.0	4 398.0	134.7	2.5	1.4	1 708.3	32.1	17.6	1 772.8	33.3	18.2	1 701.3	32.0	17.5	5 317.1	54.7	
	Jul		9 941.9	4 599.8	13.6	512.4	0.0	0.0	0.0	5 125.8	122.3	2.5	1.2	1 589.5	33.0	16.0	1 619.1	33.6	16.3	1 485.1	30.8	14.9	4 816.2	48.4	
	Aug		18 700.0	7 457.8	17.0	465.1	0.0	0.0	0.0	7 939.8	281.1	2.6	1.5	3 397.2	31.6	18.2	3 741.0	34.8	20.0	3 340.8	31.0	17.9	10 760.1	57.5	
	Sep		18 926.9	10 751.8	13.6	862.4	0.0	0.0	0.0	11 627.7	218.3	3.0	1.2	2 411.4	33.0	12.7	2 497.4	34.2	13.2	2 172.2	29.8	11.5	7 299.2	38.6	
Subtotal		**80 521.1**	**129 460.8**	**56 791.7**	**178.0**	**4 943.9**	**0.0**	**0.0**	**0.0**	**61 913.6**	**1 967.5**	**2.9**	**1.5**	**21 757.5**	**32.2**	**16.8**	**22 534.3**	**33.4**	**17.4**	**21 287.9**	**31.5**	**16.4**	**67 547.2**	**52.2**	**76.9**
2010/2011	Oct		20 395.7	10 169.6	13.6	516.8	0.0	0.0	0.0	10 700.0	304.6	3.1	1.5	3 219.1	33.2	15.8	3 321.9	34.3	16.3	2 850.1	29.4	14.0	9 695.7	47.5	
	Nov		13 929.5	6 053.9	13.6	576.1	0.0	0.0	0.0	6 643.6	232.8	3.2	1.7	2 433.8	33.4	17.5	2 456.5	33.7	17.6	2 162.8	29.7	15.5	7 285.9	52.3	
	Dec		8 181.8	3 260.2	13.6	0.0	0.0	0.0	0.0	3 273.8	161.5	3.3	2.0	1 635.7	33.3	20.0	1 661.3	33.8	20.3	1 624.0	33.1	19.8	4 908.0	60.0	
	Jan		3 136.9	1 237.0	17.0	473.3	0.0	0.0	0.0	1 727.3	45.0	3.2	1.4	435.9	30.9	13.9	457.3	32.4	14.6	471.4	33.4	15.0	1 409.7	44.9	
	Feb		9 833.3	4 221.7	13.6	478.6	0.0	0.0	0.0	4 713.9	147.4	2.9	1.5	1 515.5	29.6	15.4	1 478.5	28.9	15.0	1 977.9	38.6	20.1	5 119.4	52.1	
	Mar		9 966.8	4 558.6	13.6	0.0	0.0	0.0	0.0	4 572.1	164.0	3.0	1.6	1 742.9	32.3	17.5	1 792.8	33.2	18.0	1 695.0	31.4	17.0	5 394.6	54.1	
	Apr		3 623.0	1 418.7	13.6	469.7	0.0	0.0	0.0	1 901.9	50.0	2.9	1.4	552.2	32.1	15.2	565.8	32.9	15.6	580.0	33.7	16.0	1 721.1	47.5	
	May		5 063.1	1 681.5	17.0	650.9	0.0	0.0	0.0	2 349.4	79.4	2.9	1.6	853.8	31.5	16.9	911.7	33.6	18.0	868.9	32.0	17.2	2 713.7	53.6	
	Jun		9 514.7	3 920.0	13.6	0.0	0.0	0.0	0.0	3 933.5	141.4	2.5	1.5	1 792.5	32.1	18.8	1 861.2	33.3	19.6	1 786.1	32.0	18.8	5 581.2	58.7	
	Jul		13 820.3	5 835.5	17.0	502.3	0.0	0.0	0.0	6 354.8	190.1	2.5	1.4	2 465.2	33.0	17.8	2 512.9	33.7	18.2	2 297.4	30.8	16.6	7 465.5	54.0	
	Aug		14 550.9	6 084.3	13.6	0.0	0.0	0.0	0.0	6 097.9	221.1	2.6	1.5	2 675.0	31.6	18.4	2 941.9	34.8	20.2	2 615.0	30.9	18.0	8 453.0	58.1	
	Sep		19 454.4	10 269.6	15.6	401.7	0.0	0.0	0.0	10 686.9	262.7	3.0	1.4	2 900.7	33.1	14.9	3 002.9	34.3	15.4	2 601.1	29.7	13.4	8 767.5	45.1	
Subtotal		**80 521.1**	**131 470.3**	**58 710.6**	**175.1**	**4 069.5**	**0.0**	**0.0**	**0.0**	**62 955.1**	**1 999.9**	**2.9**	**1.5**	**22 222.4**	**32.4**	**16.9**	**22 964.7**	**33.5**	**17.5**	**21 529.7**	**31.4**	**16.4**	**68 515.2**	**52.1**	**78.2**

6.6 Losses

6.6.1 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.

The outflows consist of all the ways that water is consumed within the scheme. This includes the canal seepage, operational spills, evaporation from the canals, percolation and delivery to the irrigators and other users.

6.6.2 Gross Water losses

The total monthly losses summarised by main canal for the period October 2004 to September 2011 are shown in Table 6-2. The values in this table reflect the total losses and include seepage, evaporation, leakage and operational losses (including end of canal outflows). It therefore reflects the difference between the volume that was ordered by the water users and the volume of water released into the two main canals.

Table 6-2: Hartbeespoort IB - Historical monthly losses

Month	Eastern canal		Western canal	
	Volume (10^3m^3)	%	Volume (10^3m^3)	%
Oct-04	4 486	45.3	2 520	30.1
Nov-04	4 874	57.7	1 934	39.4
Dec-04	4 301	62.2	2 215	38.0
Jan-05	3 587	58.2	1 880	38.2
Feb-05	2 911	50.7	1 732	26.5
Mar-05	2 099	29.5	2 816	40.4
Apr-05	2 570	66.6	743	35.3
May-05	2 906	51.7	2 211	43.1
Jun-05	2 876	52.4	1 890	30.0
Jul-05	3 415	54.5	1 215	29.6
Aug-05	4 410	49.4	2 854	32.4
Sep-05	4 746	48.0	2 258	24.0
Oct-05	4 754	46.1	2 901	30.8
Nov-05	3 377	48.4	2 202	40.6
Dec-05	4 496	66.3	1 721	40.2
Jan-06	716	54.2	314	29.8
Feb-06	1 749	60.2	958	42.7
Mar-06	1 779	52.5	2 181	56.1
Apr-06	1 990	48.2	1 263	39.4
May-06	1 734	41.1	1 952	40.7
Jun-06	1 965	34.6	2 104	38.5
Jul-06	2 225	39.1	1 451	40.4
Aug-06	3 208	41.5	2 715	39.3
Sep-06	3 002	37.0	2 304	29.5
Oct-06	2 663	29.1	2 901	30.2
Nov-06	1 205	30.1	1 283	31.6
Dec-06	2 952	45.0	2 148	34.1
Jan-07	3 873	52.3	2 503	40.9
Feb-07	4 496	55.2	2 521	35.2
Mar-07	4 808	51.0	2 467	34.2
Apr-07	3 085	49.4	1 783	43.2
May-07	2 624	50.0	2 575	43.3
Jun-07	1 547	37.5	1 831	39.0
Jul-07	2 066	42.2	1 247	32.8
Aug-07	1 946	35.0	2 979	41.0

Month	Eastern canal		Western canal	
	Volume (10^3m^3)	%	Volume (10^3m^3)	%
Sep-07	4 948	50.2	3 362	37.2
Oct-07	2 846	55.6	1 022	32.8
Nov-07	3 213	51.0	2 004	46.9
Dec-07	1 690	59.9	519	30.9
Jan-08	1 545	40.8	1 451	41.1
Feb-08	2 883	52.3	2 023	44.0
Mar-08	2 390	54.0	1 656	46.0
Apr-08	3 297	56.4	1 708	47.1
May-08	1 233	43.1	1 083	37.7
Jun-08	2 425	48.2	2 264	41.6
Jul-08	2 152	38.8	1 842	33.9
Aug-08	4 348	54.6	8 148	100.0
Sep-08	4 512	46.2	3 379	33.6
Oct-08	6 042	48.6	5 229	38.8
Nov-08	34	2.4	719	41.0
Dec-08	4 630	58.0	3 750	49.3
Jan-09	2 340	60.2	1 633	54.6
Feb-09	1 448	70.6	988	47.5
Mar-09	2 790	62.3	1 984	46.8
Apr-09	1 912	47.6	1 451	39.6
May-09	1 401	44.2	2 250	48.4
Jun-09	1 952	41.9	1 581	35.3
Jul-09	3 910	55.4	1 793	33.8
Aug-09	3 312	52.1	5 803	93.6
Sep-09	4 075	45.4	3 595	37.5
Oct-09	4 552	51.6	4 429	52.4
Nov-09	3 663	52.5	3 030	56.4
Dec-09	1 872	71.5	577	66.8
Jan-10	2 367	72.8	955	64.5
Feb-10	3 770	56.7	2 720	48.2
Mar-10	4 303	58.1	3 202	47.7
Apr-10	1 594	58.8	1 136	61.9
May-10	816	45.3	740	46.6
Jun-10	2 877	60.8	2 440	49.0
Jul-10	2 912	53.4	1 904	42.4
Aug-10	5 517	59.3	5 243	55.8
Sep-10	3 416	36.5	3 883	40.6

Month	Eastern canal		Western canal	
	Volume (10^3m^3)	%	Volume (10^3m^3)	%
Oct-10	5 955	54.6	3 740	39.4
Nov-10	4 300	58.8	2 986	45.1
Dec-10	2 528	61.5	2 380	58.5
Jan-11	950	49.3	460	38.0
Feb-11	2 964	52.9	2 155	50.9
Mar-11	3 226	61.1	2 169	46.3
Apr-11	813	40.5	908	56.2
May-11	1 117	54.2	1 597	53.2
Jun-11	3 108	65.1	2 473	52.2
Jul-11	5 124	63.1	2 342	41.1
Aug-11	5 135	64.6	3 318	50.2
Sep-11	5 100	52.5	3 668	37.6
Average	**3 033**	**50.8**	**2 265**	**43.1**

A graphic representation of the total monthly losses for the Eastern and Western canals is shown in Figure 6-2. The unusually high and low losses recorded in the 2008 and 2009 water years were brought under the attention of the board to investigate as these losses were captured directly from the disposal reports. They were however excluded from the actual calculations.

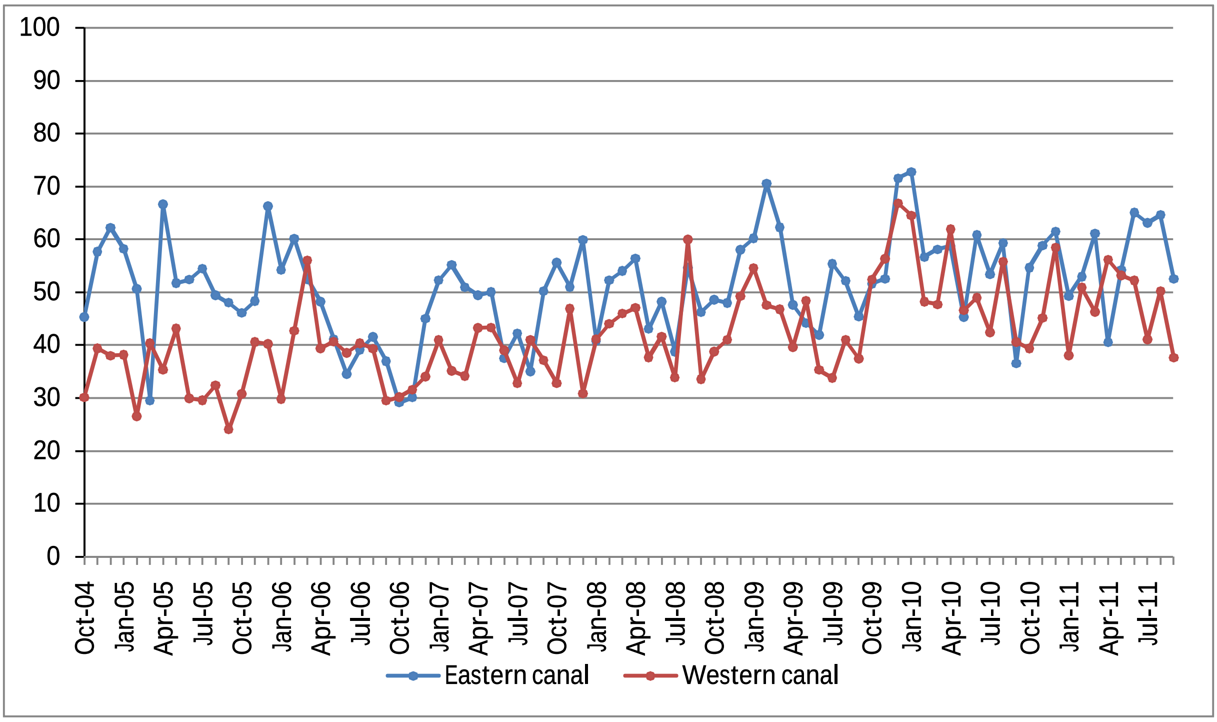

Figure 6-2: Hartbeespoort IB - Historical canal losses

From the data presented in **Table 6-2** and **Figure 6-2** it is clear that the total losses on the Eastern canal are roughly 9% more than the losses on the Western canal. This can mainly be attributed to three factors, namely;

- The distance that the water has to travel in the Eastern canal is further than that of the Western canal. The Western canal also has the 3km long siphon and 600m tunnel, resulting in lower transmission losses.
- The second factor is the types of soils through which the two canals were constructed. Large sections of the Eastern canal runs through "norite based" soils while the Western canal runs through heavy clay soils. Canal seepage and leakage losses are influenced by the type soil it traverses and these losses are lower in heavy clay soils.
- Differences in the types of crops under irrigation between water users situated at the upper sections and those at the lower and end sections of the canal.

The **average** water losses have been 47% of the released water from the dam into the canal system. This translates to an **average** of approximately 63.559 million m^3/a water losses in the Hartbeespoort Irrigation Scheme area. This volume mainly refers to the water losses that are difficult to measure including the unavoidable water losses as well as some of the avoidable losses. These include canal evaporation losses, seepage in the primary canals and distribution canals, percolation, leakage and start-up and shut-down losses, sudden drop in demand (rainfall). The tail water on average over seven years was 15.7% of the released water from the dam into the canal system.

Figure 6-3 provides a comparison between the supply and demand from Oct 2004 to Sep 2011.

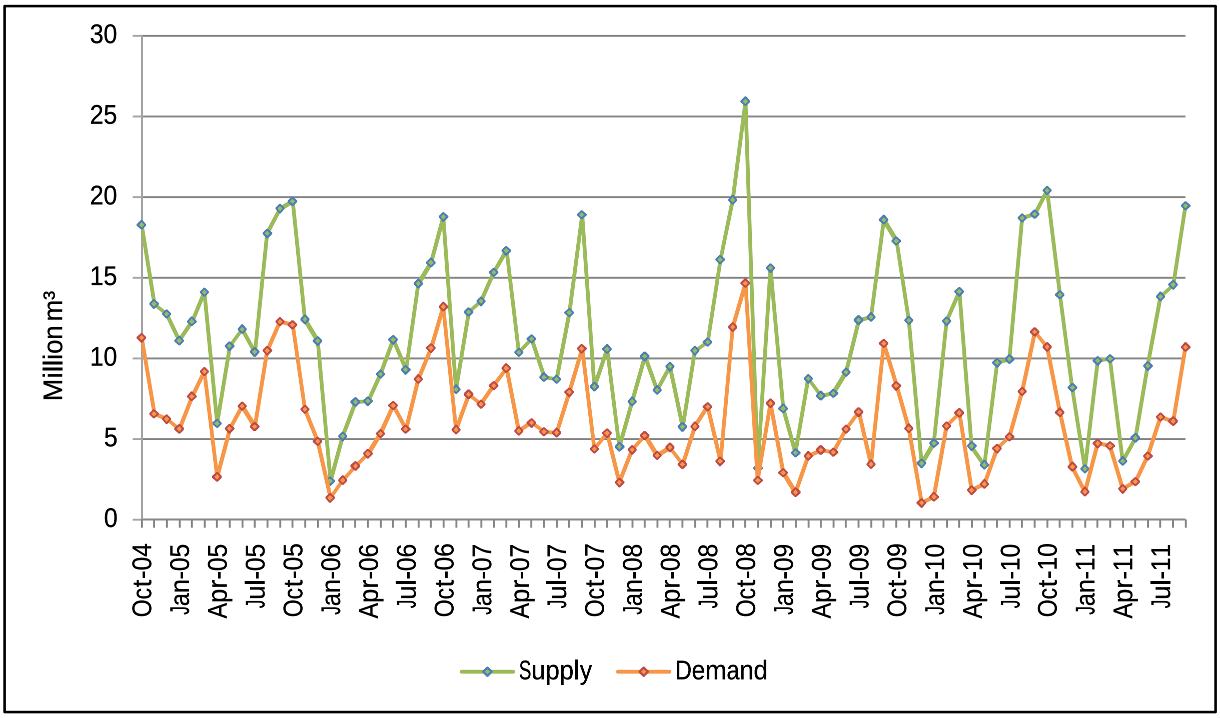

Figure 6-3: Comparison of deliveries and demands

6.6.3 Conveyance losses

Conveyance losses within a canal system can be defined as the difference between the water released at the canal inlets and the water delivered to the farm boundary. Conveyance losses are made up of unavoidable and avoidable losses.

Unavoidable losses

Unavoidable losses take place on a continual basis and the bulk of unavoidable losses are made up of seepage losses and evaporation losses.

Avoidable losses

Avoidable losses include items such as leakages and spills and include operational losses and wastages resulting from inter alia, inefficient management of the system and other factors such as algae growth, etc.

The main losses occurring within Hartbeespoort Irrigation Scheme served by canal distribution networks include the following;

6.6.3.1 Seepage losses:

Seepage losses from concrete lined, half lined and earth canals are normally expressed in l/s per 1 000 m^2 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 perimeter and this could result in an unavoidable loss rate of up to 15%. The depth of the ambient water table also has an effect on seepage losses. In an area where generally high water table levels are found, canal seepage decreases to roughly 5% 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, soil capillary tension, quantity of sediment, etc.

For Hartbeespoort Irrigation Scheme the estimated values of the seepage loss as a percentage of the calculated total loss were recorded in the monthly WUEARs. The average seepage loss over the seven years were 16.6 % of the inflow on the East canal and 14.2 % of the inflow on the West canal resulting in a total scheme seepage loss of 15.5 % of the inflow.

An additional method was used to determine the seepage losses for each canal by making use of different section widths and lengths as well as the formula for the wetted perimeter of a parabola and the Butler suggested seepage value of 1.9 l/s per 1000 m^2 wetted area. Since the flow depth at the various sections at a full capacity flow of 8.5 m^3/s was not available the formula for best hydraulic section where the top width at water surface equals 2.828 times the flow depth (Irrigation Design Manual chapter 7, p 7.10) was used.

Six sections were used for the East canal resulting in a seepage loss of 16.4 % of the inflow while five sections were used for the West canal resulting in a seepage loss of 12.1 % of the inflow. The differences in the two seepage loss calculations are small and the first method was used in the water budget.

6.6.3.2 Evaporation losses

The evaporation loss, expressed as a percentage of total inflow, is usually very low and has been estimated at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze :1986).

For Hartbeespoort Irrigation Scheme estimated values of the evaporation loss as a percentage of the calculated total loss were recorded in the monthly WUEARs. The average evaporation loss over the seven years were 1.5 % of the inflow on the East canal and 1.3 % of the inflow on the West canal resulting in a total scheme seepage loss of 1.4 % of the inflow. These percentages are a lot more than the estimated 0.3 % mentioned above.

An additional method was used to determine the evaporation losses using the same section widths and lengths as for determining the seepage losses. The surface area for the canal was multiplied with the annual evaporation for quaternary drainage region A21J resulting in an evaporation loss of 0.21 % of the inflow for the East canal and 0.37 % of the inflow for the West canal. These values correspond to the 0.3 % mentioned above.

6.6.3.3 Operational wastage:

Apart from the two losses described above there are also other losses on the canal system which can be classified as avoidable losses. Such losses include start-up and shut-down losses, water not used (outflows) due to unexpected drops in demand and losses due to incorrect measuring. These losses are estimated to fluctuate between 9% and 17% (Reid, Davidson and Kotze, 1986).

6.6.3.4 Leaks and Spills:

Leaks normally occur on broken sections of the canals and on the top sections of the canal body and can be as a result of maintenance problems and the general deterioration of the canal network due to its age. The determination of the volume of water that is lost as a result of leakages and spills is very difficult to calculate and can only really be determined through accurate measuring. An important factor that has a marked effect on leakages is the water depth in a canal system. 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.

Although the Board aims to operate the system within a range of 35% to 85% of the design capacity, the water demand during peak periods, sediment and weed/algae growth necessitates periodic operation of the system at peak capacity, resulting in high leakages and spills.

The average operational losses and leakages for the Hartbeespoort Irrigation Scheme over the seven year period were estimated at 14.3 % of the inflow. This estimation was done by subtracting all the other losses (seepage, evaporation and canal ends) from the total losses (difference between ordered and released).

6.6.3.5 Aquatic weeds

Water grass and algae growth in irrigation canal systems are fast becoming one of the major operational headaches 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 quantity 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 (sluice) working at dividing structures.
(v) Water logging of long-weirs occurs.
(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.
(vii) Aquatic weed fragments occlude irrigation systems and filters at water purification plants.
(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

A comprehensive study regarding aquatic weeds was undertaken by Modjadji Vegetation CC and their final report *"Compliance audit on the management of aquatic weeds in South African waterways"* was released in November 2007 (DWA/RSA/01-0707). This report will not try to repeat the findings of the Modjadji Vegetation CC investigation but specific detail will be discussed where necessary

Table 6-3 provides a summary of the various losses on the canal distribution network of the Hartbeespoort IB. The figures are based on the 2004/2005 to 2010/2011 water years. It is important to note that the categories included in the table are shown on the WUEARs and that a further breakdown of the losses were not possible.

Table 6-3: Hartbeespoort IB - Breakdown of water losses

Description	Unavoidable losses (m^3*10^6)	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
Seepages	21.011		21.011	33.1
Evaporation	1.889		1.889	3.0
Operational & leakages		19.395	19.395	30.6
Canal end returns		21.254	21.254	33.4
Total	**22.900**	**40.650**	**63.550**	**100**
% of total losses	**36%**	**64%**	**100%**	
% of total volume released into system	**17%**	**30%**	**47%**	

From the data presented Table 6-3 it is evident that the total losses on the scheme amount to 47%. Of the total losses occurring on the scheme, 36% or 22.9 million cubic metres can be classified as unavoidable losses while 64% or approximately 40.7 million cubic metres are avoidable losses. The bulk of the avoidable losses (21 million cubic metres) are made up of canal end return flows.

6.6.4 Avoidable water losses

Based on the above assessment and disaggregation of the gross water losses, the average estimated avoidable water losses over the seven water years have been 40.7 million m^3. This quantity can be attributed to a number of factors.

- *Measuring errors*: With the current method of manual reading of the depth of flows by the WCOs, there is a likelihood of measurement errors due to human error. The implementation of telemetry systems may reduce the avoidable losses.
- *Scheduling of deliveries.* There is potential for significant water losses to take place if the volume of water ordered is small. This lower volume can mostly be attributed to a change in the types of crops under irrigation between water users situated at the upper sections of the canal and those at the lower and end sections of the canal.
- *Volume of water ordered*: There is potential for significant water losses to take place if the volume of water ordered is very small compared to the minimum quantity to reduce water losses.
- *Leakage in the canal structure*: 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.

7 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

7.1 Overview

The Hartbeespoort Irrigation Board has been implementing measures to improve the management of delivery to the irrigators. These measures include 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.

7.2 Canal refurbishment

The Hartbeespoort IB recently rebuilt the lower section (21 km) of the Eastern Canal (below Kleinfontein balancing dam) at a cost of some R 8 million.

7.3 Flow metering/measurement

The Hartbeespoort IB has installed flow measurements at the critical diversion points to measure how much water is diverted at different points of the irrigation scheme. The existing infrastructure is however not sufficient to ensure that detailed water budgets can be conducted at scheme level as well as at sub-scheme level. Existing telemetry systems will have to be calibrated in order for data collection to be correct.

7.4 Automated releases

Automated sluice gates were installed at the outlet of the Kleinfontein dam on the Eastern Canal.

7.5 Operation and maintenance of the canal infrastructure

Although the ownership of the canal infrastructure at the Hartbeespoort Irrigation Scheme is with the Department of Water Affairs (DWA) there is an agreement that the IB is responsible for the operation and maintenance of the canal infrastructure.

The Hartbeespoort IB has an annual O&M budget which amounts to some R19.36 million per year. This is financed from the scheme charges which currently is R1 695.12 per ha/a for the 13 915 hectares that are scheduled.

All refurbishment and maintenance is financed by the Irrigation Board who operates within the available budget as financed by the water users. No subsidy is received from DWA.

The following typical maintenance works are needed within the servitude of the canals, draining canals and balancing dams:

- Removal of rocks, mud and other obstructions from the canal.
- Replacement of concrete sections when necessary.
- Sealing of concrete lining.
- Reparation of bridges and flood crossings when necessary.

- Reparation of storm water walls.
- Removal of dangerous weed (water plants) from canal.
- Cutting of grass for the total servitude width.
- Removal of trees from the servitude.
- Maintenance of canal roads.
- Painting sluices, bridge rails and other items.
- Replacement of sluices when necessary.
- Reinstallation of measuring plates on parshall flumes.
- Cleaning of siphon entrances.

The IB is totally authorised to execute any maintenance work they deem necessary. Therefore the Board has right of way for the transport of materials, equipment, labourers etc. within the servitude area.

7.6 Risk analysis

In 2011 the Hartbeespoort IB started conducting a risk analysis identifying all the potential risks involving the scheme and possible methods for resolving them. Table 7-1 summarises these risks.

Table 7-1: Risk register

Risk	Affected party	Prevention rules	Other suggestions
Canal infrastructure: Old with increasing weathering and little funds to rebuild	All water users, the Board and Government	Regular and constant rebuild and refurbishment of the canal structure	Financial support from the government and mines
Agriculture: Input costs increase more than commodity prices	Irrigators and the Board	Stricter rules and collections regarding receivables	Include Dept. of Agriculture and financial support from the government
Pollution	All water users especially the vegetable farmers	Pollution control by government	Better controls and stronger action against polluters as well as mines and industry
Water availability: Users may need to pay for full quota even though less is received	All water users	Continued communication with government and resolve water plant problem	Involve Dept. of Agriculture and DWA must finance the control of water plants
Influence of mines in the community	All water users	Continuous and regular inspection of mine slime dams	Continuous communication with mines; involve government and DWA
Land claims: Unsuccessful, slow in payment and	All water users	Regularly inspect subsidies by government; act stricter against irrigators who	Continuous communication with government in terms of paying subsidies;

Risk	Affected party	Prevention rules	Other suggestions
deterioration of canal infrastructure		don't pay	financial support
Government: Lack of support to Board and increasing tarriffs	Irrigators and Board	Regular communication with the government and negotiation regarding the implementation and determination of government tariffs	Request financial support from government
Strikes	Irrigators and Board	Contingency plan	Involve Board members to assist in management of canal system in times of strikes

7.7 Aquatic weed control

Aquatic weeds have become a serious problem amongst irrigation schemes and Hartbeespoort Irrigation Scheme is no exception. Time and again the canal structure has flooded due to algae and water grass taking up additional volume and increasing the water level or influencing the flow. Both canals are dosed with Magnacide-H Herbicide up to seven times each year resulting in an annual cost of up to R 900 000.

Photo 7: Algae growth in the canal system

8 WATER MANAGEMENT ISSUES AND GOALS

8.1 Overview of the management issues

The water budget analysis discussed in the previous chapter has helped to identify several key water management issues. First there are substantial, unexplained losses particularly in the late season. The water budget analysis did reveal that on an annual basis, there is sufficient water to meet the Hartbeespoort Irrigation Board's irrigation demands. It also highlighted that irrigators are currently not utilising their full water allocation.

In addition to the water budget analysis, discussions were held with the management and other people who are knowledgeable about the Hartbeespoort Irrigation Scheme. This was done to determine the key issues the scheme is facing. The key issues identified are discussed in more detail in the following sections of this chapter.

8.2 Flow measurement and water accounting

8.2.1 Adequacy of flow data

Good information is fundamental to making correct decisions when managing irrigation water at any irrigation scheme is involved. **Figure 8.1** below, provides the extent of flow measurement that is ideal for conducting an irrigation scheme water budget. The availability of flow measurements helps inform both the water user and the IB about the quantity, timing, and location of water use and therefore enables the IB to conduct a water budget not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated **in Figure 8.1** below, it would be ideal to have flow measurements at the inlet to the primary canals as well as at the 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 the Hartbeespoort IB does not to have adequate flow measurement data to conduct a water budget analysis at both scheme and sub-scheme levels. The IB does make regular measurements of flows at certain points but these are mainly for monitoring purposes. These include weirs and parshall flumes on the canals, and flumes and rated (but not calibrated) sluice gates on the laterals to the individual farmers.

Measuring devices are not installed at the canal end points and flows are currently estimated as a percentage of the total losses.

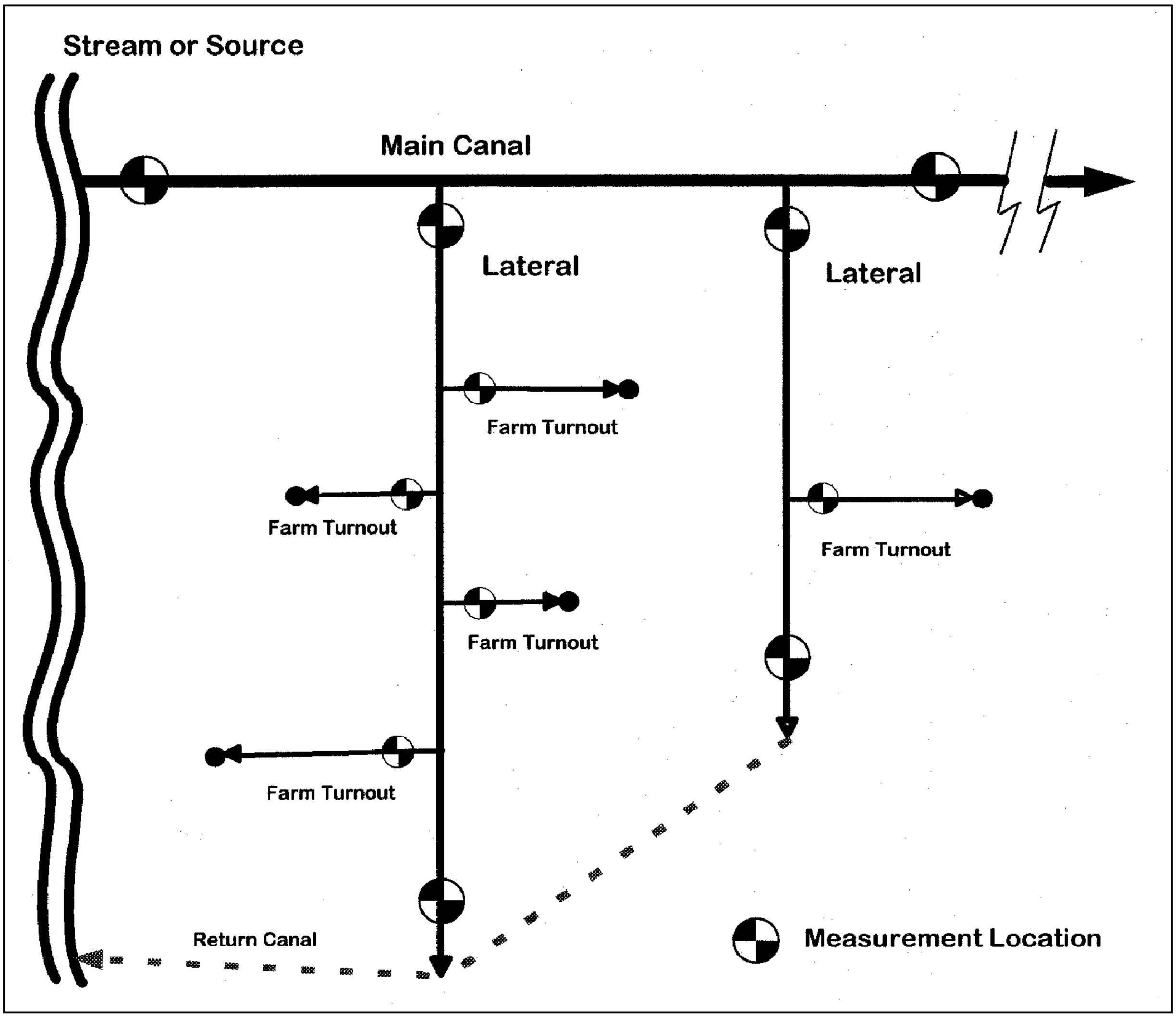

Figure 8-1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

8.2.2 Telemetry systems and compatibility with WAS

The Hartbeespoort Irrigation Scheme has six Android Telemetry Systems installed of which two are located at the Dam outlet works where water is released into the two main canals. However with the installation of the Water Administration System (WAS) to undertake water use efficiency accounting reports, it was found that the telemetry system and WAS were not compatible.

The compatibility of these systems has not been resolved and flows and water levels are manually captured on the WAS system. Even though these six telemetry systems exist in the scheme, the flow data received from them are just for monitoring purposes and are not included in the water budget. Only three of these systems (Hartbeespoort Picnic, Thatch Haven and Sonop) were transmitting data during the site visit. These existing telemetry systems should be calibrated for data collection to be correct and included in WAS.

8.2.3 Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Hartbeespoort IB:

(i) Continuation of regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system.

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

(iii) The compatibility between the existing telemetry system at the dam wall and WAS should be resolved. The flows and levels are intended to be sent by telemetry system to the Hartbeespoort IB offices for direct input into the WAS programme.

(iv) More telemetry stations must be permanently installed to monitor water supply to the different canal sections as well as to monitor any operational spills or tail water that is not used in the scheme. Installation of measuring devices at canal end points (at least on the two main canals) to enable the actual measurements of return flows is vital.

8.2.4 Irrigation water budget is not conducted in detail

It is currently difficult, if not impossible to disaggregate the losses. There is no differentiation in the water balance assessment between the losses. Losses such as leakage, spills and over delivery to users have not been disaggregated. Although a real time telemetric monitoring system is in place, the data is used for monitoring purposes only and the data is not incorporated into the WAS system automatically. Currently it is not possible to easily conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention. The accuracy of the seepage losses remains questionable and it is proposed that ponding tests be done to verify the accuracy of the theoretical calculations.

Management Goal 2

The goal to address the above issue is to ensure that all the flow measurements in the Hartbeespoort IB are included when water budgets and water loss calculations at scheme as well as ward/sub-scheme level are done. This will enable the IB to undertake comprehensive water audits to identify priority areas for improving irrigation water management as well as highlighting sections with high water losses. Ponding tests should also be undertaken to verify the theoretical calculations of the seepage losses on the canal system.

8.3 Operational water management issues

8.3.1 The WAS program is not fully utilised

The Water Administration System (WAS) was developed by Dr. Nico Benade (mainly with funding from the WRC and DWA) as a tool to be used by Irrigation Boards/Schemes to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. WAS consists of seven modules integrated into a single program and these modules can be implemented separately or as a whole.

The seven modules are the:

(i) Administration module
(ii) Water order module
(iii) Water accounts module
(iv) Water release module
(v) Measured data module
(vi) Crop water use module, and
(vii) Report module

The Water Release module for example links with the water administration and order modules and can be used to:

- Minimise distribution losses on canal networks
- Calculate water releases for the main canal(s) and all their branches, allowing for lag times and water losses such as seepage and evaporation; and
- Determine operating procedures for a dam with varying downstream inflows and outflows in a river, allowing for lag times and water losses such as seepage, evaporation and transpiration.

Four of the seven WAS models are currently used by the Hartbeespoort IB. They are the Administration module, the Water Order module, the Water Accounts module and the Report module. Although initial calibration of the WAS Water Release module was undertaken, this module is presently not being used due to factors such as the rapid growth of aquatic weeds during certain periods which affects the parameters of the module.

8.3.2 Management Goal 3

The management objective to address the above issue, is to ensure that all the modules of the WAS programme, particularly the water order and water release modules, are implemented fully and that weekly and monthly reports from the modules are generated. This could be undertaken within 2 years from the completion of this Water Management Plan (WMP).

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

8.3.3 Available datasets not integrated into a Management Information System

The Hartbeespoort IB has commissioned various studies in the past and has their own detailed datasets at their disposal. All these datasets are in standalone databases or spreadsheets and very little thereof are spatially linked. Having all this data in one integrated Management Information System will be a huge benefit and should enable quicker and better informed decision making.

Management Goal 4

The development of a spatially linked Management Information System that integrates all the relevant and available datasets of the IB.

8.4 Infrastructure related issues

8.4.1 General

In order to properly develop the Hartbeespoort Irrigation scheme water management plan, it is essential that an assessment of the overall condition of the facilities to identify potential issues is conducted. As indicated in Chapter 4, a high level condition assessment together with discussions with the Hartbeespoort IB was undertaken. That included the operation and maintenance system as well as the conveyance and distribution system. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

8.4.2 Condition of canal infrastructure

A condition assessment of the existing canal infrastructure has been conducted for this report. There are however sections in the structure requiring attention. Leakage and canal losses may be taking place on these sections or at the joints between the different canal sections. The IB is responsible for maintenance and refurbishment of the canal structure in the dry weeks but time is too little to attend to all the problem sections before supplying water to the users again. Furthermore blasting done by various mines within the scheme area may contribute to the deteriorating canal structure.

8.4.3 Limited scheme balancing capacity

Balancing dams decrease the pressure on the canal system and allows for shorter delivery periods to water users. They also intercept any surplus water in the system and act as backups to supplement supply should shortages arise (canal breaks, etc.). The Hartbeespoort IB only has the benefit of two balancing dams on the scheme, with minimal storage capacity.

8.4.4 Management Goal 5

The Hartbeespoort Irrigation Scheme does not have a good balancing system in place to ensure security of water supply during shortages or major canal failures. The goal is to investigate the possibility of creating additional storage capacity which will assist in operating the system as effectively as possible. Studies should also be undertaken to determine the impact of mining activities on the canal structure. Possible short cuts and pipe line diversions should be further investigated.

8.5 Ownership of irrigation infrastructure

8.5.1 Roles and responsibilities in infrastructure maintenance

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 ensuring that the quality of the infrastructure is maintained.

In the Hartbeespoort Irrigation Board, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the main, primary and branch canals. However, the IB operates the irrigation infrastructure as an agent of the DWA and undertakes the normal maintenance of the irrigation infrastructure.

Problems will most likely arise when the major infrastructure needs replacement/total refurbishment. It is unlikely that the IB 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. Therefore the responsibility for replacement of major assets lies with government, whose priorities may be different to those of the IB.

At present there is no service level agreement between the Hartbeespoort IB and the DWA regarding their roles and responsibilities. Assets are owned by DWA while the O&M is carried out by the Hartbeespoort IB. Without such an agreement 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.

8.5.2 Management Goal 6

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 Hartbeespoort IB are further refined than the existing draft arrangement. The signing of a service level agreement is therefore essential. This is assuming that the DWA does not want to transfer the infrastructure to the IB in the short to medium term.

8.6 Institutional Water Management Issues

8.6.1 Updating and implementation of the Water Management Plan

The CEO of the Hartbeespoort IB will amongst others, be responsible for the annual updating and implementation of the Water Management Plan (WMP) for the scheme. The roles and responsibilities of the CEO for the updating and implementation of the WMP will be the following:

- Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level
- Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office
- Develop improved water saving targets

- Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues
- Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes
- Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme
- Maintenance and modernisation of the irrigation infrastructure
- Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme
- Monitor the plan and schedule for implementing water conservation program components
- Report quarterly to DWA on the implementation status of the WMP regarding actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives.
- Annually review and update of WMP with a water conservation program for the scheme with goals, objectives, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

Management Goal 7

Implementation, monitoring, reviewing and updating of the WMP by the CEO and reporting by him/her on the status of water losses, water saving targets, goals and objectives.

8.7 Pollution

8.7.1 Water pollution upstream of the Hartbeespoort Dam

The Board is extremely concerned about the pollution upstream of Hartbeespoort Dam. Although the Department of Water Affairs has already employed countermeasures to minimise pollution, it is the Board's opinion that action against transgressors is not sufficiently enforced and strict enough.

8.7.2 Water pollution within the Hartbeespoort Irrigation Scheme

The quality of the water in the Hartbeespoort Irrigation Scheme has deteriorated over the last couple of years. This is not only due to the poor quality water flowing into the Hartbeespoort Dam but also due to informal settlements along the canal structure. The situation is shocking. Refuse bins are empty but the canal is filled with anything from nappies to orange peels. Toilets have been erected on the banks of the canal with raw sewerage seeping into the water. The canal is also used to do washing.

Rubbish and litter not only contaminates the water but also cause major blockages in the canal and delivery systems.

Picture 8-1: Informal settlements along canal

8.7.3 Management Goal 8

Revise countermeasures and apply stricter rules and regulations regarding pollution. Take action against polluters. Undertake negotiations with the Local Municipality to safeguard IB (DWA) infrastructure, particularly along informal settlements. If these prove to be unsuccessful, the possibility of pipelines for these sections should be investigated or alternatively a complete realignment of the section(s).

8.8 Alien vegetation

8.8.1 Alien vegetation downstream of Hartbeespoort Dam

Besides the indigenous vegetation taking over in the river system and resulting in losses, the Board is concerned about the alien trees that are intruding (especially in the river section below Hartbeespoort Dam). The eradication of such plants is however outside the jurisdiction of the Board.

8.8.2 Management Goal 10

Ensure and foster a close working relationship between the Hartbeespoort Irrigation Board and the manager of the Working for Water program and provide information on areas of infestation.

8.9 Aquatic weeds

8.9.1 Algae and water grass in the canal structure

Algae are an ever growing concern and if not properly controlled, cause serious problems. The canal structure is under a lot of stress when the banks are flooded due to the effect the weeds have on the water level. Algae and water grass can cause blockages in the system (from the main canal to the irrigation system) and contribute to operational losses. Both canals are dosed with Magnacide-H Herbicide up to seven times each year resulting in an annual cost of up to R 900 000 which is difficult for the Board to finance. The water grass however is not effectively reduced by the dosage of Magnacide-H Herbicide and usually grows again shortly after the application.

8.9.2 Management Goal 11

It is very important that the Magnacide-H Herbicide be dosed at the correct time especially taking into consideration the weather conditions. Alternative methods should be investigated to reduce the problem regarding water grass.

Table 8-1: Hartbeespoort Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	Lack of telemetry systems and its compatibility with WAS. The flow measurements taking place on the diversion points within the Hartbeespoort Irrigation Scheme are manually read (limited telemetry system). Errors can easily be made this way.	Link the telemetry system at the Hartbeespoort Dam with the WAS. Install more telemetry stations.
2	WAS is not fully utilised.	Eliminate problems by making use of professional advice. Training.
3	Irrigation water budget and balance assessment. Disaggregate losses. Measure canal return flows.	Include rainfall and evaporation records in the water balance. Break down losses per sub-scheme. Make use of WAS.
4	Sections of the canal structure are in a poor condition resulting in leakages and spills which contribute to the avoidable losses. These areas can only receive attention during well planned dry weeks when farmers have made provision for not irrigating when there is no water in the canal. Blasting done by various mines within the scheme area may contribute to the deteriorating canal structure.	More scheme balancing dams may allow for longer refurbishment periods. Studies should be done to determine the impact of the mine activities on the canal structure.
5	DWA still owns the irrigation infrastructure but the IB operates it as an agent of the DWA and undertakes the normal maintenance thereof. It is unlikely that the IB has the financial capacity to undertake the refurbishment of the assets which are owned by government. Therefore the responsibility for replacement of major assets lies with government.	Responsibility between the DWA and the Hartbeespoort IB should be further refined. Service level agreement.
6	The Board is also concerned about the pollution upstream of Hartbeespoort Dam and within the scheme itself. Although the Department of Water Affairs has already employed	Revise countermeasures and apply stricter rules and regulations

Item No.	Issue description	Comments
	countermeasures to minimise pollution, it is the Board's opinion that this is still not effective enough.	regarding pollution. Relocate informal settlements.
7	Besides the indigenous vegetation taking in the river system and resulting in losses, the Board is concerned about the foreign trees that are intruding, especially the river below Hartbeespoort Dam. The eradication of such plants is however outside the jurisdiction of the Board.	Eradication programme to be developed with WfW.
8	Algae and water grass growth is a common phenomenon and expensive to control.	MAGNACIDE-H Herbicide Alternative methods to reduce water grass.
9	Updating and implementation of the Water Management Plan.	Implementation, monitoring, reviewing and updating of the WMP is responsibility of the Scheme Manager as well as scheduled reporting by him/her on the status of water losses, water saving targets, goals and objectives.

9 HARTBEESPOORT IB WATER MANAGEMENT PLAN

A comprehensive Water Management Plan for the Hartbeespoort IB is included in **Annexure C** and this section will only address the pertinent matters included in the plan.

9.1 Setting of water savings targets

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) that can be achieved in the Hartbeespoort IB.

A Water Research Commission (WRC) study (Report TT465/10) 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 (Reinders 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 scheme. This amounts to 13.48 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water saving and water loss targets.

The unavoidable water losses in the Hartbeespoort IB were determined to be 17.0% of the total releases into the canal system. This water is additional to the irrigation water use required at the farm edge.

As illustrated in Table 9-3 ,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 is 27.0% of the total releases into the canal system of the Hartbeespoort IB.

The set targets for the East Canal are presented in Table 9-1.

Table 9-1: Target water losses for the East Canal

Description	***System inflow*** *(x 10⁶m³)*	***Present situation - Losses***				**Acceptable water losses**		**Target water saving**	
		Unavoidable losses *(x 10^6m^3)*	***Avoidable losses*** *(x 10^6m^3)*	***Total Losses*** *(x 10^6m^3)*	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**
Seepages		*12.0*		*12.0*	16.57%	12.0	16.57%	0	0.00%
Evaporation		*1.1*		*1.1*	1.52%	1.1	1.52%	0	0.00%
Filling losses		*0*	*11.8*	*11.8*	16.31%	7.24	10.00%	16.705	23.07%
Leakages									
Spills									
Over delivery									
Canal end returns			*12.1*	*12.1*	16.77%				
Other		*0*	*0*	*0*	0.00%	0	0.00%	0	0.00%
Total	***72.4***	***13.1***	***23.945***	***37.045***	***51.17%***	***20.34***	***28.09%***	***16.705***	***23.07%***
% of total volume released into system		***18.09%***	***33.07%***	***51.17%***					

The targets for the West Canal are presented in Table 9-2.

Table 9-2: Target water losses for the West Canal

Description	***System inflow*** *(x 10^6m^3)*	***Present situation - Losses***				**Acceptable water losses**		**Target water saving**	
		Unavoidable losses *(x 10^6m^3)*	***Avoidable losses*** *(x 10^6m^3)*	***Total Losses*** *(x 10^6m^3)*	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**	**Annual volume** (x 10^6m^3)	**% of total volume released**
Seepages		*9.011*		*9.011*	14.44%	9.011	14.44%	0	0.00%
Evaporation		*0.799*		*0.799*	1.28%	0.799	1.28%	0	0.00%
Filling losses		*0*	*7.59*	*7.59*	13.43%	6.24	10.00%	10.464	16.77%
Leakages									
Spills									
Over delivery									
Canal end returns			*9.114*	*9.114*	14.61%				
Other		*0*	*0*	*0*	0.00%	0	0.00%	0	0.00%
Total	***62.4***	***9.81***	***16.704***	***26.514***	42.49%	***16.05***	***25.72%***	***10.464***	***16.77%***
% of total volume released into system		***15.72%***	***26.77%***	***42.49%***					

The targets for the Hartbeespoort IB as a whole are shown in **Table 9-3** below.

Table 9-3: Target water losses in the Hartbeespoort IB

<table>
<tr><th rowspan="2">Description</th><th rowspan="2">System inflow (x 10^6m^3)</th><th colspan="4">Present situation - Losses</th><th colspan="2">Acceptable water losses</th><th colspan="2">Water savings targets</th></tr>
<tr><th>Unavoidable losses (x 10^6m^3)</th><th>Avoidable losses (x 10^6m^3)</th><th>Total Losses (x 10^6m^3)</th><th>% of total volume released</th><th>Annual volume (x 10^6m^3)</th><th>% of total volume released</th><th>Annual volume (x 10^6m^3)</th><th>% of total volume released</th></tr>
<tr><td>Seepages</td><td rowspan="8"></td><td>21.011</td><td>0</td><td>21.011</td><td>15.59%</td><td>21.011</td><td>15.59%</td><td>0</td><td>0.00%</td></tr>
<tr><td>Evaporation</td><td>1.899</td><td>0</td><td>1.899</td><td>1.41%</td><td>1.899</td><td>1.41%</td><td>0</td><td>0.00%</td></tr>
<tr><td>Filling losses</td><td rowspan="4"></td><td rowspan="4">19.395</td><td rowspan="4">19.395</td><td rowspan="4">14.39%</td><td rowspan="5">13.48</td><td rowspan="5">10.00%</td><td rowspan="5">27.169</td><td rowspan="5">20.16%</td></tr>
<tr><td>Leakages</td></tr>
<tr><td>Spills</td></tr>
<tr><td>Over delivery</td></tr>
<tr><td>Canal end returns</td><td>0</td><td>21.254</td><td>21.254</td><td>15.77%</td></tr>
<tr><td>Other</td><td>0</td><td>0</td><td>0</td><td>0.00%</td><td>0</td><td>0.00%</td><td>0</td><td>0.00%</td></tr>
<tr><td>**Total**</td><td>**134.80**</td><td>**22.91**</td><td>**40.649**</td><td>**63.559**</td><td>**47.15%**</td><td>**36.39**</td><td>**27.00%**</td><td>**27.169**</td><td>**20.16%**</td></tr>
<tr><td colspan="2">**% of total volume released into system**</td><td>**17.00%**</td><td>**30.16%**</td><td>**47.15%**</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Based on the projected water saving targets, the Hartbeespoort IB can achieve a 6% reduction in irrigation water losses relative to the 2011 levels in a relative short period (3 years and less).

9.1.1 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans and aquatic weed control is some 8 million m3/a.

9.1.2 Long term water saving targets

For the long term a further 21 million m3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 27% of the total diversion.

9.2 Implementation Plan

An evaluation of the potential measures for implementation in the Hartbeespoort IB area to improve water use efficiency and reduce water losses indicates that all the measures are economically justified for implementation based on the unit cost of water saved. The priority for implementation based on the amount of water savings and the average incremental cost of water saved is as follows:

(i) *Incorporating the existing telemetry system with WAS*
(ii) *Expand WUEAR to include sub-schemes*
(iii) *Fully implement the Release Module of WAS*
(iv) *Ponding tests to establish canal seepage*
(v) *Revise maintenance procedures and actions during refurbishment periods*
(vi) Develop and implement a comprehensive Management Information System

The action plan for implementation is presented in Table 9-4 .

Table 9-4: Hartbeespoort IB Action Plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	Measurement and identification of losses	(i) Start measurement of Main Canals return flows. (ii) Conduct seepage loss measurements in representative canal and pipeline segments though ponding tests where possible. Extrapolate results from tested segments to similar segments and revise water budget. (iii) Undertake sub-scheme water budgets (iv) Prioritise areas of significant water losses	Mar '13 – Feb '14 Mar '13 – Feb '14 Mar '13 – Feb '15 Mar '13 – Feb '14	HBPIB
2	Reduce leakage losses in irrigation canal infrastructure within 5 years	(i) Formalise Service Level Agreement	Mar '13 – Feb '14	HBPIB/DWA
3	Increase operational efficiency	(i) Link telemetry system with WAS (ii) Implement release module of WAS (iii) Undertake study to identify possible additional balancing capacity in the area of operation. (iv) Incorporate data in a custom Water Management System	Mar '13 – Feb '15 Mar '13 – Feb '15 Mar '13 – Feb '15 Mar '13 – Feb '15	HBPIB
4	Address pollution	(i) Engage with relevant stakeholders to resolve crisis. Investigate and implement methods to resolve problem. Escalate matter if		DWA/ HBPIB/ MADIBENG

Priority	Goal	Action Plan	Timeline	Responsible Authority
		necessary.		
5	In 5 years, implement incentive pricing structure for the IB if viable	(i) Review current irrigation water pricing strategy (ii) Engage with irrigators on incentive pricing structure (iii) Update water pricing strategy (iv) Implement water billing based on incentive pricing rate	Mar ’13 – Feb ‘18	DWA/ HBPIB

10 CONCLUSIONS AND RECOMMENDATIONS

The IB has an allocation of some 86 million cubic metres of water per annum from the Hartbeespoort Dam but this allocation excludes losses. Due to the increased return flows into the catchment of the Hartbeespoort Dam and good rainfall seasons, the dam had sufficient water and the Board could count on annual releases from the dam in excess of 120 million m^3/a to compensate for these losses. The Board only paid for 86 million m^3 although it received much more than that and it is here where the main challenge lies. Although it can be expected that the DWA will allow for a certain percentage losses, this percentage is presently unknown and if the Board is charged for system losses it will substantially reduce their income.

The success of WC/WDM through a WMP will depend on the effective participation of all the participants. A well balanced “carrot and stick” plan will be required based on the principal of a “win win “situation where the benefits of the successes of the water management plan will filter through to the users in one or other form such as less water use charges, more water or the possibility of selling any surplus water etc. In terms of WC/WDM the development of a Water Management Plan is in itself a BMP as it force water users and institutions to start thinking and planning. The main aim of a water management plan is to conserve water, to improve water supply services to the water users and to enable irrigators to use their water more efficiently in the sort and long term. The development and implementation of water management plans are progressive processes and although the initial plan may be very basic and lacking information, the completeness will improve when it is reviewed and revised by the IB each year.

The goals for the WMP have been set and the WUA believes that the targets and objectives set in the WMP are achievable through proper oversight by the CEO and support from the DWA.

This WMP must be seen as a first generation plan and has to be reviewed and updated on an annual basis. Based on the projected water saving targets, the Hartbeespoort IB can achieve a 6% reduction in irrigation water losses relative to the 2011 levels in a relative short period.

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans and aquatic weed control is some 8 million m^3/a.

For the long term a further 19 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 27% of the total diversion.

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ANNEXURE A

COST ANALYSIS

Item	Description	Total
MEASURE RETURN FLOWS		
Measuring equipment	Installing measuring equipment (preferably telemetry) at 4 major canal end points.	
Installation period		24 Months
Productive period		20 Years
Initial Capital Investment Costs	Software	R 50 000
	Telemetry infrastructure	R 380 000
	Total	**R 430 000**
Annual O&M Expenses		R 20 000
Reduction in losses	Million m^3/a	5.2
Cost per m^3 (3 years)		**R 0.03**
AQUATIC WEED CONTROL		
Intensive dosing	MAGNACIDE-H	
Annual Expenses		R 800 000
Reduction in losses	Million m^3/a	2.8
Cost per m^3 (per year)		**R 0.29**

ANNEXURE B

MAPS

ANNEXURE C

WATER MANAGEMENT PLAN : HARTBEESPOORT IRRIGATION BOARD

SUMMARISED WATER MANAGEMENT PLAN FOR THE HARTBEESPOORT IRRIGATION BOARD

APRIL 2013 TO MARCH 2014

January 2013

Submitted by:

Hartbeespoort Irrigation Board

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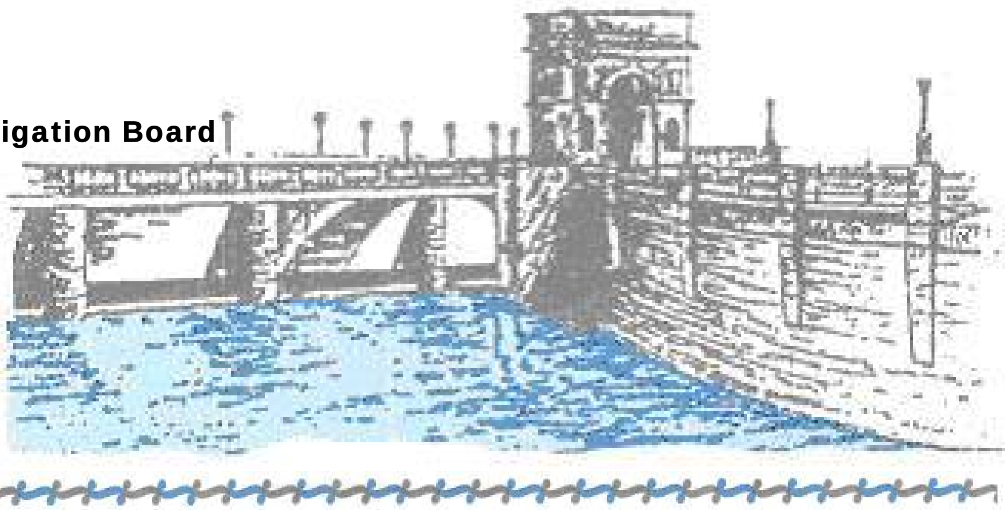

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1 BACKGROUND

The Hartbeespoort Irrigation Board is one of the oldest irrigation schemes in South Africa. The dam has a catchment of 4 112 km², which is drained by the Crocodile River and its tributaries, the most important of which are the Jukskei, Hennops and the Magalies Rivers.

With a mean annual rainfall of 685mm, the initial runoff to the dam was estimated at 163 million m³. Since 2000, this volume has already doubled due to urban development in the catchment which resulted in increased run-off and return-flows from wastewater treatment plants.

The scheme consists of the Hartbeespoort Dam (205 million m3) on the Crocodile River and approximately 134 km main canals and 532 km branch canals. The Eastern canal comprises a 78 km long, wide parabolic concrete lined canal which has a capacity of 6.8 m³/s and serves irrigators on the eastern side of the Crocodile River. There are three siphons of approximately 700 meters in length on the Eastern canal. The Western canal is a 56 km long, wide concrete lined canal structure which has a capacity of 6.8 m³/s and serves irrigators on the western side of the Crocodile River. There is a tunnel of 600 m conveying the water through granite outcrops and a 3 km siphon located on the Western canal.

There are six wards in the scheme, three for the East canal and three for the West canal and water is delivered to farmers through sluices. Depending on the size of the sluice gate opening, water can be delivered at 50 m³/hour, 70 m³/hour or 100 m³/hour. The sluices are adjusted by hand every 12 hours.

The Irrigation Board has a total scheduled area of 13 911 hectares, at a scheduled quota of 6 200 m3/ha/a which translates to a total allocation of 86 248 200 m3/annum. The various categories of water users and the annual allocations are shown in Table 1-1.

Table 1-1: Water user categories and allocations

Water Use category	***Annual allocation m³***
Commercial Farmers (13 911 ha)	*86 248 200*
Industrial users	*9 316 290*
TOTAL	***95 796 490***

Economic activity is based on commercial irrigated agriculture and the types of crops cultivated within the area of operation of the Hartbeespoort Irrigation Board are provided in Table 1-2 .

Table 1-2: Crops under irrigation

Crop	% of Total crop area under irrigation
Wheat	29.49
Soybean	20.22
Vegetables-Summer	16.85
Lucerne	11.24
Vegetables-Winter	9.83
Maize	7.30
Citrus	1.69
Table grapes	1.69
Tobacco	1.12
Chillies	0.56

2 LEGAL PROVISION FOR DEVELOPING AND IMPLEMENTING THE HARTBEESPOORT IB WATER MANAGEMENT PLAN

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 the to be established Hartbeespoort 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."

In light of the above legal requirements, the Hartbeespoort IB has developed a WMP in terms of the provisions of the NWA to enable it to manage the irrigation water in the scheme effectively and efficiently.

3 HARTBEESPOORT IRRIGATION SCHEME WATER BALANCE

3.1 Introduction

The purpose of this water balance is to summarise the inflows, consumption and outflows from the area of operation of the Hartbeespoort Irrigation Board. During the preparation of the water balance the beneficial and non-beneficial consumptive uses were determined which formed the basis for the calculation of performance indications which are necessary in identifying water savings opportunities.

Every water use component in the IB is represented in the water balance and the various categories for inflows, consumptive use and outflows are described and discussed below.

3.2 Overall scheme water balance

The water balance is based on information obtained from the Water Administration System (WAS). The records of inflows which consist of all the sources of water supply to the Hartbeespoort IB were available on a monthly basis.

Using the information obtained from the WUEARs, previous studies and institutional knowledge, the water accounting report for the Hartbeespoort IB was generated. The volume of water that is requested by the Irrigation Board varies from year to year, as does the cropping pattern for each year and the actual volume of water requested for release rarely exceeds 70% of the total annual allocation.

A breakdown of the water budget is presented in Table 3-1 **.** The consumptive uses include agriculture, domestic (drinking water and stock watering) industrial and municipality, free water, government departments and old furrows. From the table it is evident that for the 2009/10 and 2010/11 water years, no volumes were recorded for free water, government departments or old furrows. The reason for this being that these sectors obtained their entitlements from scheduled use and are therefore already included in the agricultural sector.

Table 3-1: Hartbeespoort Irrigation Scheme – Water Budget

		Inflow		Consumptive use							Unavoidable losses						Avoidable losses						Gross losses		Utilisation
Water Year	Month	Full quota	Inflow to Scheme	Agricultural use requested	Domestic	Industrial and municipality	Free Water	Government departments	Old furrows	Total use	Evaporation	% of total loss	% of inflow	Seepage	% of total loss	% of inflow	Canal end points	% of total loss	% of inflow	Operational losses & leakages	% of total loss	% of inflow	Total losses	% of inflow	% of full quota
2004/2005	Oct		18 269.7	9 537.5	159.5	768.1	32.0	88.2	679.2	11 264.5	196.1	2.8	1.1	1 977.4	28.2	10.8	2 512.3	35.9	13.8	2 319.3	33.1	12.7	7 005.2	38.3	
	Nov		13 362.0	5 232.0	127.6	278.8	25.6	81.6	808.4	6 554.0	204.2	3.0	1.5	1 972.4	29.0	14.8	2 373.1	34.9	17.8	2 258.3	33.2	16.9	6 808.0	51.0	
	Dec		12 739.3	4 857.2	153.1	251.6	30.8	51.0	880.0	6 223.7	189.0	2.9	1.5	1 858.9	28.5	14.6	2 319.4	35.6	18.2	2 148.3	33.0	16.9	6 515.6	51.1	
	Jan		11 089.8	4 666.9	122.5	223.7	24.7	0.0	585.0	5 622.8	147.6	2.7	1.3	1 568.7	28.7	14.1	1 909.9	34.9	17.2	1 840.8	33.7	16.6	5 467.0	49.3	
	Feb		12 279.5	6 457.3	98.0	309.6	19.8	122.5	628.8	7 636.0	134.7	2.9	1.1	1 344.9	29.0	11.0	1 571.8	33.8	12.8	1 592.2	34.3	13.0	4 643.5	37.8	
	Mar		14 092.5	7 462.7	117.6	705.2	23.7	88.2	779.4	9 176.8	139.7	2.8	1.0	1 818.1	37.0	12.9	1 570.2	31.9	11.1	1 387.7	28.2	9.8	4 915.7	34.9	
	Apr		5 961.1	1 731.7	94.1	333.7	18.9	1.2	468.0	2 647.6	92.8	2.8	1.6	957.6	28.9	16.1	1 097.9	33.1	18.4	1 171.2	35.3	19.6	3 313.5	55.6	
	May		10 745.7	4 186.0	111.9	612.9	23.2	54.0	641.0	5 629.0	133.0	2.6	1.2	1 469.9	28.7	13.7	1 715.6	33.5	16.0	1 798.2	35.1	16.7	5 116.7	47.6	
	Jun		11 796.2	5 827.5	90.0	455.3	19.0	124.8	514.0	7 030.6	114.4	2.4	1.0	1 390.7	29.2	11.8	1 617.4	33.9	13.7	1 643.1	34.5	13.9	4 765.6	40.4	
	Jul		10 383.7	4 924.8	72.2	173.6	15.5	42.0	524.8	5 752.9	115.8	2.5	1.1	1 495.4	32.3	14.4	1 572.0	33.9	15.1	1 447.6	31.3	13.9	4 630.8	44.6	
	Aug		17 729.2	8 723.3	86.7	875.3	18.6	136.2	625.0	10 465.1	188.9	2.6	1.1	2 322.7	32.0	13.1	2 481.5	34.2	14.0	2 271.1	31.3	12.8	7 264.1	41.0	
	Sep		19 275.5	10 672.9	69.3	704.8	14.9	126.0	683.0	12 270.9	203.1	2.9	1.1	2 300.5	32.8	11.9	2 435.6	34.8	12.6	2 065.4	29.5	10.7	7 004.6	36.3	
Subtotal		**80 521.1**	**157 724.2**	**74 279.8**	**1 302.5**	**5 692.6**	**266.7**	**915.7**	**7 816.6**	**90 273.9**	**1 859.3**	**2.8**	**1.2**	**20 477.2**	**30.4**	**13.0**	**23 176.7**	**34.4**	**14.7**	**21 943.0**	**32.5**	**13.9**	**67 450.3**	**42.8**	**112.1**
2005/2006	Oct		19 728.3	10 259.9	55.4	821.2	11.8	143.7	781.2	12 073.2	234.4	3.1	1.2	2 592.3	33.9	13.1	2 554.1	33.4	12.9	2 274.3	29.7	11.5	7 655.1	38.8	
	Nov		12 403.7	5 324.2	44.3	663.7	9.4	114.6	668.0	6 824.2	181.9	3.3	1.5	1 887.8	33.8	15.2	1 866.8	33.5	15.1	1 643.0	29.4	13.2	5 579.5	45.0	
	Dec		11 065.7	3 498.0	59.9	714.0	11.2	0.0	565.8	4 848.9	213.1	3.4	1.9	2 118.7	34.1	19.1	2 044.6	32.9	18.5	1 840.5	29.6	16.6	6 216.8	56.2	
	Jan		2 372.5	581.3	47.9	183.1	9.0	40.3	481.0	1 342.6	34.3	3.3	1.4	313.8	30.5	13.2	336.7	32.7	14.2	345.0	33.5	14.5	1 029.9	43.4	
	Feb		5 151.0	1 711.5	48.0	182.6	7.9	0.0	494.0	2 444.0	29.7	1.1	0.6	308.6	11.4	6.0	322.9	11.9	6.3	2 045.8	75.6	39.7	2 707.0	52.6	
	Mar		7 282.0	2 489.2	38.4	214.4	6.3	49.2	524.8	3 322.3	120.6	3.0	1.7	1 218.7	30.8	16.7	1 313.5	33.2	18.0	1 307.0	33.0	17.9	3 959.7	54.4	
	Apr		7 334.9	3 257.6	30.8	181.7	5.1	77.7	529.0	4 081.9	96.3	3.0	1.3	1 001.5	30.8	13.7	1 076.9	33.1	14.7	1 078.3	33.1	14.7	3 253.0	44.3	
	May		9 015.2	4 296.2	36.9	222.5	6.0	108.0	660.0	5 329.6	104.9	2.8	1.2	1 149.7	31.2	12.8	1 189.6	32.3	13.2	1 241.4	33.7	13.8	3 685.6	40.9	
	Jun		11 142.7	6 158.4	29.4	255.9	4.8	48.6	577.0	7 074.1	111.8	2.7	1.0	1 317.0	32.4	11.8	1 304.6	32.1	11.7	1 335.2	32.8	12.0	4 068.6	36.5	
	Jul		9 278.1	4 725.6	23.5	241.4	3.9	19.0	589.0	5 602.4	105.1	2.9	1.1	1 187.8	32.3	12.8	1 180.6	32.1	12.7	1 202.1	32.7	13.0	3 675.7	39.6	
	Aug		14 625.4	7 679.4	29.1	239.8	5.0	34.8	715.0	8 703.1	171.7	2.9	1.2	1 915.6	32.3	13.1	2 115.7	35.7	14.5	1 719.2	29.0	11.8	5 922.3	40.5	
	Sep		15 930.0	9 648.4	22.2	232.7	5.4	96.0	620.0	10 624.7	159.2	3.0	1.0	1 804.3	34.0	11.3	1 842.3	34.7	11.6	1 499.5	28.3	9.4	5 305.3	33.3	
Subtotal		**80 521.1**	**125 329.5**	**59 629.7**	**465.8**	**4 153.0**	**85.8**	**731.9**	**7 204.8**	**72 271.0**	**1 563.1**	**2.9**	**1.2**	**16 815.7**	**31.7**	**13.4**	**17 148.4**	**32.3**	**13.7**	**17 531.3**	**33.0**	**14.0**	**53 058.5**	**42.3**	**89.8**
2006/2007	Oct		18 755.6	12 059.0	26.7	311.0	6.1	125.4	664.0	13 192.2	169.6	3.0	0.9	1 913.6	34.4	10.2	1 938.7	34.8	10.3	1 541.5	27.7	8.2	5 563.4	29.7	
	Nov		8 065.7	4 191.0	32.0	577.2	7.2	72.3	698.0	5 577.7	83.3	3.3	1.0	858.3	34.5	10.6	851.0	34.2	10.6	695.4	28.0	8.6	2 488.0	30.8	
	Dec		12 864.9	6 948.1	25.6	150.0	5.8	46.2	589.6	7 765.3	176.3	3.5	1.4	1 768.2	34.7	13.7	1 748.4	34.3	13.6	1 406.7	27.6	10.9	5 099.6	39.6	
	Jan		13 522.7	6 080.1	30.7	259.6	6.9	27.6	742.0	7 146.9	227.0	3.6	1.7	2 220.1	34.8	16.4	2 170.3	34.0	16.0	1 758.4	27.6	13.0	6 375.8	47.1	
	Feb		15 319.2	7 286.8	30.3	268.1	6.6	110.4	599.4	8 301.6	264.1	3.8	1.7	2 492.7	35.5	16.3	2 438.5	34.7	15.9	1 822.3	26.0	11.9	7 017.6	45.8	
	Mar		16 659.1	8 318.3	30.4	269.2	6.8	144.0	615.0	9 383.7	281.3	3.9	1.7	2 592.3	35.6	15.6	2 517.0	34.6	15.1	1 884.8	25.9	11.3	7 275.4	43.7	
	Apr		10 365.1	4 627.0	24.4	294.3	5.4	25.8	521.0	5 497.9	178.3	3.7	1.7	1 738.4	35.7	16.8	1 671.6	34.3	16.1	1 278.9	26.3	12.3	4 867.2	47.0	
	May		11 186.0	4 927.5	29.3	254.5	6.5	90.0	680.0	5 987.8	179.4	3.5	1.6	1 832.1	35.2	16.4	1 783.3	34.3	15.9	1 403.4	27.0	12.5	5 198.2	46.5	
	Jun		8 820.7	4 624.1	23.4	295.0	5.2	0.0	495.0	5 442.7	106.3	3.1	1.2	1 175.6	34.8	13.3	1 148.6	34.0	13.0	947.5	28.0	10.7	3 378.0	38.3	
	Jul		8 693.5	4 568.5	18.7	284.0	4.1	1.8	504.0	5 381.1	101.4	3.1	1.2	1 128.8	34.1	13.0	1 139.0	34.4	13.1	943.2	28.5	10.8	3 312.4	38.1	
	Aug		12 817.1	6 901.8	13.8	517.1	2.7	24.0	432.0	7 891.4	139.9	2.8	1.1	1 714.3	34.8	13.4	1 663.9	33.8	13.0	1 407.7	28.6	11.0	4 925.7	38.4	
	Sep		18 896.2	9 768.0	17.9	173.7	3.7	95.4	528.0	10 586.7	287.5	3.5	1.5	2 847.4	34.3	15.1	2 829.8	34.1	15.0	2 344.9	28.2	12.4	8 309.5	44.0	
Subtotal		**80 521.1**	**155 965.8**	**80 300.2**	**303.2**	**3 653.7**	**67.0**	**762.9**	**7 068.0**	**92 155.0**	**2 194.4**	**3.4**	**1.4**	**22 281.7**	**34.9**	**14.3**	**21 900.0**	**34.3**	**14.0**	**17 434.7**	**27.3**	**11.2**	**63 810.8**	**40.9**	**114.4**
2007/2008	Oct		8 233.7	3 597.1	38.4	182.2	8.6	0.0	540.0	4 366.3	138.2	3.6	1.7	1 329.2	34.4	16.1	1 298.0	33.6	15.8	1 102.0	28.5	13.4	3 867.4	47.0	
	Nov		10 568.5	4 402.5	30.8	278.5	6.7	56.6	576.0	5 351.1	158.5	3.0	1.5	1 807.6	34.6	17.1	1 698.5	32.6	16.1	1 552.8	29.8	14.7	5 217.4	49.4	
	Dec		4 503.7	1 368.1	24.6	279.5	5.3	56.4	560.9	2 294.8	72.4	3.3	1.6	766.2	34.7	17.0	729.2	33.0	16.2	641.1	29.0	14.2	2 208.9	49.0	
	Jan		7 316.0	3 015.8	29.5	670.0	6.2	0.0	598.9	4 320.4	85.4	2.9	1.2	1 043.9	34.8	14.3	976.7	32.6	13.3	889.6	29.7	12.2	2 995.6	40.9	
	Feb		10 109.8	4 312.8	23.6	298.0	4.9	0.0	565.0	5 204.3	145.1	3.0	1.4	1 724.7	35.2	17.1	1 576.7	32.1	15.6	1 459.0	29.7	14.4	4 905.5	48.5	
	Mar		8 027.9	3 022.4	18.8	401.8	3.8	19.2	516.0	3 982.0	119.7	3.0	1.5	1 433.0	35.4	17.9	1 296.3	32.0	16.1	1 196.9	29.6	14.9	4 045.9	50.4	
	Apr		9 476.2	3 510.9	22.5	382.2	4.4	0.0	551.0	4 471.0	150.2	3.0	1.6	1 786.6	35.7	18.9	1 613.3	32.2	17.0	1 455.2	29.1	15.4	5 005.2	52.8	
	May		5 738.3	2 453.3	18.0	382.2	3.5	0.0	565.0	3 422.0	80.0	3.5	1.4	815.8	35.2	14.2	795.4	34.3	13.9	625.1	27.0	10.9	2 316.3	40.4	
	Jun		10 465.7	4 697.7	14.3	476.0	2.7	0.0	586.0	5 776.7	147.8	3.2	1.4	1 625.1	34.7	15.5	1 597.5	34.1	15.3	1 318.6	28.1	12.6	4 689.0	44.8	
	Jul		10 990.7	5 980.8	17.1	439.4	3.2	15.4	540.0	6 995.9	106.0	2.7	1.0	1 404.9	35.2	12.8	1 363.5	34.1	12.4	1 120.4	28.0	10.2	3 994.8	36.3	
	Aug		16 106.6	3 059.1	7.3	350.4	1.2	0.0	192.0	3 610.0	324.9	2.6	2.0	3 837.1	30.7	23.8	4 265.7	34.1	26.5	4 068.9	32.6	25.3	12 496.6	77.6	
	Sep		19 819.1	10 927.8	11.1	350.8	2.1	24.0	613.0	11 928.8	241.2	3.1	1.2	2 768.4	35.1	14.0	2 615.1	33.1	13.2	2 265.6	28.7	11.4	7 890.3	39.8	
Subtotal		**80 521.1**	**121 356.2**	**50 348.3**	**256.0**	**4 491.0**	**52.6**	**171.6**	**6 403.8**	**61 723.3**	**1 769.5**	**3.0**	**1.5**	**20 342.6**	**34.1**	**16.8**	**19 825.7**	**33.2**	**16.3**	**17 695.1**	**29.7**	**14.6**	**59 632.9**	**49.1**	**76.7**

Water Year	Month	Inflow		Consumptive use							Unavoidable losses						Avoidable losses						Gross losses		Utilisation
		Full quota	Inflow to Scheme	Agricultural use requested	Domestic	Industrial and municipality	Free Water	Government departments	Old furrows	Total use	Evaporation	% of total loss	% of inflow	Seepage	% of total loss	% of inflow	Canal end points	% of total loss	% of inflow	Operational losses & leakages	% of total loss	% of inflow	Total losses	% of inflow	% of full quota
2008/2009	Oct		25 926.5	13 042.5	13.8	653.9	2.5	88.0	854.0	14 654.7	361.5	3.2	1.4	3 944.3	35.0	15.2	3 804.6	33.8	14.7	3 161.3	28.0	12.2	11 271.8	43.5	
	Nov		3 174.6	1 571.6	11.0	379.0	1.9	26.0	432.0	2 421.5	24.2	3.2	0.8	265.0	35.2	8.3	251.6	33.4	7.9	212.3	28.2	6.7	753.1	23.7	
	Dec		15 590.2	6 352.0	13.1	301.4	2.2	1.2	540.0	7 209.9	285.8	3.4	1.8	2 940.6	35.1	18.9	2 799.9	33.4	18.0	2 354.0	28.1	15.1	8 380.3	53.8	
	Jan		6 881.4	2 279.3	10.4	75.9	2.1	0.0	540.0	2 907.7	113.6	2.9	1.7	1 384.5	34.8	20.1	1 296.1	32.6	18.8	1 179.5	29.7	17.1	3 973.7	57.7	
	Feb		4 131.9	1 047.3	8.2	110.2	1.7	0.0	528.0	1 695.4	72.1	3.0	1.7	899.5	36.9	21.8	781.1	32.1	18.9	683.7	28.1	16.5	2 436.5	59.0	
	Mar		8 722.0	2 982.1	9.8	293.0	1.9	0.0	661.0	3 947.8	136.5	2.9	1.6	1 767.3	37.0	20.3	1 525.8	32.0	17.5	1 344.7	28.2	15.4	4 774.2	54.7	
	Apr		7 677.0	3 376.3	7.8	334.2	1.6	0.0	594.0	4 313.9	89.4	2.7	1.2	1 252.0	37.2	16.3	1 071.4	31.9	14.0	950.4	28.3	12.4	3 363.1	43.8	
	May		7 821.9	3 079.5	6.2	428.7	1.3	128.2	527.0	4 170.9	89.0	2.4	1.1	1 356.2	37.1	17.3	1 152.9	31.6	14.7	1 052.9	28.8	13.5	3 651.0	46.7	
	Jun		9 134.4	4 532.0	4.9	452.1	1.5	120.0	491.0	5 601.5	79.7	2.3	0.9	1 346.9	38.1	14.7	1 120.3	31.7	12.3	986.1	27.9	10.8	3 532.9	38.7	
	Jul		12 365.3	5 657.2	5.8	346.0	1.7	0.0	652.0	6 662.7	123.7	2.2	1.0	2 159.5	37.9	17.5	1 805.9	31.7	14.6	1 613.5	28.3	13.0	5 702.6	46.1	
	Aug		12 551.7	2 583.7	6.9	227.7	1.9	15.6	600.5	3 436.3	258.5	2.8	2.1	3 173.8	34.8	25.3	3 078.5	33.8	24.5	2 604.5	28.6	20.8	9 115.4	72.6	
	Sep		18 582.9	9 965.3	5.4	349.2	1.5	0.0	591.0	10 912.4	234.2	3.1	1.3	2 691.9	35.1	14.5	2 542.5	33.1	13.7	2 201.9	28.7	11.8	7 670.5	41.3	
Subtotal		**80 521.1**	**132 559.8**	**56 468.8**	**103.3**	**3 951.3**	**21.8**	**379.0**	**7 010.5**	**67 934.7**	**1 868.1**	**2.9**	**1.4**	**23 181.5**	**35.9**	**17.5**	**21 230.7**	**32.9**	**16.0**	**18 344.8**	**28.4**	**13.8**	**64 625.1**	**48.8**	**84.4**
2009/2010	Oct		17 269.4	8 273.7	14.4	0.0	0.0	0.0	0.0	8 288.1	281.2	3.1	1.6	2 978.4	33.2	17.2	3 076.1	34.3	17.8	2 645.5	29.5	15.3	8 981.3	52.0	
	Nov		12 345.8	4 919.6	15.7	717.5	0.0	0.0	0.0	5 652.9	213.7	3.2	1.7	2 234.6	33.4	18.1	2 256.4	33.7	18.3	1 988.2	29.7	16.1	6 693.0	54.2	
	Dec		3 479.2	1 017.7	13.1	0.0	0.0	0.0	0.0	1 030.7	80.9	3.3	2.3	818.9	33.4	23.5	828.4	33.8	23.8	720.2	29.4	20.7	2 448.5	70.4	
	Jan		4 732.9	1 100.5	18.0	292.2	0.0	0.0	0.0	1 410.8	106.1	3.2	2.2	1 026.5	30.9	21.7	1 077.0	32.4	22.8	1 112.6	33.5	23.5	3 322.2	70.2	
	Feb		12 294.6	5 380.2	13.8	410.8	0.0	0.0	0.0	5 804.8	186.8	2.9	1.5	1 920.5	29.6	15.6	1 873.6	28.9	15.2	2 508.8	38.7	20.4	6 489.8	52.8	
	Mar		14 117.5	6 598.6	13.8	0.0	0.0	0.0	0.0	6 612.4	228.0	3.0	1.6	2 425.5	32.3	17.2	2 493.8	33.2	17.7	2 357.7	31.4	16.7	7 505.1	53.2	
	Apr		4 547.5	1 231.6	13.8	571.6	0.0	0.0	0.0	1 817.0	79.5	2.9	1.7	877.6	32.1	19.3	898.6	32.9	19.8	874.8	32.0	19.2	2 730.5	60.0	
	May		3 390.0	1 076.4	17.3	1 111.9	0.0	0.0	0.0	2 205.6	34.8	2.9	1.0	368.8	31.1	10.9	399.9	33.8	11.8	380.8	32.2	11.2	1 184.4	34.9	
	Jun		9 715.1	4 384.1	13.8	0.0	0.0	0.0	0.0	4 398.0	134.7	2.5	1.4	1 708.3	32.1	17.6	1 772.8	33.3	18.2	1 701.3	32.0	17.5	5 317.1	54.7	
	Jul		9 941.9	4 599.8	13.6	512.4	0.0	0.0	0.0	5 125.8	122.3	2.5	1.2	1 589.5	33.0	16.0	1 619.1	33.6	16.3	1 485.1	30.8	14.9	4 816.2	48.4	
	Aug		18 700.0	7 457.8	17.0	465.1	0.0	0.0	0.0	7 939.8	281.1	2.6	1.5	3 397.2	31.6	18.2	3 741.0	34.8	20.0	3 340.8	31.0	17.9	10 760.1	57.5	
	Sep		18 926.9	10 751.8	13.6	862.4	0.0	0.0	0.0	11 627.7	218.3	3.0	1.2	2 411.4	33.0	12.7	2 497.4	34.2	13.2	2 172.2	29.8	11.5	7 299.2	38.6	
Subtotal		**80 521.1**	**129 460.8**	**56 791.7**	**178.0**	**4 943.9**	**0.0**	**0.0**	**0.0**	**61 913.6**	**1 967.5**	**2.9**	**1.5**	**21 757.5**	**32.2**	**16.8**	**22 534.3**	**33.4**	**17.4**	**21 287.9**	**31.5**	**16.4**	**67 547.2**	**52.2**	**76.9**
2010/2011	Oct		20 395.7	10 169.6	13.6	516.8	0.0	0.0	0.0	10 700.0	304.6	3.1	1.5	3 219.1	33.2	15.8	3 321.9	34.3	16.3	2 850.1	29.4	14.0	9 695.7	47.5	
	Nov		13 929.5	6 053.9	13.6	576.1	0.0	0.0	0.0	6 643.6	232.8	3.2	1.7	2 433.8	33.4	17.5	2 456.5	33.7	17.6	2 162.8	29.7	15.5	7 285.9	52.3	
	Dec		8 181.8	3 260.2	13.6	0.0	0.0	0.0	0.0	3 273.8	161.5	3.3	2.0	1 635.7	33.3	20.0	1 661.3	33.8	20.3	1 624.0	33.1	19.8	4 908.0	60.0	
	Jan		3 136.9	1 237.0	17.0	473.3	0.0	0.0	0.0	1 727.3	45.0	3.2	1.4	435.9	30.9	13.9	457.3	32.4	14.6	471.4	33.4	15.0	1 409.7	44.9	
	Feb		9 833.3	4 221.7	13.6	478.6	0.0	0.0	0.0	4 713.9	147.4	2.9	1.5	1 515.5	29.6	15.4	1 478.5	28.9	15.0	1 977.9	38.6	20.1	5 119.4	52.1	
	Mar		9 966.8	4 558.6	13.6	0.0	0.0	0.0	0.0	4 572.1	164.0	3.0	1.6	1 742.9	32.3	17.5	1 792.8	33.2	18.0	1 695.0	31.4	17.0	5 394.6	54.1	
	Apr		3 623.0	1 418.7	13.6	469.7	0.0	0.0	0.0	1 901.9	50.0	2.9	1.4	552.2	32.1	15.2	565.8	32.9	15.6	580.0	33.7	16.0	1 721.1	47.5	
	May		5 063.1	1 681.5	17.0	650.9	0.0	0.0	0.0	2 349.4	79.4	2.9	1.6	853.8	31.5	16.9	911.7	33.6	18.0	868.9	32.0	17.2	2 713.7	53.6	
	Jun		9 514.7	3 920.0	13.6	0.0	0.0	0.0	0.0	3 933.5	141.4	2.5	1.5	1 792.5	32.1	18.8	1 861.2	33.3	19.6	1 786.1	32.0	18.8	5 581.2	58.7	
	Jul		13 820.3	5 835.5	17.0	502.3	0.0	0.0	0.0	6 354.8	190.1	2.5	1.4	2 465.2	33.0	17.8	2 512.9	33.7	18.2	2 297.4	30.8	16.6	7 465.5	54.0	
	Aug		14 550.9	6 084.3	13.6	0.0	0.0	0.0	0.0	6 097.9	221.1	2.6	1.5	2 675.0	31.6	18.4	2 941.9	34.8	20.2	2 615.0	30.9	18.0	8 453.0	58.1	
	Sep		19 454.4	10 269.6	15.6	401.7	0.0	0.0	0.0	10 686.9	262.7	3.0	1.4	2 900.7	33.1	14.9	3 002.9	34.3	15.4	2 601.1	29.7	13.4	8 767.5	45.1	
Subtotal		**80 521.1**	**131 470.3**	**58 710.6**	**175.1**	**4 069.5**	**0.0**	**0.0**	**0.0**	**62 955.1**	**1 999.9**	**2.9**	**1.5**	**22 222.4**	**32.4**	**16.9**	**22 964.7**	**33.5**	**17.5**	**21 529.7**	**31.4**	**16.4**	**68 515.2**	**52.1**	**78.2**

3.3 Losses

3.3.1 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 determinations, inaccurate water measuring structures and other restricting factors such as aquatic weeds, 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.

The outflows consist of all the ways that water is removed from the scheme. This includes the canal seepage, operational spills, evaporation from the canals, percolation and delivery to the irrigators and other users.

3.3.2 Gross Water losses

The total monthly losses summarised by main canal for the period October 2004 to September 2011 are shown in Table 3-2. The values in this table reflect the total losses and include seepage, evaporation, leakage and operational losses (including end of canal outflows). It therefore reflects the difference between the volume that was ordered by the water users and the volume of water released into the inlets of the two main canals.

Table 3-2: Hartbeespoort IB - Historical monthly losses

Month	Eastern canal		Western canal	
	Volume (10^3m^3)	%	Volume (10^3m^3)	%
Oct-04	4 486	45.3	2 520	30.1
Nov-04	4 874	57.7	1 934	39.4
Dec-04	4 301	62.2	2 215	38.0
Jan-05	3 587	58.2	1 880	38.2
Feb-05	2 911	50.7	1 732	26.5
Mar-05	2 099	29.5	2 816	40.4
Apr-05	2 570	66.6	743	35.3
May-05	2 906	51.7	2 211	43.1
Jun-05	2 876	52.4	1 890	30.0
Jul-05	3 415	54.5	1 215	29.6
Aug-05	4 410	49.4	2 854	32.4

Month	Eastern canal		Western canal	
	Volume (10^3m^3)	%	Volume (10^3m^3)	%
Sep-05	4 746	48.0	2 258	24.0
Oct-05	4 754	46.1	2 901	30.8
Nov-05	3 377	48.4	2 202	40.6
Dec-05	4 496	66.3	1 721	40.2
Jan-06	716	54.2	314	29.8
Feb-06	1 749	60.2	958	42.7
Mar-06	1 779	52.5	2 181	56.1
Apr-06	1 990	48.2	1 263	39.4
May-06	1 734	41.1	1 952	40.7
Jun-06	1 965	34.6	2 104	38.5
Jul-06	2 225	39.1	1 451	40.4
Aug-06	3 208	41.5	2 715	39.3
Sep-06	3 002	37.0	2 304	29.5
Oct-06	2 663	29.1	2 901	30.2
Nov-06	1 205	30.1	1 283	31.6
Dec-06	2 952	45.0	2 148	34.1
Jan-07	3 873	52.3	2 503	40.9
Feb-07	4 496	55.2	2 521	35.2
Mar-07	4 808	51.0	2 467	34.2
Apr-07	3 085	49.4	1 783	43.2
May-07	2 624	50.0	2 575	43.3
Jun-07	1 547	37.5	1 831	39.0
Jul-07	2 066	42.2	1 247	32.8
Aug-07	1 946	35.0	2 979	41.0
Sep-07	4 948	50.2	3 362	37.2
Oct-07	2 846	55.6	1 022	32.8
Nov-07	3 213	51.0	2 004	46.9
Dec-07	1 690	59.9	519	30.9
Jan-08	1 545	40.8	1 451	41.1
Feb-08	2 883	52.3	2 023	44.0
Mar-08	2 390	54.0	1 656	46.0
Apr-08	3 297	56.4	1 708	47.1
May-08	1 233	43.1	1 083	37.7
Jun-08	2 425	48.2	2 264	41.6
Jul-08	2 152	38.8	1 842	33.9
Aug-08	4 348	54.6	8 148	100.0
Sep-08	4 512	46.2	3 379	33.6

Month	Eastern canal		Western canal	
	Volume ($10^3 m^3$)	%	Volume ($10^3 m^3$)	%
Oct-08	6 042	48.6	5 229	38.8
Nov-08	34	2.4	719	41.0
Dec-08	4 630	58.0	3 750	49.3
Jan-09	2 340	60.2	1 633	54.6
Feb-09	1 448	70.6	988	47.5
Mar-09	2 790	62.3	1 984	46.8
Apr-09	1 912	47.6	1 451	39.6
May-09	1 401	44.2	2 250	48.4
Jun-09	1 952	41.9	1 581	35.3
Jul-09	3 910	55.4	1 793	33.8
Aug-09	3 312	52.1	5 803	93.6
Sep-09	4 075	45.4	3 595	37.5
Oct-09	4 552	51.6	4 429	52.4
Nov-09	3 663	52.5	3 030	56.4
Dec-09	1 872	71.5	577	66.8
Jan-10	2 367	72.8	955	64.5
Feb-10	3 770	56.7	2 720	48.2
Mar-10	4 303	58.1	3 202	47.7
Apr-10	1 594	58.8	1 136	61.9
May-10	816	45.3	740	46.6
Jun-10	2 877	60.8	2 440	49.0
Jul-10	2 912	53.4	1 904	42.4
Aug-10	5 517	59.3	5 243	55.8
Sep-10	3 416	36.5	3 883	40.6
Oct-10	5 955	54.6	3 740	39.4
Nov-10	4 300	58.8	2 986	45.1
Dec-10	2 528	61.5	2 380	58.5
Jan-11	950	49.3	460	38.0
Feb-11	2 964	52.9	2 155	50.9
Mar-11	3 226	61.1	2 169	46.3
Apr-11	813	40.5	908	56.2
May-11	1 117	54.2	1 597	53.2
Jun-11	3 108	65.1	2 473	52.2
Jul-11	5 124	63.1	2 342	41.1
Aug-11	5 135	64.6	3 318	50.2
Sep-11	5 100	52.5	3 668	37.6
Average	**3 033**	**50.8**	**2 265**	**43.1**

A graphic representation of the total monthly losses for the Eastern and Western canals is shown in Figure 3-1. The unusually high and low losses recorded in the 2008 and 2009 water years were omitted from the calculations.

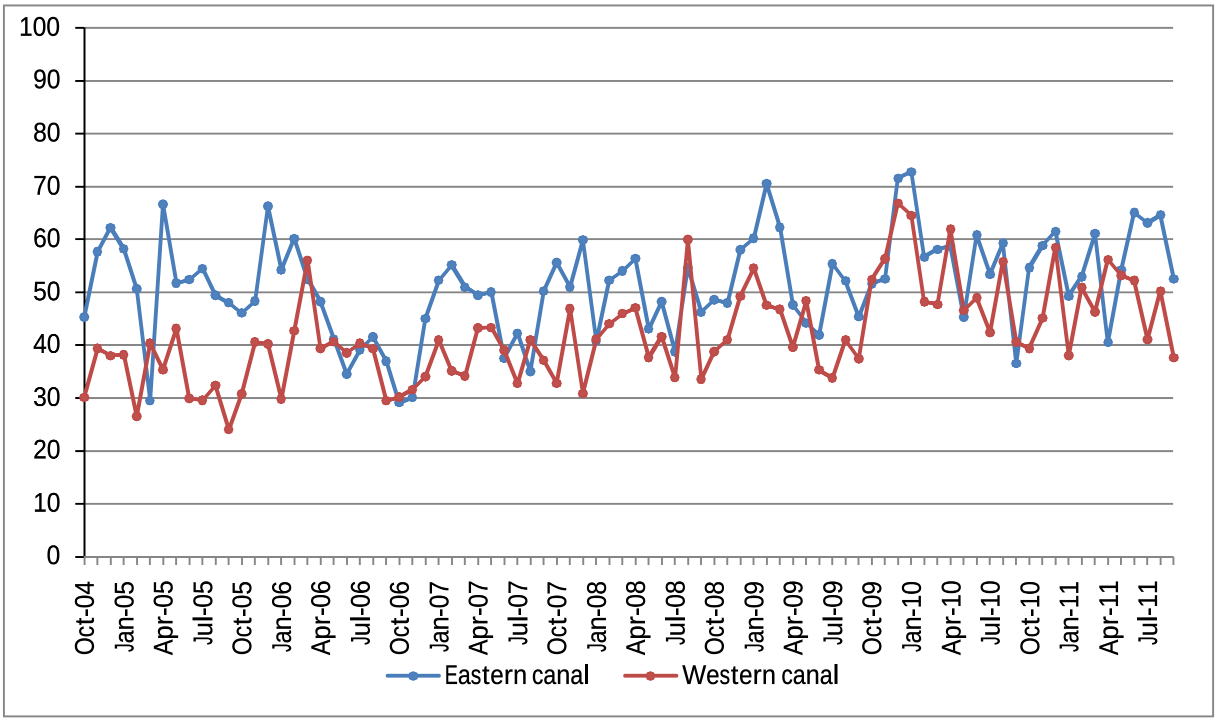

Figure 3-1: Hartbeespoort IB - Historical canal losses

From the data presented in Table 3-2 and Figure 3-1 it is clear that the total losses on the Eastern canal are roughly 8% more than the losses on the Western canal. This can mainly be attributed to three factors, namely;

- The distance that the water has to travel in the Eastern canal is further than that of the Western canal. The Western canal also has a 3km siphon and 600m tunnel, resulting in lower transmission losses.
- The second factor is the types of soils through which the two canals were constructed. Large sections of the Eastern canal runs through "norite based" soils while the Western canal runs through heavy clay soils. Canal seepage and leakage losses are influenced by the type soil it traverses and these losses are lower in heavy clay soils.
- Differences in the types of crops under irrigation between water users situated at the upper sections of the canal and those at the lower and end sections of the canal.

The **average** water losses have been 47% of the released water from the dam into the canal system. This translates to an **average** of approximately 40.7 million m^3/a water losses in the

Hartbeespoort Irrigation Board area of operation. This volume mainly refers to the water losses that are difficult to measure, including the unavoidable water losses as well as some of the avoidable losses. These include canal evaporation losses, seepage in the primary canals and distribution canals, percolation, leakage, start-up and shut-down losses and sudden drops in demand (rainfall). The tail water on average over seven years was 15.7% of the released water from the dam into the canal system (Table 3-3).

Figure 3-2 shows the comparison between the supply and demand from Oct 2004 to Sep 2011.

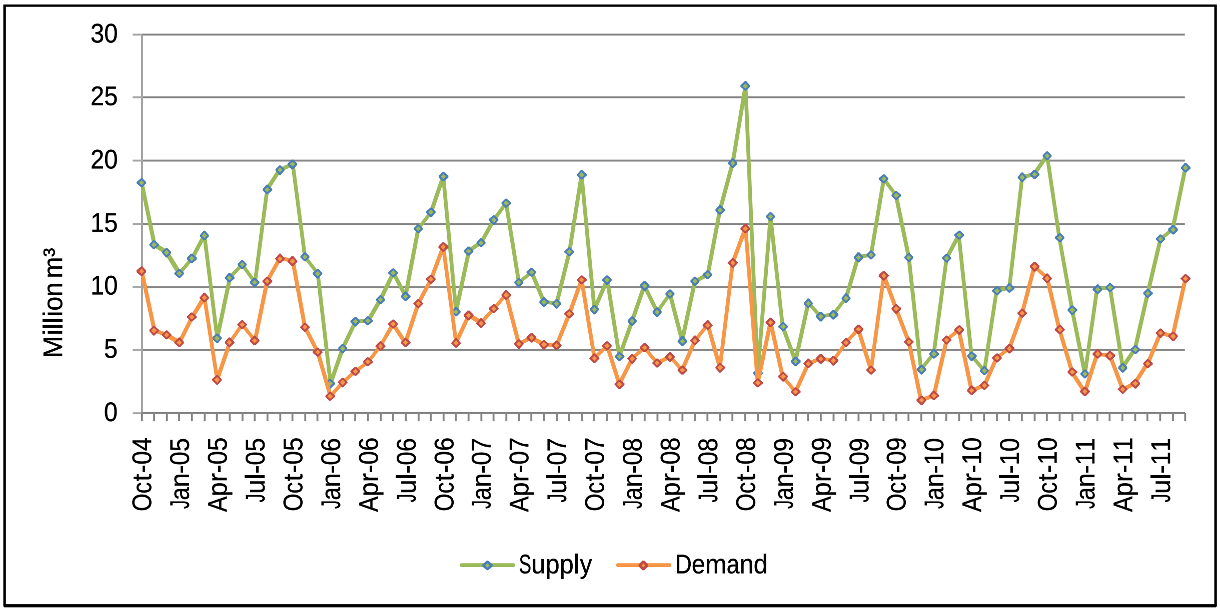

Figure 3-2: Comparison of the deliveries and demands

3.3.3 Conveyance losses

Conveyance losses are made up of unavoidable and avoidable losses.

Unavoidable losses

Unavoidable losses take place on a continual basis and the bulk of unavoidable losses are made up of seepage and evaporation losses.

Avoidable losses

Avoidable losses include items such as leakages and spills and include operational losses and wastages resulting from inter alia, inefficient management of the system and other factors such as algae growth, etc.

The main losses occurring within Hartbeespoort Irrigation Scheme served by canal distribution networks include the following;

3.3.3.1 Seepage losses:

Seepage losses from concrete lined, half lined and earth canals are normally expressed in l/s per 1 000 m^2 and fluctuates 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 perimeter and this could result in an unavoidable loss rate of up to 15%. The depth of the ambient water table also has an effect on seepage losses. In an area where generally high water table levels are found, canal seepage decreases to roughly 5% 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, soil capillary tension, quantity of sediment, etc.

For Hartbeespoort Irrigation Board the estimated values of the seepage loss as a percentage of the calculated total loss were recorded in the monthly WUEARs. The average seepage loss over the seven years were 16.6 % of the inflow on the East canal and 14.2 % of the inflow on the West canal resulting in a total scheme seepage loss of 15.5 % of the inflow.

An additional method was used to determine the seepage losses for each canal by making use of different section widths and lengths as well as the formula for the wetted perimeter of a parabola and Butler suggested a seepage value of 1.9 l/s per 1000 m^2 wetted area. Since the flow depth at the various sections at a full capacity flow of 8.5 m^3/s was not available the formula for best hydraulic section where the top width at water surface equals 2.828 times the flow depth (Irrigation Design Manual chapter 7, p 7.10) was used.

Six sections were used for the East canal resulting in a seepage loss of 16.4 % of the inflow while five sections were used for the West canal resulting in a seepage loss of 12.1 % of the inflow. The differences in the two seepage loss calculations are small and the results of the first method were used in the water budget.

3.3.3.2 Evaporation losses

The evaporation loss, expressed as a percentage of total inflow, is usually very low and has been estimated at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze :1986).

For Hartbeespoort Irrigation Scheme estimated values of the evaporation loss as a percentage of the calculated total loss were recorded in the monthly WUEARs. The average evaporation losses over the seven years were 1.5 % of the inflow on the East canal and 1.3 % of the inflow on the West canal, resulting in a total scheme seepage loss of 1.4 % of the inflow. These percentages are more than the estimated 0.3 % mentioned above.

An additional method was used to determine the evaporation losses using the same section widths and lengths as for determining the seepage losses. The surface area for the canal was multiplied with the annual evaporation for quaternary drainage region A21J resulting in an evaporation loss of 0.21 % of the inflow for the East canal and 0.37 % of the inflow for the West canal. These values correspond to the 0.3 % mentioned above.

3.3.3.3 Operational wastage:

Apart from the two losses described above there are also other losses on the canal system which can be classified as avoidable losses. Such losses include start-up and shut-down losses, water not used (outflows) due to unexpected drops in demand and losses due to incorrect measuring. These losses are estimated to fluctuate between 9% and 17% (Reid, Davidson and Kotze, 1986).

3.3.3.4 Leaks and Spills:

Leaks normally occur on broken sections of the canals and on the top sections of the canal body and can be as a result of maintenance problems and the general deterioration of the canal network due to its age. The determination of the volume of water that is lost as a result of leakages and spills is very difficult to calculate and can only really be determined through accurate measuring. An important factor that has a marked effect on leakages is the water depth in a canal system. 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.

Although the Board aims to operate the system within a range of 35% to 85% of the design capacity but the water demand during peak periods and the problems with sediment and aquatic weed growth necessitates periodic operation of the system at peak capacity, resulting in high leakages and spills.

The average operational losses and leakages for the Hartbeespoort Irrigation Scheme over the seven year period were estimated at 14.3 % of the inflow. This estimation was done by subtracting all the other losses (seepage, evaporation and canal ends) from the total losses (difference between ordered and released).

3.3.3.5 Aquatic weeds and algae:

Aquatic weed and algae growth in irrigation canal systems is fast becoming one of the major operational headaches in scheme management, especially on those schemes where water is becoming progressively eutrophic.

Table 3-3 provides a summary of the various losses on the canal distribution network of the Hartbeespoort IB. The figures are based on the 2004/2005 to 2010/2011 water years. It is important to note that the categories included in the table are shown on the WUEARs and that a further breakdown of the losses were not possible.

Table 3-3: Hartbeespoort IB - Breakdown of water losses

Description	Unavoidable losses (m^3*106^6)	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
Seepages	21.011		21.011	33.1
Evaporation	1.889		1.889	3.0
Operational & leakages		19.395	19.395	30.6
Canal end returns		21.254	21.254	33.4
Total	**22.900**	**40.650**	**63.550**	**100**
% of total losses	**36**	**64**	**100**	
% of total volume released into system	**17**	**30**	**47**	

From the data presented Table 3-3 it is evident that the total losses on the scheme amount to 47%. Of the total losses occurring on the scheme, 36% or 22.9 million cubic metres can be classified as unavoidable losses while 64% or approximately 40.7 million cubic metres are avoidable losses. The bulk of the avoidable losses (21 million cubic metres) are made up of estimated canal end return flows.

3.3.4 Avoidable water losses

Based on the above assessment and disaggregation of the gross water losses, the average avoidable water losses over the seven water years have been 40.7 million m^3. This quantity can be attributed to a number of factors.

- *Flow measuring errors*: With the current method of manual reading of the depth of flows by the WCOs, there is a likelihood of flow measuring errors due to human error. The implementation of telemetry systems may reduce the avoidable losses.
- *Scheduling of deliveries.* The next reason could be that, although there is weekly scheduling of deliveries and water is delivered only when needed, it is a very complicated process of trying to match the deliveries with the water applications. This happens particularly when the irrigators change their requests. There is also a time lag in adjusting the volume required not only at the individual sluices but through the canal system.
- *Volume of water ordered*: There is potential for significant water losses to take place if the volume of water ordered is small. This lower volume can mostly be attributed to a change in the types of crops under irrigation between water users situated at the upper sections of the canal and those at the lower and end sections of the canal.
- *Leakage in the canal structure*: 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.

4 WATER MANAGEMENT ISSUES AND GOALS

4.1 Overview of the management issues

The water budget analysis discussed in the previous chapter has helped to identify several key water management issues. First there are substantial, unexplained losses particularly in the late season. The water budget analysis did reveal that on an annual basis, there is sufficient water to meet the Hartbeespoort Irrigation Scheme's irrigation demands. It also highlighted that irrigators are currently not utilising their full water allocation.

In addition to the water budget analysis, discussions were held with the management and other people who are knowledgeable about the Hartbeespoort Irrigation Scheme. This was done to determine the key issues the scheme is facing. The key issues identified are discussed in more detail in the following sections of this chapter.

4.2 Flow measurement and water accounting

4.2.1 Adequacy of flow data

Good information is fundamental to making decisions when managing irrigation water at any irrigation scheme. **Figure 8.1** below, provides the extent of flow measurement that is ideal for conducting an irrigation scheme water budget. The availability of flow measurements helps inform both the water user and the IB about the quantity, timing, and location of water use and therefore enables the IB to conduct a water budget not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated **in Figure 8.1** below, it would be ideal to have flow measurements at the inlet to the primary canals as well as at the 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 the Hartbeespoort IB does not to have adequate flow measurement data to conduct a water budget analysis at both scheme and sub-scheme levels. The IB does make regular measurements of flows at certain points but these are mainly for monitoring purposes. These include weirs and parshall flumes on the canals, and flumes and rated (but not calibrated) sluice gates on the laterals to the individual farmers.

Measuring devices are not installed at the canal end points and flows are currently estimated as a percentage of the total losses.

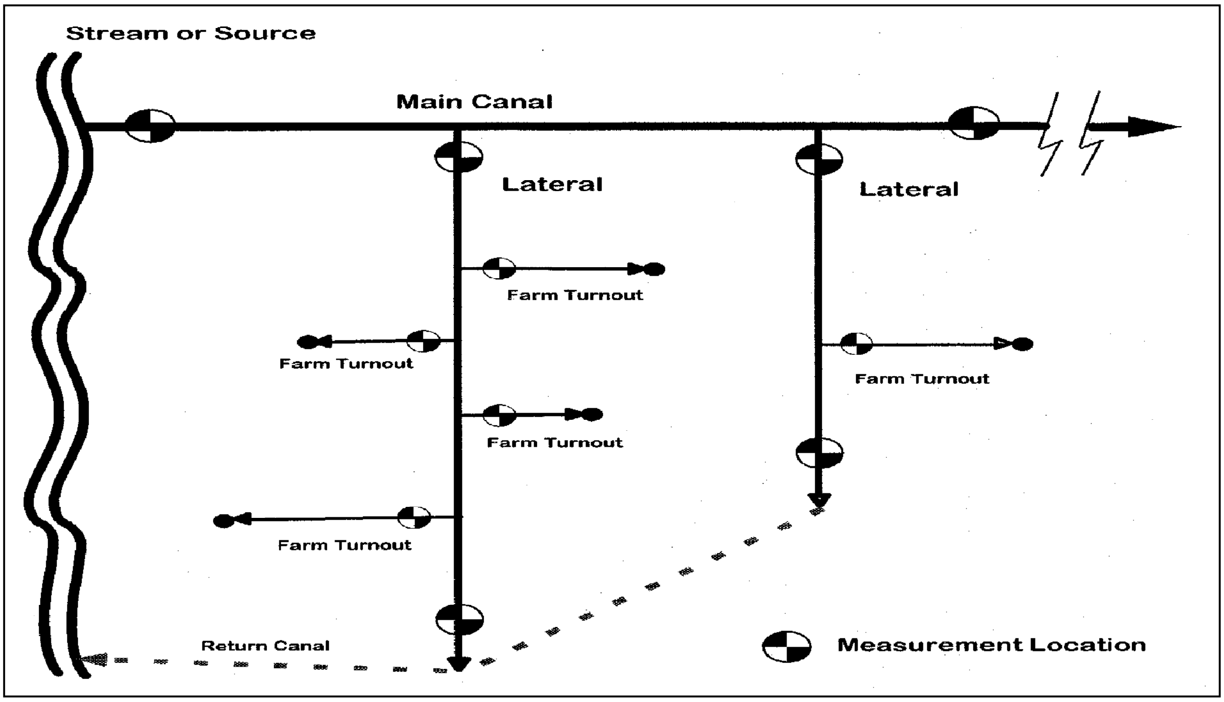

Figure 4-1: Irrigation Scheme with ideal water measurement system

4.2.2 Telemetry systems and compatibility with WAS

The Hartbeespoort Irrigation Scheme has six Android Telemetry Systems installed of which two are located at the Dam outlet works where water is released into the two main canals. However with the installation of the Water Administration System (WAS) to undertake water use efficiency accounting reports, it was found that the telemetry system and WAS were not compatible. The compatibility of these systems has not been resolved therefore flows and levels are manually captured on the WAS system. Even though these six telemetry systems exist in the scheme, the flow data received from them are just for monitoring purposes and are not included in the water budget. Only three of these systems (Hartbeespoort Picnic, Thatch Haven and Sonop) were sending data during the site visit. These existing telemetry systems should be calibrated for data collection to be correct and included in WAS.

4.2.3 Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Hartbeespoort IB:

(i) Continuation of regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system.
(ii) Ensuring that all measuring devices in the scheme are in good operating condition and regularly calibrated.
(iii) The compatibility between the existing telemetry system at the dam wall and WAS should be resolved. More telemetry systems must be permanently installed to monitor water supply to the different canal sections as well as to monitor any operational spills or tail water that is not used in the scheme. The flows and levels are intended to be sent by telemetry system to the Hartbeespoort IB offices for direct input into the WAS programme.
(iv) Installation of measuring devices at canal end points (at least on the two main canals) to enable the actual measurements of return flows.

4.2.4 Irrigation water budget is not conducted in detail

It is currently difficult or impossible to disaggregate the losses. There is no differentiation in the water balance assessment between the losses. The remaining losses such as leakage, spills and over delivery to users have not been disaggregated. Although a real time telemetric monitoring system is in place, the data is used for monitoring purposes only and the data is not incorporated into the WAS system automatically. Currently it is not possible to easily conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention. The accuracy of the seepage losses remains questionable and it is proposed that ponding tests be done to verify the accuracy of the theoretical calculations.

<u>Management Goal 2</u>

The goal to address the above issue is to ensure that all the flow measurements in the Hartbeespoort IB are included in determining water budgets and calculating water losses at scheme as well as ward/sub-scheme level. This will enable the IB to undertake comprehensive water audits to identify priority areas for improving irrigation water management as well as highlighting sections with high water losses. Ponding testes should also be undertaken to verify the theoretical calculations of the seepage losses on the canal system.

4.3 Operational water management issues

4.3.1 The WAS program is not fully utilised

The Water Administration System (WAS) was developed by Dr. Nico Benade (mainly with funding from the WRC and DWA) as a tool to be used by Irrigation Boards/Schemes to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. WAS consists of seven modules integrated into a single program and these modules can be implemented separately or as a whole.

The seven modules are the:

(viii) Administration module
(ix) Water order module
(x) Water accounts module
(xi) Water release module
(xii) Measured data module
(xiii) Crop water use module, and
(xiv) Report module

The Water Release module for example links with the water administration and order modules and can be used to:

- Minimize distribution losses on canal networks
- Calculate water releases for the main canal(s) and all their branches, allowing for lag times and water losses such as seepage and evaporation; and
- Determine operating procedures for a dam with varying downstream inflows and outflows in a river, allowing for lag times and water losses such as seepage, evaporation and transpiration.

Four of the seven WAS models are currently used by the Hartbeespoort IB. They are the Administration module, the Water Order module, the Water Accounts module and the Report module. Although initial calibration of the WAS Water Release module was undertaken, this module is presently not being used due to factors such as the rapid growth of aquatic weeds during certain periods which affects the parameters of the module.

4.3.2 Management Goal 3

The management objective to address the above issue, is to ensure that all the modules of the WAS programme, particularly the water order and water release modules, are implemented fully and that weekly and monthly reports from the modules are generated. This could be undertaken within 2 years from the completion of this Water Management Plan (WMP).

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

4.3.3 Available datasets not integrated into a Management Information System

The Hartbeespoort IB has commissioned various studies in the past and has their own detailed datasets at their disposal. All these datasets are in standalone databases or spreadsheets and very little thereof are spatially linked. Having all this data in one integrated Management Information System will be a huge benefit and should enable quicker and better informed decision making.

Management Goal 4

The development of a spatially linked Management Information System that integrates all the relevant and available datasets of the IB.

4.4 Infrastructure related issues

4.4.1 General

In order to properly develop the Hartbeespoort Irrigation scheme water management plan, it is essential that an assessment of the overall condition of the facilities to identify potential issues is conducted. As indicated in Chapter 4, a high level condition assessment together with discussions with the Hartbeespoort IB was undertaken. That included the operation and maintenance system as well as the conveyance and distribution system. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

4.4.2 Condition of canal infrastructure

A condition assessment of the existing canal infrastructure has been conducted for this report. There are however sections in the structure requiring attention. Leakage and canal losses may be taking place on these sections or at the joints between the different canal sections. The IB is responsible for maintenance and refurbishment of the canal structure in the dry weeks but time is too little to attend to all the problem sections before supplying water to the users again. Furthermore blasting done by various mines within the scheme area may contribute to the deteriorating canal structure.

4.4.3 Limited scheme balancing capacity

Balancing dams decrease the pressure on the canal system and allows for shorter delivery periods to water users. They also intercept any surplus water in the system and act as backups to supplement supply should shortages arise (canal breaks, etc.). The Hartbeespoort IB only has the benefit of two balancing dams on the scheme, with minimal storage capacity.

4.4.4 Management Goal 5

The Hartbeespoort Irrigation Scheme does not have a good balancing system in place to ensure security of water supply during shortages or major canal failures. The goal is to investigate the possibility of creating additional storage capacity which will assist in operating the system as effectively as possible. Studies should also be undertaken to determine the impact of mining activities on the canal structure. Possible short cuts and pipe line diversions should be further investigated.

4.5 Ownership of irrigation infrastructure

4.5.1 Roles and responsibilities in infrastructure maintenance

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 ensuring that the quality of the infrastructure is maintained.

In the Hartbeespoort Irrigation Scheme, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the main, primary and branch canals. However, the IB operates the irrigation infrastructure as an agent of the DWA and undertakes the normal maintenance of the irrigation infrastructure.

The problems will most likely arise, when the major infrastructure needs replacement/total refurbishment. It is unlikely that the IB 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. Therefore the responsibility for replacement of major assets lies with government, whose priorities may be different to those of the IB.

At present there is no service level agreement between the Hartbeespoort IB and the DWA regarding their roles and responsibilities. Assets are owned by DWA while the O&M is carried out by the Hartbeespoort IB. Without such an agreement, 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.

4.5.2 Management Goal 6

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 Hartbeespoort IB are further refined than the existing draft arrangement. The signing of a service level agreement is therefore essential. This is assuming that the DWA does not want to transfer the infrastructure to the IB in the short to medium term.

4.6 Institutional Water Management Issues

4.6.1 Updating and implementation of the Water Management Plan.

The CEO of the Hartbeespoort IB will amongst others, be responsible for the annual updating and implementation of the Water Management Plan (WMP) for the scheme. The roles and responsibilities of the CEO for the updating and implementation of the WMP will be the following:

- Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level
- Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office
- Develop improved water saving targets
- Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues
- Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes
- Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme
- Maintenance and modernisation of the irrigation infrastructure
- Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme
- Monitor the plan and schedule for implementing water conservation program components
- Report quarterly to DWA on the implementation status of the WMP regarding actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives.
- Annually review and update of WMP with a water conservation program for the scheme with goals, objectives, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

Management Goal 7

Implementation, monitoring, reviewing and updating of the WMP by the CEO and reporting by him/her on the status of water losses, water saving targets, goals and objectives.

4.7 Pollution

4.7.1 Water pollution upstream of the Hartbeespoort dam

The Board is extremely concerned about the pollution upstream of Hartbeespoort Dam. Although the Department of Water Affairs has already employed countermeasures to minimise pollution, it is the Board's opinion that action against transgressors is not sufficiently enforced and strict enough.

4.7.2 Water pollution within the Hartbeespoort Irrigation Scheme

The quality of the water in the Hartbeespoort Irrigation Scheme has deteriorated over the last couple of years. This is not only due to the poor quality water flowing into the Hartbeespoort Dam but also due to informal settlements along the canal structure. The situation is shocking. Refuse bins are empty but the canal is filled with anything from nappies to orange peels. Toilets have been erected on the banks of the canal with raw sewerage seeping into the water. The canal is also used to do washing.

Rubbish and litter not only contaminates the water but also cause major blockages in the canal and delivery systems.

Picture 4-1: Informal settlements along canal

4.7.3 Management Goal 8

Revise countermeasures and apply stricter rules and regulations regarding pollution. Take action against polluters. Undertake negotiations with the Local Municipality to safeguard IB infrastructure, particularly along informal settlements. If these prove to be unsuccessful, the possibility of pipelines for these sections should be investigated or alternatively a complete realignment of the section(s).

4.8 Alien vegetation

4.8.1 Alien vegetation downstream of Hartbeespoort Dam

Besides the indigenous vegetation taking over in the river system and resulting in losses, the Board is concerned about the alien trees that are intruding (especially in the river section below Hartbeespoort Dam). The eradication of such plants is however outside the jurisdiction of the Board.

4.8.2 Management Goal 10

Ensure and foster a close working relationship between the Hartbeespoort Irrigation Board and the manager of the Working for Water program and provide information on areas of infestation.

4.9 Aquatic weeds

4.9.1 Algae and water grass in the canal structure

Algae are an ever growing concern and if not properly controlled, cause serious problems. The canal structure is under a lot of stress when the banks are flooded due to the effect the weeds have on the water level. Algae and water grass can cause blockages in the system (from the main canal to the irrigation system) and contribute to operational losses. Both canals are dosed with Magnacide-H Herbicide up to seven times each year resulting in an annual cost of up to R 900 000 which is difficult for the Board to finance. The water grass however is not effectively reduced by the dosage of Magnacide-H Herbicide and usually grows again shortly after the application.

4.9.2 Management Goal 11

It is very important that the Magnacide-H Herbicide be dosed at the correct time especially taking into consideration the weather conditions. Alternative methods should be investigated to reduce the problem regarding water grass.

Table 4-1: Hartbeespoort Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	Lack of telemetry systems and its compatibility with WAS. The flow measurements taking place on the diversion points within the Hartbeespoort Irrigation Scheme are manually read (limited no telemetry system). Errors can easily be made this way.	Link the telemetry system at the Hartbeespoort Dam with the WAS. Install more telemetry stations.
2	WAS is not fully utilised.	Eliminate problems by making use of professional advice. Training.
3	Irrigation water budget and balance assessment. Disaggregate losses. Measure canal return flows.	Include rainfall and evaporation records in the water balance. Break down losses per sub-scheme. Make use of WAS.
4	Sections of the canal structure are in a poor condition resulting in leakages and spills which contribute to the avoidable losses. These areas can only receive attention during well planned dry weeks when farmers have made provision for not irrigating when there is no water in the canal. Blasting done by various mines within the scheme area may contribute to the deteriorating canal structure.	More scheme balancing dams may allow for longer refurbishment periods. Studies should be done to determine the impact of the mine activities on the canal structure.
5	DWA still owns the irrigation infrastructure but the IB operates it as an agent of the DWA and undertakes the normal maintenance thereof. It is unlikely that the IB has the financial capacity to undertake the refurbishment of the assets which are owned by government. Therefore the responsibility for replacement of major assets lies with government.	Responsibility between the DWA and the Hartbeespoort IB should be further refined. Service level agreement.
6	The Board is also concerned about the pollution upstream of Hartbeespoort Dam and within the scheme itself. Although the Department of Water Affairs has already employed	Revise countermeasures and apply stricter rules and regulations

Item No.	Issue description	Comments
	countermeasures to minimise pollution, it is the Board's opinion that this is still not effective enough.	regarding pollution. Relocate informal settlements or realign canal sections.
7	Besides the indigenous vegetation taking in the river system and resulting in losses, the Board is concerned about the foreign trees that are intruding, especially the river below Hartbeespoort Dam. The eradication of such plants is however outside the jurisdiction of the Board.	Eradication programme to be developed with WfW.
8	Algae and water grass growth is a common phenomenon and expensive to control.	MAGNACIDE-H Herbicide Alternative methods to reduce water grass.
9	Updating and implementation of the Water Management Plan.	Implementation, monitoring, reviewing and updating of the WMP is responsibility of the Scheme Manager as well as scheduled reporting by him/her on the status of water losses, water saving targets, goals and objectives.

5 ESTABLISHING WATER SAVINGS TARGETS

5.1 Acceptable water losses

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) that can be achieved in the Hartbeespoort IB.

A Water Research Commission (WRC) study (Report TT465/10) 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 (Reinders 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 scheme. This amounts to 13.48 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water saving and water loss targets.

5.2 Water savings targets

The unavoidable water losses in the Hartbeespoort IB were determined to be 17.0% of the total releases into the canal system. This water is additional to the irrigation water use required at the farm edge.

As illustrated in Table 9-3, 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 is 27.0% of the total releases into the canal system of the Hartbeespoort IB.

The target water losses for the East and West Canals are presented in Table 5-1 and Table 5-2 respectively.

Table 5-1: Target water losses for the East Canal

Description	System inflow (x $10^6 m^3$)	Present situation - Losses				Acceptable water losses		Target water saving	
		Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		12.0		12.0	16.57%	12.0	16.57%	0	0.00%
Evaporation		1.1		1.1	1.52%	1.1	1.52%	0	0.00%
Filling losses		0	11.8	11.8	16.31%	7.24	10.00%	16.705	23.07%
Leakages									
Spills									
Over delivery									
Canal end returns			12.1	12.1	16.77%				
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**72.4**	**13.1**	**23.945**	**37.045**	**51.17%**	**20.34**	**28.09%**	**16.705**	**23.07%**
% of total volume released into system		**18.09%**	**33.07%**	**51.17%**					

Table 5-2: Target water losses for the West Canal

Description	System inflow (x $10^6 m^3$)	Present situation - Losses				Acceptable water losses		Target water saving	
		Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		9.011		9.011	14.44%	9.011	14.44%	0	0.00%
Evaporation		0.799		0.799	1.28%	0.799	1.28%	0	0.00%
Filling losses		0	7.59	7.59	13.43%	6.24	10.00%	10.464	16.77%
Leakages									
Spills									
Over delivery									
Canal end returns			9.114	9.114	14.61%				
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**62.4**	**9.81**	**16.704**	**26.514**	**42.49%**	**16.05**	**25.72%**	**10.464**	**16.77%**
% of total volume released into system		**15.72%**	**26.77%**	**42.49%**					

Table 5-3: Target water losses in the Hartbeespoort IB

Description	System inflow (x $10^6 m^3$)	Present situation - Losses				Acceptable water losses		Water savings targets	
		Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		21.011	0	21.011	15.59%	21.011	15.59%	0	0.00%
Evaporation		1.899	0	1.899	1.41%	1.899	1.41%	0	0.00%
Filling losses / Leakages / Spills / Over delivery			19.395	19.395	14.39%	13.48	10.00%	27.169	20.16%
Canal end returns		0	21.254	21.254	15.77%				
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**134.80**	**22.91**	**40.649**	**63.559**	**47.15%**	**36.39**	**27.00%**	**27.169**	**20.16%**
% of total volume released into system		**17.00%**	**30.16%**	**47.15%**					

Based on the projected water saving targets, the Hartbeespoort IB can achieve a 6% reduction in irrigation water losses relative to the 2011 levels in a relative short period (3 years and less).

5.2.1 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans and aquatic weed control is some 8 million m^3/a.

5.2.2 Long term water saving targets

For the long term a further 19 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 27% of the total diversion.

6 PRIORITISED WATER MANAGEMENT MEASURES

6.1 Overview

There are numerous water management measures that accomplish the 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 Hartbeespoort IB.

The priority water management measures to improve irrigation water use efficiency in Hartbeespoort IB include the following:

(1) Flow measurement and telemetry infrastructure
   a. Link the telemetry system with the WAS.
   b. Fully implement the Release Module of WAS.
   c. Expand the WUEAR to show disaggregated losses.
   d. Undertake ponding tests to determine seepage as accurately as possible.
   e. Install devices and measure return flows on the two main canals.

(2) Canal maintenance and refurbishment
   a. Service Level Agreement.
   b. Treatment of aquatic weeds.

(3) Infrastructure related
   a. Undertake study to identify suitable locations for additional balancing capacity and the possibility to increase present storage.

(4) Operation and management related
   a. Address pollution at informal settlements.
   b. Incorporate all relevant data in a custom Management Information System.
   c. Assess the possibility to implement incentive based water pricing.

6.2 Flow measurement and telemetry infrastructure

6.2.1 Check compatibility of telemetry system with WAS

The Hartbeespoort IB will review the current telemetry system and investigate the possibility to link the current system with WAS. If attainable it will allow for flow measurements to be read in real time into the WAS. It may indicate that a specialist telemetry expert is required to update the existing software to ensure compatibility with the WAS.

6.2.2 Fully implement Release Module of WAS

The population of the required scheme and various canal parameters have already been undertaken by the IB and the Release Module of WAS should have been implemented. There are however some problems with changing parameters (rapid aquatic weed growth) which hampers implementation of the module. The revision of the various parameters will be undertaken to pinpoint and address the problem to allow the module to be fully implemented. This module is essential from an operational point of view since the system is functioning close to full capacity during periods of high demand and correct releases should minimise operational losses due to spills.

6.2.3 Expand the WUEAR

Currently the Water Use Efficiency Accounting Report only provides the figures for the two main canals and no individual reporting is done on the various sections of the distribution network. By undertaking the report at a detailed level it would be possible to compile water balances for the individual sections which could assist in highlighting specific problem areas and allow for the prioritisation of interventions. This issue will be discussed with NB Systems to indentify the actions that must be incorporated to allow reporting at sub-scheme level.

6.2.4 Calculate seepage losses

During the assessment of the canal infrastructure the theoretical values for seepage losses in the system were calculated. Some of these calculations show very high losses and in order to calculate seepage losses as accurately as possible, ponding tests should be undertaken to verify the theoretical values. This task is critical since seepage losses are evaluated as unavoidable losses and incorrect assumptions could hide other losses such as canal leaks.

6.2.5 Measure return flows of the two main canals

Presently the return-flows at the canal end points are no measured and the quantities shown in the WUEAR as estimates. The return flows are very high and measurement is imperative. It may not be necessary to install a telemetric unit at the end points of the two main canals and Orpheus Mini Meters may suffice. Based on experience most of the return flows occur on the two main canals but the measurement of the major branch canals may be required. If these return-flows are available, detailed and trust worthy water balances can be undertaken for the IB.

6.3 Canal maintenance and refurbishment

6.3.1 Service level agreement

At present there is no service level agreement between the Hartbeespoort IB and the DWA regarding their roles and responsibilities. Assets are owned by DWA while the O&M is carried out by the Hartbeespoort IB. Without such an agreement, 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.

6.3.2 Treatment of aquatic weeds

Aquatic weeds are a major concern in the Hartbeespoort IB. The presence of weeds in the canal can cause an increase in the water surface level resulting in higher water loss due to overtopping, higher leakages and over-delivery due to higher pressure at sluice gates. Algae therefore decrease the water delivery capacity and create the potential of erosion along the canal banks. Sandbars and berms can also be created by filtration of sediment or silt by aquatic vegetation.

The Board has been using an new product, MAHNACIDE H Herbicide (a product of Baker Hughes Inc.). It is a water soluble herbicide for the control of submerged aquatic weeds and algae in irrigation canals and irrigation reservoirs.

Both canals are dosed with Magnacide-H Herbicide up to seven times each year resulting in an annual cost of up to R 900 000 which is very difficult for the Board to finance. The water grass however is not effectively reduced by the dosage of Magnacide-H Herbicide and usually grows again shortly after the application. Alternative methods must be investigated to reduce the problem regarding water grass.

6.4 Infrastructure relates issues

6.4.1 Investigate possible additional balancing capacity

The Hartbeespoort IB has a very limited balancing system in place which limits the security of water supply during shortages, major canal failures and critical periods of high demand. The WUA will investigate the possibility of creating additional storage capacity or increasing the present capacity which will assist in operating the system as effectively as possible.

6.5 Operational and management related

6.5.1 Address pollution at informal settlements

Pollution has become an increasing problem in the Hartbeespoort Irrigation Scheme. Not only does it affect the water quality but also the already deteriorating canal structure. Even though the catchment area of the Hartbeespoort Dam is subject to a lot of pollution, actions have been taken by DWA to improve the quality of the water in the dam. The poor water quality in the scheme therefore can mainly be attributed to the pollution taking place along the canal structure and not only the water released from the Hartbeespoort Dam. Many informal settlements are located next to the canal resulting in all forms of pollution.

Previous attempts to address the problem were fruitless and a clear plan of action is required. The infrastructure still belongs to the DWA and they should be one of the main parties when this matter is escalated. The Board will therefore again engage with the DWA to try and resolve this problem. Many of the crops produced are exported (especially grapes) and if this problem is not addressed as a matter of urgency, the whole export business may be jeopardised.

6.5.2 Development of a Management Information System

The Hartbeespoort IB has commissioned various studies in the past and has their own detailed datasets at their disposal. All these datasets are in standalone databases or spreadsheets and very little thereof are spatially linked. Having all this data in one integrated Management Information System will be a huge benefit and should enable quicker and better informed decision making. The IB will therefore identify and catalogue all available datasets and assess the possibility to standardise and link these sets to a spatial database. It should even be possible to link results obtained from the WAS system.

6.5.3 Investigate possibility of incentive based water pricing

To achieve an incentive for efficient water use, the price of irrigation water must be directly related to the volume delivered unlike the current situation where it is based on the scheduled quota.

In order to encourage irrigators to use water efficiently, incremental water pricing may considered, based on the optimal crop water requirements. 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. The Hartbeespoort IB will investigate the possibility, costs and viability of incentive based water pricing.

7 IMPLEMENTATION PLAN

The evaluation of the potential measures for implementation in the Hartbeespoort IB area of operation to improve water use efficiency and reduce water losses indicates that all the measures are economically justified for implementation based on the unit cost of water saved.

The priorities for implementation are as follows:

(i) Linking the existing telemetry system with WAS.
(ii) Measure and record return-flows of the two main canals.
(iii) Expand WUEAR to enable water budget analysis at both scheme and sub-scheme level.
(iv) Fully implement the Release Module of WAS.
(v) Investigate possibility to increase balancing capacity.
(vi) Address pollution problems.
(vii) Formalise Service Level Agreement.
(viii) Develop and implement a comprehensive Management Information System.
(ix) Implement incentive based pricing.

The action plan for implementation is presented in Table 7-1.

Table 7-1: HBPIB action plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	Measurement and identification of losses	- Start measurement of Main Canals return flows. - Conduct seepage loss measurements in representative canal and pipeline segments though ponding tests where possible. Extrapolate results from tested segments to similar segments and revise water budget. - Undertake sub-scheme water budgets - Prioritise areas of significant water losses	Apr '13 – Feb '14 Apr '13 – Feb '14 Apr '13 – Feb '15 Apr '13 – Feb '14	HBPIB
2	Reduce leakage losses in irrigation canal infrastructure within 5 years	- Formalise Service Level Agreement	Apr '13 – Feb '14	HBPIB/DWA
3	Increase operational efficiency	- Link telemetry system with WAS - Implement release module of WAS - Undertake study to identify possible additional balancing capacity in the area of operation. - Incorporate data in a custom Water Management System	Apr '13 – Feb '15 Apr '13 – Feb '15 Apr '13 – Feb '15 Apr '13 – Feb '15	HBPIB

Priority	Goal	Action Plan	Timeline	Responsible Authority
4	Address pollution	- Engage with relevant stakeholders to resolve crisis. Investigate and implement methods to resolve problem. Escalate matter if necessary. - Investigate “short cuts” and possible realignment of certain canal sections.	Apr ’13 – Feb ‘15 Apr ’13 – Feb ‘15	DWA/ HBPIB/ MADIBENG
5	In 5 years, implement incentive pricing structure for the IB if viable	- Review current irrigation water pricing strategy - Engage with irrigators on incentive pricing structure - Update water pricing strategy - Implement water billing based on incentive pricing rate	Apr ’13 – Feb ‘18	DWA/ HBPIB