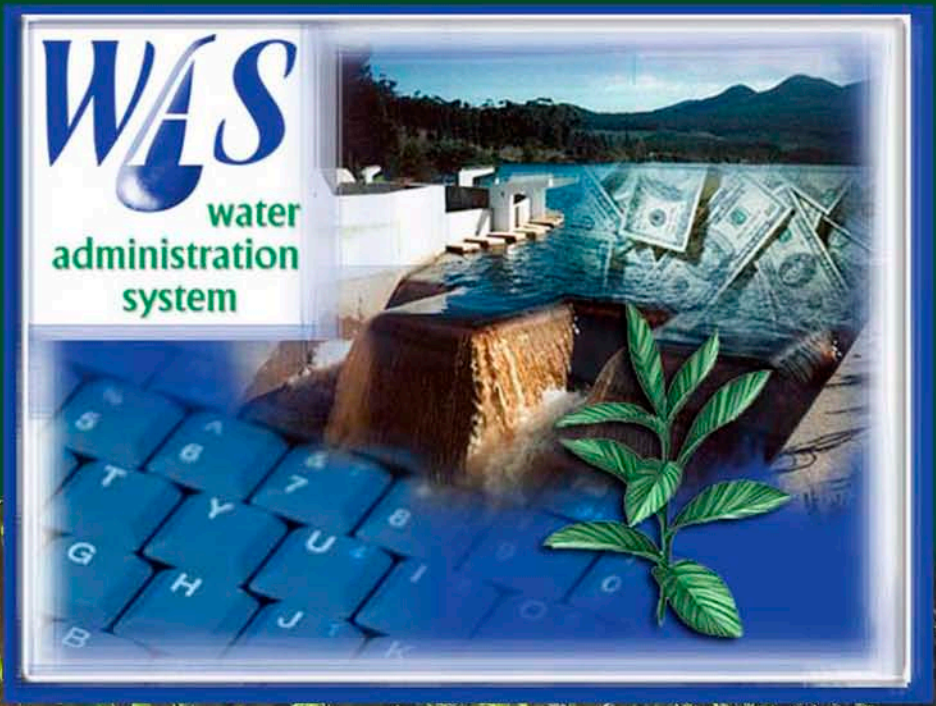
RESEARCH IMPACT ASSESSMENT of the Water Administration System



David Winter

WATER RESEARCH COMMISSION

TT 447/09

RESEARCH IMPACT ASSESSMENT

OF THE

WATER ADMINISTRATION SYSTEM

Report to the
Water Research Commission

by

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Table of Contents

1. Introduction

South Africa has a well developed agricultural sector that supports 60 per cent of the labour force, accounts for 20 per cent of total exports and is a significant contributor to GDP. However, South Africa is a water scarce country with an average rainfall of 470mm per annum, well below the global average of 840 mm. Without productivity growth, this limits agricultural production and threatens food security.

South Africa's commercial agricultural sector has well developed infrastructure to address water scarcity and distribution challenges. Dams, pipelines and irrigation canals have formed the base of growth in commercial farming through management and entrepreneurship.

South Africa's typically dry conditions require that water is carefully measured, managed and correctly allocated to farmers, who collectively account for approximately 60 per cent of total water consumption. Water distribution and allocation systems in the agricultural sector are typically manually operated. These schemes are effective, however they cannot account for water losses and they sometimes result in poor water utilisation with the knock-on effect of low productivity levels.

The need to improve water management in the agricultural sector, particularly water release, distribution and utilisation culminated in the development of an integrated information system to manage these processes. This system, the Water Administration System (WAS), was designed as a management tool for Water User Associations (WUA's), Catchment Management Agencies (CMA's) and water management offices to effectively measure and manage agricultural water resources.

The Water Administration System project was developed over the last 25 years with continuous support by WRC, DWAF and WUAs.

As a water knowledge hub that is committed to ensuring that the publicly funded research under its management provides social, economic, health and environmental benefits to South African society, the WRC embarked on this project to portray the benefit of its research investment, made in support of the WAS. Due to the WRC's limited capacity to carry out such evaluations the WRC commissioned international growth consulting company Frost & Sullivan to conduct the impact assessment so as to portray the benefits of its research on South African society.

1.1. Project Aim and Objectives

Project Aim

The aim of this project is to provide the WRC and its stakeholders with a concise assessment of the impact (to date and future potential impact) of the WRC's Water Administration System on economic, environmental and social aspects of South African and international society.

Project Objectives

- **Capture and communicate the key aims & objectives of WAS**
- **Detail the key areas of benefit of WAS within regional irrigation schemes**
- **Map the implementation of WAS across South Africa and illustrate how the system is being used**
- **Determine the impact (where relevant) of WAS modules on the operations of Water User Associations, Catchment Management Agencies and water management offices.**
- **Relate such impacts of WAS, where possible to a common measure such as "Rand" value of research product impact".**
- **Provide illustrative supporting examples of impact areas attributable to the successful implementation of WAS.**

Source: Frost & Sullivan

1.2. Project Scope

Technical Scope

This project considered and evaluated all relevant elements incorporated within the WAS as highlighted through discussion and material provided to Frost and Sullivan by the WRC.

Geographic Scope

The research considered the impact of the WAS in all regions within South Africa. However, where international applications of WRC research were apparent, these were also incorporated in the analysis.

1.3. Consulting approach and methodology

The project was carried out using primary research (telephone or face-to-face interviews) as the principal method of data gathering, supported by secondary research (published and online material).

The primary research was conducted in order to obtain information directly from various irrigation boards and water user associations (WUA's) in South Africa. The focus of the interviews predominantly included the respondent types outlined in the figure below. For more information on the consulting approach & methodology refer to the appendix.

Interview Participants

Interviews with primary participants involved:

- Loskop Irrigation Board
- Hartbeespoort Irrigation Board
- Sundays River Water User Association
- Korente Vette River Irrigation Board
- Groenland Irrigation Board
- Gamtoos Irrigation Board
- Impala Irrigation Board
- Lower Olifants River Water User Association
- Orange Riet Water User Association
- Vaalharts Government Water Scheme
- Kalkfontein Irrigation Board
- Department of Water Affairs: Worcester
- Hartbeespoort Irrigation Board
- Komati Basin Water Authority (KOBWA)
- Groot Marico Government Water Scheme
- Sandvet Government Water Scheme
- Mooiriver Government Water Scheme

Total interviews: (32)

Figure 1: List of Interview Participants

*** Most respondents were contacted on more than one occasion to verify specific information and data**

Information gathered during the primary research process was verified across all participants to check for consistency and any deviations. An indication of key patterns in the information was established and these were discussed with other participants for the purpose of improving the depth, quality and accuracy of the information. This information was then included in this report after thorough verification and refinement.

1.4. Overview of the WRC: Key Strategic Area 4

The WRC is a dynamic hub for water-centred knowledge, innovation and intellectual capital. It provides leadership for research and development through the support of knowledge creation, transfer and application. There are five key strategic areas (KSAs) which relate to water-centred knowledge namely:

- Water Resource Management,
- Water Linked Eco-Systems,
- Water Use and Waste Management,
- Water Utilisation in Agriculture
- Water-Centred Knowledge.

1.4.1. Key Strategic Area: Water Utilisation in Agriculture

Key Strategic Area (KSA 4) focuses on water utilisation in agriculture. The scope of KSA 4 includes increasing the efficient use of water for production of food, fibre, fuel-wood and timber; ensuring sustainable water resource use; reducing poverty and increasing wealth of people dependent on water-based agriculture.

The main aim of this strategic area is to ensure that needs and requirements of present and future generations of subsistence, emergent and commercial farmers will be addressed through creation and application of water-efficient production technologies, models and information systems. This can only be achieved through the effective implementation of these systems in the following sections of agriculture: irrigated agriculture, dry-land agriculture, woodlands and forestry, grasslands and livestock watering and aquaculture. One such system is the WAS.

1.5. Background to Water Administration System

Since 1985 the Water Research Commission has been working closely with the DWAF together with NB Systems in developing water management systems that simplify the task of managing canal water for irrigation purposes. This has resulted in the production of a broad range of research reports that have been focused on the development of the WAS.

The figure below provides an overview of the research studies that have been undertaken in developing and improving the WAS.

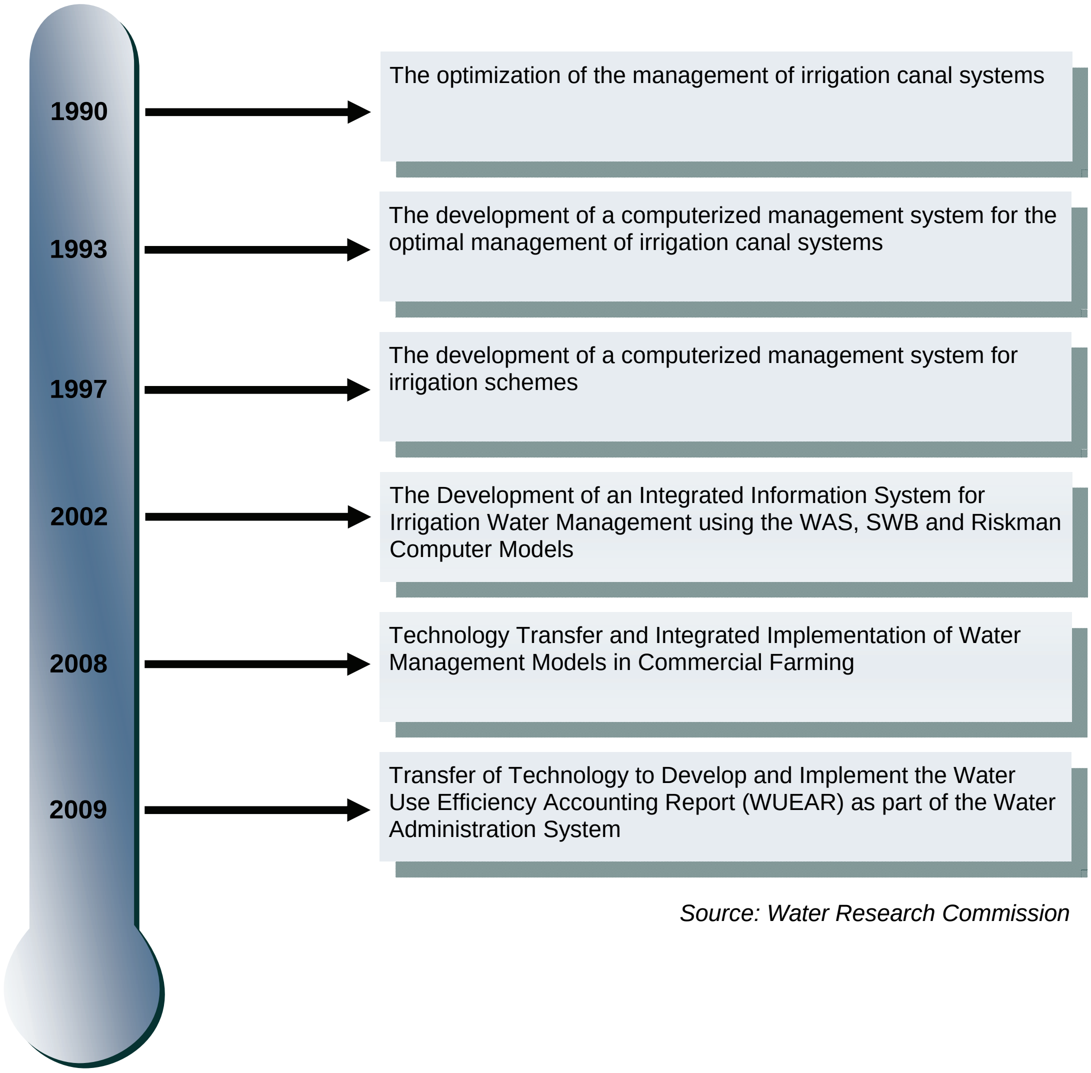


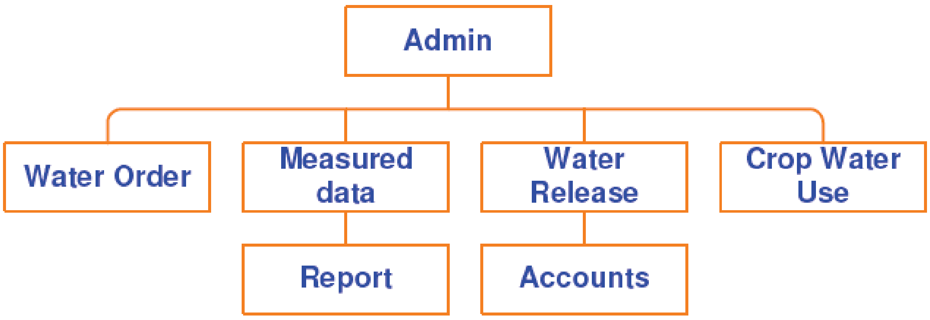
Figure 2: Mapping of research projects conducted towards the development of the WAS program

1.6. Overview of the Water Administration System

The WAS program is designed to be a water management tool for irrigation schemes, Water User Associations (WUA's), Catchment Management Agencies (CMA's) and water management offices that need to manage their water usage, distribution and accounts. It is an integrated database-driven system with many water management capabilities that include handling any number of farmers, abstraction points and measuring stations on canal networks, pipelines and rivers. The system involves simplified and controlled ways of managing water allocations, use, distribution and billing.

The WAS program saves all information on a Firebird database that can be installed on a single PC or on a server for use over a network. This makes it possible for scheme managers, accounts personnel and water office personnel to access the database from their PCs. In addition to this there is no limitation on the number of PCs that can be linked to the database. The program automatically generates monthly invoices using water usage or scheduled areas information captured in the database.

The main objective of developing the WAS program was to minimise water losses for irrigation schemes that work on the demand system and that distribute water through canal systems. The program consists of seven modules that are integrated into a single program that can be used on a single PC or multi-user environment. These seven modules can be implemented partially or as a whole, depending on the requirements of a specific scheme or office. The seven modules are:



Source: Water Research Commission

Figure 3: Water Administration Systems Modules

Figure 4: Description of WAS Modules

Module 1: Administration: This module is used to administer the details of all water users or accounts on an irrigation scheme. Information managed by this module includes addresses, notes, cut-off list, images and photos, list of rateable areas, scheduled areas, household and livestock pipes installed on canals. The module also administers crop yields and areas planted. The administration module must be implemented before any other module.

Module 2: Water Order: This module is used to administer water abstractions from canal networks, pipelines and rivers. It keeps track of water quota allocations and can be used to capture date and time based inflows and outflows on river systems. The Water Order module summarises water usage per abstraction and all the abstractions per farmer on a monthly basis.

Module 3: Measured Data: The module is used to capture date and time data into the WAS database. The data can be from graphs, electronic loggers, measuring plate readings, dam levels or meter readings. This module is also used to capture inflows and outflows for river systems and to generate discharges for stations that are linked to an indicator. Water volumes can easily be calculated between dates and converted to meter readings if necessary.

Module 4: Water Release: This module calculates the water releases from the main canal or river and all its branches or tributaries, allowing for lag times and any water losses and accruals. The module can capture detail such as cross-sectional properties of canals, positioning of sluices or pumps and canal or river capacities. Discharges are converted to corresponding measuring plate readings where needed. Water distribution sheets and water loss analysis reports can be generated for canal or river systems.

Module 5: Crop Water Use: This module is used to calculate water usage per crop between two specified dates for all planted crops on a scheme based on the plant date, the area planted and the crop water use curve. The crop yield (ton/ha) can be captured at the end of a growing season which is used to calculate the total yield (ton) and the yield in g/m^3. A summary of water used for a specified period can easily be generated per crop type.

Module 6: Reports: This module includes an extensive range of water and financial reports. Water balance sheets, distribution reports and various operator defined reports can be generated.

Module 7: Accounts: This module is used to administer all water accounts for an irrigation scheme or water management office. The Water Accounts module is a full debit system, from which monthly reports can be printed, including invoices on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

Source: Water Research Commission

The WAS can be implemented in a small office that manages a few abstractions and measuring stations up to a Catchment Management Area (CMA) level that manages thousands of abstractions and measuring stations. The WAS is used for the efficient administration of:

- Address information
- Scheduled areas
- Water quota allocations
- Water delivered through pressure-regulated sluice gates, measuring structures and water meters
- Water transfer between users, both automatically and manually
- Water-use calculations for planted areas based on crop water use data
- Water delivered through pressure-regulated sluice gates, measuring structures and water meters
- Date and time related flow data collected from electronic loggers or mechanical chart recorders
- Discharge tables (DT) to do conversions between water depth and flow rate for measuring structures or visa versa
- List of rateable areas (LRA) information
- Calculation of scheme water balances
- Generation of water use efficiency accounting (WUEA) reports
- Calculation of water releases for water distribution through canal networks, pipelines and rivers taking lag times, evaporation, transpiration and seepage into account
- Billing system that links to the water usage information
- E-mailing of invoices
- Flexible tariff sets based on water usage calculated using a flat rate or scheduled area
- Images and photos that can be linked to different types of information in the database
- Mail merge facility of sending letter to clients

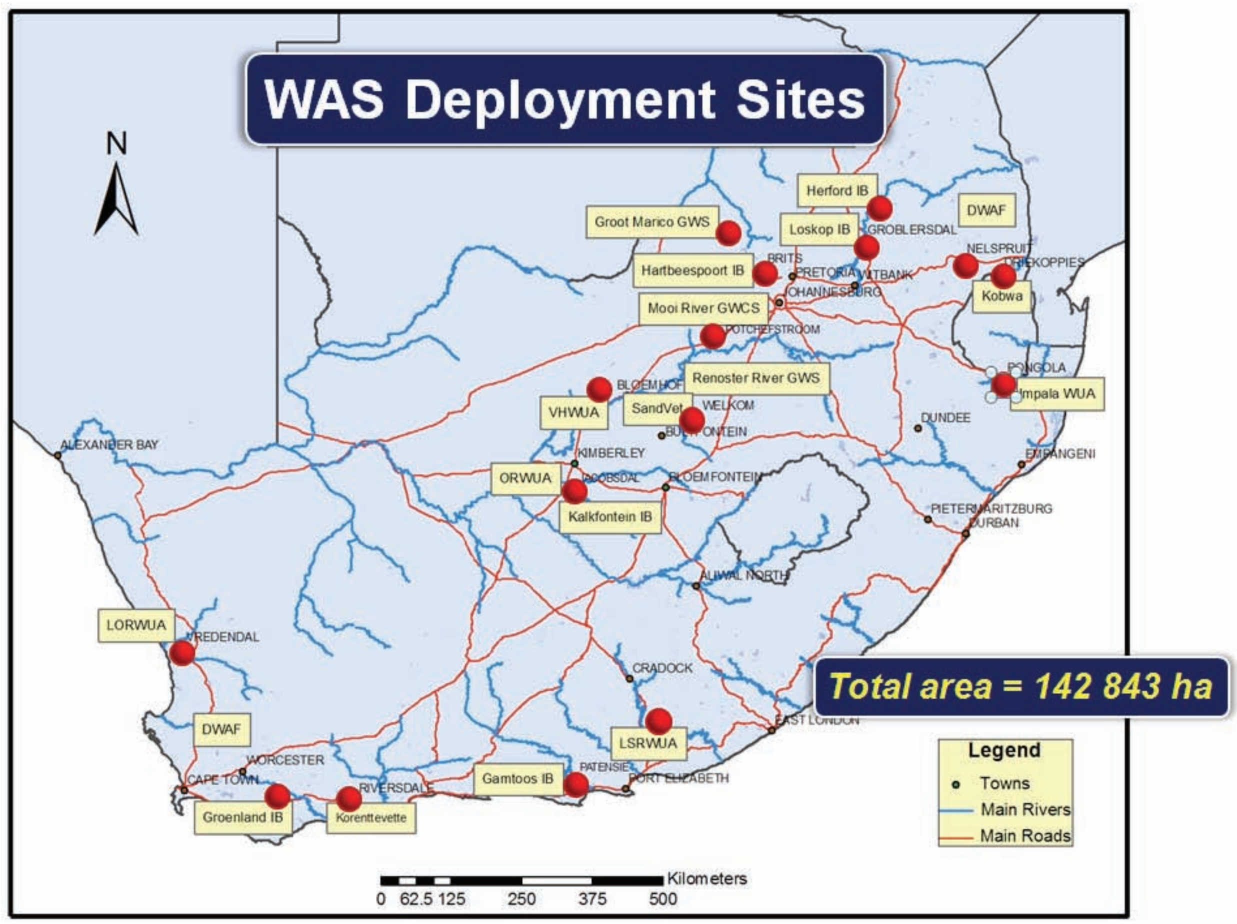
Other benefits that can be realised through implementation of the WAS program include:

- Minimise water losses
- Maximise water usage
- Make personnel more productive
- Increased financial control
- Improve office management

2. Implementation of the Water Administration System

2.1 Region Overview

The WAS program is currently used at all major irrigation schemes throughout South Africa and manages an irrigated area of more than 142 000 ha including 9 500 farmers. Major irrigation schemes where the WAS is currently in use are indicated in the figure below.



Source: Water Research Commission

Figure 5: Location of irrigation schemes utilising the WAS by region

North West

The North West province currently has 3 irrigation schemes that make use of the WAS. These are: the Hartbeespoort Irrigation Board, Mooiriver Government Water Scheme and the Groot Marico Government Water Scheme. The 3 irrigation schemes in this region have a combined total water allocation of 137,790,700 m^3 of water and a total of 2633 abstraction points.

Table 1: North West irrigation schemes using WAS

North West Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Hartbeespoort Irrigation Board	13,915	6,200	86,273,000	1,721	9
Mooiriver Government Water Scheme	4,954	7,700	38,145,800	603	12
Groot Marico Government Water Scheme	2,523	5,300	13,371,900	309	5
Total	**21,392**	**19,200**	**137,790,700**	**2,633**	**26**

Source: Water Research Commission

The Hartbeespoort Irrigation Board has been using the WAS for 9 years and its main source of water is the Hartbeespoort Dam. It makes use of the Administration module, Accounting module, Water Order module and is in the process of implementing the Water Release module.

The main water sources for the Mooiriver Government Water Scheme are Klerkskraal Dam, Boskop Dam, Gerhardminnebron eye and Lakeside Dam. It has been using the system for 12 years and only makes use of the Administration module and the Water Order module. Groot Marico Government Water Scheme makes use of the Administration module, Water Order module and the Water Release module. It has been using the WAS for 5 years and its main sources of water are the Riekets and Kromellenboog Dams.

Western Cape

The Western Cape has the following irrigation schemes: the Lower Olifants River WUA, Groenland Irrigation Board and Korentte Vetteriver Irrigation Board. The DWAF regional offices at Worcester manage the water usage of over 30 irrigation schemes in the Western Cape. The region has a total water quota allocation of 153,534,400 m^3 for all irrigation schemes combined with ± 1682 abstraction points

Table 2: Western Cape irrigation schemes using WAS

Western Cape Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Lower Olifants River WUA	9,212	12,200	112,386,400	1,415	10
Groenland Irrigation Board	5,864	6,000	35,184,000	146	6
Korentte Vetteriver Irrigation Board	852	7,000	5,964,000	121	4
Total	**15,928**	**25,200**	**153,534,400**	**1,682**	**20**

Source: Water Research Commission

The main water sources for the Lower Olifants River WUA are the Clanwilliam and Bulshoek dams. The irrigation scheme has been using the WAS for 10 years and makes use of the Administration module, Accounting module, Water Order module and they are in the process of implementing the Water Release module. Both the Groenland and Korentte Vetteriver Irrigation Boards make use of the Administration module, Water Order module, Accounting module and Report module. The DWAF regional office in Worcester makes extensive use of the measured data and the Reporting module.

Eastern Cape

The Eastern Cape has a total of 7,408 Ha under irrigation using the WAS. The Gamtoos irrigation board is currently utilising the WAS, with total water quota allocation of 44 488 000 m3 and approximately 880 abstraction points.

Table 3: Eastern Cape irrigation schemes using WAS

Eastern Cape Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Gamtoos Irrigation Board	7,408	6,000	44,448,000	808	3
Total	**7,408**	**6,000**	**44,448,000**	**808**	**3**

Source: Water Research Commission

The Gamtoos Irrigation Board has been using the WAS for 3 years. It makes use of the Administration module and the Water Order module and its main source of water is the Kouga Dam.

KwaZulu-Natal

The irrigation scheme found in KwaZulu-Natal is the Impala WUA. It has been using the WAS for 10 years with the Bivane Dam as its main water source. The Impala WUA makes use of the Administration module, Accounting module and the Water Order module.

Table 4: KwaZulu-Natal irrigation schemes using WAS

KwaZulu Natal Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Impala Water Users Association	17,012	10,000	170,120,000	423	10
Total	**17,012**	**10,000**	**170,120,000**	**423**	**10**

Source: Water Research Commission

Mpumalanga

The Loskop Irrigation Board located in Mpumalanga has been using the WAS for 15 years. The irrigation scheme's main source of water is the Loskop Dam. The scheme makes use of the Administration module, Accounting module, Water Order module and they are in the process of implementing the Water Release module. The Hereford Irrigation Board has been using the WAS for 3 years and makes use of the Administration module, Water Order module, Accounting module and Report module.

Table 5: Mpumalanga irrigation schemes using WAS

Mpumalanga Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3 /ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Loskop Irrigation Board	16,135	7,700	124,239,500	794	15
Hereford Irrigation Board	3,425	7,700	26,372,500	53	3
Total	**19,560**	**15,400**	**150,612,000**	**847**	**18**

Source: Water Research Commission

Free State

The Free State currently has one irrigation scheme that makes use of the WAS. The Sandvet Government Water Scheme has been using the WAS for 10 years. Its main source of water is the Erfenis and Allemanskraal Dams and it only makes use of the Administration module, Water Order module and the Water Release module

Table 6: Free State irrigation schemes using WAS

Free State Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Sandvet Government Water Scheme	10,542	1,080	11,385,360	616	10
Total	**10,542**	**1,080**	**11,385,360**	**616**	**10**

Source: Water Research Commission

Northern Cape

In the Northern Cape the Vaalharts WUA obtains its water from the Vaalharts weir which is filled from the Bloemhof Dam. This irrigation scheme has been using the WAS for 12 years and makes use of the Administration module, Accounting module, Water Order module and is currently in the process of implementing the Water Release module. The main water source for the Orange Riet WUA is the Van der Kloof Dam. This irrigation scheme has been using the WAS for 6 years and makes use of the Administration module, Accounting module, Water Order module, Water Release module and the Crop Water Use module.

Table 7: Northern Cape irrigation schemes using WAS

Northern Cape Province					
Irrigation Scheme	**Area (ha)**	**Quota allocation (m^3/ha)**	**Full quota (m^3)**	**Abstraction points**	**Years in use**
Vaalharts Water Users Association	35,060	9,140	320,448,400	1,873	12
Orange Riet Water Users Association	15,941	11,000	175,351,000	679	6
Total	**51,001**	**20,140**	**495,799,400**	**2,552**	**18**

Source: Water Research Commission

Limpopo

The following irrigation schemes are found in the Limpopo region: Sterkriver, Njelele and Levuvhu Government Water Schemes. The main source of water at the Sterkriver Government Water Scheme is the Doorndraai Dam. The water source for the Njelele Government Water Scheme is the Njelele Dam. The Levuvhu Government Water Scheme obtains its water from Albasini Dam, Latonyanda weir, Levuvhu weir, Barotta weir and the Levhangwe weir. The WAS is currently not in use in this region.

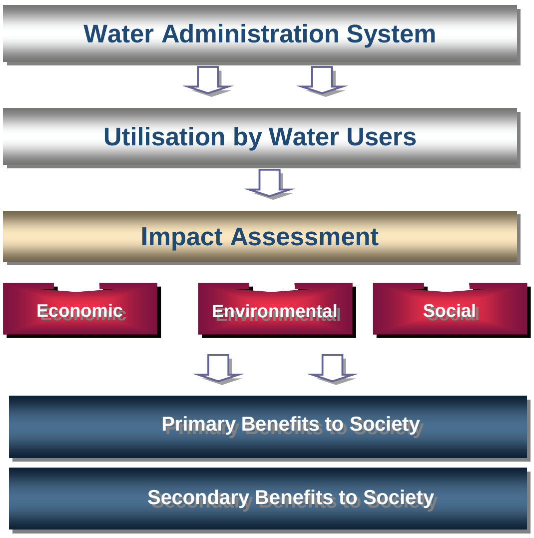
3. Impacts of the Water Administration System

3.1 Overview

The WRC has funded a wide range of projects aimed at agricultural water management and sustainability. These projects have been implemented country wide with the intended purpose of furthering national goals of efficient and effective water utilisation. One such project is the WAS.

This impact assessment conducted on the WAS has been separated into 3 main categories **Economic**, **Social** and **Environmental**. Each of these impact areas plays an important, but different role within South African society. Hence, it is important that the current benefits of the WAS be determined. Technical aspects such as improvement in information capturing, convenience in storing information, ease of accessing data are characteristics of the WAS. As such, the impacts stemming from these technical aspects are qualified and quantified within the economic, environmental and social sections of this document. No significant health impacts were directly attributable to the WAS hence this section was not included in this report.

Impacts in these three broad categories have been analysed using a qualitative and quantitative approach. With each impact the following approach has been taken where possible. An introduction of the impact is given followed by a summary of the characteristics of previous water administration methods utilised in South Africa. The WAS system is then discussed and the major impacts of its utilisation are identified. Examples of each impact are then identified from the various regions of the country and where possible these are either qualified or quantified.



Source: Frost & Sullivan

Figure 6: Overview of impact assessment

Impacts

The **economic impacts** identified in this document refer to aspects such as improved cost savings and improved revenue generation that result from using the WAS system. These impacts are quantified and represent the economic benefits of the WAS to society as a whole. The **environmental impacts** focus on the impacts that the WAS has had on ecological reserves, instream flow requirements and overall water allocation decisions in South Africa. **Social impacts** concentrate on direct and indirect benefits to South Africa's population currently employed in the various irrigation boards and water administration schemes. These range from skills development to personnel employee development.

3.2 Assumptions

Impact assessment, particularly related to research and specific activities, can be a challenging and sometimes subjective process. In light of this, this project has aimed to utilise a common quantifiable measure that is both relevant and measurable across the three impacts areas namely economy, environment and society.

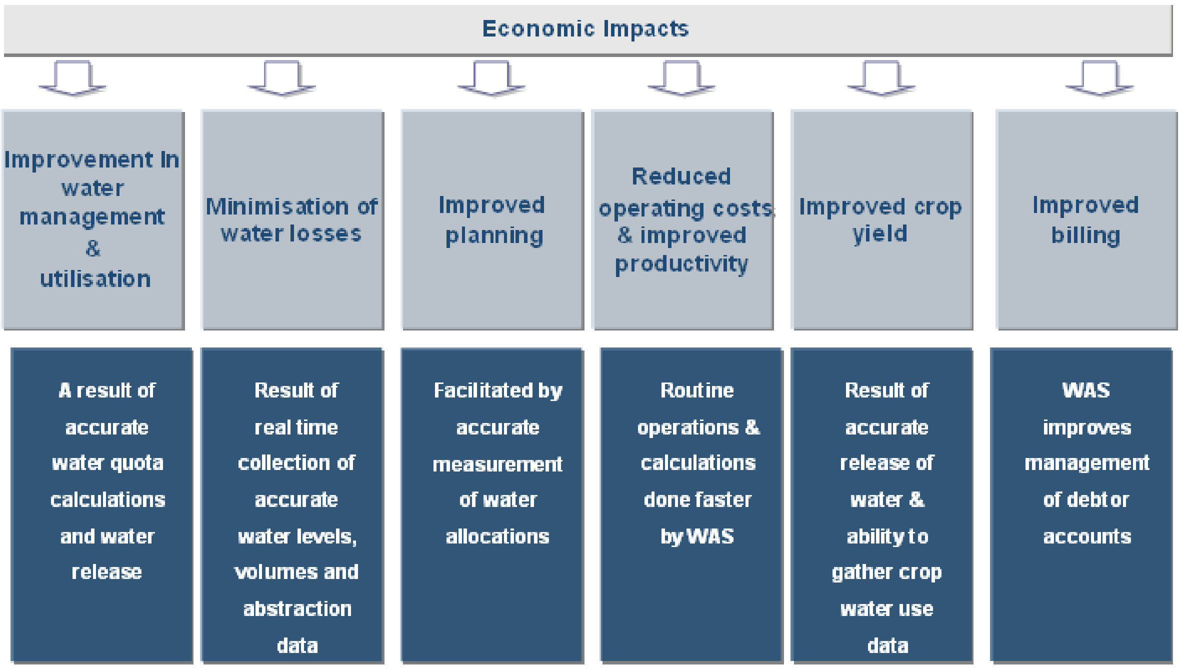
For this reason, the focus of this project was to try and quantify each impact identified across the impact areas. This was not always possible, owing to the qualitative nature of some of the research areas, however where possible this was conducted.

3.3 Economic Impacts

3.3.1 Introduction

Water is a scarce resource in South Africa, as such its efficient utilisation and management is a top priority. Inefficiencies in water utilisation and mismanagement of water allocations result in water losses and shortages. This poses significant knock-on effects for society and the South African economy as whole.

Implementation of the WAS in various regions of the country was a significant step in automating water administration and distribution. This implementation resulted in economic benefits that where realised by water administrators as well as water users. These impacts are discussed in the section below.



Source: Frost & Sullivan

Figure 6: Overview of impact assessment

Table 8: Overview of Impacts

Economic Impacts	Description of Impacts
Improvement In Water Management and Utilisation	• Reduced spillages • Improved monitoring of users exceeding allocated quotas • Improved management of water use entitlements
Minimisation of Water Losses	• Accurate and real time collection of data regarding water levels, volumes and abstractions. • Accurate and timely identification of water losses in the system • Savings measured in terms of water volumes and costs
Improved Planning	• Knowledge of exact water allocations available to each farmer • Improved planning for future crop production • Better planning by farmers for expansion
Reduced Operating Costs and Improved Productivity	• Routine operations and calculations done using WAS, which saves time • Reallocation of labour skills to increase productivity • Cost and time savings
Improved Crop Yield	• Increased crop output due to improved water management distribution. • Increased revenue due to increased crop output
Improved Billing	• Improved transparency • Better overview and insight into debtor accounts

Source: Frost & Sullivan

3.3.2 Quantification of impacts

Improvement in water management and utilisation

One of the shortcomings of previous methods of administering water in some regions of the country was that farmers would overdraw water. As a result some farmers would receive less water than anticipated or an amount that is insufficient for farming

Introduction of the WAS in various regions of the country has greatly reduced incidences of certain farmers exceeding their allocated quotas. This has been a result of utilising the Water Order and Water Release modules in collaboration with other modules of the WAS program. One such example is in the Free State Province of South Africa. The WAS has improved water use management in this region through accurate water quota calculations and allocations based on water orders from farmers and crop water use data. The WAS has reduced spillages due to excessive water release and overall, has improved the utilisation and management of water in this region.

Minimisation of water losses in South Africa

Water losses in an irrigation scheme can be a result of a number of factors. These could include seepage, evaporation, infrastructural damage or malfunctioning equipment in the various sections of canals, rivers or dams. Identification of the exact locations and volumes of water lost is important to minimise water losses.

The manual method of administering water requires physical checks and balances of water levels to establish the volumes of water lost. This method is inefficient and results in significant water losses that cannot be accounted for and hence cannot be mitigated effectively. Implementation of the WAS in various regions of the country has enabled accurate and real time collection of data regarding water levels, volumes and abstractions. The system is able to produce water use efficiency accounting reports that enable water administrators to identify any water losses in the system at any given time. They are able to accurately and timeously identify the location and volume of the water lost, thus help mitigate any further losses.

Most irrigation schemes that implement the WAS have managed to reduce water losses by significant amounts. The Gamtoos Irrigation Board has benefited the most through utilising the WAS. It has managed to save 69.6% of its annual irrigation water through implementing the system. Other water savings realised by all irrigation schemes that utilise the WAS are shown in the table below

Table 9: Water savings in South Africa's irrigation schemes

Irrigation Scheme	Prior water losses (m^3)	Current water losses (m^3)	Percentage water savings
Sandvet Government Water Scheme	3,984,876	2,789,413	30.0%
Orange Riet Water Users Association	49,975,035	37,700,465	24.6%
Vaalharts Water Users Association	115,361,424	111,516,043	3.3%
Loskop Irrigation Board	30,438,678	17,269,291	43.3%
Impala Water Users Association	81,147,240	57,840,800	28.7%
Gamtoos Irrigation Board*	10,223,040	3,111,360	69.6%
Lower Olifants River WUA	42,706,832	26,972,736	36.8%
Groenland Irrigation Board	2,462,880	1,759,200	28.6%
Hereford Irrigation Board	9,230,375	6,461,263	30.0%
Korentte Vetteriver Irrigation Board	894,600	715,680	20.0%
Hartbeespoort Irrigation Board	40,548,310	39,685,580	2.1%
Mooiriver Government Water Scheme	9,536,450	6,484,786	32.0%
Groot Marico Government Water Scheme	4,680,165	3,717,388	20.6%
Total	**401,189,905**	**316,024,005**	**21.2% (average)**

* A significant portion of water savings by Gamtoos irrigation Board is attributed to the replacement of water meters at all abstraction points and the measurement of all water rejected by farmers.

Prior to implementing the WAS, approximately 401,189,905 m^3 of irrigation water was lost from these schemes through seepage, evaporation and infrastructural damages. This was approximately 34.5% of the total irrigation water released to farmers annually.

However the WAS has helped reduce water losses to approximately 316,024,005 m^3 which is 27.2% of the total volume of irrigation water released to farmers annually. This has resulted in 85,165,900 m^3 of water being saved.

South African Irrigation Schemes			
Water Losses	Prior water losses	Current water losses	Water savings (m^3)
Volume of water lost (m^3)	401,189,905	316,024,005	85,165,900
Percentage volume of water lost (%)	34.5	27.2	

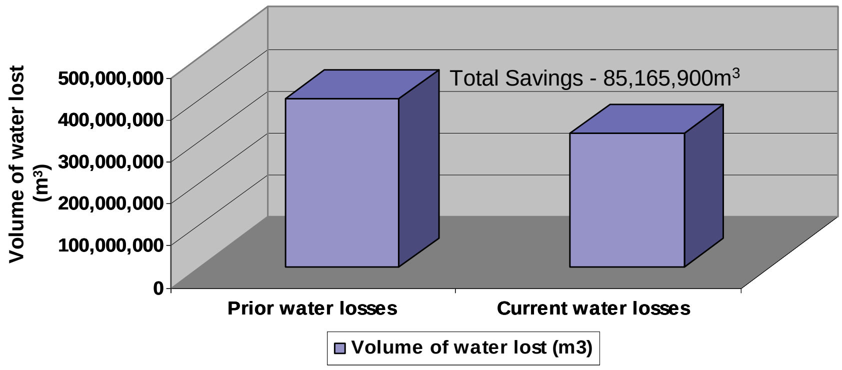


Figure 8: Improved water utilisation in South Africa

The average raw water tariff for irrigation water as set by the Department of Water and Environmental Affairs is approximately R0.02 per cubic meter. Hence, the implementation of the WAS has resulted in water savings totalling R1 703 318 for the 85,165,900 m^3 of irrigation water that is currently saved annually.

> The Water Services Act (Act No. 108 of 1997) prescribes that every South African should have access to at least 25 litres of water per day. This translates to 9 125 litres per person per year. Hence, the 85,165,900 m^3 of irrigation water that is currently saved annually through the implementation of the WAS is the equivalent amount to service approximately 9.3 million people per year.

Source: Frost & Sullivan

Improved planning

Farmers in the Free State have highlighted the fact that their ability to better plan for future crop production has been greatly improved because of the WAS. Knowledge of exact water allocations available to each farmer enables precise calculation of additional crop sowing and production limits. It also improves timing for fertiliser application and internal allocation of available water to different crops on individual farms. Reduced uncertainty of when water will be released and the volumes available enables farmers to plan better for expansion through sowing of additional crops.

Free State Farmer: *"We can plan better and calculate upfront how much we can produce given allocated water volumes; this also increases security in terms of how much we will reap*"

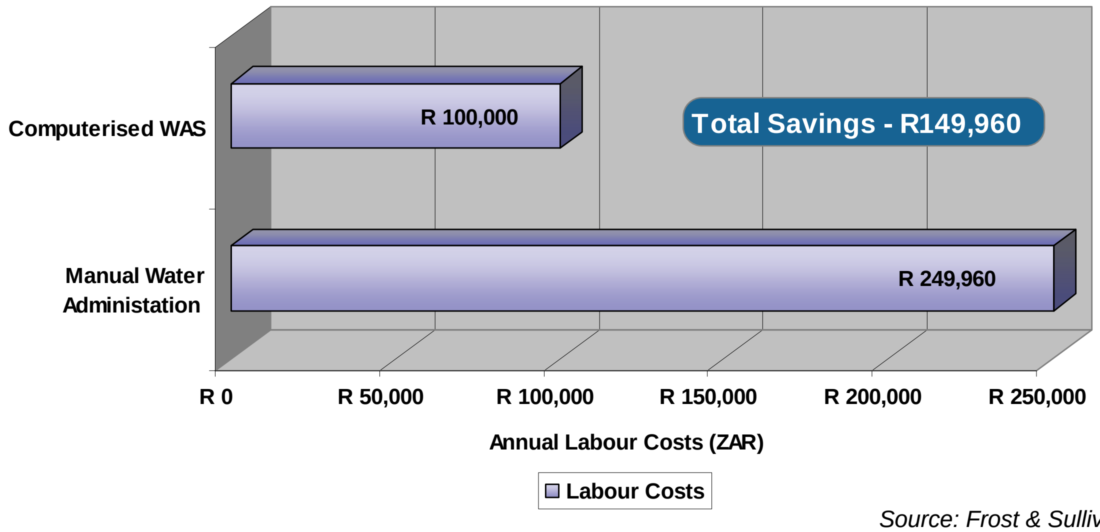
Reduced operating costs and improved productivity

The manual method of water administration had high labour costs associated with manual calculations and data capture. A significant number of water control officers were required to do the checks and balances of all water accounts and calculate water quota allocations among other routine operations. This posed a significant labour cost that could be greatly reduced by automation of the administration system. Introduction of the WAS thus reduced labour costs for many irrigation schemes across the country because the system enabled many of the routine operations that required a significant number of water control officers to be done quickly using less labour.

Water irrigation schemes in the Western Cape realised significant cost savings due to utilisation of the WAS. Activities such as manual calculations that previously required 14 water control officers were reduced to only requiring 6 water control officers. This presented a significant saving in labour cost and time.

Western Cape Water Administrator*:* "*Manual calculations and entering information into a log sheet required 14 water control officers, but now using the WAS we only use 6*"

For an irrigation scheme in the Free State a labour force of at least 5 distribution officers had to be physically sent to collect information in the fields to check debtor information and verify various water data. At a labour cost of R 4166 per month this would translate to an annual cost of R249 960. Since the inception of the WAS however only 1 person is required to do the checks and balances as well as verifying water usage information using the WAS. This costs an estimated R100 000 which translates to an annual cost saving of at least R149 960.



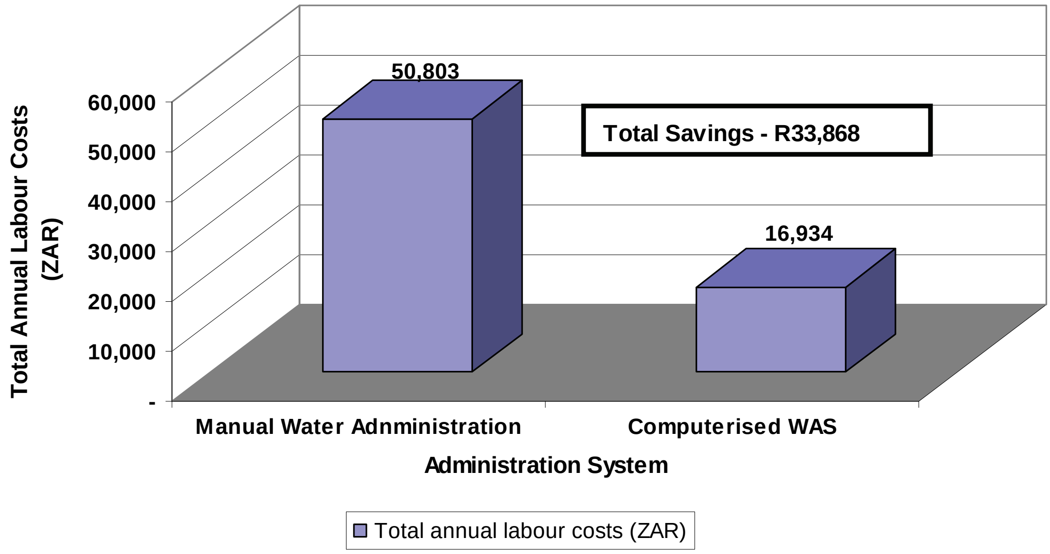
Source: Frost & Sullivan

Figure 9: Labour cost savings

The labour that is freed-up from manual routine activities can now be better utilised in other important activities such inspecting canals for damages, proposing corrections and rehabilitation measures as well as ensuring that sluice gates have been opened according to WAS calculations. All this ultimately leads to an increase in productivity and efficient utilisation of labour hours as skills are reallocated and utilised where they add the most value.

> **Eastern Cape Farmer:** "The system is increasing productivity because we can do more with the same amount of water"

The ability to do more with the same amount of water also saves time which can be translated to labour cost savings. A farmer from the Eastern Cape managed to reduce his labour force from 3 farm workers to 1 worker. At a labour cost of R6.30 an hour this represents an annual cost reduction of approximately R36 792. Larger labour force reductions and reallocation of labour could result in even greater savings and increased productivity.



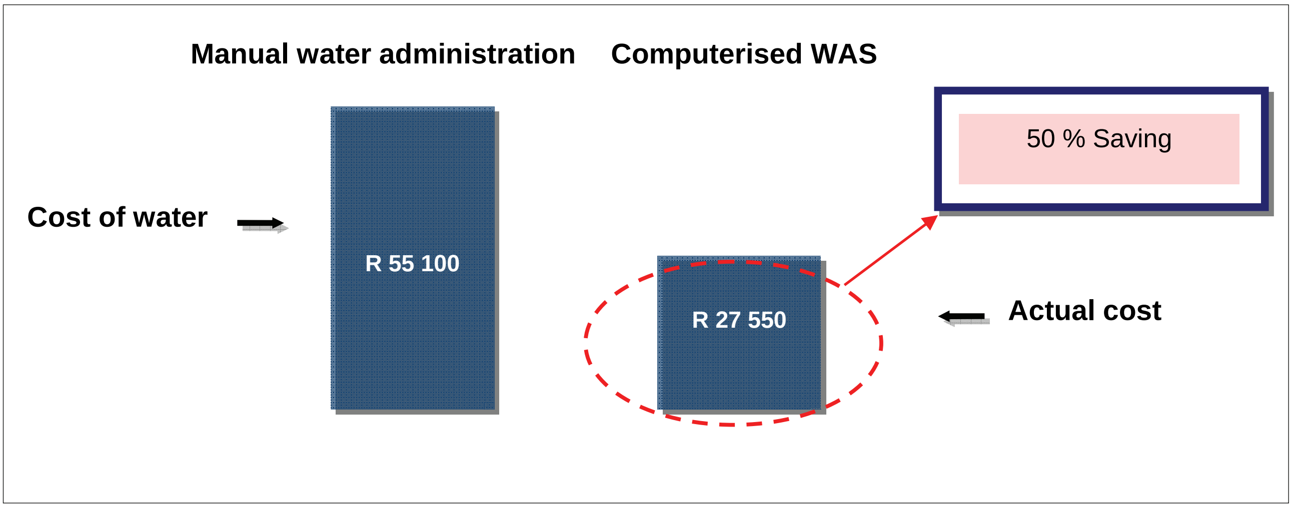
Source: Frost & Sullivan

Figure 10: Reduced operating costs

The WAS has increased productivity in irrigation offices in the Western Cape. This has been a direct result of skilled labour such as water control officers being removed from routine activities such as data capturing and water release calculations, and being reallocated to activities were their skills set could add more value such as administrative functions, monitoring and evaluating activities. A new skills set has also been introduced in the form of data capturers responsible for entering information into the WAS, and utilising the WAS to do various water release calculations.

Western Cape Farmer: *"I have managed to achieve 50% better usage of water since the introduction of the WAS. I can better allocate my water internally between my crops because I am guaranteed a known volume of water."*

Accurate knowledge of water allocations from the WAS and assurance of specific water volumes has enabled farmers to improve their internal reallocation of water for their crops. For farmers in the Eastern Cape better water usage of up to 50% has been realised. Farmers irrigating an area of 100 hectares, facing water tariffs costs of up to R551 per hectare per year have managed to save R 27 550 per year due to better water usage.



Source: Frost & Sullivan

Figure 11: Cost savings derived from improved water utilisation

Crop yield improvement

A combination of all the impacts identified which are: reduced operating costs, improved planning, better water utilisation, reduced water losses, accurate release of water and crop water use data have resulted in increased crop yields for farmers. In the Eastern Cape, irrigation under the old manual water distribution system would yield an output of between 1.5 – 2.5 tons of wheat on a 100 hectare farm. Irrigation under the WAS however has increased the output of wheat to about 6.5 - 7.5 tons. With each ton of wheat selling at R3000 per ton this increased output translates to an increase in revenue of approximately R15 000 per wheat crop alone.

Table 10: Output comparison (Wheat crop)

Output comparison for wheat crop		
Administration System	**Output Range (Tons)**	**Revenue Range**
Manual System	1.5 – 2.5	R4 500 –R7 500
Computerised WAS	6.5 – 7.5	R19 500 – R22 500

Source: Frost & Sullivan

Output from crops such as lucerne, maize, grain and sorghum have also realised significant increases. In the Eastern Cape farmers irrigating under the old manual system would reap crop yields of between 1.5 - 2.5 tons of maize. Irrigation under the WAS however has increased output to between 8.5 - 10.5 tons. With maize selling at R1500 per ton this represents an increase in revenue of between R10 500 - R12 000.

Table 11: Output comparison (Maize crop)

Output comparison for maize crop		
Administration System	**Output Range (Tons)**	**Revenue Range**
Manual System	1.5 – 2.5	R2 250 – R3 750
Computerised WAS	8.5 – 10.5	R12 750 – R15 750

Source: Frost & Sullivan

Improved Billing

Utilisation of the WAS in the Free State has also improved records of debtors that in some cases were unknown to the water administrators. Full utilisation of the system in the Free State has also ensured that farmers are unable to abstract water without the full knowledge of the water distribution administrators. This is because the WAS reports and monitors all increases and decreases in water levels in the various dams and canals. Farmers that overdraw water can easily be identified and billed using the WAS.

Conclusion

- The WAS has helped reduce water losses that result from seepage, evaporation, infrastructural damage or malfunctioning equipment in the various sections of canals, rivers and dams. This has been achieved due to the system's ability to timeously produce reports that enable water administrators to identify water losses at any given time.
- Approximately 85,165,900 m^3 per annum of irrigation water has been save through utilisation of the WAS. This translates into total water savings of approximately 21.2% per annum. At the average tariff for irrigation water of approximately R0.02 per m^3, total savings that result from the WAS amount to R1, 703,318 per annum.
- Farmers have been able to better plan for future crop production because of the WAS. Knowledge of exact water allocations available to each farmer enables precise calculation of additional crop sowing and production limits.

Implications for South Africa

The benefits realised from utilisation of the WAS are not only limited to water administrators and users. These impacts also extend to the South African economy as a whole. Impacts such as increased crop yield and the improvement in water management impact national issues such as food security, water allocation and management in addition attribute to GDP.

3.4 Environmental Impacts

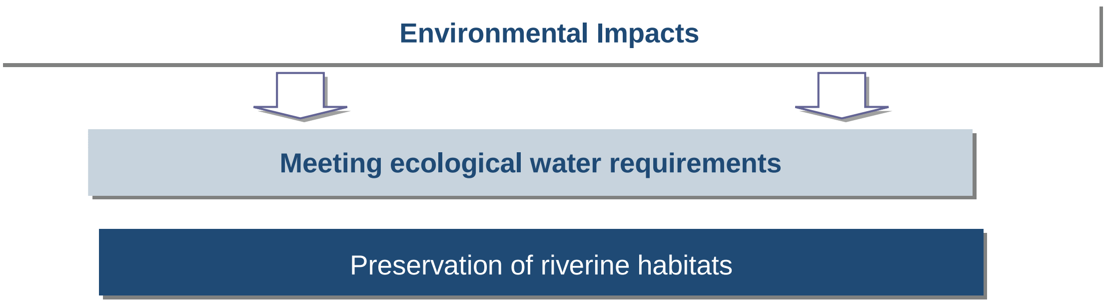
3.4.1 Introduction

South Africa's scarce water resources require that water allocation decisions are managed very closely. The economic benefits of careful, measured allocation of water to the agricultural sector are clear. However human and environmental demands need to be catered for as well. South Africa's National Water Act states that human and environmental needs should be addressed before economic (agricultural) requirements are considered.

Within the context of the WAS, environmental impacts are linked to the concept of ecological reserve and instream flow requirements. Ecological reserve refers to the water required to protect and sustain aquatic ecosystems in order to secure ecologically sustainable development and water use (Watermark, the lasting impression of the ecological reserve, 2007). Similarly, the instream flow requirements of a river refer to the flow rates required to sustain the ecological integrity of that system.

As South Africa's largest consumer of water, the correct allocation of water within the agricultural sector is crucial due to the significant volumes involved. Even small losses can have a high impact on water allocation within a region. Hence, poor water allocation or water losses in the agricultural sector could have negative impacts on the ecological reserve or instream flow requirements of rivers.

The environmental impact assessment portion of this report focuses on the concepts of ecological reserve, instream flow requirements and effective water allocation.



Source: Frost & Sullivan

Figure 12: Overview of environmental impacts

Table 12: Overview of environmental impacts

Environmental Impacts	Description of Impacts
Meeting ecological water requirements	• Maintenance of ecological reserve • Maintenance of instream flow requirements

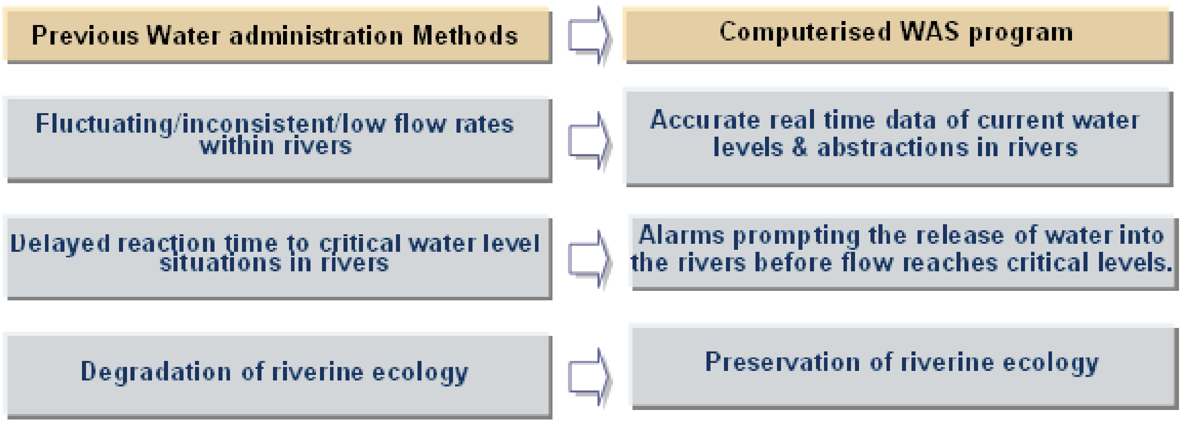
Source: Frost & Sullivan

3.4.2 Qualification of impacts

Ecological Water Requirements

One of the shortcomings of the water administration method used before implementation of the WAS is that there was no real-time information regarding current water levels and abstraction in rivers and canals. As a result rivers could run low before water administrators were aware that the rivers have receded below critical ecological requirement levels.

Utilisation of the WAS has allowed for more careful management and allocation of water within canals and river systems. The real-time nature of the WAS allows water administrators to monitor flow levels and ensure that rivers meet their instream flow requirements.



Source: Frost & Sullivan

Figure 13: Comparison of previous water administration methods and the WAS

An example that illustrates these environmental impacts is the implementation of the WAS on the Berg river in the Western Cape. This river has four weirs which monitor water abstraction rates from farmers. The WAS allows for careful monitoring of water levels within the Berg River, which aids the monitoring of flow levels and the maintenance of instream flow requirements. Prior to the implementation of the WAS flow levels within the river would reach critical levels, which would result in negative impacts on the rivers ecology. Since the implementation of the WAS, administrators are better able to manage flow rates, which helps maintain the ecological integrity of the system.

In addition, the significant water savings that result from the implementation of the WAS ensure that valuable water is not wasted and hence can be allocated for basic human and ecological needs.

Implications for South Africa

Tools like the WAS enable water administrators to better manage water resources in the agricultural sector. However, within the context of environmental impacts, the WAS is a useful tool for the monitoring of water allocation, the instream flow requirements of rivers and rivers' ecological reserve. Without systems like WAS it would be difficult for water administrators across South Africa to ensure that the environmental integrity of river systems is maintained.

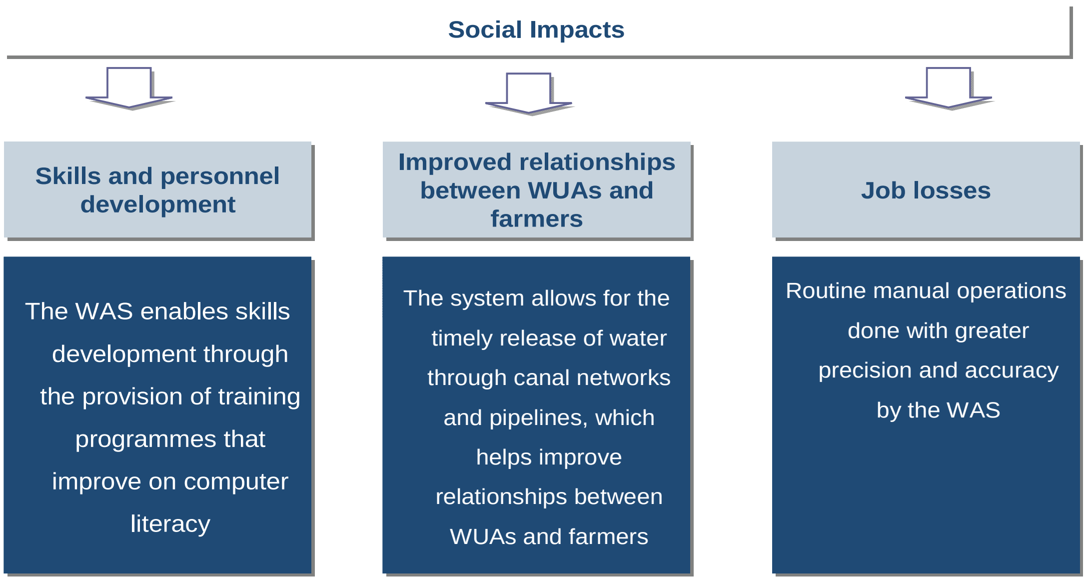
3.5 Social Impacts

3.5.1 Introduction

The economic impacts of the WAS are typically direct and easily identified. Social impacts are not always obvious and are often a result of an indirect influence. There is a significant skills shortage within the South African water sector; there are insufficient numbers of skilled personnel and average skill levels are low.

This situation requires that water organisations retain, effectively train and empower key personnel. Implementation of the WAS typically includes training programmes for operators, which is beneficial, however, there are also instances where personnel numbers are reduced because the WAS streamlines previously manual and routine operations.

The impacts identified in this section look at issues such as skills development, focusing particularly on computer literacy, personnel employee development focusing on expansion of employee duties and finally improved relationships between water organisations and farmers.



Source: Frost & Sullivan

Figure: 14 Overview of social impacts

Table 13: Overview of social impacts

Social Impacts	Description of Impacts
Skills and personnel development	• Computer literacy training programs • Introduction of new skills set • Expansion of employee duties
Improved relationships between WUAs and farmers	• Improved lines of communication • Improved information flow • Accurate data requirements
Job losses	• Routine manual operations done faster by WAS

Source: Frost & Sullivan

3.5.2 Qualification of impacts

Skills and personnel development

Improved computer literacy in many irrigation scheme offices across South Africa has been realised due to the introduction of the WAS. For example, computer literacy development programs have been conducted in the Eastern Cape's Gamtoos irrigation Board for employees to enable them to use the WAS effectively and efficiently.

Further, the WAS has allowed water distribution officers and water control assistants to focus on other activities which include;

- Monitoring and verifying if sluices have been opened according to WAS calculations
- Assisting in supplying equipment
- Inspecting canals for any damages
- Proposing corrections or rehabilitation of canal systems
- Monitoring and evaluating canal networks

These additional activities have expanded their responsibilities and skills base.

Improved communication between water organisations and farmers

The WAS enables better interaction between Water User Associations (WUAs) and farmers. The Water Order module, a component of the WAS program, manages information that includes;

- Weekly based quota allocations
- Weekly based water requests that are divided into original, additional and cancellation request types
- Weekly based water transfer types between plots. Links can be created between master plots with extensions that allow for automatic transfer between a master plot and an extension

Implementation of this module results in constant interaction between users that helps build communication channels and improve on existing relationships between farmers and water organisations such as WUAs, Irrigation boards and Government water schemes.

For example, the WAS improved communication for the Gamtoos irrigation board as it enabled them to produce graphical reports and print data schedules, which allowed the use of email to communicate important irrigation information to farmers. This free flow of accurate information, via WAS, increased the communication levels between the irrigation board and the farmers, which helped improve their overall working relationship. Prior to the implementation of the WAS, when water was administered manually, the relationship between irrigation boards and farmers was at times strained because accurate water volume information was not made available to farmers, which hindered their decision making.

Job losses

In addition to the impacts highlighted above, the WAS has also resulted in social costs. This has been a result of the fact that the WAS can be operated by a single individual and most tasks such as water quota allocations are handled by specific modules within the system. Manual and routine calculations that previously required numerous personnel can now be executed using the WAS in shorter periods of time, with greater precision and accuracy, hence fewer staff are required for these particular functions.

Implications for South Africa

Development of staff within South Africa's water sector is critical to its success. Theory-based learning at tertiary institutions is important, however, on-the-job skills-based teaching also plays a critical role in developing staff. Systems like the WAS present an important opportunity for staff to learn computer and system-based skills, which can applied further in other applications and roles.

4. Conclusion

The agricultural sector is a significant contributor to South Africa's GDP; the effective management of water resources is central to its success. As demand for water rises, allocation decisions will become increasingly difficult, and the effective management of water, through systems such as the WAS, will become paramount.

The features and benefits of the WAS are clear, however the aim of this project was to determine the impact that this system has had on economic, environmental and social aspects of South African society. Determining such impacts on a national scale is a challenge; hence a localised, case study approach was adopted.

Major economic impacts that have been realised as a result of the WAS include; minimisation of water losses; better planning by farmers; reduced operating costs; and improved crop yield. Approximately 85,165,900 m^3 per annum of irrigation water has been saved through the utilisation of the WAS. In terms of revenues, total savings that have resulted from the WAS amount to approximately R1, 703,318 per annum.

The WAS has resulted in a reduction in labour costs for most irrigation schemes. Only one person is required to do checks and balances that typically require five people to undertake without the WAS. Cost savings from reduced labour requirements amount to R149, 960 for some irrigation schemes in the Eastern Cape. Further, farmers have been able to plan better for their crop production since they have data about their exact water quota allocations. This has improved their crop yield.

Environmental impacts identified focused on ecological reserve and instream flow requirements. The WAS has helped maintain ecological reserve and instream flow requirements through the provision of accurate real-time data of current water levels and abstractions in rivers. The WAS triggers alarms prompting the release of water into rivers before flow reaches critical levels, thereby helping preserve the riverine ecology.

Social impacts identified focused on skills development on the part of WUAs employees. Utilisation of the WAS allows employees to improve their computer literacy skills through development programmes conducted by Dr. N Benade from NB Systems in close cooperation with the Directorate Water Use Efficiency of the Department of Water and Environmental Affairs. In addition, employees in senior positions are able to dedicate more of their time to other aspects of their operations. Improved information flow and interaction between WUAs using the WAS and farmers has helped build better working relationships. A downside of the WAS is that in some instances fewer people are required to fulfil on certain functions, thus reducing employment levels.

All of the impacts identified during this project indicate that the WAS program has had an impact across economic, environmental and social aspects of South African society.

5. References

BENADÉ N, ENGELBRECHT RJ & ANNANDALE G.W. (1990) Die optimalisering van die bedryf van besproeiingskanaalstelsels. *Report for the Water Research Commission. Report 176/1/90*. Translated title: The optimization of the management of irrigation canal systems.

BENADÉ N. (1993) Die ontwikkeling van 'n gerekenariseerde bestuurstelsel vir die optimale bedryf van besproeiingskanaalstelsels. *Report for the Water Research Commission. Report 367/1/93.* Translated title: The development of a computerized management system for the optimal management of irrigation canal systems.

BENADÉ N, ANNANDALE J & VAN ZIJL H. (1997) The development of a computerized management system for irrigation schemes. *Report for the Water Research Commission. No. 513/1/97.* Pretoria, South Africa

BENADÉ N, ANNANDALE J, JOVANOVIC NZ, MEIRING JA & CROUS CI (2002) The development of an integrated information system for irrigation water management using the WAS, SWB and RiskMan computer models. *Report for the Water Research Commission. No. 946/1/02*. Pretoria, South Africa

BENADÉ N, ANNANDALE JG, POTT A, VAN HEERDEN PS, GROVÉ B & STEYN M (2008) Technology transfer and integrated implementation of water management models in commercial farming. *Report for the Water Research Commission. No. TT 267/08*. Pretoria, South Africa

BENADÉ N (2009) Transfer of technology to develop and implement the water use efficiency and accounting report as part of the Water Administration System. *Report for the Water Research Commission.* Pretoria, South Africa

6 Appendices

6.1 Quantitative matrix

The table below shows a list of metrics used to quantify and qualify impacts of the WAS

Table 14: Quantitative matrix

Economic Impacts		
Product/Impact	**Description**	**Quantification**
Monetary value of water losses avoided	Quantifying the amount of water saved due to WAS	Value saved (ZAR)
Improvement in revenue generation	Evaluate the improvement in revenue generated through the billing system that is linked to the water usage information	Revenue generated (ZAR)
Improved efficiency in crop production	The WAS enables accurate data collection on the required amounts of water for optimum crop production	Value of crops (ZAR)
Reduced operating costs	Establishing the operation costs saved due to the integrated system that managed administration, water distribution and accounts in a single package.	Costs reduced (ZAR)
Reduced maintenance costs	The WAS database is robust, easy to install and has a low maintenance requirement.	Costs reduced (ZAR)
Technical Impacts		
Product / Impact	**Description**	**Quantification**
Improvement in information capturing	Establishing the costs saved due to improved information capturing by the WAS system.	Cost of labour hours (ZAR)
Convenience in storing information	All data is archived in a single database which makes it possible to access old records quickly	Cost of labour hours (ZAR)
Convenience in presenting information	WAS information is presented in graphs and images that are easy to interpret	Qualify
Improved accuracy in water requirement predictions	The WAS is linked to water usage information and this helps accurately predict water requirements for crop production	Volumes of water saved (ZAR)
	Environmental Impacts	
Product / Impact	**Description**	**Quantification**
Reduced damage to habitats due to flooding	Systematic and controlled release of water reduces damage caused by flooding	Rehabilitation costs saved (ZAR)

Reduced water losses, seepage and rising water tables	Water losses, seepage and rising water tables are reduced due to effective management of water allocation and distribution.	Volumes of water saved (ZAR)
Social Impacts		
Product / Impact	**Description**	**Quantification**
Improvement in crop yield for communities	Establishing the impact that the WAS has had on the crop yield	Ton/ha then convert to Rands
Improved staff effectiveness	The WAS systems ease of use and its integrated database increases staff effectiveness	Time saved - hourly wages ZAR
Improved relationships between Water User Associations & farmers	The WAS enables accurate data collection on the required amounts of water for optimum crop production, which will improve the relationship between WUA's and farmers	Qualify

6.2 Survey Respondents

The table below illustrates all interview respondents by region. These include WUA's, government water schemes, irrigation boards and farmers

Table 15: Survey respondents

Region	Irrigation Scheme
North West	Hartbeespoort Irrigation Board
	Mooiriver Government Water Scheme
	Groot Marico Government Water Scheme
Western Cape	Lower Olifants River WUA
	Groenland Irrigation Board
	Korentte Vetteriver Irrigation Board
	Various Farmers
Eastern Cape	Gamtoos Irrigation Board
	Various Farmers
KwaZulu-Natal	Impala Water Users Association
Mpumalanga	Loskop Irrigation Board
	Hereford Irrigation Board

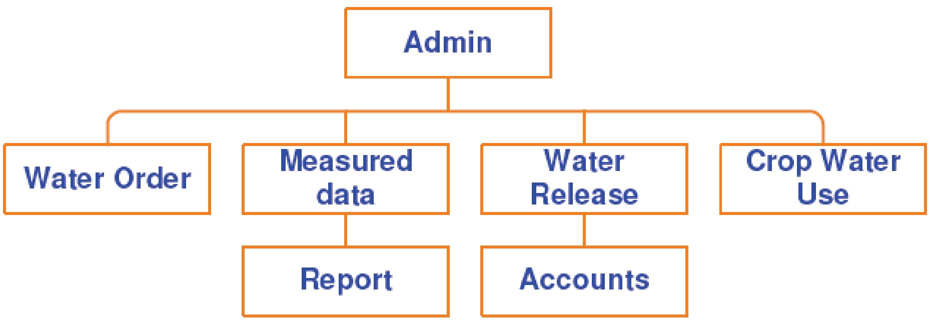
Free State Region	Sand-vet WUA
	Various Farmers
Northern Cape	Vaalharts Water Users Association
	Orange Riet Water Users Association
Limpopo	Sterkriver Government Water Scheme
	Njelele Government Water Scheme
	Levuvhu Government Water Scheme

6.3 Survey Questionnaire

Below is a set of questions canvassed to all stakeholders during the survey.

Water Administration System: Impact Assessment

The following modules are used by the WAS users to manage the allocation of water in the South African agricultural sector.



The following questions aim to **qualify** and **quantify** (Rand value) the impacts that the WAS is having on economic, environmental, social and technical aspects of South Africa society.

Economic Impact

Maximisation of water usage

- What would you say have been the impacts of the WAS with regards to maximising water usage?

Minimisation of water losses

- What volume of water has been saved as a direct result of the implementation of the WAS?
- Can you place a monetary value to the amount of water saved?

Improved management and production

- The WAS makes it possible for management and staff to access the information database from their individual personal computers. This helps improve on office

Improved revenue generation

- Has there been an improvement in the total revenue generated due to usage of the WAS billing system?
- Has there been any improvement in transparency and accountability for the revenues generated from irrigation water use?

Reduced operating costs

- What impact has the integrated nature of the WAS system had in reducing your operation costs?

- How much has been saved in operating costs due to the usage of this system?

Reduced maintenance costs

- Has there been a reduction in maintenance costs of equipment due to usage of the WAS system to automatically release and manage water distribution?

Environmental Impact

Reduced damage to habitats due to flooding

- What impact on the surrounding ecosystem has the systemic controlled release of water had?
- How much would it cost to rehabilitate any damages caused as a result of flooding from uncontrolled discharge?

Reduced water losses, seepage and rising water tables

- Are you aware of any situations where water losses, seepage and rising water tables have been reduced as a result of implementing the WAS?
- How much has been saved in costs due to this?

Technical Impacts

Improvement in information capturing

- How has the WAS helped improve the process of capturing information? How much revenue has been saved in the process?

Convenience in storing information

- How has the WAS helped improve access to old records?
- Can you put a monetary figure to the cost-savings that have resulted in this regard?

Convenience in presenting information

- The WAS allows information to be presented in graphical methods and images that are easy to interpret. How has this had an impact on your operations? Can you put any monetary value to this?

Improved accuracy in water requirement predictions

- The WAS is linked to water usage information and this helps accurately predict water requirements for crop production. What have been the major benefits from such an arrangement?

Social Impacts

Improvement in crop yield to society's benefit

- The WAS enables accurate data collection on the required amounts of water for optimum crop production. Has the WAS had any positive impact on society with regards to improving peoples crop yield? How much yield was realised in the process?

Improved staff effectiveness

- The WAS allows access to information for all employees. This helps improve personnel productivity. How has the WAS impacted your operations in this regard?

Improved relationships between Water User Associations (WUAs) and farmers

- The WAS allows for the timely release of water through canal networks and pipelines. This helps improve relationships between Water User Associations and farmers. Has the WAS helped improve WUAs – farmer relationships?

6.4 WAS utilisation

The table below provides details of WAS modules utilised by each irrigation scheme interviewed during the survey.

	Administration	Water Order	Measured Data	Water Release	Crop Water Use	Accounts	Reports
Harbeespoort Irrigation Board	■	■		■		■	
Mooiriver Government Water Scheme	■	■					
Groot Marico Government Water Scheme	■	■		■			
Lower Olifants River WUA	■	■		■		■	
Groenland Irrigation Board	■	■				■	■
Korentte Vetteriver Irrigation Board	■	■				■	■
Gamtoos Irrigation Board	■	■					
Impala WUA	■	■				■	
Loskop Irrigation Board	■	■		■		■	
Hereford Irrigation Board	■	■				■	■
Sandvet Government Water Scheme	■	■		■			
Vaalharts WUA	■	■		■		■	
Orange Riet WUA	■	■		■	■	■	
Worcester (DWAF regional offices)			■				
Sterkriver Government Water Scheme							
Njelele Government Water Scheme							
Levuvhu Government Water Scheme							

Figure 15: WAS modules used by each irrigation scheme