Guidance for Sustainable On-farm and On-scheme Irrigation Water Measurement

I van der Stoep, A Pott, JH Viljoen & AMJ van Vuuren

WATER RESEARCH COMMISSION

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Report to the
Water Research Commission

and

Department of Agriculture, Forestry and Fisheries

by

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DISCLAIMER

Executive Summary

Introduction

This report presents the results of a technology transfer project initiated and funded by the Water Research Commission (WRC) and undertaken from April 2007 until September 2012. It follows on from the publication of two previous reports, the "Guidelines for Irrigation Water Measurement in Practice" (2005) and "Training Guidelines for Implementation of On-farm and On-scheme Water Measurement and Metering" (2010) by the WRC

The National Water Act (NWA) (Act No. 36 of 1998) calls for efficient, sustainable and beneficial use of water in the public interest which implies that effective water management must be done. The management cycle of water consists, if presented in a simplified format, of a continuous process of planning, allocation, operation, monitoring, analysis, and feedback.

For effective water management to take place, and to address the requirements of efficient, sustainable and beneficial use, it is imperative that firstly there is verification that every user receives their fair share of the water, as allocated. Secondly, water losses (non-beneficial use) should be limited to a minimum. Finally, accurate, reliable and appropriate data must be recorded and made readily available so that the right decisions can be made at any point in the continuous process of managing the water and related infrastructure.

The WRC recognised the need for information on irrigation water measurement, and initiated a project in 2001 that resulted in the publication of the 2005-report mentioned above (WRC Report No. TT 248/05). This first project was followed by a 12-month consultation project to prepare training guidelines for the implementation of measurement (WRC Report No. KV 247/10). The theoretical guidelines produced for TT 248/05 needed to be verified in practice before technology transfer could commence, and this third project was initiated to promote awareness of, and develop implementation plans and guidelines for management of sustainable on-farm and on-scheme water measurement.

National water conservation and water demand management (WC/WDM) strategies have been developed in terms of the National Water Resource Strategy (NWRS) of 2004. The strategy for irrigated agriculture provides a framework of regulatory support and incentives to improve efficiency, with a plan of action towards achieving, amongst other things, the following goals:

- Implementation measures that reduce wastage
- Convincing users to progressively modernise their water conveyance infrastructure and irrigation equipment

The Water Conservation and Water Demand Management Conditions for Water Use Sector Authorisation (DWAF, 2006a)[1] imposes a duty to measure, record aspects of water use, and requires that the licensee shall measure the amount of water supplied to each farm or user on a monthly basis using an appropriate flow measurement device.

In response, the WRC has published reports and guidelines for the direct and indirect measurement of water use on irrigation schemes to meet the practical need to measure and manage water effectively and efficiently. However in most cases, the water management system in operation does not incentivise water measurement, and consequently measurement of water use and volumetric charging is not widely practiced.

This project aimed to facilitate a process towards effective implementation of water measurement at river, irrigation scheme and farm level in South Africa. In order to achieve this, end users of water measurement technology were made aware of and encouraged to adopt the technology. Specific

[1] DWAF, Department of Water Affairs *and Forestry* (pre July 2009), and DWA (post July 2009)

attention was given to technical constraints and the financial justification for implementing the technologies for water measurement.

A definite change in attitude towards irrigation water use measurement had taken place in the sector since the first WRC project on the topic was undertaken from 2001 to 2005. The question to be addressed had now become *how* rather than *whether* water measurement should be implemented in the irrigation sector. This project sought to answer the question by developing an implementation plan that would address the specific issues typically encountered by stakeholders during implementation:

1. When irrigation water use measurement should be implemented.
2. What the organisational arrangements are regarding measurement.
3. Where measuring devices be should installed.
4. Which measuring devices should be used and how they should be installed.
5. How the measuring devices should be operated.
6. Where information on funding and incentives can be accessed.
7. What process of implementation to follow to deal effectively with these issues.

Project activities

The project was undertaken in 3 phases: preparation, analysis and implementation. It commenced with a country-wide survey amongst irrigation organisations regarding the current status of water measurement, prior to shifting the focus to localised study areas, and then finally to specific pilot studies where the implementation plans were tested.

Initially, three case study areas were identified where water measurement was to be implemented or upgraded: the Crocodile River in Mpumalanga, the Steenkoppies groundwater area in North-West, and the Hereford Smallholder Irrigation Scheme near Groblersdal in Mpumalanga.

The case studies are all described in the report, together with supporting information from three other irrigation areas: the Middle Komati and Thabina Smallholder Irrigation Schemes in Mpumalanga, and the Orange-Riet Water User Association (ORWUA) on the Free State/Northern Cape border, where measurement implementation had been undertaken independently over the last 10 years. These additional areas were included to provide supplementary information to be used in the development of material for knowledge dissemination.

Project results

The main product of the project is this Technology Transfer report, which is structured into five parts, plus an introduction (Chapter 1) and a conclusion (Chapter 15):

Part A: Setting the scene (Chapters 2, 3 and 4)

Part A introduces the topic of irrigation water measurement, starting with the results of the survey of Irrigation Boards (IBs) during the first year of the project. It then discusses the proposed irrigation water measurement strategy that was developed in parallel for the Department of Water Affairs (DWA), and concludes by introducing the structure of the irrigation water measurement implementation plan developed during this project.

Part B: Implementation guidelines (Chapters 5 to 8)

This section of the report contains the implementation guidelines which provide an implementing agent with information on the different aspects of water measurement implementation and how they should be addressed when developing an implementation plan for a specific situation. The guidelines are structured according to the same headings as the implementation plan (see below), and provide background information and references to assist with the development of the plan. It is based on the previous WRC report on irrigation water measurement (Report No. TT 248/05) by Van der Stoep, Benadé, Smal & Reinders (2005).

Part C: The implementation plan (Chapters 9 to 12)

This part of the report comprises the general (generic) implementation plan, structured into three sections based on the logical steps to be taken during implementation:

- Measurement implementation planning.
- The measurement system.
- Implementing the plan.

The generic plan or template is based on the work undertaken and reported on in the implementation phase of this project, and was adapted after field work was undertaken in the case study areas. It can be customised and completed as a site specific implementation plan for irrigation water users in a specific area.

Part D: Lessons learnt (Chapter 13)

This part of the report describes the work undertaken in selected case study areas, as well as key areas that were included as case studies (because of the contribution they make to the knowledge base) even though the project team did not undertake work there during the project period. The activities undertaken in the case study areas were used to refine the implementation plan and the lessons learnt during the field experiences formed the basis of completed and future knowledge dissemination activities.

During the implementation phase when the plan and guidelines were tested, it was found that in some cases the benefits of measurement implementation was not clear to those persons who must be the drivers of the process.

Where implementation has failed, it is more often than not the human relationship issues that were the obstacles – organisations, individuals and the institutions that determine their behaviour are more difficult to change to achieve a desired outcome than technical issues. Of great importance in this regard are the parts played by the different role players and how these contribute to the success of a project. Failure of one role-player to accept the responsibilities associated with the position they hold can jeopardise implementation. DWA, the irrigation organizations (IO), the water users, local government, equipment suppliers and other organisations all have roles to play and should be made aware of the importance thereof in the context of the whole project.

Part E: Awareness creation (chapter 14)

This part of the report presents information regarding the technology transfer activities undertaken to present the project outputs to a wider audience, by means of workshops, radio and television interviews, the project website, and popular articles.

The case studies presented the project team with opportunities to assess the usefulness of measuring irrigation water use in a number of situations. The activity of measurement is seemingly simple but its role in water management is not always fully understood. A significant amount of knowledge dissemination is still required to convince the average water user or IO of the value of measurement in terms of being essential for water loss control and on-farm savings.

Especially in the case of smallholder irrigation schemes, the potential of flow measurement as a management tool is still largely under-estimated. International experiences in irrigation revitalisation, focused on collapsed or largely dysfunctional schemes, have shown that investment in infrastructure alone is likely to fail. Recent South African experiences have been documented where infrastructure degradation is observed on a scheme at the same time as new infrastructure rehabilitation initiatives are being undertaken. Provincial policies, where they exist, are characterised by an emphasis on capital expenditure and infrastructure development (i.e. irrigation hardware and technology) and a heavy reliance on the concept of commercial partnerships for the production component. The links between irrigation scheme operation, management and engineering design present an opportunity in the revitalisation initiative to make water apportionment, management and policing more equitable and with lower transaction costs. At its simplest level, the engineering team must not only consider rehabilitation of existing infrastructure but also think about adding new engineered components (such as flow measuring devices) that will change the behaviour of water users. Technology is an instrument of social change in this sense and small technical interventions can greatly reduce conflict and time spent dealing with water.

DWA is in the process of developing regulations with regard to measurement of water in the irrigation sector which will address some of the constraints identified during the project. Entitled "*Proposed regulations requiring the taking of water from a water resource for irrigation purposes be limited, monitored, measured and recorded*", the latest version of the document puts forward a process to monitor water use by irrigation farmers using remote sensing applications as a starting point, with direct measurement of water only recommended as a final solution in the case of confirmed transgressors. The regulations are still under development, with an extended stakeholder engagement process still to take place before being introduced into practice.

Until the regulations have been approved, the advantages of water measurement from an on-farm water or business management perspective should be pointed out through knowledge dissemination, specifically relating to:

- The potential to make more profit, and/or
- The potential to help improve the convenience of farming operations to the farmer.

Emerging trends suggest that water meters are becoming increasingly important, as they provide irrigators with vital information (often with other sets of complementary information) to help improve or protect profits, and water meters and associated technologies and products are offering information to irrigators in a convenient, affordable and reliable format.

The cost of water meters is easily quantified, with the capital cost of a meter usually insignificant compared with the capital costs of the pumps, pipes, filters and other components that comprise the irrigation system itself. It is more difficult to quantify the benefits of metering as clearly as the costs; however, water meters can and do offer significant value to irrigators in South Africa as described in this report and given this fact, it is in the interests of irrigators to invest in water meters sooner rather than later.

Due to rapidly rising electricity costs, and the threat of curtailments to existing lawful water use in over-allocated catchments, there is significant pressure on irrigators to improve their irrigation practices. Decision support may be required and measuring devices have a role to play in helping irrigators remain financially viable.

Conclusions

The outputs of the implementation phase of the project can be summarised into four key messages for potential users of measuring devices for irrigation water:

Assign the responsibility for implementation to a skilled person

A knowledgeable and skilled person employed by the Water User Association (WUA) or IB is required if water measurement is to be implemented successfully. Such a person should preferably have a technical background and be involved with the process of implementation right from the start, to ensure that they share all the experiences in the process of finding a sustainable measurement solution for the area under consideration. This person must be able to develop a measurement system for the specific situation and also be able to see to the day-to-day operation and maintenance of the measuring devices (with assistance if necessary).

Preparation is key

In order to find the best solution, it is recommended that any possible technology that is being considered for wide-scale implementation must first be evaluated on a trial basis to obtain first-hand experience with its installation, operation and maintenance requirements. It is better to try out as many technologies as possible on a small scale before making a final selection, as this can prevent inappropriate, costly systems from being purchased that may become redundant after a short while of operation. The cost of single units of a few different technologies is money well-spent in view of selecting the best solution.

Commit to an implementation plan

Any project should be planned and implemented as simply and practically as possible – unnecessary complication is a threat to successful project implementation. This can only be achieved if knowledgeable implementing agents manage the project through careful planning and in-depth assessment of the situation presenting itself, as every project will be different in its own right and therefore require site-specific solutions, an outcome that will hopefully be achieved through the careful application of the proposed implementation guidelines and plan.

Install the most appropriate technology that can be afforded

Research work undertaken over the last 10 years has shown that suitable technologies and devices are available for the measurement of irrigation water, even in challenging situations with regards to aspects such as water quality and installation conditions. Failure of measuring devices or systems can usually be blamed on incorrect selection, application, installation or maintenance rather than on the technology itself. Under demanding conditions, it is imperative that the best technology or device available and affordable is obtained, to ensure a sustainable system that will serve the purpose that the owners of the system intended it for. The benefits of a suitable system will pay for itself within a short period of time but an unreliable system will only cause frustration and lead to unnecessary expenses and an additional work load on the water managers of a scheme.

Recommendations

The project has provided the project team with opportunities to evaluate and improve the water measurement guidelines developed during the preceding WRC project. The project activities have resulted in a range of case study material being available for further use to support and promote the use of water measuring devices in irrigation for improved water management.

The following recommendations are made regarding future use and application of the project output:

Crocodile River case study area:

The recently installed energy monitoring equipment should be transferred to the new WRC project entitled "The optimisation of electricity and water use for sustainable management of irrigation farming systems" that is due to commence in April 2013. It would provide the new project team with accurate and recent historical data of water and energy use at easily accessible sites.

Short term project on knowledge dissemination:

It is recommended that a knowledge dissemination project be undertaken to implement the project outputs through the distribution of results by means of pamphlets, brochures, posters or other forms of promotional material. The project should entail the development of the material, based on the lessons learnt and the documentation generated during the projects undertaken from 2001 until 2012, as well as the distribution thereof.

In order to ensure long-term use and achieve greater impact of the project output, it is recommended that a non-commercial entity with a vested interest in irrigation water measurement, such as the South African Association for Water User Associations (SAAFWUA) be targeted as the primary partner of the project team to create a credible point of entry into the target group. This organisation should take ownership of the tools that have been developed – guidelines, implementation plan, project website and other promotional material – and promote it as wide as possible. If necessary, the tools should be aligned with the DWA regulations (once approved) and DWA regional office staff also targeted for capacity building.

The project approach should be one where partnerships are formed with other organisations such as the South African Irrigation Institute (SABI), the South African Committee on Irrigation and Drainage (SANCID), and meter manufacturers, to distribute the promotional material.

The project should also explore additional funding mechanisms that can be used to promote measurement technology. Options exist, such as the Technology Innovation Agency (TIA) which was established in terms of the TIA Act, 2008 (Act No. 26 of 2008) with the objective of stimulating and intensifying technological innovation in order to improve economic growth and the quality of life of all South Africans by developing and exploiting technological innovations.

Acknowledgements

The funding of this solicited research project by the Water Research Commission (WRC) is sincerely appreciated. The project was initiated by the WRC and was well-timed to address the needs of water users in South Africa.

Gratitude is also expressed towards the Department of Agriculture, Forestry and Fisheries, who provided additional funds for project application in 2011 and 2012.

The members of the Reference Group are thanked for their significant contributions towards this project. The Reference Group comprised the following members:

Dr GR Backeberg	:	Water Research Commission (Chairperson)
Dr AJ Sanewe	:	Water Research Commission
Ms MJ Gabriel	:	Department of Agriculture, Forestry and Fisheries
Ms P Mofokeng	:	Department of Agriculture, Forestry and Fisheries
Mr P Herbst	:	Department of Water Affairs
Mr J Fourie	:	Department of Water Affairs
Mr FB Reinders	:	ARC – Institute for Agricultural Engineering
Mr NE Knoetze	:	South African Association for Water User Associations
Mr P Joubert	:	Gamtoos Irrigation Board
Mrs AM Jansen van Vuuren	:	WSM Leshika Consulting

We would also like to personally acknowledge all those organisations and people who, in addition to the Reference Group members, assisted the project and made major contributions:

All the attendees at the workshops held with DWAF staff on 12 March 2008 and with industry stakeholders on 8 March 2012, for their valuable inputs and lively participation.

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- The Crocodile River Main Irrigation Board
- The Hereford Smallholder Irrigation Scheme
- Mr Danie de Wet, Orange-Riet Water User Association
- Mr Leonard Rakgotso, Thabina Smallholder Irrigation Scheme
- Messrs W du Toit and W Hickey, Water Management & Maintenance
- Messrs R Radley and J Vermaak, Malelane Irrigation Board

- Mr A Joubert from Joubert & Sons citrus farms
- Mr D van der Merwe, Datha Besproeiing
- Mr M Kolesky, Inkomati Catchment Management Agency
- Mr S Raath, PD Naidoo & Associates Consulting Engineers (Nelspruit)
- Mr S Brown, UIC Instrumentation (Pty) Ltd
- Messrs P Herbst, J Fourie and A Padi from the Department of Water Affairs
- Ms L Forster for keeping the minutes of reference group meetings and editing the deliverables and reports throughout the course of the project.

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List of Acronyms and Abbreviations

ACRU	Agricultural Catchments Research Unit Model
Agri SA	Agriculture South Africa: An agricultural trade association
ARC-IAE	Agricultural Research Council – Institute for Agricultural Engineering
CASP	Comprehensive Agricultural Support Programme
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
CRMIB	Crocodile River Major Irrigation Board
DAFF	Department of Agriculture Forestry and Fisheries (Post July 2009)
DoA	The Department of Agriculture (Pre July 2009)
DWA	The Department of Water and Environmental Affairs (Post July 2009)
DWAF	The Department of Water Affairs and Forestry (Pre July 2009)
ELU	Existing Lawful Use
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile communications
GWS	Government Water Scheme
IB	Irrigation Board
ICMA	Inkomati Catchment Management Agency
IO	Irrigation Organisition
KOBWA	Komati Basin Water Authority
KRIB	Komati River Irrigation Board
LDA	Limpopo Department of Agriculture
LRIB	Lomati River Irrigation Board
MIB	Malelane Irrigation Board
NAFU	National African Farmers Union
NO	National Office
NWA	National Water Act (Act No.36 of 1998)
NWRS	National Water Resource Strategy (2004)
ORWUA	Orange Riet Water User Association
PLC	Programmable Logic Controller
QDNR&M	Queensland Department of Natural Resources and Mines
RAP	Rapid Appraisal Process
RF	Radio Frequency
RO	Regional Office

SAAFWUA	South African Association of Water User Associations
SABI	The South African Irrigation Institute
SAMA	Steenkoppies Aquifer Management Authority
SAPWAT	A PC based procedure for the estimation of irrigation requirements of crops in Southern Africa
SMS	Short Message Service
SWB	Soil Water Balance (a PC based crop growth and irrigation requirement model)
VSD	Variable Speed Drive
WAMS	Water Allocation Management System
WAR	Water Allocation Reform
WARMS	Water Use Authorisation and Registration Management System
WAS	Water Administration System
WC/WDM	Water Conservation/Water Demand Management
WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plan
WRC	Water Research Commission
WRM	Water Resource Management
WUA	Water User Association
WUE	Water Use Efficiency

1. Introduction

This report presents the results of a technology transfer project initiated and funded by the Water Research Commission (WRC) and undertaken from April 2007 until September 2012. It follows on from the publication of the “Guidelines for Irrigation Water Measurement in Practice” published in 2005 by the WRC, and is aimed at facilitating the process towards effective implementation of water measurement at river, irrigation scheme and farm level in South Africa.

The National Water Act (NWA) (Act No. 36 of 1998) calls for efficient, sustainable and beneficial use of water in the public interest, which implies that effective water management must be done. The management cycle of water consists, if presented in a simplified format, of a continuous process of planning, allocation, operation, monitoring, analysis, and feedback.

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National water conservation and water demand management (WC/WDM) strategies have been developed in terms of the National Water Resource Strategy (NWRS) of 2004. The strategy for irrigated agriculture provides a framework of regulatory support and incentives to improve efficiency, with a plan of action towards achieving, amongst other things, the following goals:

- Implementation measures that reduce wastage
- Convincing users to progressively modernise their water conveyance infrastructure and irrigation equipment.The Water Conservation and Water Demand Management Conditions for Water Use Sector Authorisation (DWAF, 2006a)[2] imposes a duty to measure, record aspects of water use, and requires that the licensee shall measure the amount of water supplied to each farm or user on a monthly basis using an appropriate flow measurement device.

In preparation, the WRC has published reports and guidelines for the direct and indirect measurement of water on irrigation schemes to meet the practical need to measure and manage water effectively and efficiently (WRC Report No. TT 248/05 by Van der Stoep et al., and WRC Report No. 1190/1/04 by Du Plessis, 2004). However in most cases, the water management system in operation does not incentivise water measurement, and consequently measurement of water use and volumetric charging is not widely practised.

This project aimed to facilitate a process towards effective implementation of water measurement at river, irrigation scheme and farm level in South Africa. In order to achieve this, end users of water

[2] DWAF, Department of Water Affairs *and Forestry* (pre July 2009), and DWA (post July 2009)

measurement technology were made aware of and encouraged to adopt the technology. Specific attention was given to technical constraints and the financial justification for implementing the technologies for water measurement.

Purposeful capacity building and training of end users formed an important aspect of this work, using the successful model of "train-the-trainer" to achieve a common understanding of the practical requirements of water measurements by water users, water managers and regulators, with the support of Department of Agriculture Forestry and Fisheries (DAFF) and DWA. With Water User Associations (WUAs) playing an increasingly important advisory role, the managers of WUAs and leader farmers whom they serve were targeted for training. During the preparatory phase interaction took place with these stakeholders to practically illustrate how to implement effective water measurement.

The final output of this technology transfer project (WRC, 2008) is this report that documents the implementation process, the lessons learnt and guidelines towards general implementation of irrigation water measurement.

This project involved a survey of 90 irrigation organisations (IOs) across the country, as well as extensive field work at irrigation schemes to assess and evaluate the selection, installation and operation of measuring devices in the irrigation sector. The project was undertaken in three phases in accordance with the original project aims:

1. To interact with stakeholders as part of the preparatory phase, including:

    a) To engage with key Department of Water Affairs and Forestry (DWAF) officials on the topic of water measurement to ascertain DWAF's understanding, perceptions and requirements of water measurement.
    b) To analyse the requirements of the regulator (DWAF) for implementation of water measurement.
    c) To determine the current status and to synthesise the available knowledge on water measurement in practice at irrigation scheme level on a national basis with an appropriate survey technique through contact with DWAF Regional Offices (ROs), Agriculture South Africa (Agri SA), the National African Farmers Union (NAFU), WUAs and Irrigation Boards (IBs).
    d) To engage with selected representative WUAs/IBs at different levels of water management capability and to ascertain their understanding, perceptions and requirements of water measurement.
    e) Following on from objectives 1 c) and 1 d): to analyse the needs of water users in terms of water measurements for selected representative or case study areas.

2. To determine the incentives for water measurement as part of the analysis phase, including:

    a) To identify existing constraints hindering successful implementation of water measurement at different user levels (farm, WUA, catchment, DWAF) and functional levels (management, technical, data capturing, etc.).
    b) To identify and assess which constraints could not be changed and which constraints could be changed (technological, organisational), and to propose improvements or alternatives.
    c) To estimate the cost-benefit (financial, economic, social, environmental) of the alternatives under objective 2 b) and to formulate appropriate incentives from the perspective of the farmer, WUA and general public.
    d) To formulate key variables that would lead to financially viable water measurement and to design an implementation plan for the regulator and the water user for improvement of water measurement in practice with and without subsidies.

3. To practically demonstrate how to undertake effective water measurement in the implementation phase, including:

   a) To select suitable sites (WUAs/IBs/individual farmers at different levels of management capabilities, including smallholders) to co-operate with as part of pilot studies.
   b) To undertake a process to obtain buy-in of role players in the selected pilot study areas/sites for the implementation plan.
   c) To adapt the general implementation plan into specific implementation plans for the selected pilot studies.
   d) To implement, test, and adjust the guidelines for water measurement, considering at least the following aspects:

      - A reason for measuring ("trigger").
      - Acceptance and support by the water users.
      - Assessment of the current situation and planning the system.
      - Choosing appropriate systems.
      - Correct installation by skilled technicians.
      - Sound operation and maintenance policies.
      - A system for data retrieval and management.
      - Comprehensive financial planning, and
      - Procedures for handling disputes and tampering.

   e) To measure effectiveness of the guidelines for water measurements against set targets.

4. To document the implementation process and the lessons learnt and to refine the general implementation plan and the guidelines for water measurement.

5. To formulate exit strategies for the Project Team and continuation of the processes by the selected WUAs and farmers.

6. To disseminate knowledge on the lessons learnt in the pilot studies to a wider audience of WUA/IB water users.

The report consists of five parts, plus an introduction (Chapter 1) and a conclusion (Chapter 15):

- Part A: Setting the scene (Chapters 2, 3 and 4)

  Part A introduces the topic of irrigation water measurement, starting with the results of the survey done amongst IBs during the first year of the project period. It then discusses the proposed irrigation water measurement strategy that was developed for the Department of Water Affairs (DWA) in a process parallel to this project, and concludes by introducing the structure of the irrigation water measurement implementation plan developed during this project.

- Part B: Implementation guidelines (Chapters 5 to 8)

  This section of the report contains the implementation guidelines, which provide the supporting documentation for the implementation plan. It is structured according to the same headings as the plan, and provides background information and references to assist the person or organisation developing the plan. It is based on the previous WRC report on irrigation water measurement (Report No. TT 248/05) by Van der Stoep, Benadé, Smal & Reinders (2005).

- Part C: The implementation plan (Chapters 9 to 12)

This part of the report presents the general (generic) implementation plan that was developed during the project, which consists of three sections based on the logical steps to be taken during a period of implementation:

  - Measurement implementation planning
  - The measurement system
  - Implementing the plan

The generic plan or template can be customised and completed as a site specific implementation plan for irrigation water users in a specific area. It is based on the work undertaken and reported in the implementation phase of this project, and was adapted after field work was undertaken in the case study areas.

- Part D: Lessons learnt (Chapter 13)

This part of the report covers the work undertaken in selected case study areas, as well as other key areas that were included as case studies because of the contribution they made to the knowledge base, even though the project team did not work there during the project period. This section of the report forms the basis of the material used during the workshop and other technology transfer activities undertaken to address Project Objective 6.

- Part E: Awareness creation (Chapter 14)

This part of the report describes the technology transfer activities undertaken to promote the project outputs to a wider audience of interested parties, via workshops, radio and television interviews, the project website, and popular articles.

PART A: SETTING THE SCENE

2. The importance of measurement

Although attempts had been made since the 1980s to increase the use of water meters in the irrigation sector, it was the introduction of the NWA in 1998 that really opened the door to more widespread implementation of measurement.

The first recorded initiative concerning the formal implementation of irrigation water measurement in South Africa was completed in 1986. This was an investigation by the “Water Meter Committee” of DWAF, chaired by the Section Engineer for the Western Transvaal Region, CJ Kriek. The committee was created to address uncertainty amongst departmental officials on the selection and installation of water meters at government water schemes, as required by the Department of Environmental Affairs (Kriek, 1986).

The result of the investigation was a report recommending the use of mechanical flow meters for measurement of water abstraction from rivers in which the flow is regulated, for instance through releases from an upstream dam, as well as in rivers that normally flow fairly full (Kriek, 1986). The report also provided an overview of available equipment with guidelines for typical costs and installation practices.

The urgent need for economic growth, together with an alignment to global thinking regarding the sustainable use of natural resources, shaped the South African government’s policy towards water use in the early 1990s. This in turn led to the transformation of legislation dealing with water resources management, resulting in the promulgation of the NWA which replaced the previous Water Act (Act 54 of 1956).

The NWA provides two bases upon which measurement can be given effect:

a) According to Section 26 (b), the Minister may make regulations requiring that the use of water from a water resource be monitored, measured and recorded.

b) Section 29 (b)(ii) states that a responsible authority may attach conditions to every general authorisation or licence relating to water management by requiring the monitoring and analysis of and reporting on every water use and imposing a duty to measure and record aspects of water use, specifying the measuring and recording devices to be used.

Changes that have occurred in the water industry in South Africa in the last decade include the creation of new water management organisations such as the Catchment Management Agencies (CMAs) and the WUAs. One of the functions of a WUA, according to Schedule 5 of the NWA, is to supervise and regulate the distribution and use of water from a water resource according to the relevant water use entitlements, by erecting and maintaining devices for measuring, and dividing or controlling the diversion of the flow of water. It is a requirement that a WUA, through its constitution and business plan, should show how it makes progress towards measuring the quality and quantity of inflows and outflows, losses and water supplied to its customers, and towards the use of acceptable measuring devices or techniques (DWAF, 2004).

While Section 137 (1) of the NWA requires the Minister to establish national monitoring systems for water resources, Section 137 (2) (a) states that the systems must provide for the collection of appropriate data and information necessary to assess, among other things, the quantity of water in the various water resources. According to Section 141, the Minister may require in writing that any person must, within a reasonable given time or on a regular basis, provide DWA with any data, information, documents, samples or materials reasonably required for:

(a) the purposes of any national monitoring network or national information system; or

(b) the management and protection of water resources.

These tasks are impossible to perform without accurate measurement.

A change in law requires changes in approaches, both by those who are tasked with carrying out the law, and those who fall within its jurisdiction. Recognising the need in the agricultural water use sector for reliable information and guidance on the implementation of water measurement as a result of the new NWA, the WRC initiated a three-year research project in 2001. The project was awarded for implementation to the Department of Civil and Biosystems Engineering of the University of Pretoria (WRC Project No. K5/1265). The main objective of the project was to develop guidelines for the selection, installation and maintenance of water measurement devices by WUAs for canal, pipeline and river distribution systems. The original project period was extended by one year and the final project report entitled "Guidelines for irrigation water measurement in practice" was published by the WRC in 2005 (WRC Report No. TT 248/05).

The 2001-2005 project provided the project team with valuable insight into irrigation water measuring practices and problems. The wide network of useful contacts that was established during the initial field visits was maintained through the field and laboratory evaluations that took place over three years. It was found that each WUA's situation was unique, and in order to identify relevant measuring requirements, needed to be evaluated as such: No two WUAs can blindly use or apply the same devices or methods. Due to improvements since the 1980s, suitable technologies were found to be available, with failure more often than not linked to incorrect application (i.e. unsuitable for specific conditions), poor installation practices, or lack of maintenance, rather than to unreliability. It was clear that a greater awareness of the availability of suitable devices amongst WUAs was required, especially as far as new technological development was concerned. Furthermore, it was clear that there was an urgent need for water measuring policy to guide WUAs in selecting appropriate measuring devices and systems.

The main output of the 2001-2005 project were guidelines for the selection, installation and management of devices for irrigation water measurement, supported by a KBS (Knowledge Base System): a computer-based database of irrigation measuring devices and their characteristics, incorporating extensive search and sort functions. It was recommended that this information should be made as widely available to the WUAs and their members as possible, and accordingly, a 12 month consultation project funded by the WRC was undertaken from 2006 to 2007 to prepare the way for transferring the technology to the relevant stakeholders by determining the technology transfer needs of the target groups (WRC Report No. KV 247/10).

The 2006-2007 project presented a unique opportunity for the researchers to obtain an overview of the water measurement situation at grass roots level. It was found that awareness of the benefits of accurate measurement had increased amongst both DWAF officials and water users, but communication was poor, and there was a great deal of confusion regarding government policies. Therefore, whilst the 2001-2005 project was focused on the technical performance of measuring devices, the challenge had become one of implementation, with water users regarding the cost of measurement as the biggest constraint.

A third project was therefore initiated by the WRC, of which this is the final report. The project took place from 2007 to 2012 and was aimed specifically at recording instances of water measurement implementation according to the guidelines previously developed, as well as creating greater awareness amongst water users and other stakeholders. It ran in parallel with two supporting projects funded by DWA which influenced the WRC project outputs: a project aimed at developing a strategy for irrigation water measurement in the agricultural sector, which took place from 2007 to 2009, and a project that funded the implementation of irrigation water use measurement and the development of a water management plan for the Steenkoppies dolomitic compartment, which took place between 2008 and 2012. The WRC project team provided support to DWA on both these projects, leading to some of the results documented in this report.

This third WRC technology transfer project closely followed the implementation of water measurement at a number of case study areas, providing firsthand experience of the challenges faced by water users during implementation. It became quite clear that the active participation of all the identified role players is required for successful implementation of water measurement. From initial motivation (be it for legislative or business reasons), through the planning, procurement, installation, operation and maintenance stages, it is absolutely essential that the water users, government, the meter suppliers and other organisations take responsibility for the part they have to play in the implementation of water use measurement.

2.1. Baseline information gathering

The preparatory phase of this third WRC project on irrigation water measurement provided the project team with the opportunity to interact with various role players from the irrigation water use sector. In order to collect baseline information on the current status of irrigation water measurement in South Africa, a questionnaire was developed and sent out to 297 irrigation organisations (IOs), such as WUAs and IBs, from all 19 WMAs in the country. The questionnaire covered the following sections:

1. IO background.
2. Water source/s from which the water users have irrigation water allocations.
3. Quotas and scheduled areas (per source, per water year).
4. Water control infrastructure – Dam, river, canal and pipeline schemes.
5. Water control infrastructure – Groundwater schemes.
6. Water control infrastructure – On-farm dams.
7. Water quality.
8. WUA management.

The data was collected electronically by e-mail as far as possible, although mailed and faxed submissions were also received. A total of 73 completed questionnaires were returned.

The data was captured into an Excel spreadsheet for analysis, and is presented graphically in Appendix A. This chapter discusses the analysis of the data, undertaken during the analysis phase of the project.

2.2. Requirements of the role players

The water measurement implementation requirements of the two main groups of role players (the regulators and the water users) identified during the preparatory and analysis phases of this project are discussed below.

2.2.1. Requirements of the regulators

Representatives from the various DWA directorates, a number of ROs and IOs (IBs or WUAs), considered irrigation water measurement to be a tool that can assist them to:

Improve water use planning by providing more accurate data on which to base decisions.

Determine the Reserve more accurately based on actual data (quantity and quality).

Monitor compliance with the Reserve, once it has been determined.

Improve water allocation, if information is readily available on how much water is used and how much therefore still allocable.

Set conditions for and issue licenses more rapidly, as information will be more readily available (assuming an effective data management system is in place).

Review licenses (and compliance with license conditions) more easily against records of water use.

Improve operations by releasing water more accurately based on real-time data.

Improve water use efficiency (WUE) in terms of determining the non-beneficial and non-recoverable water use fractions more accurately.

Audit the implementation of Water Allocation Reform (WAR) policy by assessing whether the targeted user groups are receiving the water that has been allocated to them.

Obtain information about water resources status and trends.

Assess water resources on a national basis, since more information on resource status and consumption trends will be available.

Implement a volumetric billing system in stressed catchments using records of actual use.

Improve infrastructure maintenance and management using available information on the efficiency of water distribution infrastructure.

2.2.2. The water users

Information provided by the water users indicated that the implementation of measurement could address some of their water management needs in the following ways:

- Volumetric allocations could be implemented and monitored more effectively, especially in areas where water trading takes place.
- Irrigation scheme managers felt that better water service delivery could be achieved, in terms of both the right amount and the right time of delivery to their members.
- Better control over water conveyance and abstraction can be achieved.
- Water losses in conveyance infrastructure can be reduced.
- Telemetry systems could be installed to make water management easier, if measurement systems were in place.
- Water management plans (WMPs) could be implemented and reporting done more easily if more information on actual use was available from measuring devices.

2.3. Constraints hindering implementation

The regulators and the water users identified the following constraints hindering successful implementation of irrigation water use measurement:

- An incomplete and inaccurate register of water users and points of use, making implementation of water measurement and enforcement of allocations difficult.
- Lack of useful benchmarks against which to judge the actual use figures, should measurement be implemented, due to inaccurate water use registrations captured in the Water Use Authorisation and Registration Management System (WARMS) data base.

- Relatively low cost of water, combined with a history of flat rate billing leading to uneconomic water use and a lack of consideration for WUE.
- Fragmented and ambiguous organisational arrangements for water management across the country. Dissimilar management structures apply to water users, making uniform implementation of a strategy by the regulator very difficult.
- A shortage of skilled staff at various levels in the water management hierarchies, from hands-on technical level (for installations, etc.) up to management level (to develop WMPs, etc.).
- A lack of a standardised approach across Water Management Areas (WMAs) and well as within them, when advice is given regarding what measuring device should be installed where, and by whom.
- The remoteness of locations where measurement must take place, both in terms of the management of the measurement locations as well as actually getting devices installed.
- Lack of guidance on the type of device that is acceptable to the regulator for monitoring water use, if required for the purposes of compliance monitoring.
- Lack of guidance on operational practices for water measuring devices in terms of a standardised approach to data collection methods and data storage formats.
- Little information on funding options for implementation, e.g. possible rebates from DWA or partners (such as Eskom) that can be approached for financial assistance.
- Poor communication between IOs and DWA regarding aspects such as resource management and the application of water resource management (WRM) levies
- Confusion regarding organisational issues amongst the water users, such as the establishment of WUAs and CMAs, and the roles and responsibilities of these organisations (in general, but especially regarding water measurement).
- Inequality in policy application: any policy on water measurement should be fair, and applicable to all raw water users. Other sectors (mining and domestic were named specifically) are reputed to use water and manage resources indiscriminately, especially where water quality is concerned. This causes major problems for agricultural water use for food production.
- Socio-political issues: many farms are subject to land claims which need to be finalised before major investment in management infrastructure can be made. New farmers should also comply with water use conditions and cannot be exempted.

Many of these constraints refer to challenges in water management in general, and not to water measurement specifically. They do however represent some of the obstacles to successful measurement implementation. If the social, political, organisational and environmental issues are not addressed, technical solutions cannot be implemented successfully, no matter how technologically appropriate or advanced they are.

2.4. A strategic approach to addressing the issue of measurement

The constraints listed above were synthesised into the following seven issues that form the basis of the analysis phase of this project:

1. When should measurement of irrigation water use be implemented?
2. What are the organisational arrangements regarding measurement?
3. Where should measuring devices be installed?
4. What measuring devices should be used and how should they be installed?

5. How should the measuring devices be operated?
6. Where is information on funding and incentives available?
7. What is the process of implementation to address the above issues?

These are the issues on which role players sought clarification, and which need to be addressed through a water measurement strategy. However, the majority of the respondents were of the opinion that measurement can be a useful tool for water management, and should be implemented in the irrigation sector. There had been a definite change in attitude towards measurement in the sector since the first WRC project on the topic was undertaken from 2001 to 2005. The question to be addressed had now become *how* rather than *whether* water measurement should be implemented in the irrigation sector.

The seven issues listed above are discussed in the following chapters.

3. A water measurement strategy for South Africa

South Africa has limited water resources and an urgent need for economic growth. This, together with an alignment to global thinking regarding the sustainable use of natural resources, shaped the South African government's policy towards water use in the early 1990s. This in turn led to the transformation of legislation dealing with water resources management, resulting in the promulgation of the NWA.

This legislative change requires changes in approach from those tasked with carrying out the law, as well as those falling within its jurisdiction. New strategies are needed, and the means by which these strategies are to be implemented needs to be formalised, to ensure a fair, equitable, transparent and uniform approach.

In order to guide the policy makers in decision-making on issues regarding water measurement in the agricultural water use sector, the seven points identified in the previous chapter are discussed here in more detail.

3.1. Triggers for measurement of irrigation water use

The cost and effort involved with the implementation of water measurement in the irrigation sector raises a number of concerns about the practicality of across-the-board application, regardless of the situation at a specific IO or area. The NWA provides two bases upon which measurement can be given effect:

a) According to Section 26 (b) the Minister may make regulations requiring that the use of water from a water resource be monitored, measured and recorded.

b) Section 29 (b)(ii) states that a responsible authority may attach conditions to every general authorisation or license relating to water management by requiring the monitoring and analysis of and reporting on every water use and imposing a duty to measure and record aspects of water use, specifying measuring and recording devices to be used.

In addition to these legislative requirements, there may also be other conditions or "triggers" that determine when measurement should or must be implemented. A "trigger" is a clearly identified and defined situation or circumstance that requires the immediate implementation of an irrigation water use measurement strategy: in other words, the installation of meters, according to levels of responsibility and measurement opportunities which are outlined later in this report.

The specific trigger for irrigation water use measurement is likely to determine not only the timing, but also the intensity and sophistication of the measuring programme to be implemented, as well as the specifications and acceptable costs of the measuring devices themselves

Examples of triggers include:

- Catchment stress or over-allocation: Increased user demand on a water resource, requiring irrigation water use losses to be quantified and reduced through WC/WDM.
- Implementation of the Reserve.
- Compulsory licensing.
- WAR: The need to more equitably allocate water resources to effect redress and increase the beneficial use of water.
- The need to recover the costs of new or refurbished infrastructure.
- Prolific illegal water use in a catchment.

- The need for increased on-farm WUE to improve profitability.
- The requirement for accurate irrigation water use measurement as a tool for dispute resolution amongst water users.
- The growth of water trading, taking place between different users and requiring accurate measurement of the volumes traded.
- The need to monitor and enforce license conditions and/or restrictions.

Measurement of irrigation water use should however be seen as a tool in the water manager's toolbox to solve specific management problems, rather than as a general solution to all water management problems. It should also be kept in mind that the implementation of measurement brings with it a considerable additional amount of information management: data have to be collected from the measuring devices, processed and distributed in a useful format to the relevant stakeholders in order for measurement to be effective, while devices should be maintained in good working order. If there is not an urgent need for measurement to be implemented, and a clear use for the data that will be generated, other possible solutions or tools should be considered that may be less time consuming and costly to implement. If measurement is selected as the appropriate solution, care should be taken with the implementation process to increase the chances of success.

3.2. Organisational arrangements regarding measurement

In order to address the various organisational constraints identified by the regulator and the water users, there is a clear need to define those organisations or persons responsible for implementing irrigation water measurement, and to outline their responsibilities.

3.2.1. Role players

The parties involved with irrigation water use measurement in the agricultural sector include bodies and organisations who manage (supply or regulate) agricultural irrigation water, organisations and individuals who use it, and bodies and organisations who provide support:

- DWA National Office (NO).
- DWA ROs or CMAs.
- IOs such as WUAs, IBs, and Government Water Schemes (GWSs).
- End users, i.e. irrigation farmers.
- Supporting organisations such as DAFF and its provincial departments

3.2.2. Responsibility levels

The roles played by the parties are shaped by, and can be described in terms of four regulatory management Responsibility Levels as shown in **Figure 1**:

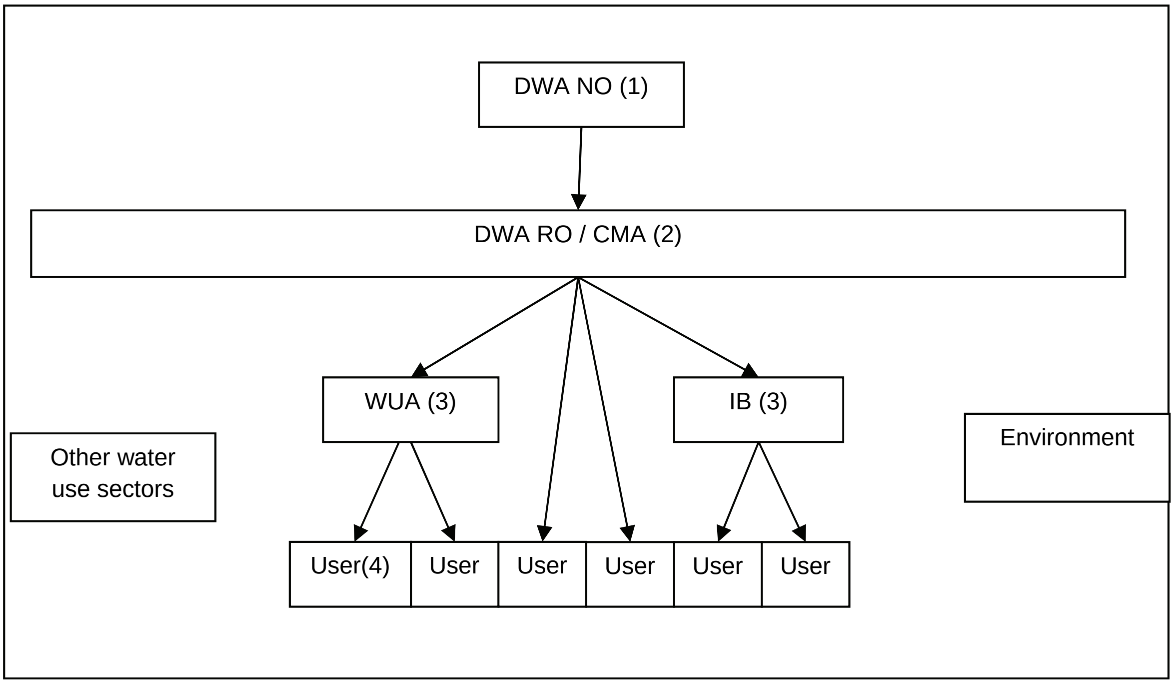


Figure 1: Levels of management responsibility of parties involved with irrigation water use measurement

- Level 1: management responsibilities of the custodian, i.e. DWA NO.
- Level 2: management responsibilities at WMA level, i.e. DWA RO or CMA.
- Level 3: management responsibilities of IOs such as WUAs, IBs, and GWSs.
- Level 4: management responsibilities of end users, i.e. irrigation farmers.

Responsibility Levels 1, 2 and 3 correspond to the first, second and third tiers of water management institutions as provided for in the NWA.

3.3. Selecting locations for measuring device installation

The Responsibility Levels identified above give rise to five opportunities for water use measurement:

- Opportunity 1: Where water management functions are within the domain of DWA NO and/or DWA RO/CMAs (e.g. measurement at major dams and in DWA-managed river/canal/groundwater systems).
- Opportunity 2: Where water enters the domain of IOs (e.g. measurement at the point of bulk supply to the WUA).
- Opportunity 3: Where water enters the domain of the end user (e.g. measurement at the point of supply to the end users).
- Opportunity 4: Where water is within the domain of IOs (e.g. water measurement at various points, typically on-scheme, for management and efficiency purposes).
- Opportunity 5: Where water is within the domain of the agricultural irrigation water user (e.g. water measurement at various points, typically on-farm, for management and efficiency purposes).

Table 1 summarises the Responsibility Levels and opportunities for measurement.

Table 1: Responsibility levels and opportunities for measurement

Responsibility Level	Measurement opportunity
1 (NO)	Opportunity 1 (dams/rivers/aquifers)
2 (RO/CMA)	Opportunity 1 (dams/rivers/aquifers) Opportunity 2 (IO entrance) Opportunity 3 (user entrance)
3 (IO)	Opportunity 3 (user entrance) Opportunity 4 (IO domain efficiency)
4 (User)	Opportunity 5 (on-farm efficiency)

Thus:

- Opportunity 1 measurements can be done by Level 1 and 2 organisations.
- Opportunity 2 measurements can be done by Level 2 or Level 3 organisations.
- Opportunity 3 measurements can be done by Level 2, 3 or 4 organisations/users.
- Opportunity 4 measurements can only be done by Level 3 organisations.
- Opportunity 5 measurements can only be done by Level 4 users.

Measurement opportunities 1, 2, and 3 are a basic requirement in terms of national WRM, whilst measurement opportunities 4 and 5 allow for improved on-scheme and on-farm WUE through loss control and volume management.

3.4. Measuring device selection, installation and maintenance

The recent and useful information in WRC Report TT248/05 was used as a basis to address the constraints regarding the type of devices that should be used and how they should be installed.

3.4.1. Definition of a measuring device

For the purpose of this report a “measuring device” is understood to comprise a combination of two distinct sub-units: a primary sub-unit that interacts with the water, and a secondary sub-unit that translates the interaction into flow quantities (volumes or weights) or discharge rates (quantity per unit time), in either open or closed conduits. For the purposes of this Report, the application of this definition will be limited to the flow of water. Furthermore, the signal could be either electronic or mechanical.

Measurement devices should cover the following applications:

- River flow, taking into consideration low and high flows, environmentally sensitive and/or remote locations.
- Pipe flow, taking into consideration whether it is a gravity or pumped pipeline, pipe size and material, etc.
- Canal flow taking into consideration type of lining, capacity, slope, and location.
- Water levels, taking into consideration the measurement depth and location of the measuring point, etc.

3.4.2. Device selection

The selection of an appropriate measuring device for a particular installation will depend on how the characteristics of the available devices satisfy the requirements set by the responsible authority identified during a situation assessment. In general, these requirements will meet the following needs:

- The device performs certain functions (according to/defined by its specifications).
- The device performs to a certain standard.
- The device is the most affordable solution that satisfies the first two needs.

The appropriate device will therefore constitute the most economical option to provide the type of information required, at the specified level of accuracy, to meet the practical needs and any other standards set by the responsible authority, i.e. the IO, the CMA, or DWA.

The responsible authority should set standards to be met by the envisaged measuring devices, and assess the existing infrastructure accordingly. These standards should also be acceptable to the CMA and/or DWA. Different standards may need to be set for different measurement opportunities.

3.4.3. Installation

The responsible authority should take responsibility for the correct installation, operation and maintenance of water use measuring devices. The measuring device should be installed according to the manufacturer's recommendations, and its measurement accuracy verified by an independent party after installation. Each installation should be signed off by the responsible authority after it has been completed and verified. The performance of all measuring devices should be verified in situ after installation by an independent authority and certified (signed off) for use.

3.4.4. Maintenance

The responsible authority should ensure that all measuring devices are maintained as recommended by the manufacturers. Provision should be made annually for replacement of outdated or unreliable equipment.

3.5. Operation of measuring devices

The operation of measuring devices is probably the most complex yet important aspect of the measurement implementation process. Data will need to be retrieved from a variety of situations, in differing formats, and reported to different authorities for a number of purposes. The interval and format for data collection will be determined by the purpose for which it is required. Further input on this aspect is required from different role players such as the Directorate: Water Resources Information Management and CMAs. ROs or CMAs may even want to set their own specifications for data submissions across a WMA.

The different levels of responsible authorities have different reasons for accessing irrigation water use data. For example, while a NO directorate may be satisfied by receiving an annual report on actual water used by a registered user, whilst a WUA that operates a canal system might want to access updated water use data at least weekly in order to be able to monitor and control consumption, and to plan releases.

Additionally, the data has to be compatible with different computer programs which are already in use, the most significant of which are the WARMS at levels 1 and 2, and the Water Administration System (WAS) at Levels 2 and 3.

The following data management structure is proposed:

- Data collection of weekly (or an interval as set by the CMA) water use by registered water users should be the responsibility of Level 3 organisations (including ROs/CMAs that act as Level 3 organisations); records should be stored in the WAS, and reported monthly in a format compatible with WARMS, to the Level 2 organisation directly above it, as well as weekly to the registered water users within its area. Weekly water use records should be stored for a minimum of 5 years and then archived by the Level 3 organisation. Level 3 and 4 measurement data should be captured and managed through WAS.
- Data collection of monthly water use as collected by the Level 3 organisations should be the responsibility of Level 2 organisations; records should be stored in the WARMS at the RO/CMA, and reported annually to DWA NO (Level 1).

3.6. Information on funding and incentives

3.6.1. Cost components of a measurement system

Irrigation water use measurement implementation costs include:

The cost of a feasibility study for the proposed measurement implementation area.

The capital cost of implementation, including purchasing, installation, in-situ verification, certification and development of organisation-specific operational policies.

The operating and maintenance costs – for maintenance, reading and administration costs. (Maintenance charges should be sufficient to ensure continuity of service).

3.6.2. Perceived benefits

The following are some of the potential benefits of measurement implementation to the different water management levels.

3.6.2.1 Level 1: DWA NO

Various Directorates within DWA will benefit from readily available, good quality irrigation water use data, as described in Chapter 2.

3.6.2.2 Level 2: DWA ROs/CMAs or Bulk suppliers

The expected benefits of irrigation water use measurement to Level 2 role players such as DWA RO/CMAs are likely to include:

Better quality irrigation water use data.

Fair irrigation water use allocation, with fewer disputes.

Billing for actual use rather than for the quota available.

Better irrigation water use control within the WMA.

Ability to provide better quality agricultural irrigation water use information to DWA.

3.6.2.3 Level 3: IOs/responsible water authorities

The benefits to IOs of irrigation water use measurement may include:

Better control over water allocations.

Better management of infrastructure.

Early warning of deteriorating infrastructure through detection of losses.

Possibility of trading surplus water.

Accurate billing of users for actual volume of water used.

3.6.2.4 Level 4: Irrigation water users in the agricultural sector

- The benefits that an irrigation water user may enjoy due to effective measurement include:
- Equitable allocation.
- Better awareness of the actual amount of water used.
- Greater security of supply.
- Early awareness that they may exceed their allocation, allowing time to buy or "rent" additional water.
- Opportunities to increase production and income.
- Opportunities to sell un-utilised allocations.
- Reduced water charges if their full quota is not utilised (if charges are levied on actual use and not full quota).
- Early warning of deteriorating on-farm infrastructure, (such as leaks in pipes, pump efficiency and nozzle wear) through loss detection or unexplained increase in water use.
- More effective and efficient use of fertilisers and other farming inputs administered through irrigation infrastructure.

3.6.3. The business case for irrigators to install water meters

3.6.3.1 Background

Reference has been made to a "trigger" for water meters to be installed. The triggers can in principle be grouped into two categories, i.e. triggered by:

- Legislation "push" forces, and/or
- Market "pull" forces.

From recent feedback from DWA on the regulations around water use monitoring, it seems that water meters per se will not necessarily be mandated, but rather the putting in place of water use monitoring steps by the irrigator. For example, an irrigator could record the pumping hours and details of the irrigation pump, from which irrigation volumes and rates can be calculated. The physical recording of pumping hours may be a tedious task: however, installing a water meter with a datalogger would enable the irrigator to comply with the legislative requirement, while at the same time providing very valuable information to help improve or maintain profits.

This section focuses on the "market pull" forces. The term "market pull" suggests that willing people want or need water meters, as opposed to being forced ("pushed") into installing them. An analysis of the irrigation business environment in South Africa suggests that there significant market pull forces which are making it not only viable, but virtually essential for irrigators to install water meters.

The dominant pull forces which can trigger the use of water meters by irrigators relate largely to:

- The potential to make more profit, and/or
- The potential to help improve the convenience to the farmer.

Whilst the profit argument is readily understandable, as most commercial farmers will want to reduce costs and increase profits where possible, the term "convenience" requires further discussion: an irrigator may adopt management practices that make farming operations more convenient, without necessarily improving profits. For example, the automation of certain tasks may cost the irrigator significant sums of money, and may not necessarily yield increased profits, but may be very attractive to the irrigator it improves the convenience of the irrigator.

Water meters can help to improve and/or protect profits, as discussed in the following sections.

Emerging trends suggest that:

- Water meters are becoming increasingly important, as they provide irrigators with vital information (often with other sets of complementary information) to help improve or protect profits, and
- Water meters and associated technologies and products are offering information to irrigators in a convenient, affordable and reliable format.

3.6.3.2 Water meters and farm profits

The costs of the water meters is easily quantified, as discussed in more detail elsewhere in this report: The capital cost of a R15 000 to R30 000 meter is insignificant compared with the capital costs of the pumps, pipes, filters and other components that comprise the irrigation system, while the maintenance costs are also modest.

It is more difficult to quantify the benefits of metering as clearly as the costs; however, water meters can and do offer significant value to certain irrigators in South Africa. Furthermore, the trend is that over time the benefit of water meters will extend to many other irrigators, and given this fact, it is in the interests of irrigators to invest in water meters sooner rather than later.

Key profit related considerations in the South African context include the rapid rise in electricity costs, and the threat of curtailments to existing lawful water use in over-allocated catchments.

The rise in electricity prices, often at well above the rate of inflation, is a very clear emerging trend, both in South Africa and internationally. In South Africa the electricity price increase exceeds 25% per annum, whereas the inflation rate is less than 10% per annum. This is a very important consideration to irrigators, for the following reasons:

- South Africa is currently experiencing an energy crisis, and new energy-producing infrastructure is being planned. Eskom is dramatically increasing its electricity cost to customers in an attempt to recover funds to help pay for the new infrastructure, and also to help curb the growing demand for electricity by end users. Electricity prices will continue to rise into the foreseeable future in South Africa. Irrigators need to give increasing attention to managing this growing cost.
- The electricity costs of pumping are often the dominant water related costs faced by irrigators, as the water use charge (payment for the water) is often a fraction of the cost of pumping the water onto fields. Indeed, the electricity cost is often in the order of 5 to 10% of the farm costs, and is rising rapidly relative to the other costs. Irrigators need to think long and hard as to how to improve irrigation efficiency from an energy perspective: there is a direct correlation with water use.

Many of the irrigation systems currently in use in South Africa were designed and installed 10 to 30 years ago, during a period when South Africa had some of the cheapest electricity in the world. The result was that systems were not designed to be energy-efficient, as the electricity charge was not as large a consideration as it is now. Even irrigators with newer, intrinsically more efficient irrigation systems need to take appropriate actions to curb their rising electricity consumption.

Assuming that the correct amount of water is being applied according to an appropriate irrigation schedule as required by the crop, the options available to the irrigator to contain or reduce their rising electricity costs include variations of the following:

- To change the irrigation hardware to be more energy efficient. For example, pump stations can be optimised or larger diameter pipes can be used in mainlines, to reduce the power requirement of the system. This option has large capital cost implications, and the payback period of such investments should be calculated in order to assess the feasibility of implementation. Water meters and pressure gauges are essential monitoring equipment for system optimisation.
- To change the irrigation management (scheduling) for profit maximisation where:
    - Too much water is being applied, resulting in sub-optimal net farm return and profit. Here, it will be in the interests of the irrigator to reduce irrigation and/or to improve the pattern of irrigation. This may help to bring down the irrigation electricity cost in cases where the irrigator is unable to utilise the saved water on other fields currently not irrigated. Where the irrigator is able to utilise the saved water on other lands, it may be that the increased profits can be attained even if the electricity bill is not reduced (due to the extra crop yields obtained on these irrigated lands).
    - Too little water is being applied. Here, it may be in the financial interest of the irrigator to increase irrigation (assuming that the irrigator is using less than their water use entitlement). The increased electricity pumping costs may be exceeded by the financial return generated from the increased crop yield.
    - Either way, a water meter will be of great benefit to check actual water applications against the planned amounts.
- To change the timing of irrigation so as to use the pump less in peak electricity periods and reduce the electricity bill in this way. The installation of a water meter is not an absolute requirement in this price mitigation strategy but if installed and fitted with a datalogger, information on the water usage pattern of the farmer can be obtained. This option may be restricted by the on-farm irrigation hardware or on-scheme water supply system.

Determining the financially optimal level of irrigation may not be a straightforward task: if too little water is applied, profits may be lost due to crops yielding less than their full potential. If too much water is applied, then water is wasted through evaporation or percolation past the crop roots; crop yield or quality many be negatively affected; and electricity is also wasted. With the cost of electricity rising, more pressure is going to be placed on irrigators to find the optimal amount and pattern. The optimal irrigation amount is of course dependent on the net financial return, and NOT the maximum crop yield.

A financial decision-support system is required to help identify the optimal irrigation amount and pattern. This financial support system requires a sound understanding of the crop yield response to irrigation, and of the costs associated with irrigation including electricity cost. Crop growth models have been developed and are continually refined over time. The WRC has sponsored the development of a number of crop models, including SAPWAT, (a PC based procedure for the estimation of irrigation requirements of crops in Southern Africa), SWB (a PC based crop growth and irrigation requirement model) and the irrigation module in Agricultural Catchments Research Unit Model (ACRU). The models simulate crop yields in response to bioclimatic conditions, as well as rainfall received and irrigation applied, while the cost of irrigation has been structured in the IrriCost model (Irrigation cost estimation procedures for different irrigation systems).

This provides the link with water meters, which are able to provide details of irrigation water application. This information can then be fed into the hydro-financial irrigation models in order to help irrigators identify the optimal irrigation amount and pattern.

There is a strong correlation between water use and electricity usage. Rising electricity prices therefore provide a “trigger” for the implementation of irrigation water use measurement by putting pressure on irrigators to assess ways of improving the efficiency of their energy usage. There is a growing need for irrigators to not only calculate the optimal level of irrigation (including the pattern of irrigation over time), but also how best to apply the water so as to be energy efficient. Water meters have a significant role to play in this regard.

3.6.3.3 Convenience

Emerging trends show that there are a number of technologies which offer increased information and decision support to irrigators, making water use management more convenient and accurate. These include:

- Cell phone technology
- The internet
- Advances in computer codes and processing
- Advances in weather forecasting
- Advances in satellite and other remotely sensed data related to crop growth and soil water content

Irrigators are in effect being forced to make better irrigation decisions, particularly from a water and energy use point of view. Irrigation-related decision support may not be straight forward, as there are many things to consider.

The internet in particular is a platform through which decision support can be offered to irrigators in a cost effective way. Cellular network geographic coverage is broadening every year, with platforms allowing both data and voice to be transmitted: the transmission of data by cell phone can be very cost effective. Data from loggers attached to water meters, soil water content probes and other forms of instrumentation can be transmitted via the cellular network and utilised by either computer-based systems based on the internet cloud, or physically downloaded onto computers in homes or offices. Quick, reliable and accurate access to data from the water meters makes it very easy and convenient for irrigators to monitor water use, and more, at any given point in time with respect to irrigation.

Consultants with expertise in hydro-financial modeling can utilise the data from observed water use, soil moisture conditions, weather forecasts, crop prices, satellite imagery of field biomass and more to help provide real-time advice on irrigation scheduling.

The trend is such that satellite images will become more frequently updated, at higher resolution and more cost effective. As more water meters and loggers are installed, prices are likely to come down and/or the accuracy, reliability and cost effectiveness of maintenance will improve.

3.6.4. Conclusion

An analysis of trends in irrigation suggests that due to rising electricity costs there is a growing need for irrigators to consider more energy efficient irrigation options. Energy usage is strongly correlated to water usage. The financial returns to an irrigator are in turn strongly correlated with the volume and pattern of irrigation water application. The water scarcity situation in South Africa may result in some irrigators being restricted, which will result in them making do with less water.

The net result is that there are significant pressures on irrigators to improve their irrigation practices. Decision support services may be required. Water meters thus have a role to play in helping irrigators remain financially viable. New technologies and support services are emerging, largely supported by the internet platform which can assist irrigators with making improved decisions in a convenient and cost effective manner.

The installation of water meters with loggers will also assist irrigators to comply with legislation in a manner that is more convenient than having to manually record pumping hours and other sets of information that would otherwise be required.

4. Towards implementation of the water measurement strategy

4.1. Proposed Regulations

DWA is in the process of developing regulations with regard to the measurement of water in the irrigation sector. Entitled "*Proposed regulations requiring the taking of water from a water resource for irrigation purposes be limited, monitored, measured and recorded*", the latest version of the document outlines a process to monitor water use by irrigation farmers using remote sensing applications as a starting point, with direct measurement of water only recommended as a final solution in the case of confirmed transgressors. The regulations are still under development, with an extended stakeholder engagement process still to take place before being introduced into practice. The draft regulations that were circulated for comment in July 2012 are attached as Appendix B.

These Regulations propose that (1) the flow rate at which water can be abstracted should be limited according to quaternary drainage regions, (2) the responsible authority may direct a water user to install a water measuring device, and (3) the responsible authority can install a temporary measuring device.

The flow rates in litres per second per field hectare as provided in the document are calculated on a total irrigation time of 120 hours per week. They must be calculated for any other irrigation time by dividing 120 hours per week by the water user's actual irrigation hours per week, and multiplying the result by a value given as the volumetric limit on daily abstraction per hectare. The total volume of water abstracted from a water resource may not exceed the authorised volume during any relevant period of time. It is however not clear how these limits are aligned with current lawful abstractions according to existing lawful use or licenses applicable in different areas of the country.

The proposed Regulations require water use to be "accurately monitored by a water measuring device or method". The responsible authority may, where there is no acceptable water measuring device or method being applied, direct that a water measuring device be installed or a method be applied by the water user within three months of receiving a written directive by the responsible authority to do so. Alternatively the responsible authority may itself install a temporary water measuring device to monitor the water use, in order to ascertain whether it is within the parameters as specified. If the responsible authority is of the opinion that a water measuring device or method is not monitoring the water use accurately, it may direct the water user to limit their abstraction volume, rate, time or irrigated area, until an appropriate water measuring device is installed or method applied.

Where a water measuring device is to be installed, the device must be approved by the responsible authority, and operated and maintained in accordance with the operational requirements of the supplier in order to accurately record the water use data, and must be calibrated at least once every five years, or when the water user is instructed to do so by the responsible authority or other party acceptable to the responsible authority. Certified proof of the calibration must be submitted upon request.

Where a water measuring method is to be applied, the water user must obtain prior written approval from the responsible authority to ensure that the method to be used complies with the specified tolerances.

The measurement data acquired must be recorded on official DWA forms, or on forms approved by the responsible authority and submitted as requested.

Any person who contravenes or fails to comply with any provision of these Regulations is guilty of an offence and is liable on conviction to a fine or imprisonment not exceeding a period of five years.

4.2. The implementation process

In order to support the proposed DWA regulations, a structure and procedures for the implementation of irrigation water use measurement is also put forward as part of this report. This includes locating responsibility for decision-making, and describing the steps to be taken once implementation is initiated by one of the triggers discussed in Chapter 3.

Figure 2 summarises these aspects.

The effectiveness of irrigation water use measurement implementation should be critically evaluated following the completion of projects. Evaluation and performance measurement should occur through a range of qualitative and quantitative activities such as surveys of licence holders and RO staff to assess the impact of new measuring device roll-out processes, as well as the assessment of:

- Meter maintenance contracts.
- Reliability of data collection processes.
- Compliance statistics.
- Effectiveness of billing processes.
- Meter examiner statistics.

Performance measurement results should be used to review pilot irrigation water use projects prior to full implementation in subsequent catchment areas. Ongoing performance evaluation of irrigation water use measurement results against performance benchmarks and criteria should occur in all implementation areas.

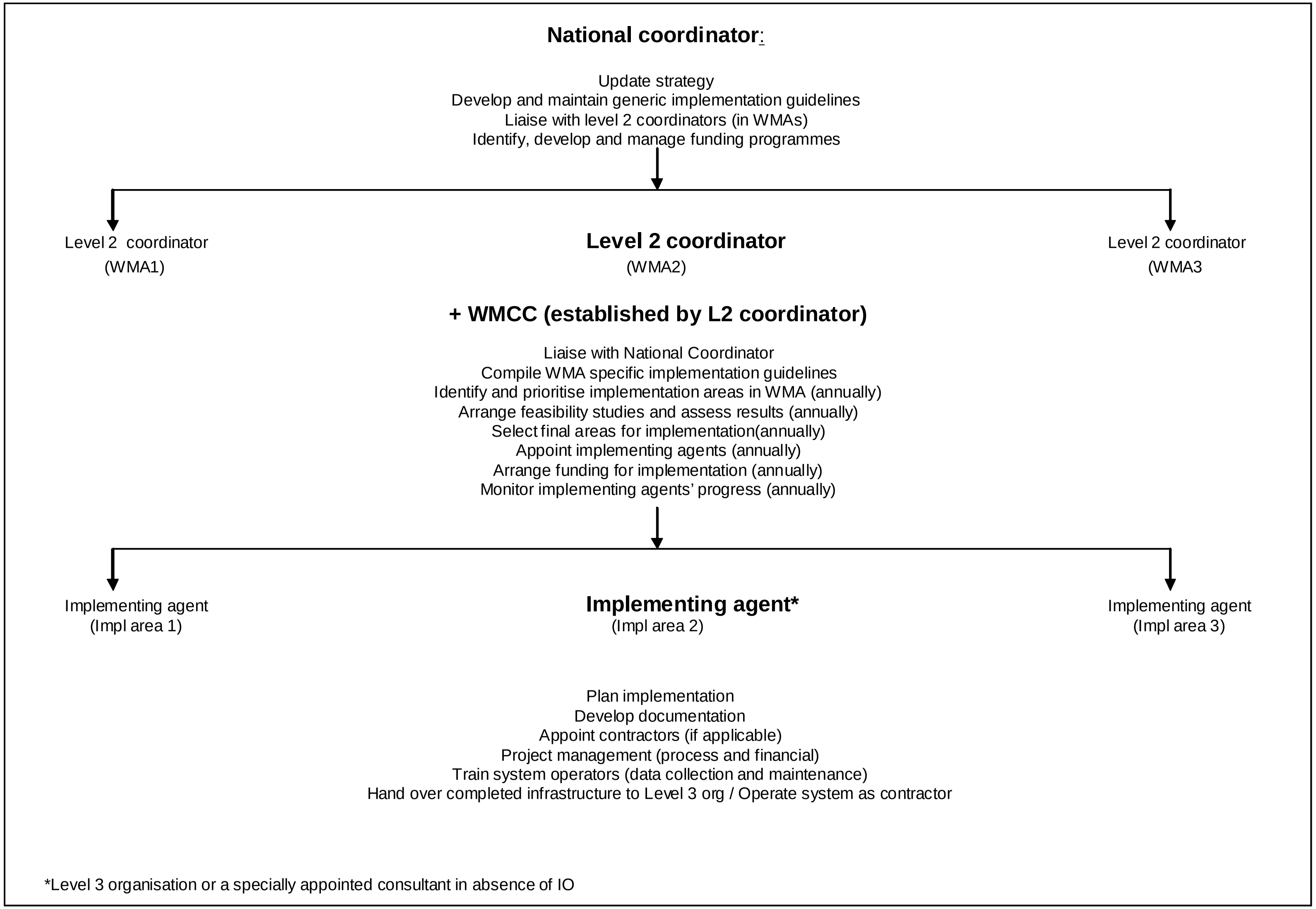


Figure 2: The implementation process

PART B: THE IMPLEMENTATION GUIDELINES

5. Introduction to the implementation guidelines

Changes that have taken place in South Africa with regard to water legislation since the first water meter committee led by CJ Kriek concluded its work in the 1980s, include improved access to information and technologies over the past two decades which are making it more likely that irrigation water measurement will be implemented successfully.

No two WUAs are likely to follow the same route, but the approach to be taken should show that the WUA makes progress towards measuring the quantity of inflows and outflows, losses and water supplied to its customers, and towards the use of acceptable measuring devices or techniques, as required by the Water Conservation and Demand Management Strategy (DWAF, 2000). Actual water measurement and even automation of measurements is the goal: however, the use of crop water requirements may be a manageable and achievable intermediate step to estimate water use, particularly as a seasonal planning figure for the WUA's water management.

More suitable, better adapted devices have become available, but in order for them to be used successfully, they need be installed correctly, well maintained, and read accurately. In order to achieve this, a WUA's water measuring system has to be planned and managed. This approach of managed implementation consists of the steps as shown in Figure 3.

If this approach is followed, it is more likely that measurement solutions will be found that are acceptable, affordable and sustainable for a specific WUA. It is therefore according to this structure that water measuring implementation will be discussed in this report.

The guidelines that are presented here are aimed at providing supporting information when compiling an implementation plan. They are based on the guidelines published in TT 248/05 (Van der Stoep, Benadé, Smal & Reinders, 2005) and have been adapted to match the structure of the implementation plan. The guidelines should be read and used in conjunction with TT248/05 and cross-references to the relevant chapters are provided.

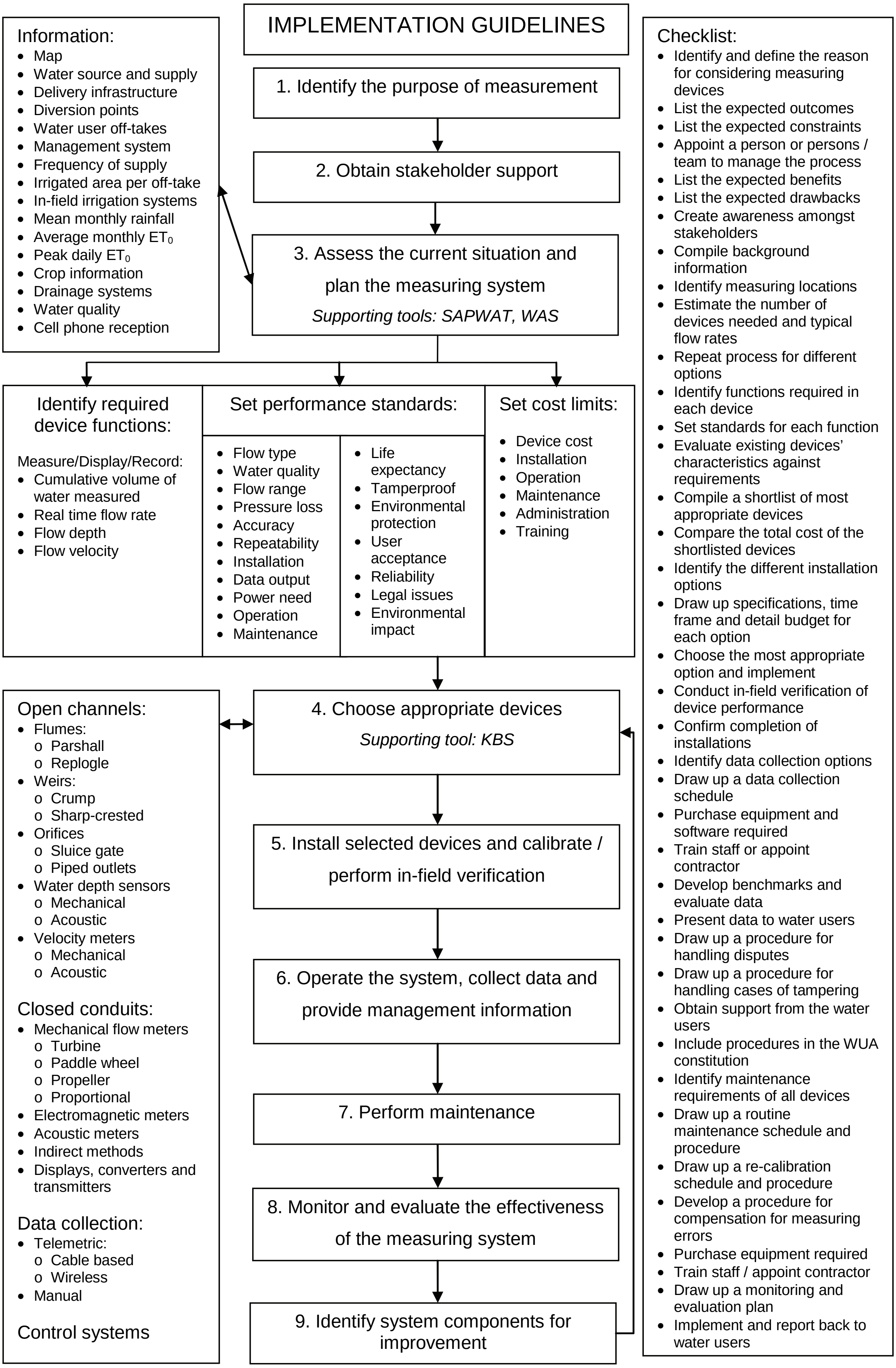


Figure 3: Water measurement implementation guidelines (Van der Stoep et al., 2005)

6. Measurement implementation planning

6.1. Background to the implementation area

In order to implement measurement effectively at a scheme, the management strategy of the particular scheme has to be understood. Unnecessary measurement is not only expensive, but will also generate a large amount of irrelevant data that has to be processed and stored.

The assessment of the existing circumstances and needs can be done on the basis of existing Rapid Appraisal Process (RAP) (Burt, 2001) and irrigation benchmarking method (Malano & Burton, 2001) making extensive use of maps, on-site inspections, historical flow data and planting records. If this information is not already kept by the WUA this will also provide an opportunity to gather such information, which will in any case be required in a WMP. The following information should at least be gathered:

- Map with lay-out of the scheme infrastructure and irrigated areas indicated (ideally Geographic Information System (GIS) based so that it can be updated regularly).
- Water source and method(s) of water abstraction (into main supply).
- Water delivery infrastructure (type and length of each type, m).
- Type and location of water diversion points, with or without existing control equipment (number, type of control equipment and condition).
- Type and location of water user off-takes, with or without existing flow measurement facilities (number, type and condition / age, accuracy).
- Type of water distribution management (on-demand, rotational, etc.).
- Frequency of abstraction at main supply and farm levels.
- Irrigated fields per water user and/or off-take (ha).
- On-farm irrigation systems (types and areas per field).
- Average rainfall per month (mm/month).
- Average reference evapotranspiration per month (mm/month).
- Peak daily reference evapotranspiration (mm/day).
- Crops grown, with typical growing seasons and crop factors (list).
- Any known drainage systems or return flow systems.
- Any water quality information available.
- Cellular phone network availability at measuring locations.

The gathering of this data ensures that a thorough understanding is obtained of the water supply and demand processes of the WUA. The climatic and agronomic data will not be used directly to select appropriate measuring devices but can be used to estimate the total water requirement of the WUA. An analysis of the data should be done to develop a baseline of information for comparison against actual performance in future, as well as a basis for making specific recommendations for modernisation and improvement of the water control system, such as where measuring devices are necessary. The importance of local knowledge of the system should not be disregarded; most WUAs have a number of experienced staff members who know the system and its problems, and who can provide very valuable information on modernising the management.

6.2. Measurement trigger

In Australia the term "triggering" has been adopted for the situations and circumstances that make measurement an urgent need. The circumstances are important in determining not only the timing but also the intensity and sophistication of the measuring program as well as the specification and acceptable costs of the measuring devices themselves. The need for measurement devices specifically may not be obvious initially but may follow when a need for improved water management had been identified.

Examples of reasons for measuring to take place in a WUA's command area are:

- Catchment stress or over-allocation: Increased user demand on a water resource, requiring irrigation water use losses to be quantified and reduced through WC/WDM.
- Implementation of the Reserve.
- Compulsory licensing.
- WAR: The need to more equitably allocate water resources to effect redress and increase the beneficial use of water.
- The need to recover the costs of new or refurbished infrastructure.
- Prolific illegal water use in a catchment.
- Increased on-farm and on-scheme WUE to reduce costs and improve profitability.
- The ability to use accurate irrigation water use measurement as a tool for dispute resolution amongst water users.
- The growth of water trading, taking place between different users and requiring accurate measurement of the volumes traded.
- The need to monitor and enforce license conditions and/or restrictions.

The reason for measuring will determine the functions that the measuring device will have to perform as well as the standard of the functions, thereby directly influencing the final selection of the measuring device(s), discussed below. It is therefore important that the reason should be clearly identified and defined at the beginning of the process.

A typical example of an urgent need for measuring in South Africa is the instance where a number of farmers pumped directly from a river with marginal capacity. Inevitably, accurate and verifiable water metering became urgent and facilities were incorporated in the system that automatically shut down a farmer's pump if their entitlement was exceeded. Under these circumstances the cost of the measuring device and its electronic control system becomes a secondary consideration.

On the other hand there is the example of a large WUA served by a complex canal system that was upgraded to advanced electronic control with telemetric remote control system that could be monitored and managed via mobile phone from anywhere in the country. Here the chances are good that it will be many years before there is a clamour for individual farm metering. This example, which is not unique, illustrates that there can be sophisticated management without conventional metering.

What these examples illustrate clearly, however, is that when implementing such an approach one needs to take into account that each WUA's situation is unique, and in order to identify the relevant measuring requirements, needs to be evaluated as such.

The specific trigger for irrigation water use measurement is likely to determine not only the timing, but also the intensity and sophistication of the measuring programme to be implemented, as well as the specifications and acceptable costs of the measuring devices themselves

6.3. Purpose of the proposed system

The purpose of the measurement system is closely linked to the trigger, but in general the system will serve on of the two following purposes:

(a) Measure the volume of water taken by water users for irrigation, or

(b) Monitor water distribution and/or use to assess losses and improve efficiency.

The purpose of the system can be expanded on, as long as the statement remains simple enough to always be used as a check against which decisions made during implementation planning can be tested.

6.4. Locations for measurement

The next step would be to identify the locations where measuring devices are required. At most WUAs, flow measurement is required at either main supply system or farm off-take level (or a combination of the two) to manage distribution.

Every irrigation scheme has to make use of a unique combination of approaches to manage these two levels. Even in cases where the infrastructure at two schemes is similar, some aspects of the management approaches will differ. However, within each level generic or typical approaches can be taken as discussed in more detail in below.

In most cases, the obvious starting point is the measurement of bulk supply to the WUA and to follow this through down to individual farm level, if necessary. In analysing the situation it is important to concentrate on what needs to be done to achieve effective management. Over simplistic solutions such as insisting that all farmers must be individually metered in the short term can be impractical and expensive.

6.5. Benefits of measurement

Lessons learnt have shown that measurement will only be implemented if there are clear benefits to the group or groups affected by the implementation plan. The following are some of the benefits that may occur:

6.5.1. Level 1: DWA National Office

Various Directorates within DWA will benefit from readily available, good quality irrigation water use data.

6.5.2. Level 2: DWA Regional Offices/CMAs or Bulk suppliers

The most important role of these organisations is the management and distribution of water at a catchment level. Important benefits of implementing measurement include the improved quality of water use data; the ability to allocate water fairly, with fewer disputes between the organisation and users; and better water abstraction control within their areas of jurisdiction. Although not yet widely implemented, billing for actual consumption rather than for full quotas is also possible if water is measured at user level.

6.5.3. Level 3: IOs/responsible water authorities

This level of role-player is mainly responsible for the day-to-day management and distribution of water, and measurement gives these organisations better control over water allocations, and improved management of infrastructure, especially by providing early warning of deteriorating infrastructure through detection of losses. User-level measurement also opens up the possibility of trading surplus water at this level as accurate recording and billing of users for actual volume of water used is possible.

6.5.4. Level 4: Irrigation water users in the agricultural sector

To the water user, the benefits of measurement include a greater awareness of the actual amount of water used, and equitable allocation of the available water. If water is better managed by the level 2 and level 3 role players, end users also enjoy greater security of supply, and early warning that they may exceed their allocation, allowing time to buy or "rent" additional water. The reverse of these transactions in turn benefits other users, who then have opportunities to sell un-utilised allocations and to benefit from reduced water charges if the full quota is not utilised (and if charges are levied on actual use and not full quota).

Improved water availability at farm level creates opportunities for increased production and income, while on-farm costs can be reduced through early warning of deteriorating on-farm infrastructure, (such as leaks in pipes, pump efficiency and nozzle wear) through detection of losses or unexplained increase in water use, and more effective and efficient use of fertilisers and other farming inputs administered through irrigation infrastructure.

6.6. Water user support and organisational arrangements

Once the decision has been made to install measuring devices, it is recommended that a specific person or team should be given the responsibility of driving the process. This could be either existing staff members from the WUA or consultants appointed specifically for the purpose. One of the most important tasks to be undertaken, however, is to obtain the support of the water users by creating awareness of the envisaged plan and its outcomes through written and verbal communication.

The support is crucial in making further steps of measurement implementation possible since information will be required on aspects such as the location and specification of farm off-takes, planted areas, water delivery preferences, etc., and the water users will have to be consulted for this.

Decisions will have to be taken on the ownership and responsibilities involved with the new infrastructure, and in this regard obtaining the support of the water users is also the first step towards preventing vandalism and tampering with equipment to be installed. It is most likely that any infrastructure will be owned and maintained by the WUA with any costs recovered from the water users. This approach, rather than individual ownership, helps to prevent inconsistencies in types of devices installed, installation practices and maintenance levels but requires support from the users at grassroots level.

Successful project implementation can be enhanced by the support of other organisations with the capacity to advise on specific issues. These organisations include government departments, consulting engineers, universities, the ARC institutes, the South African Irrigation Institute (SABI), agribusinesses, and suppliers of equipment.

The costs that will need to be recovered will include the initial capital cost of the equipment as well as running costs for on-going operation and maintenance. The capital cost will have to be recovered over a number of years, which does not exceed the expected life of the devices, while the running costs will have to be revised annually to meet expenses associated with data retrieval, repairs, calibrations, etc. It is important that cost can be justified by the envisaged benefit for the water users as a result from the proposed measuring system. It is therefore recommended that different scenarios be investigated to present the users with a range of options from which they can choose.

7. The measurement system

Once the required measuring locations have been identified, the number of devices likely to be needed at the different levels as well as the flow rates each type would need to handle should be determined. At this stage it may be quite possible that there is more than one possible solution; they can all be investigated further and compared in terms of cost and appropriateness as described in the following sections. Further information on measuring device selection and installation can be found in Chapters 6, 7, 8 and 9 of the TT 248/05 report (Van der Stoep et al, 2005).

7.1. Measuring device selection

The selection of a measuring device for a particular installation will depend on how the characteristics of the available devices satisfy the requirements set by the IO, as identified during the situation assessment described above. In general, these requirements will make sure the following needs are addressed:

The device performs certain functions.

The device performs to a certain standard.

The device is the most affordable solution that satisfies the first two needs.

The method for choosing the appropriate device should focus first on what type of information and what level of precision is required by the WUA, and then on choosing the least expensive device that meets the practical needs and any other standards set by the IO or the CMA or DWA.

7.1.1. Device functions

In order to decide which devices are required at the different locations and whether existing devices can be used, the required functions of the devices should be identified. The measuring device will be required to perform any of the following functions ((QDNR&M, 2002):

- Measure cumulative flow volume.
- Memorise and continuously display cumulative flow volume.
- Measure instantaneous flow rate.
- Display instantaneous flow rate continuously.
- Memorise history of instantaneous flow rate.
- Measure depth of flow
- Measure flow velocity.

It has to be emphasized at this point that for neither open channel nor piped flow conditions is there an “ultimate” flow measuring device that will be the answer to all problems under all conditions. Each situation is unique and has to be assessed as such, and the specific needs matched to a suitable device. This approach will hopefully lead to the most appropriate solution being found – this may not necessarily be the least expensive, or the most sophisticated option, but the most suitable one for the specific circumstances.

7.1.2. Performance standards

The IO will have to set standards what they require the envisaged measuring devices to meet (and which is acceptable to the CMA or DWA) and assess the existing infrastructure accordingly. Standards should be set for all levels, keeping in mind that it may not necessarily be same at all levels. For example, a measurement accuracy (standard) of ± 2% may be required at farm off-take level because the farmer is billed according to the measurement, but an accuracy of ± 10% may be good enough at main supply level because it is only required to give an indication of the flow conditions in the system.

Standards usually have to be set for all or some of the following parameters, which are discussed in WRC Report TT248/05 and can be downloaded from the WRC website or from watermeter.co.za:

- Type of flow and flow conditions.
- Water quality.
- Flow range.
- Pressure head.
- Accuracy.
- Repeatability.
- Installation conditions.
- Data output
- Power requirement.
- Operating requirements.
- Life expectancy
- Maintenance, trouble shooting and repair.
- Resistance to tampering.
- Environmental protection.
- Existing devices and user acceptance of new methods.
- Reliability.
- Legal constraints.
- Impact on the environment.
- Cost.

The different devices show varying degrees of sensitivity to the parameters listed above, underlining the fact that there is no “ultimate” device that will work under all conditions. The characteristics of the various commercially available devices, including installation and maintenance requirements, advantages and disadvantages are discussed in detail in WRC Report No. TT 248/05. The characteristics should be studied carefully before making a final selection.

7.1.3. Water quality

The measurement and interpretation of the quality of the water to be used for irrigation is one of the first steps to be taken in the planning of an irrigation project. Irrigation water influences the growth of plants, as well as the properties of the soil, the biological balance in soils and it also has an influence on the irrigation equipment to be used.

Irrigation water is classified according to the quantity of physical, organic and chemical impurities in it, as discussed below (Burger et al., 2003).

Physical impurities

Physical impurities are those particles which occur in the water and which can be "measured". Sediment, for example, refers to physical impurities that have a diameter of higher than 0.001 mm, while turbidity refers to the impurities that have a diameter of less than 0.001 mm. Sediment may be removed by the use of sediment dams, sand filters, disc filters or cyclonic separators. Turbidity is removed using flocculants, followed by settlement or filtration.

Organic impurities may be sub-divided into organic colloids, algae and bacterial growths. Organic colloids may be flocculated out with the help of slaked lime. Problems with algae may be rectified with copper sulphate (if the pH < 7), and/or with chlorination. Chlorination may also be used for the treatment of bacterial growths.

Physical impurities can lead to the wearing out of equipment parts, caused for example by the scouring effect of sand in the water. With high sediment or organic loads, blockage of small openings or mechanisms can occur. Both problems can lead to the incorrect performance or complete failure of meters.

Chemical impurities

Chemical impurities are chemical elements and/or compounds which separately, or in combination with each other, give rise to problems in plants and soils. There is an increasing demand for the determination of the presence of heavy metals, such as mercury, lead and manganese – which are found as a result of increasing industrial pollution – and/or micro-elements in irrigation water analyses.

Problems with iron and manganese blockages occur where iron ions (Fe^{2+}) and manganese ions (Mn^{2+}) are found in water. These ion forms occur in solution in water. Oxidation (Fe^{2+} to Fe^{4+} and Mn^{2+} to Mn^{4+}) causes sedimentation. The sediment is usually $Fe(OH)_3$ and/or MnO_2 which may cause blockage of drip and micro-irrigation systems. However, water containing more than 0.4 mg/l of iron should not be chlorinated, as it forms insoluble iron compounds which accelerate blocking. This irrigation water should be exposed to air as much as possible in order to promote flocculation and sedimentation.

Acid treatment is done when magnesium, calcium and carbonate salts pose a threat of blocking small openings. A water sample should first be analysed in the laboratory before recommendations are made. Acid should not be added at the same point as chlorine. Acid treatment may increase the effectiveness of chlorine if the pH is reduced to between 4.5 and 5.0.

The pH of irrigation water gives an indication of acidity and can be used in conjunction with the pH_s value to assess the nature of the water from a corrosive or sedimentary perspective. pH_s is defined as the pH of water in a saturated state. According to Langelier's saturation index, pH minus pHs, these characteristics of water may be determined. Water with an index value of 0 up to approximately 0.2 is regarded as being neutral. However, positive values indicate a sedimentary characteristic. This tendency is especially important for prospective irrigation farmers regarding the purchase or installation of new irrigation equipment. Negative values indicate corrosive qualities.

Treatment

In cases where irrigation water has more solids than 200 ppm in suspension, it is advisable to settle the solids in a dam before it is filtered through the system. If the specific density of these materials is very low, it may even be necessary to flocculate it chemically before settling will be practically possible. Settling can prevent the filters from being overloaded and from being backflushed unduly. Important considerations for a settling dam include the following:

- Water should be extracted as far away as possible from the inlet.

- Back-wash water should be dumped as far away as possible from the extraction point.
- It should be possible to clean the dam with little effort.
- Water should be extracted from the supernatant for filtering.
- A long narrow dam is more effective than a square one.

7.1.4. Types of devices available

Van der Stoep et al. (Van der Stoep et al., 2005) compiled information on the different types of measuring devices that are available and typically used for irrigation water measurement in pipes and open channels.

Flow measurements in pipes are usually achieved by installing a flow meter that measures velocity using mechanical, electromagnetic or ultrasonic principles. The velocity reading is converted to a volumetric flow rate, and presented on a mechanical or electronic display.

Open channel flow measurements are normally made by measuring the water depth (head) or average velocity, which is then converted to flow rate. The devices commonly used for these measurements are flumes, weirs, gauges and many types of mechanical, electromechanical, and electronic sensors. The three most commonly-used types are float-driven sensors, pressure sensors, and ultrasonic sensors. A summary of the types of devices are presented in Table 2 and Table 3. The original WRC report (WRC Report No. TT 248/05) can be consulted for more information.

7.2. Installation

If the data obtained from any measuring device is to be useful and worth the expense of purchasing, installing, maintaining and reading, the meter must be installed, calibrated and maintained according to predetermined standards. The water user can then be sure it operates as accurately as possible, that it remains accurate over time, and that a verification system is in place.

Proper installation is achieved through careful planning of the installation process which should be kept as simple as possible, with construction and other site work kept to a minimum to reduce costs, whilst still complying with the selected device's installation requirements.

Many IOs, especially smaller ones, may find it more cost-effective to outsource supply and installation to a knowledgeable contractor. Not only may this save the IO from buying expensive equipment that may not be used often after the installations have been completed, but another possible advantage is that the contractor may be able to negotiate better prices on measuring devices with the supplier if buying in bulk.

Table 2: Summary of pipe flow meters

Method	Volumetric data output (standard)	Flow rate data output (standard)	Sensitivity to installation conditions (hydraulic)	Needs ext. electric power (standard)	Accuracy (relative)	Sensitivity to dirty water	Additional pressure loss in system	Continuous data recording possible	Typical cost of standard unit (including installation)***
Turbine	Yes	No	High	No	Moderate	High	Low	Yes*	<R 10 000
Impeller	Yes	No	High	No	Moderate	Moderate	Low	Yes*	<R 10 000
Propeller	Yes	No	High	No	Moderate	Moderate/High	Low	Yes*	<R 15 000
Bypass	Yes	No	High	No	Moderate/Low	High	Moderate	Yes*	<R 10 000
Electromagnetic (inline)	Yes	Yes	Moderate	Yes	High	Low	None/Low	Yes*	R 1 5000- R 35 000
Electromagnetic (insert)	Yes	Yes	High	Yes	Moderate	Moderate/Low	None/Low	Yes*	R 8 000- R 15 000
Acoustic Doppler	Yes	Yes	High	Yes	High	Low	None	Yes**	R 30 000- R 60 000
Acoustic Transit Time	Yes	Yes	High	Yes	High	Low	None	Yes**	R 40 000- R 100 000
Electric power	Yes	Yes	Low	No	Moderate/High	Low	None	Yes*	<R 12 000
kiloWatt-hour	Yes	No	Low	No	Low	Low	None	No	<R 3 500
Hour meters	Yes	No	Low	No	Low	Low	None	No	<R 1 500

* Additional hardware always required

** Additional hardware sometimes required

*** Price will vary with size and quality

Table 3: Summary of open channel measuring devices

Method	Volumetric data output (standard)	Flow rate data output (standard)	Sensitivity to installation conditions (hydraulic)	Needs ext. electric power (standard)	Accuracy (relative)	Sensitivity to dirty water	Additional pressure loss in system	Continuous data recording possible	Relative cost of standard unit (including installation)***
Weir	No	Yes	High	No	Moderate/High	High	High	Yes*	Moderate/Low
Flume	No	Yes	High	No	Moderate/High	Moderate	Moderate/High	Yes*	Moderate/High
Mechanical velocity	No	Yes	Moderate	No	Moderate	High	Low	Yes*	Moderate
Doppler velocity	No	Yes	Moderate/High	Yes	Moderate/High	Moderate/High	Low	Yes*	Moderate/High
Floats	No	Yes	Moderate/Low	No	Low	Low	None/Low	No	Low
Orifices (Pressure controlled sluice gate)	No	Yes	High	No	Moderate	Moderate	Low	No	Moderate
Acoustic Doppler	No	Yes	High	Yes	High	Low	None	Yes**	Low-high****
Acoustic Transit Time	No	Yes	High	Yes	High	Moderate/Low	None	Yes**	Low-high****

* Additional hardware always required

** Additional hardware sometimes required

*** Prices vary widely with size and therefore only relative.

**** Often “one size” device for all flow rates – expensive for small canals but affordable for big canals

If this route is followed, it is suggested that it is done through a tender system which will require comprehensive technical documentation and careful management from the IO to ensure work is completed on time, according to the specifications and within the agreed budget.

The IO should ensure that each installation is complete and done according to the plans before the contractor leaves the sites. This can be done by compiling a database with information on each installation as it is completed, including a photograph of the completed work, global positioning system (GPS) location, a checklist of important information of the installation, and written confirmation by the IO, the contractor and the water user that the installation is correct and operating as intended.

In order to ensure that a device is accurate at a specific installation, it is strongly recommended that all measuring devices be checked or calibrated in the field after installation. Experience has shown that even if a device comes with a calibration certificate from the manufacturer it is not guaranteed that the device will perform accordingly in the field. In the case of open channels, handheld current meters, (mechanical or acoustic type), can be used to measure instantaneous flow rates, with the acoustic type especially producing quick and accurate results. For piped flows, a clamp-on type acoustic meter (preferable the transit time type) can be used for verification.

Specific guidelines for the installation of different measuring devices in pipes and open channels are presented in Van der Stoep et al (2005). Some general guidelines are presented here, but in order to ensure successful implementation, detailed installation guidelines should be provided and followed:

- The device should be installed in the position and orientation recommended by the manufacturer, supplier or designer, to ensure it operates as intended.
- There should be no air or vapour in the water, since this can cause damage to components or incorrect measurements.
- If the water quality is poor and the selected device will not be able to let the debris past, filtration elements have to be installed upstream of the measuring location to protect the measuring device. These filters should be installed so that they do not interfere with the effective operation of the device, and should be easily accessible for maintenance and cleaning.
- Good quality construction materials should be used for the installation, and occupational health and safety procedures followed where necessary.
- There should be enough clearance around the installation for easy maintenance, calibration and removal of the device, if necessary. A concrete slab should be put around the area to stop excessive growth of grass and weeds, and to protect the device in case of veld fires. In general, the site should be easily accessible.
- If necessary and possible, install connections for in-field calibration or verification permanently so that they are in place when required. These may include pressure tappings, inspection inlets, or positioning guides for current meters.
- If the measuring device is installed in a critical section of the water supply network, providing a bypass will make it possible to remove the device for repairs without stopping the flow.
- Once all the equipment has been installed, a pre-commissioning check should be done to make sure everything is in place, fastened, connected, etc. The device should then be filled with water to see if it is operating correctly and if there are any leaks or faults. In-field calibration to check the accuracy after installation should be done and any corrections made, if necessary.

- After commissioning and calibration, seals should be installed to prevent further adjustments or tampering. Other anti-vandalism devices may also need to be installed.
- An installation certificate should be drawn up which must be signed by the IO, the water user and the contractor, if relevant, after completion of the installation to confirm that all parties involved is satisfied that the device is properly installed and operating correctly.
- The location of the measuring device should be sign-posted so that it can be found and identified in future. It is also good practice take at least one photograph of the completed installation and to find the location's GPS coordinates for future reference.

7.3. Operation and maintenance

7.3.1. Operation

The purpose for which measuring was initially implemented usually determines how the devices are operated (read), and when data is collected. For instance, if the devices are used to manage the supply to a number of water users sharing an on-demand type distribution system, the IO would be interested in real-time data to ensure all users get their fair share. This may necessitate a technologically advanced data collection system based on telemetry. On the other hand, if the IO is merely interested in monitoring water users' abstractions against their allocations, periodic readings taken manually by IO officials may be adequate.

Data can therefore be collected either manually, or via remote sensing technology. If the readings are taken manually, it must be ensured that the device is fitted with a suitable display unit that can be easily read, and that the person taking the readings has been trained to do so correctly. This will make mistakes in data collection less likely to occur.

It is also possible to connect most measuring devices to a datalogger which can store data for longer periods and thereby reduce the number of visits required for manual collection. Data from a datalogger can also be transmitted telemetrically. If electronic equipment is used to collect data, the equipment must be properly protected against the elements, especially lightning and frost which can cause serious damage, resulting in data loss. Whichever data collection system is decided on, it will have certain implications for cost and quality of the data.

It is important that only necessary data is collected. The data should as far as possible be made available to the water users, and preferably in user friendly formats such as graphs or tables with short discussions or summaries. Presenting the data in this way can help to create greater awareness amongst water users of their water use, possibly encouraging them to increase efficiency.

The data obtained from the measuring devices should be critically evaluated, requiring benchmarks against which it can be compared. This may take the form of a framework for calculating the water requirements of the IO for a specific season, based on irrigated areas and gross irrigation requirements of the various crops planted on the areas (i.e. the information collected during the initial assessment). A purpose-made module has been developed for the WAS program (WRC Report No. 513/1/97) to perform these calculations once the necessary data has been captured in the database. The actual measured results can then be compared with the theoretical estimations, making it possible for the IO to advise the farmers on WUE and the cost of water as an input for different crops, as well as identifying inefficiencies and losses in the distribution system. It will also provide useful pointers for the IO as to where further measurement is necessary.

As in the case of the installation, data collection can be outsourced to consultants. Some manufacturers also offer data collection services, especially when telemetry is used in conjunction with their equipment. The data is usually sent to a dedicated internet address from where it can be accessed by the IO at any time.

7.3.2. Disputes

Disputes regarding the accuracy of a meter may occur despite careful installation and maintenance. The procedure that should be in place to handle such a problem should meet at least with the following requirements:

The water user should report the suspected faulty device, presenting any evidence on which the claim is based.

If at all possible an attempt should be made to verify the accuracy of the device in situ, since installation conditions can often be the cause of the problem and this will not be picked up if the device is evaluated in a laboratory under ideal flow conditions.

If no fault is found with the device, the costs involved with verifying the device will be recovered from the complainant.

If the device if found to be faulty, it will have to be replaced and the historical data assessed in order to determine whether the water user needs to compensated or adjustments made to his/her water use records.

7.3.3. Tampering

A procedure should be in place to deal with any evidence of tampering encountered during maintenance or any other inspection of measuring devices. Tampering may or may not have been done by the water user, but in both cases it is a serious situation, especially if it affected the performance of the measuring device. It has to be investigated since it affects the fair allocation of water amongst the users as well as cost recovery. The procedure should provide for the following:

The case should immediately be reported to the IO.

If possible, a photograph should be taken, and the effect of the tampering noted on the measuring device.

The tampering should be corrected / repaired, or the device replaced as soon as possible.

The relevant water user should be informed, and allowed to present his argument, if required.

Provision should be made in the IO constitution for disciplinary actions that can be implemented if necessary.

7.3.4. Maintenance

A maintenance schedule that adheres to the manufacturers specifications, if relevant, should be drawn up and followed to ensure that measuring devices operate effectively for as long as possible. Preventative maintenance includes regular inspection of devices or structures for damage and signs of wear, as well as accuracy verification, which can be performed in the same way as in-field verification. Recalibration may be necessary, either due to general wear or due to changes in the distribution system (and therefore flow conditions).

In some cases maintenance may require the device to be removed from the installation. In these cases, maintenance should be planned to take place during periods when there is no irrigation, or a replacement device should be installed. In the case of open channel systems, it is customary to schedule a number of “dry periods” in the year during which general maintenance and repairs can be undertaken, since infrastructure can usually not be removed. As in the case of the installation and data collection, maintenance can be outsourced, but it should however never be made the responsibility of the water user.

The interval between inspections will be determined by, amongst other things, the type of device, its age as well as the quality of the water, but surveys amongst water users as part of this project showed that it should be done at least once a year. An agreed procedure for handling measuring errors should be in place in case faults or failures are encountered. Maintenance procedures have to be evaluated periodically and revised if found to be ineffective.

7.4. Monitoring and evaluation

An essential element of a sustainable measuring system is an effective monitoring and evaluation programme. Once a system has been designed and implemented, it has to be monitored to assess whether it is actually addressing the needs that were identified. Mechanisms can be built into the process to allow for learning, correction and adjustments to benefit the system as a whole and all parties concerned. This will require the development of a clear set of objectives and performance indicators, linked to the identified device functions and standards, which promote accountability and participation, and which can be monitored and evaluated by the relevant decision-makers.

8. Implementing the plan

8.1. Budget and funding

The issue of cost effectiveness over the life of the device is often the deciding factor when selecting an appropriate device. The total cost of a measuring device depends not only on the actual cost of purchasing the device but also on its installation, management and maintenance requirements.

In order to summarise the cost components and their elements, a framework has been drawn up for use by IOs to compile budgets for comparison as an aid to selecting the most appropriate solution, as shown in Table 4 below. The total capital cost of an installation consists of the measuring device and installation components, and should be recovered from the water user over an agreed number of years not exceeding the expected life time of the device.

The total operation (running) cost consists of components related to the equipment, administration and maintenance required to manage the devices. These costs are annual expenses that will also be recovered from the user by the IO.

The cost of capacity building through training of technicians, data collectors and data analysts will also have to be recovered, although these costs may not necessarily occur every year. As mentioned earlier, some of the functions of the IO can be outsourced to contractors, if this seems to be more cost-effective, and the savings passed on to water users in the form of reduced water charges.

The information in Van der Stoep et al (2005) can be used by IOs to compile such budgets and select appropriate devices and implementation methods, but it is advisable that suppliers of equipment also be contacted if a device has been selected.

Financing the implementation is often the main obstacle to be overcome. The first source of finance will be the water users themselves, in which case the benefits of implementation from both a water management and a business perspective should be very clear and presented as such (see discussion in paragraph 3.6 of this report). If the users can be brought to understand the possibilities that measurement opens up for improved water management and increased on-farm profitability, it is often possible to install more sophisticated systems that offer additional advantages and convenience than very basic measurement systems.

Alternatively, financing may need to be sought from third parties such as the Land Bank, commercial banks or other interested parties. Intimate knowledge of the economic linkages in an irrigation area will make it easier to identify and take advantage of existing opportunities where both the water users and businesses in the area will benefit.

Table 4: Cost framework

Component	Element	Cost
Measuring device	Primary element (standard physical device or structure)	R/installation
	Secondary element (additional data display or read-out, if not part of the primary device, e.g. pulse output)	R/installation
	Data retrieval device (datalogger or telemetry)	R/installation
Installation	Supporting infrastructure (pipes, flanges, reducers, sieves, etc.)	R/installation
	Electricity supply and connection	R/installation
	Security devices (lockable enclosures, tamper-proofing)	R/installation
	Labour cost (technicians, electricians)	R/installation
	Consumables	R/installation
	Traveling	R/installation
	In-field calibration (expenses or contractor)	R/installation
	Specialist installation equipment	R (once-off)
Operation (equipment)	Electricity	R/installation /year
	Telemetry (Cell phone contracts)	R/installation /year
	Additional energy due to increased friction loss	
Operation (administrative)	Data retrieval (staff and expenses, or contractor)	R/installation /year
	Data processing (staff and hardware)	R/year
	Software (for retrieval or processing)	R/year
	Other overhead costs to IO	R/year
Operation (maintenance)	Routine inspections (staff and traveling, or contractor)	R/installation /year
	Routine servicing (in-field or laboratory, incl. cost of removal if necessary)	R/installation /year
	Re-calibration (equipment and expenses, or contractor)	R/installation /year
	Spare devices for replacement (ex-stock)	R/year
Capacity building	Training of technicians for installation	R
	Training of technicians for maintenance	R/year*
	Training of data collectors (meter reading, etc.)	R/year*
	Training of data processors (software use)	R/year*

* If required.

8.2. Role players and responsibilities

8.2.1. Level 1: DWA National Office

As the custodian of the nation's water resources, DWA NO plans, monitors and evaluates the implementation of irrigation water use measurement in the agricultural sector, and co-ordinates the collection, storage, analysis and use of the resulting data and information. DWA NO already undertakes measurements for the purpose of national WRM, and is responsible for the purchase, installation, operation and maintenance of measuring devices at this level, through the relevant NO Directorates. It is not, however, directly involved with the measurement of water use by individual end-users.

The responsibilities of the DWA NO are to:

Develop and maintain the irrigation water use measurement strategy, and to provide guidelines for its implementation.

Assign the functions of irrigation water use measurement implementation to appropriate Directorates.

Identify and prioritise areas where the irrigation water use measurement strategy must be implemented.

Set up financial mechanisms or channels, (by developing policies or regulations to assist Level 2 and 3 organisations such as DWA ROs/CMAs and IOs in obtaining funding or finance for irrigation water use measurement implementation.

Coordinate and facilitate the collection, evaluation, use and reporting of irrigation water use data required for decision-making at National and Regional/CMA level.

8.2.2. Level 2: DWA Regional Offices/Catchment Management Agencies

DWA ROs and CMAs manage the water flowing into, within and out of their WMA. They need to know the exact status of the resources they are responsible for managing, and what quantity of water is being used at the point where water use authorisations apply.

DWA ROs and CMAs are responsible for managing the water resources from which IOs take their water, and they are the body to whom IOs will report their irrigation water use data. They provide this agricultural irrigation water usage data and information to the DWA NO.

Together with water use data from other sectors, agricultural irrigation water use measurements provide input to the day-to-day regional management of the water resource as a whole.

The RO or CMA is responsible for the purchase, installation, operation and maintenance of measuring devices at this level.

DWA ROs/CMAs are responsible for co-ordinating the implementation of the strategy for irrigation water use measurement in the agricultural sector by the IOs in their WMA by:

- Developing locally relevant irrigation water use measurement implementation guidelines and procedures based on this Strategy Document and on generic irrigation water use measurement implementation guidelines developed by DWA HO.
- Identifying and prioritising the points where agricultural irrigation water use measurement is required at bulk supply level (Measurement Opportunity 2) within its area of jurisdiction.
- Identifying and prioritising all the agricultural irrigation water use organisations in its area that should implement irrigation water use measurement.
- Drawing up an agricultural irrigation water use measurement implementation plan for the installation, operation and maintenance of irrigation water use measuring devices.
- Obtaining funding for the implementation plan, and assisting IOs such as WUAs, IBs and GWSs with obtaining funding.
- Appointing the personnel necessary to implement the plan.

- Developing an effective data collection and processing programme that will ensure that useful irrigation water use information is available to both the water users and DWA HO in an accessible and appropriate format.
- Recovering the cost of irrigation water use measurement implementation from the users.
- Analysing the data on a regular basis in order to identify changes in agricultural irrigation water use patterns which may require adaptations to WRM plans.

8.2.3. Level 3: Irrigation organisations

IOs such as WUAs, IBs, and GWSs operate at this Level. They are responsible for managing the water sources from which agricultural irrigators take their water, and they are the body to whom such irrigators should report their measured agricultural irrigation water use. They, in turn, provide agricultural irrigation water usage data and information to the relevant DWA RO/CMA. Such IOs may or may not have their own conveyance infrastructure.

In some cases a DWA RO or future CMA may act as the IO responsible for managing the source and/or monitoring water use, for example where individual agricultural irrigation water users abstract water directly from a regulated or unregulated river.

Irrigation water use measurements of the flow within the IOs own conveyance systems tend to be aimed at monitoring conveyance efficiency rather than actual use.

IOs are responsible for implementing the strategy for irrigation water use measurement in the agricultural sector by:

- Identifying and prioritising all the points within their scheme or area where irrigation water use measurement may be required.
- Drawing up an implementation plan for the purchase, installation, operation and maintenance of agricultural irrigation water use measuring devices.
- Obtaining funding for implementing agricultural irrigation water use measurement.
- Appointing and/or training personnel to implement the agricultural irrigation water use measurement plan.
- Improving WUE through refining best management practices and in response to feedback from irrigation water use measurement.
- Collecting agricultural irrigation water use data.
- Recovering the cost of implementation from the water users.
- Reporting the irrigation water use data to the users and to the RO/CMA.

The Water Management Plan Implementation Guidelines (DWAF, 2006b) document the implementation of WC/WDM by WUAs, and includes detailed guidelines on water measurement at different levels. Those Guidelines should be updated to reflect the recommendations of this Strategy Document.

8.2.4. Level 4: Irrigation water users in the agricultural sector

Irrigation water users in the agricultural sector can be described in different ways, but they may all be required to implement agricultural irrigation water use measurement. They include commercial farmers and smallholders, those grouped into WUAs, IBs, GWSs or other IOs, as well as those outside of schemes, regardless of whether they receive water from a river, canal, pipeline, groundwater, farm dam or other regulated or unregulated source.

Such water users may be involved with implementing the strategy for irrigation water use measurement in the agricultural sector by:

Identifying all the points where their registered agricultural irrigation water use should be measured, and reporting them to the appropriate agency.

Ensuring access to the agricultural irrigation water use measurement points for installation, operation and maintenance by appropriate agencies.

Paying fully or partly for agricultural irrigation water use measurement implementation, as part of agricultural irrigation water use charges.

Reporting any damage to or problems with agricultural irrigation water use measuring devices to the responsible authority.

Complying with their agricultural irrigation water use water allocation, and any other relevant conditions that are set by the responsible authority.

Making available any additional information that the responsible authority may be required to assess in terms of efficient, beneficial and sustainable agricultural irrigation water use in the public interest.

An important application of the measurement data will be to assess whether a user complies with their allocation ELU or license and it will therefore be necessary for the measurement to cover all the possible sources of water that a user may have access to on the applicable property. In the case of highly stressed catchments, the socio-economic benefit of water use may also have to be assessed, requiring additional information to be collected such as production and employment figures.

In addition, an individual user may implement irrigation water use measurement on their own initiative, in order to improve on-farm water use management and efficiency. In this case they may be responsible for the purchase, installation, operation and maintenance of measuring devices at this level.

PART C: THE IMPLEMENTATION PLAN

9. Structure of the implementation plan

The implementation process should begin with a feasibility study in which a preliminary assessment of the situation is undertaken. If the outcome of the feasibility study is positive, a site specific implementation plan can be developed and the system installed. The general implementation plan presented here should be adapted into a specific implementation plan when applied.

It is proposed that the implementation plan should consist of chapters with the same headings as shown below, containing the detailed information specified under the different headings:

Measurement implementation planning.

- Background to the implementation area.
- Measurement trigger.
- Purpose of the proposed system.
- Locations for measurement.
- Benefits of measurement.
- Water user support and organisational arrangements.

The measurement system.

- Measuring device selection.
- Installation.
- Operation and maintenance.
- Monitoring and evaluation.

Implementing the plan.

- Budget and funding.
- Role-players and responsibilities.
- Gantt chart.
- Invitation for inputs.

This section of the report (Part C) should be read in conjunction with Part B, the Implementation Guidelines, wherein more detail of the implementation process is provided.

A MSWord template of the implementation plan is published with the report in electronic format.

10. Measurement implementation planning

The implementation plan can be compiled as part of the feasibility study and should be as complete as possible in order to provide a document for future reference on how and why certain decisions were taken. The first part of the plan should reflect the planning process.

10.1. Background to the implementation area

The Plan should start off with a brief description of the area where measurement is to be implemented, including the location, province, WMA, IO status, registered irrigation area, type of water distribution system, number of water users, water users' representative and contact details.

Implementation area name:	
Irrigation Organisation name (if applicable):	
Contact details	
Name of contact person:	
Position:	
Postal address line 1:	
Postal address line 2:	
Postal code:	
Tel.nr:	
Fax nr:	
E-mail:	
Website:	
Province:	
WMA that the area falls within:	
DWA RO that the area falls under:	
Number of water users in the area:	
Registered irrigation area (ha)	
Type of water distribution system	River (individual pump stations) Canal Pipeline (central pump station) Other:

It would also be valuable for this section to include a reference to the date and reason for the official decision made to implement water measurement in the area. IOs should incorporate the directives regarding water measurement into their constitutions in order to make it binding upon their members.

10.2. Measurement trigger

The trigger, the objective(s) and envisaged benefits/incentives of the proposed measurement system to be implemented should be defined.

Examples of triggers include:

Catchment stress or over-allocation: Increased user demand on a water resource, requiring irrigation water use losses to be quantified and reduced through WC/WDM.

Implementation of the Reserve.

Compulsory licensing.

- *Water Allocation Reform (WAR): The need to more equitably allocate water resources to effect redress and increase the beneficial use of water.*
- *The need to recover the costs of new or refurbished infrastructure.*
- *Prolific illegal water use in a catchment.*
- *Increased on-farm WUE to improve profitability.*
- *The ability to use accurate irrigation water use measurement as a tool for dispute resolution amongst water users.*
- *The growth of water trading, taking place between different users and requiring accurate measurement of the volumes traded.*
- *The need to monitor and enforce license conditions and/or restrictions.*

10.3. Purpose of the proposed system

The purpose of the measurement system should be clearly stated, for example:

The purpose of the measurement system to be implemented is to:

(a) Measure the volume of water taken by water users for irrigation, or

(b) Monitor water distribution and/or use to assess losses and improve efficiency.

10.4. Locations for measurement

The locations where measuring devices are to be installed should be defined, together with a map of the locations and a picture(s) of typical location(s).

10.4.1. Location type(s)

In order to address the objectives defined above, it is proposed that measuring devices will be installed at the following locations:

	Location type 1	**Location type 2**
Location description:	*For example – Private pump station*	*For example – Borehole*
Nr of locations in area:		
Electricity available (y/n):		
GSM* signal (y/n):		
Possible threats to measurement at sites:		

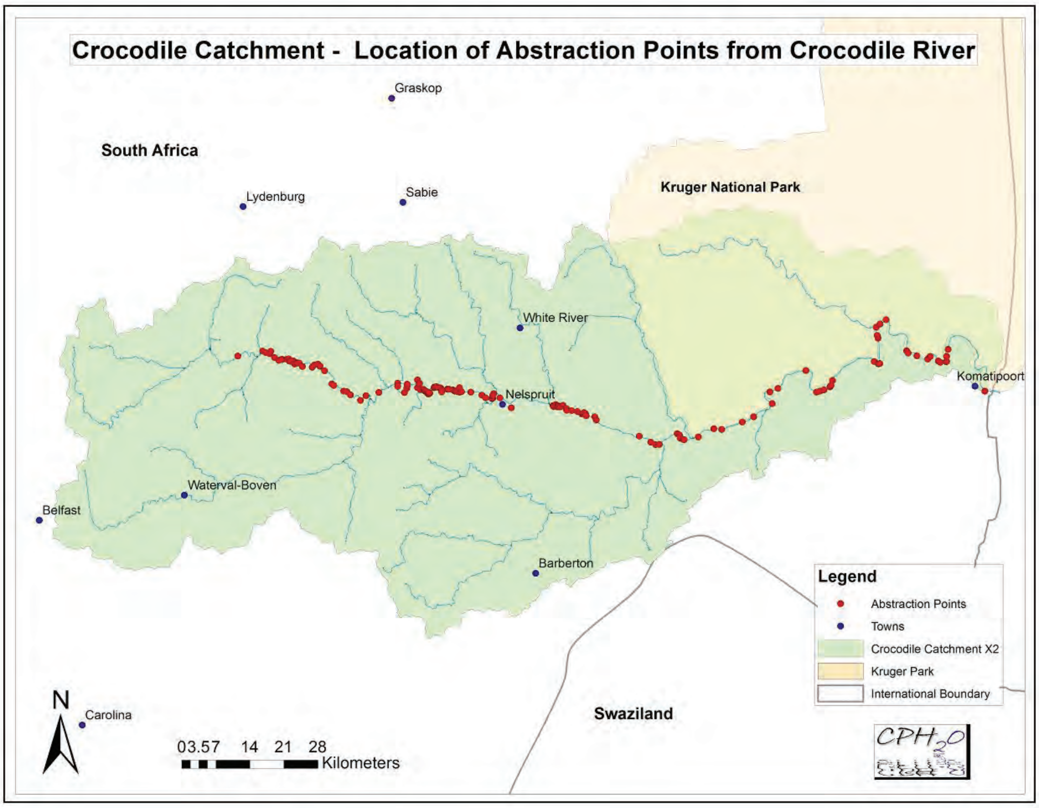
* Global System for Mobile communications

10.4.2. Map of measurement locations

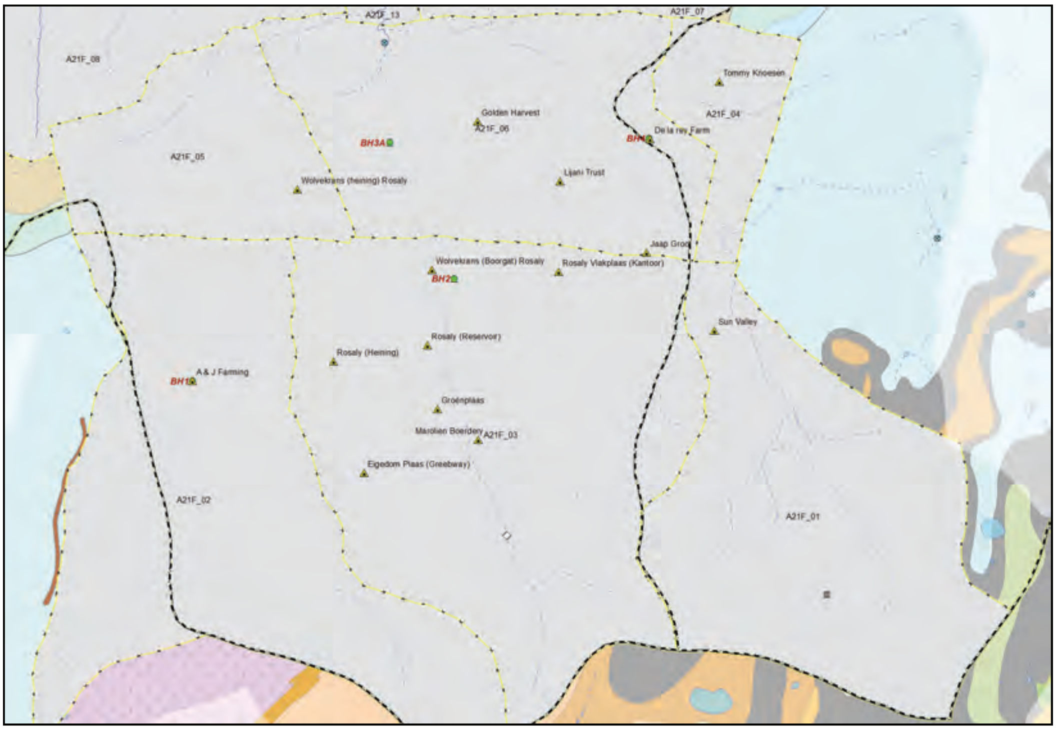
The locations of the measuring points are shown in the following figure(s):

For example:

Location type 1:



Location Type 2:



10.4.3. Picture(s) of typical measurement location(s)

Typical location(s) where measurement device(s) of the different types as defined above are shown in the following figure(s):

For example:

Location type 1 – Private pump station:

Location type 2 – Boreholes:

10.5. Benefits of measurement

The envisaged benefits for the role players at the different levels involved in the area should be defined.

For example:

Level 1: DWA NO

Various Directorates within DWA will benefit from readily available, good quality irrigation water use data.

Level 2: DWA ROs/CMAs or Bulk suppliers

The level 2 organisations will benefit in the following ways from measurement implementation:

- *Better quality irrigation water use data.*
- *Fair irrigation water use allocation, with fewer disputes.*
- *Billing for actual use rather than for the quota available.*
- *Better irrigation water use control within the WMA.*
- *Ability to provide better quality agricultural irrigation water use information to DWA.*

Level 3: IOs/responsible water authorities

The level 3 organisations will benefit in the following ways from measurement implementation:

- *Better control over water allocations.*
- *Better management of infrastructure.*
- *Early warning of deteriorating infrastructure through detection of losses.*
- *Possibility of trading surplus water.*
- *Accurate billing of users for actual volume of water used.*

Level 4: Irrigation water users in the agricultural sector

The water users will benefit in the following ways from measurement implementation:

- *Equitable allocation.*
- *Better awareness of the actual amount of water used.*
- *Greater security of supply.*
- *Early awareness that users may exceed their allocation, allowing time to buy or "rent" additional water.*
- *Opportunities to increase production and income.*
- *Opportunities to sell un-utilised allocations.*
- *Reduced water charges if users' full quota is not utilised (if charges are levied on actual use and not full quota).*
- *Early warning of deteriorating on-farm infrastructure, (such as leaks in pipes, pump efficiency and nozzle wear) through loss detection or unexplained increase in water use.*
- *More effective and efficient use of fertilisers and other farming inputs administered through irrigation infrastructure.*

10.6. Water user support and organisational arrangements

Provide the name of the person who will be liaising with the water users, list the most likely objections from the water users against measurement implementation and briefly describe which actions or activities will be undertaken to obtain the support of all the water users affected.

Name of person to liaise with water users:	
List of the most likely objections from water users to the implementation plan:	
Brief description of activities planned to obtain stakeholder support:	

11. The measurement system

Information should be provided on the proposed measuring devices to be installed at the different locations – specifications, pictures and installation requirements. – expand.

11.1. Measuring device selection

The following measuring devices are proposed to be installed at the identified locations:

For example:

Location type 1:	
Measuring device brand name:	*McCrometer McPropeller flow meter*
Measuring method / principle:	*Mechanical turbine type meter*
Life expectancy of devices:	*10 years*
Name and contact details of local supplier / representative (for sales support):	*ABC Instrumentation* *Tel. 011 456 2500*
Brief motivation why device have been selected:	*Developed specifically for non-purified water – self-cleaning mechanism* *Low maintenance requirements* *Can be easily fitted to existing pipeline systems with the minimum amount of disruption* *Flow rate indicator on dial*

Provide a friction loss graph for in-line applications.

Complete the following table to summarise the proposed measuring devices selected for the system:

Component	**Element**	**Location type 1**	**Location type 2**
Measuring device	Primary element (standard physical device or structure):		
	Secondary element (additional data display or read-out, if not part of the primary device, e.g. pulse output):		
	Accuracy of installed device (error % of reading):		
	Number of units required (per size if applicable):		
Installation	Supporting infrastructure (pipes, flanges, reducers, sieves, etc.):		
	Electricity supply and/or connection required:		
	Security devices required (lockable enclosures, tamper-proofing):		
	In-field calibration required:		
	Specialist installation equipment required:		
Capacity building required	Training of technicians for installation		

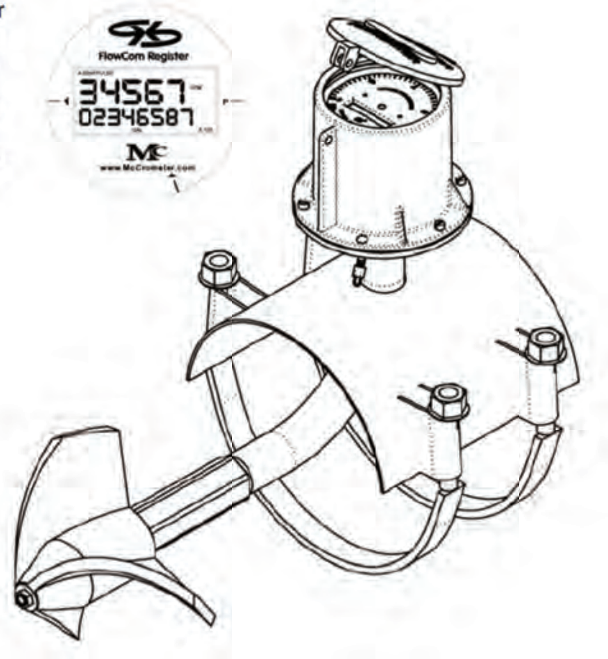
11.1.1. Pictures of devices

Attach pictures of the selected devices together with specifications if required.

For example:

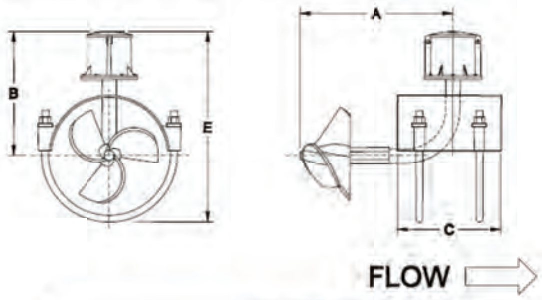
Typical measuring device proposed for location type 1:

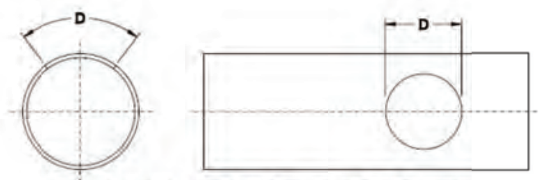
The McCrometer Propeller flowmeter comes with a standard instantaneous flowrate indicator and straight-reading totalizer. An optional FlowCom register is also available.
Typical face plates.



APPLICATIONS

- Center pivot systems
- Sprinkler irrigation systems
- Drip irrigation systems
- Golf course and park water management
- Gravity turnouts from underground pipelines
- Commercial nurseries
- Water and wastewater management





Meter Tube Installation Cut-Out Detail

M0300	DIMENSIONS						
Meter and Nominal Pipe Size	**4"**	**6"**	**8"**	**10"**	**12"**	**14"**	**16"**
Maximum Flow U.S. GPM	600	1200	1500	1800	2500	3000	4000
Minimum Flow U.S. GPM	50	90	100	125	150	250	275
Approx. Head Loss in Inches at Max. Flow	23.00	17.00	6.75	3.75	2.75	2.00	1.75
Approx. Shipping Weight-lbs.	18	22	26	30	34	38	44
A (inches)	7 5/8	15	15	15	15	15	15
B (inches)	8 1/4	10 3/4	10 3/4	10 3/4	11 3/4	13 3/4	13 3/4
C (inches)	7	8	8	9 1/2	9 1/2	9 1/2	9 1/2
D (inches)	4*	5 1/8*	6*	7*	7 1/4	7 1/4	7 1/4
E (inches)	10 3/4	14	15	17	19	20 5/8	21 5/8

For larger sizes see Model M1400. *McCrometer reserves the right to change design or specification without notice.*
**Standard pipe only. For other than standard pipe, consult factory for cutout dimensions.*
Please specify the inside diameter of the pipe when ordering.

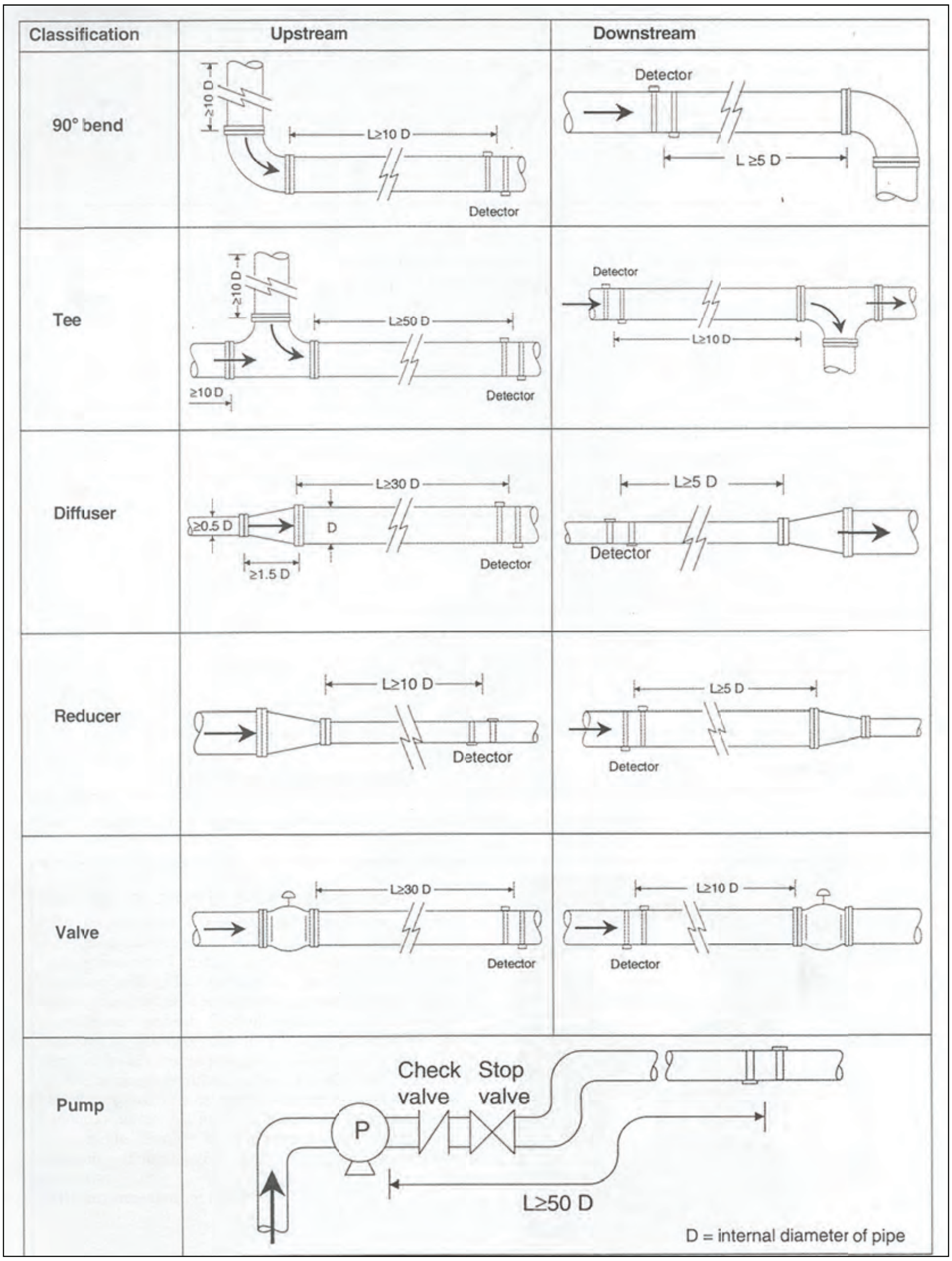
11.2. Installation

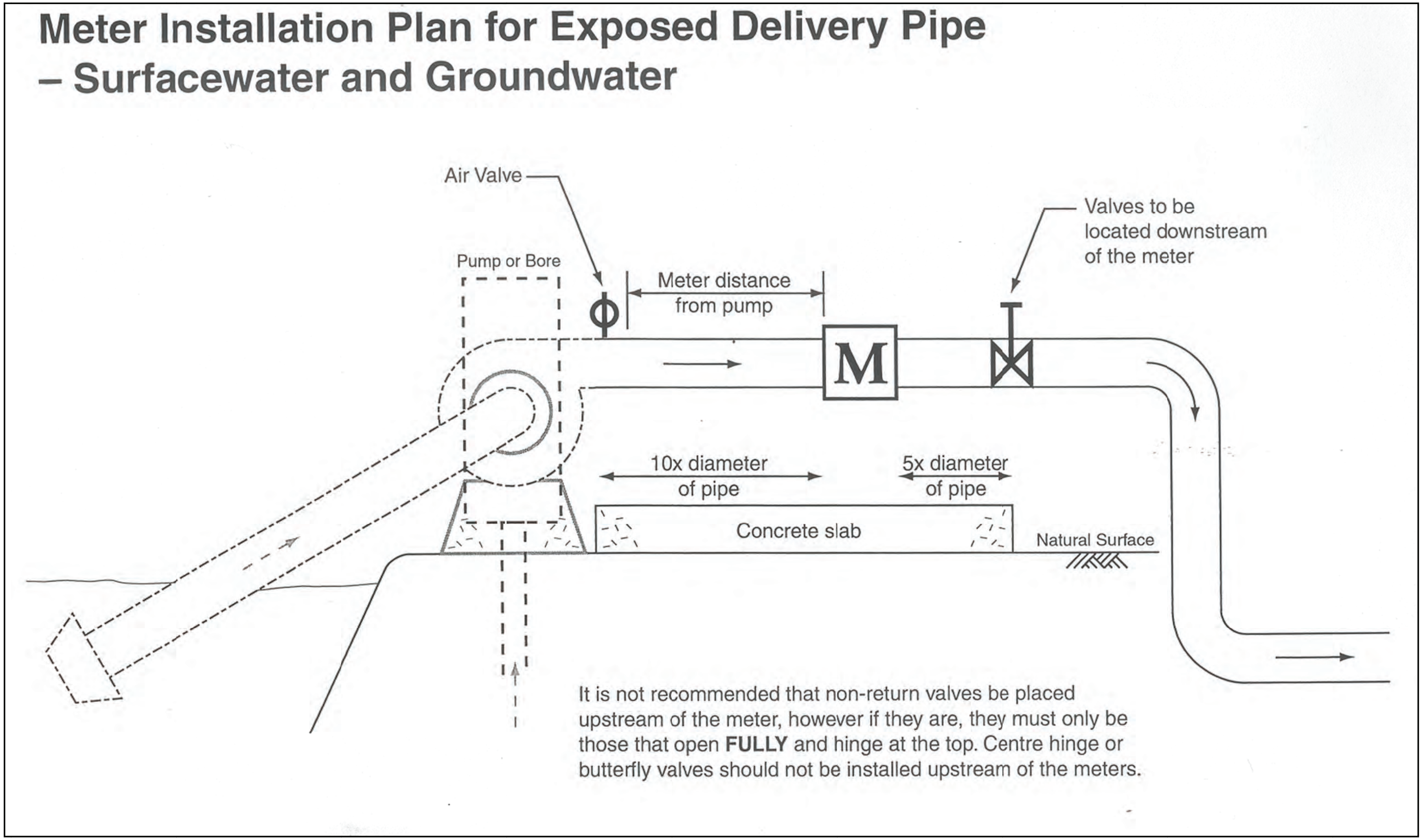
Detailed instructions regarding the installation of the measuring devices should be provided, preferably based upon the specifications of the manufacturer. An installation certificate should be drawn up that can be signed by all the affected parties (IO, water user, installation contractor, etc.) to confirm the completion of installation.

11.2.1. Installation requirements

For example:

Installation requirements for measuring device selected for location type 1 (Crabtree, 2000)*:*





(QDNR&M, 2002)

Or:

Alternatively the site specific installation positions can be provided to the installer:

11.2.2. Installation certificate

An installation certificate should be prepared for each site and signed by the relevant parties to confirm that the meter installation has been completed, with copies provided to each party.

For example:

Installation Certificate

Merchant Copy

Affidavit

I hereby confirm the installation of the McCrometer water meter at Site nr ____________, and that the meter was is working order on the date of the signing of this document.

By signing this document I verify that I have received a copy of the *McCrometer Installation, Operation & Maintenance Manual* and the calibration certificate of the meter.

Information:

Name of Farm____

Name of Farm representative________________________________

Name of UIC representative_________________________________

McCrometer Serial number__________________________________

McCrometer Totaliser Value (m^3) ____________________________

Farm Representative Signature:	UIC Representative Signature:	Date:

11.3. Operation and maintenance

Information should be provided regarding how the system will be operated, once installed (data collection), and on envisaged maintenance.

11.3.1. System operation

Briefly describe the data collection system with specific reference to:

- *How data will be collected (manually / telemetrically / other) and at what intervals.*
- *Who will be responsible for the data collection.*
- *How data will be processed and stored (software, location, reporting).*
- *Procedure to be followed if there is a dispute between the water user and the IO about the data obtained from a measuring device.*

11.3.2. System maintenance

Briefly describe the maintenance requirements of the system with specific reference to:

- *Inspections of measuring devices and data retrieval devices to be made.*
- *Routine serving requirements of all devices, including re-calibration requirements.*
- *Responsibility for maintenance.*
- *Procedure to be followed if a measuring device is found to be faulty.*
- *Procedure to be followed if tampering with a measuring device is suspected.*

It is strongly recommended that a log sheet be opened for each meter by the party responsible for maintenance and that accurate records be kept of any maintenance and repairs carried out.

11.4. Monitoring and evaluation

Briefly describe how the measurement system's effectiveness is to be monitored and evaluated.

- *Methods to be used.*
- *Responsible person.*
- *Feedback and communication.*

Complete the following table to summarise the operation and maintenance requirements of the system:

Component	Element description	Location type 1	Location type 2
Operation (equipment)	Data retrieval device (meter reading, datalogger download or telemetry):		
	Nr of units required:		
	Telemetry base station, if required:		
	Data retrieval and processing – hardware required:		
	Electricity at devices required:		
Operation (administrative)	Telemetry system (Global System for Mobile communications (GSM) or RF contract type):		
	Data retrieval and processing – staff / resources required:		
	Data retrieval and processing – Software required:		
	Other overhead costs to IO:		
Operation (maintenance)	Routine inspections required (staff or contractor, measuring devices and data retrieval devices):		
	Routine servicing required (in-field or laboratory, measuring devices and data retrieval devices):		
	Re-calibration required (intervals):		
	Spare devices for replacement (ex-stock to be kept):		
Capacity building	Training of technicians for maintenance:		
	Training of data collectors (meter reading, etc.):		
	Training of data processors (software use):		

12. Implementing the plan

12.1. Budget and funding

Information on the expected cost of system installation, operation and maintenance, as well as the way in which the implementation will be funded (source of funds, repayment structure, etc.) should be provided.

For example:

The budget breakdown is shown in the table below.

The capital cost for implementation at all the boreholes is estimated to be R4 725 000 which will include the devices, telemetry and training of staff. This works out to R23 300 per meter, of which the cost of the measuring devices alone works out to R15 500 per meter. The installation costs include sophisticated telemetry and also a portable ultrasonic flow meter. The capital cost of the measuring devices and their installation will be paid for by the farmers with their own funds.

The operational cost of the system works out to approximately R12 830 per farmer per year (there are 30 farmers), or approximately R2 000 per meter per year. This excludes other operational costs of the IO.

			Location type 1				
Component	**Element**	**Costing unit**	**Unit Cost**	**Nr of units**	**Installation cost**	**Operational cost**	**Notes**
Measuring device	Primary element (standard physical device or structure)	R/installation	R 10 000	200	R 2 000 000		Average price for McCrometer
	Secondary element (additional data display or read-out, if not part of the primary device, e.g. pulse output)	R/installation	R 2 000	200	R 400 000		Pulse output
	Data retrieval device (datalogger or telemetry)	R/installation	R 3 500	200	R 700 000		Telemetry – modem plus "starter pack"
Installation	Supporting infrastructure (pipes, flanges, reducers, sieves, etc.)	R/installation	R 2 500	200	R 500 000		
	Electricity supply and connection	R/installation	R 500	200	R 100 000		
	Security devices (lockable enclosures, tamper-proofing)	R/installation	R 1 000	200	R 200 000		
	Labour cost (technicians, electricians)	R/installation	R 500	200	R 100 000		
	Consumables	R/installation	R 250	200	R 50 000		
	Traveling	R/installation	R 100	200	R 20 000		10 km x 2 visits x R5 per km
	In-field calibration (expenses or contractor)	R/installation	R 2 500	200	R 500 000		
	Specialist installation equipment	R (once-off)	R 100 000	1	R 100 000		Portable ultrasonic flow meter
Operation (equipment)	Electricity at meters	R/installation /year	R 320	200		R 64 000	80W for 8000 hours per year @ R0.50/kWh
	Telemetry (Cell phone contracts)	R/installation /year	R 100	200		R 20 000	Airtime window for downloads
	Telemetry (Base station)	R/year	R 7 200	1		R 7 200	Cell phone contract plus data download
	Additional energy due to increased friction loss					R –	
Operation (administrative)	Data retrieval and processing – hardware	R (once off)	R 15 000	1	R 15 000		PC with modem

	Data retrieval and processing – staff and expenses	R/year	R 75 000	1		R 75 000	R 60 000 salary and R 15 000 for traveling
	Software (for retrieval or processing)	R/year	R 12 000	1		R 12 000	
	Other overhead costs to WUA	R/year				R –	
Operation (maintenance)	Routine inspections (staff and traveling, or contractor)	R/installation /year	R 350	200		R 70 000	
	Routine servicing (in-field or laboratory, incl. cost of removal if necessary)	R/installation /year	R 250	100		R 25 000	
	Re-calibration (equipment and expenses, or contractor)	R/installation /year	R 1 250	40		R 50 000	20% of units installed
	Spare devices for replacement (ex-stock)	R/year	R 46 500	1		R 46 500	3 devices, in case of theft or off-site maintenance
Capacity building	Training of technicians for installation	R (once-off)	R 30 000	1	R 10 000		
	Training of technicians for maintenance	R/year*	R 10 000	1	R 10 000	R 5 000	
	Training of data collectors (meter reading, etc.)	R/year*	R 10 000	1	R 10 000	R 5 000	
	Training of data processors (software use)	R/year*	R 10 000	1	R 10 000	R 5 000	
Totals					R 4 725 000	R 384 700	

12.2. Role players and responsibilities

Information should be provided on the people and/or organisations that will be involved with the installation, operation and maintenance processes.

12.2.1. Installation

The following role players will be involved with the installation of measuring devices:

Roleplayer	Name	Define responsibilities (if required)
Water users' representative (or implementing agent in future)		
DWA representative (or WMCC regional coordinator in future)		
Financial institution / funder		
Supplier of measuring devices		
Supplier of telemetry equipment		
Installers (water users or contractors)		
Electrician		
Verification / calibration / quality control specialist		
Data systems specialist		
Telemetry specialist		
Other – specify:		

12.2.2. System operation and maintenance

The following role players will be involved with the operation and maintenance of measuring devices:

Roleplayer	Name	Define responsibilities (if required)
Water users representative (or implementing agent in future)		
DWA representative (or WMCC regional coordinator in future)		
Supplier of measuring devices		
Supplier of telemetry equipment		
Water users		
Electrician		
Verification / calibration specialist		
Data systems specialist		
Telemetry specialist		
Other – specify:		

12.3. Gantt chart

Provide information on the envisaged project implementation to install measuring devices and the data collection system.

For example:

In the following figure the envisaged implementation process is presented in the form of a Gantt chart.

Feasibility study

The feasibility study was undertaken in 2008 and resulted in the proposed measuring systems as described in this implementation plan.

Implementation plan

This report is the first draft of the implementation plan for discussion by the water users of the implementation area. After their inputs have been obtained and addressed, a final draft implementation plan will be presented to DWA (or the WMCC in future). When approval has been obtained at this level, feedback will be provided to the water users.

Funding

Once the implementation plan has been finalised and approved by both DWA (WMCC) and the water users, funding requirements will be finalised in conjunction with the identified potential funders of the project. Confirmed availability of funds will be needed before the implementation phase commences.

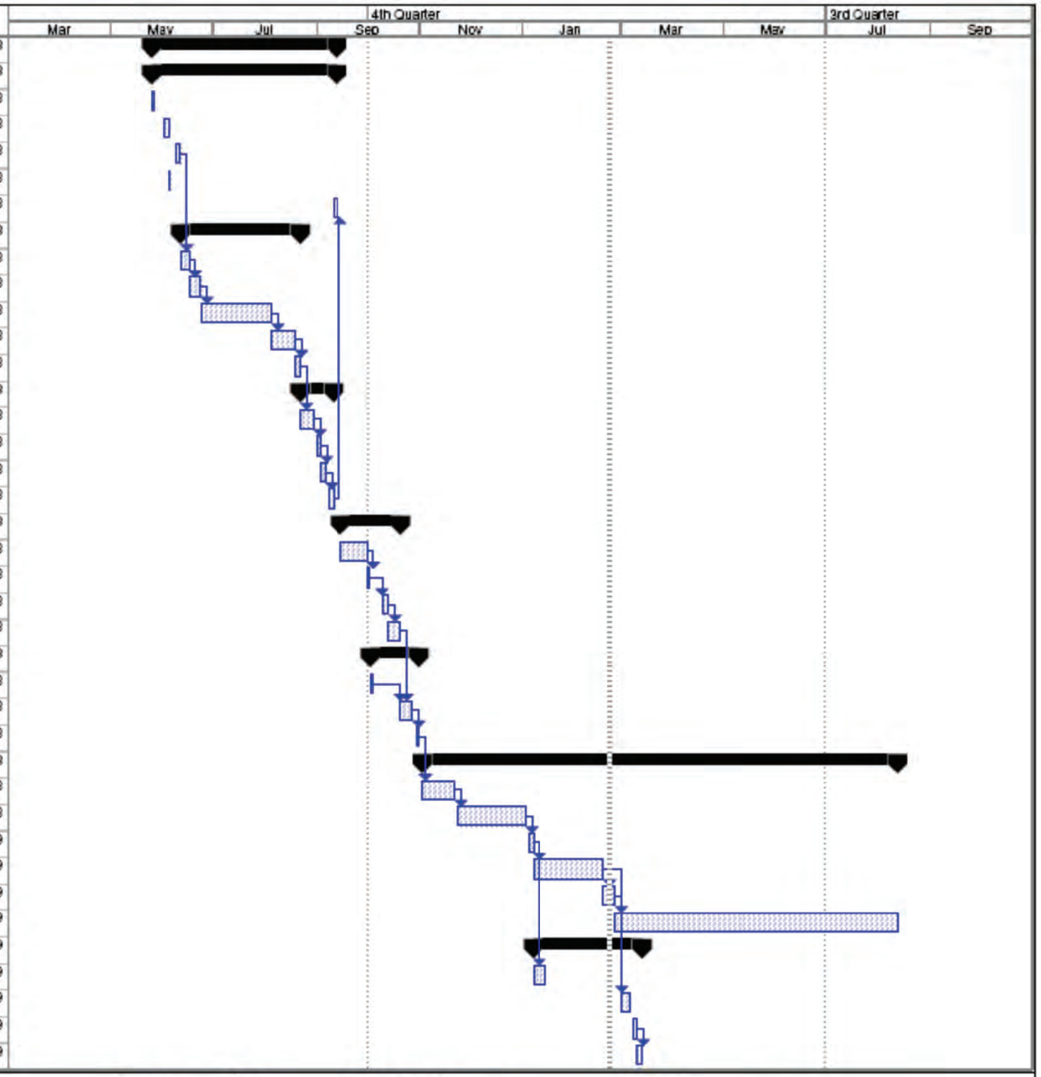
Implementation

Once the funding arrangements have been confirmed, the necessary documentation will be prepared. The water users would like to appoint a consultant to undertake the necessary designs and prepare installation drawings, guidelines and verification documents. Some of the water users have indicated that they are willing to install the measuring devices themselves, while other would like to appoint a contractor, in which case tender documentation will have to be prepared and suitable contractor(s) appointed. All telemetry systems will be installed by a qualified electrician (a contractor will be appointed). Training will be provided to all installers (water users and contractors) in collaboration with the measuring device and telemetry system suppliers. A pilot area will be identified where an initial number of meters with telemetry are to be installed. Parallel to this installation process, the data system specialist will be appointed and the telemetry data collection system installed at the IOs offices. When installation has been completed in the pilot area, the system will be tested and adjustments to the initial designs made, if required. Thereafter installations will continue in the remaining part of the implementation area.

Capacity building

Following completion of the pilot phase's installation and testing, technicians to provide maintenance will be identified and trained, as well as data collectors and processors for the data collection system.

ID		Task Name	Duration	Start
1		Steenkopples measurement feasibility study	80 days	Mon 26/05/08
2		High level assistance	80 days	Mon 26/05/08
3		Project clarification	1 day	Mon 26/05/08
4		Liaison with DWAF	3 days	Mon 02/06/08
5		Liaison with water users	3 days	Mon 09/06/08
6		Liaison with ESKOM	1 day	Thu 05/06/08
7		Presentation of scenarios	2 days	Thu 11/09/08
8		Survey and compilation of database	51 days	Thu 12/06/08
9		Design database	3 days	Thu 12/06/08
10		Arrange and coordinate data collection	5 days	Tue 17/06/08
11		Field work	30 days	Tue 24/06/08
12		Data capturing	10 days	Tue 05/08/08
13		Data assessment	3 days	Tue 19/08/08
14		Scenario development	14 days	Fri 22/08/08
15		Data analysis	6 days	Fri 22/08/08
16		Additional data collection	2 days	Mon 01/09/08
17		Costing estimates	3 days	Wed 03/09/08
18		Reporting	3 days	Mon 08/09/08
19		Implementation plan	26 days	Mon 15/09/08
20		Compile first draft	12 days	Mon 15/09/08
21		Present to water users for approval	2 days	Wed 01/10/08
22		Present final draft to WMCC	2 days	Fri 10/10/08
23		Final report to IO	5 days	Tue 14/10/08
24		Funding	21 days	Fri 03/10/08
25		Identify potential funders	1 day	Fri 03/10/08
26		Liaison for funders	5 days	Tue 21/10/08
27		Final proposal to IO	1 day	Fri 31/10/08
28		Implementation	203 days	Mon 03/11/08
29		Prepare documentation	15 days	Mon 03/11/08
30		Tender process	30 days	Mon 24/11/08
31		Contractor on site	3 days	Mon 05/01/09
32		Installations complete - pilot phase	6 wks	Thu 08/01/09
33		Test and review	1 wk	Thu 19/02/09
34		Installation complete - whole area	6 mons	Thu 26/02/09
35		Capacity building	47 days	Thu 08/01/09
36		Training of installers	5 days	Thu 08/01/09
37		Training of technicians for maintenance	5 days	Mon 02/03/09
38		Training of data collectors	2 days	Mon 09/03/09
39		Training of data processers	3 days	Wed 11/03/09



Project: Example gantt chart
Date: Sun 22/02/09

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Page 1

12.4. Invitation for inputs

The implementation plan should be concluded with contact details of the responsible persons or organisations as well as invitation to stakeholders to take part in the process.

For example:

This version of the implementation plan represents the draft version of the document as on ____________________________ (date). However, input from role players is always welcomed to improve the document and the process of implementation.

As such, this should be seen as a living document, and open to amendment and update. Kindly address any comments and inputs to:

Chief Engineer: Water Resources Management – Crocodile/Marico Water Management Area *Private Bag X995,* *Pretoria* *0001* *Tel 012 392 1308* *Fax 012 392 1408* *Cell 082 808-9560*	*Water users' representative – Steenkoppies Aquifer Management Association (SAMA)* *PO Box 10* *Tarlton* *0005* *Tel 011 567 7001*	*Irrigation water use measurement implementation coordinator: Department of Water Affairs and Forestry – Directorate Water Use Efficiency* *Private Bag X 313* *Pretoria* *0001* *Tel 012 336 7194*

PART D: LESSONS LEARNT

13. Case study results

This section of the report covers the activities undertaken during the implementation phase of the project. Initially, three case study areas were identified where water measurement was to be implemented or upgraded: the Crocodile River in Mpumalanga, the Steenkoppies groundwater area in North-West, and the Hereford Smallholder Irrigation Scheme near Groblersdal in Mpumalanga.

These case studies are described here, together with supporting information from two other irrigation areas: the Middle Komati and Thabina Smallholder Irrigation Schemes in Mpumalanga, and the Orange-Riet Water User Association (ORWUA) on the Free State/Northern Cape border, where measurement implementation had been undertaken independently over the last 10 years.

13.1. Steenkoppies groundwater area

13.1.1. Case study background information

The Steenkoppies area is situated north-west of Johannesburg, near the town of Tarlton. The Steenkoppies Dolomitic Compartment covers an area of 170 km^2, and is situated between latitudes 26° 02' to 26° 13' south, and longitudes 27° 29' to 27° 39' east, as shown in Figure 4.

Figure 4: Locality map of the Steenkoppies case study area

The area is covered by gently rolling plains, the topography varying between ± 1540 m and ± 1560 m above sea level in the east and rising towards the north and west, attaining a maximum elevation of ± 1640 m in the extreme north-west corner of the compartment.

The study area is further characterised by the absence of significant surface water drainage. The lack of pans and marshes indicates that most of the natural water supply gained from precipitation drains directly into the aquifer.

A spring, Maloney's Eye, situated approximately 0.75 km north of the northern boundary of the compartment, is the lowest point of the water level contour map and serves as a natural outlet for the groundwater stored in the compartment. The outflow from this spring varies between 11 x 10^6 m^3 and 22 x 10^6 m^3 per year and is approximately 1490 m above sea level. This spring is the only natural outflow for water from the Steenkoppies Compartment (Barnard, 1996).

The compartment is bounded on the east and west by the Venterspost and Bank dykes respectively, both dykes striking north-south. The area is underlain by dolomitic limestone, which together with interbedded chert lenses, forms the Malmani Subgroup of the Chuniespoort Group. To the south the outcropping quartzites of the underlying Black Reef Quartzite Formation forms the southern boundary of the compartment, while to the north an unconformity separates the Chuniespoort group from overlying quartzite and shale of the Pretoria group, effectively forming the northern boundary of the compartment (Foster, 1984).

The Steenkoppies area is one of South Africa's main vegetable production areas under irrigation, producing mainly cash crops such as carrots, cabbage and lettuce. The 21 Tarlton farmers have an annual estimated turnover of around R500 million and employ more than 3 500 people directly. The capital investment in the area by these farmers is estimated to be around R750 million, and the annual salary and wage bill of around R75 million per year maintains the local economy.

In 1996 a study examining the decline in flow rate of Maloney's Eye (from 1.3 x 10^6 m^3 in 1985 to 0.5 x 10^6 m^3 in 1995) found that:

- The cultivation under irrigation increased to 1951.5 ha.
- The production of vegetables increased to more than half of the surface area.
- The total volume of groundwater abstracted from the aquifer increased to 20.1 x 10^6 m^3 per year (Barnard, 1996).

A reduction in the flow of water from Maloney's Eye, from 11.9 x 10^6 m^3 $year^{-1}$ (in 1986/1987) to 7.04 x 10^6 m^3 $year^{-1}$ (1995) resulted in a petition from farmers downstream of Maloney's Eye to the Minister of Water Affairs and Forestry. In the petition the farmers asked the Minister to declare the catchment area (Steenkoppies Compartment) of Maloney's Eye an underground WMA, and to stop the withdrawal of underground water from the Steenkoppies Compartment. The conflict escalated over the years, peaking in 2007 when the Minister finally declared restrictions upon the withdrawal of groundwater based on the flow measured from Maloney's Eye.

The area was selected as a case study due to the urgency of improved water management as well as the fact that the water users themselves had already identified water measurement of the abstracted volumes as a possible means to prove that they are within their lawful allocations.

13.1.2. Case study aims and overview

The objective of the measurement system to be implemented was to:

- Measure the volume of water taken by water users for irrigation.
- Monitor groundwater levels for aquifer management.

This is the case study area in which the project aims have been addressed most successfully. The project team compiled an implementation plan in consultation with the farmers, and suitable meters were selected for installation. Seven boreholes were selected for pilot installations so that the farmers could assess the suitability of the meters, and the installations facilitated by the project team. The farmers also indicated that they wanted a telemetric data collection system, and the meter manufacturer began the development of a custom-made datalogging and transmission system for the meters. The telemetry was also tested at one of the pilot sites.

The results of the pilot phase were presented to the water users from the area at a meeting held on 29 July 2010, where it was agreed that implementation should continue. The project team undertook a detailed borehole census in conjunction with the suppliers of the selected meters during August and September 2010. A total of 116 boreholes were identified as being actively used for irrigation on the Compartment.

Order forms were prepared for each irrigation water user on the compartment, using the borehole data collected during the census, and the forms sent to the water users in November 2010.

No reaction (orders) was received from any of the water users, and it was decided that each water user should be visited in person to discuss his/her situation. These visits took place in December 2010 and January 2011, and order forms were amended to accommodate water users' financial situations, which was the reason cited most often for not ordering meters. Other water users rejected the water metering initiative because it was not compulsory or because they felt that there were other users illegally using water, a situation which should first be addressed. By the end of April 2011, eight signed order forms (out of 32 identified farms) have been received, representing 54 of the 116 boreholes. The order forms were reconciled and the orders placed in May 2011.

In June 2011, the water users were approached to sign contracts with Vodacom for the SIM cards required for the modems that are fitted on the meters. The meters had in the meantime arrived from the USA in July 2011, and the local suppliers were in the process of fitting and testing the modems. This process required the SIM cards, and the last water user signed their Vodacom contract in August 2011.

With the meters being ready for delivery, an installation demonstration was arranged on 27 September 2011 for the seven water users, coinciding with the first water meter deliveries. The delivery of all the ordered meters was completed by 21 October 2011.

The modem supplier developed a newer version of the website to record the meter readings, which was compliant with DWA requirements for monitoring and information systems. The meter readings were collected via Short Message Service (SMS) until the website was operational.

The reporting period also included the installation of an automatic weather station, five groundwater level sensors and 15 tipping bucket rain gauges to assist with aquifer management and Reserve determination. This equipment was funded by DWA together with a subsidy that was provided for the water meters (approximately 12% discount received by the water users effectively).

The process of supplying water meters to the water users in the Steenkoppies area is described here. The process, starting with the agreement reached during the meeting on 29 July 2010, took 15 months to complete the installation of 54 meters at 116 of the identified boreholes.

13.1.2.1 Data capturing

The first step of the process was to capture all the data collected during the survey in a spreadsheet. The data collected included:

- Water user name and contact details.
- Borehole number.
- Coordinates.
- Pipe material.

- Pipe size (outer diameter).
- Pipe wall thickness.
- Straight pipe length available for installation.
- Type of water usage from borehole (irrigation, industrial, domestic).

The census also included a large number of photographs that were taken of the different boreholes, from different angles, in order to select the best installation position for the meter. These photographs were sorted and numbered according to the borehole numbers.

13.1.2.2 Borehole selection criteria

The captured data showed that a total of 145 boreholes were used on the aquifer by the Steenkoppies Aquifer Management Authority (SAMA) members, with the distribution in envisaged meter sizes as shown in Figure 5.

At the beginning of the project, the initial approach towards selecting boreholes for meter fitment was to consider that all boreholes with supply pipelines 100 mm and larger in size were being used for irrigation or industrial purposes (in other words, not domestic use), and thus were to be fitted with water meters. The detailed census revealed that more than a third of the boreholes were 120 mm and smaller, leading to the decision that the selection criteria should be the type of water use, rather than the size of the pipes.

Of the 145 metering opportunities, 15 boreholes were found to be used for either domestic water supply only, or were situated on farms that were no longer actively being farmed, leaving 130 meters to be fitted. During the final ordering process, a further 14 potential meters were eliminated due to disrepair or financial difficulties experienced by the farmers, leaving 116 boreholes to be fitted.

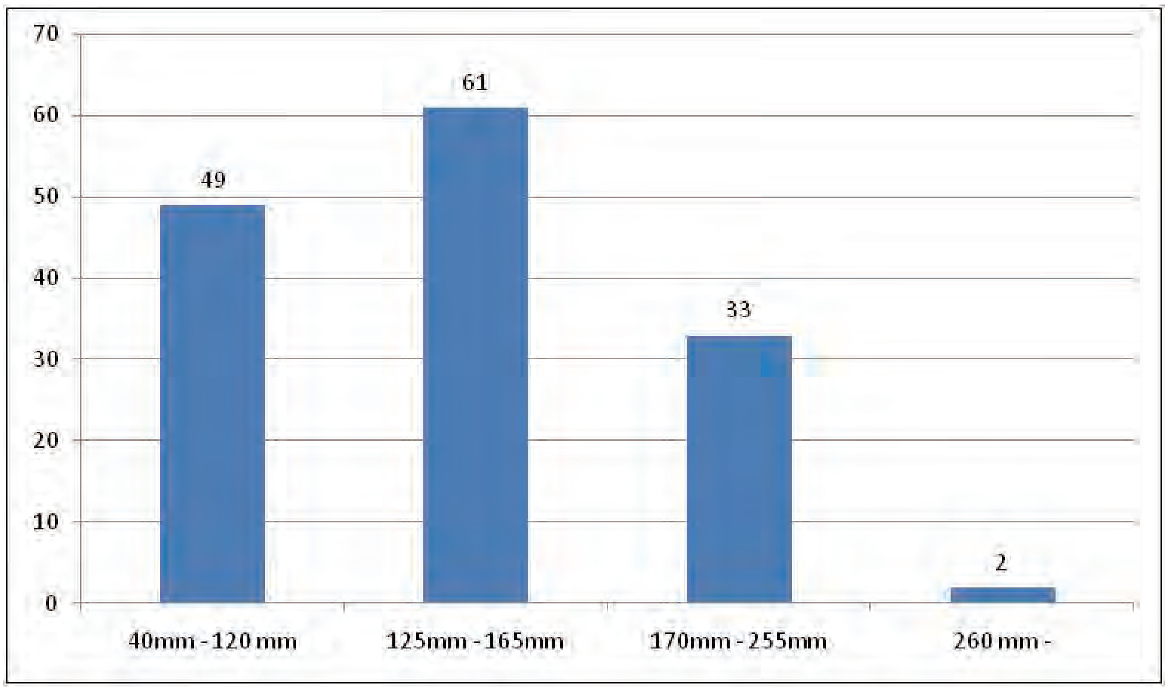


Figure 5: Distribution of pipe sizes in 145 boreholes on the Steenkoppies aquifer

13.1.2.3 Meter installation location selection and orientation

The next step was to assess each borehole and select a suitable installation location for the meter on the borehole pipe work.

Ideally, a mechanical flow meter requires a straight pipe length of 10 times the pipe diameter before the meter, and 5 times the pipe diameter after the meter to ensure optimal hydraulic conditions for meter accuracy. However, these ideal conditions are seldom found, and more relaxed conditions of a straight approach of 5 diameters followed by 3 diameters after the point of installation is acceptable in practice. The McCrometer meter (Figure 6) that had been selected by SAMA for installation has also proven in practice that it is relatively insensitive to turbulence in pipes, most likely due to the size of the impeller relative to the inside pipe diameter.

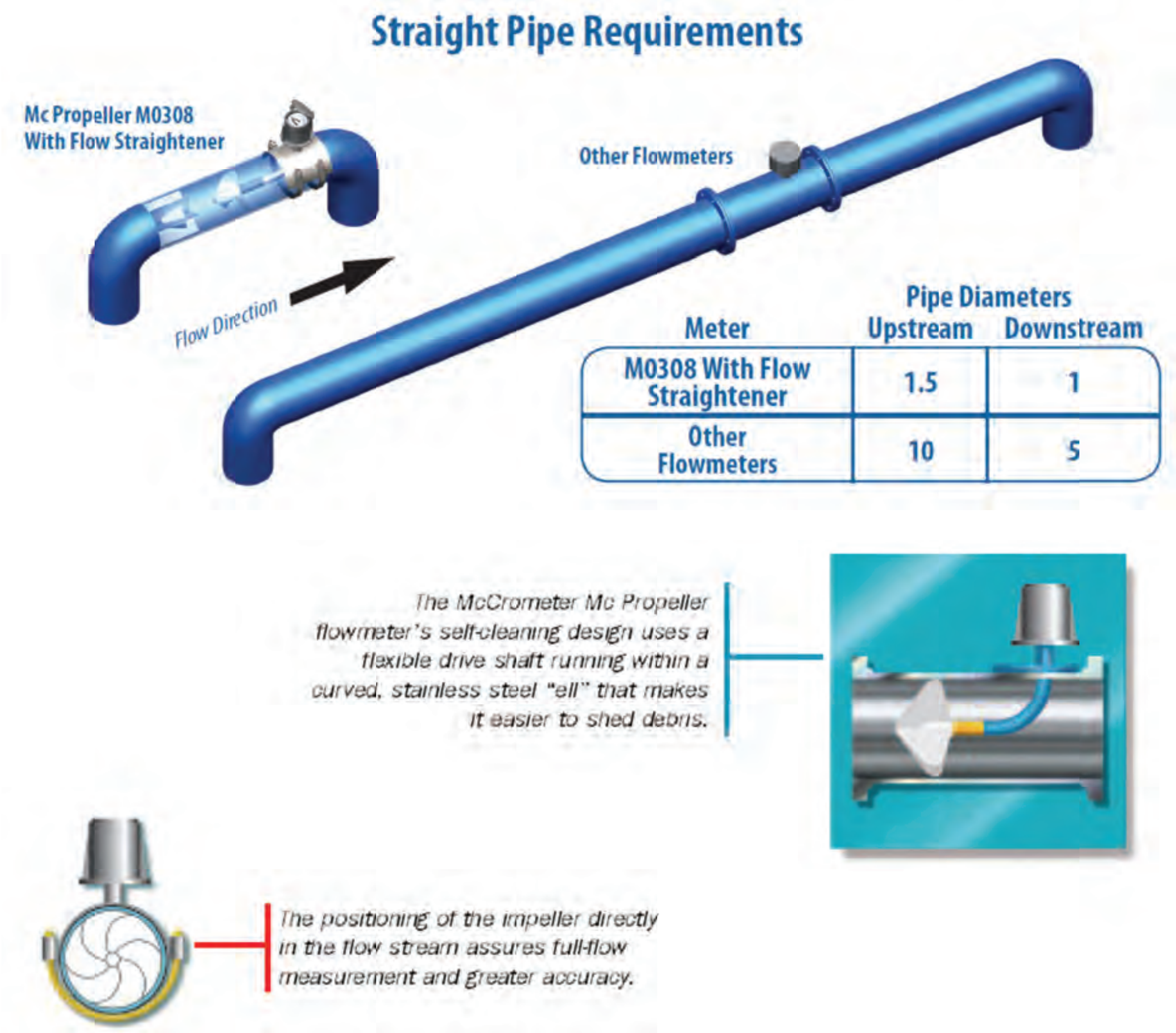


Figure 6: Advantages of installation of the selected water meter (McCrometer, 2009)

Typical installation locations are shown in Figure 7, illustrating that in many cases the existing pipe work needed some modification to accommodate the meter installation.

Figure 7: Typical boreholes to be fitted with meters

Every borehole was then assessed to determine the best location for the meter to be installed. The required orientation of the meter was noted (horizontal / vertical), together with the need to reverse-fit the impeller to improve straight pipe lengths where necessary, and the requirement for either a saddle or a body with threaded ends. In approximately 30 of the cases, some adjustment to the existing pipe work was made by the water user to accommodate the meter installations.

13.1.2.4 Preparation of order forms

The next step was to prepare an order form for each water user with the details of the boreholes for which meters had to be ordered. The forms included all the information discussed above, as well as photographs of the boreholes. An example of an order form and accompanying photos are shown in Figure 8 and Figure 9.

13.1.2.5 Procurement process

Once the quotation was accepted by the water user, the order form was faxed to the meter supplier who then invoiced the water user for 50% of the total of the sale, of which receipt is required before the meters were dispatched from the USA. The balance of the sale amount was payable upon delivery of the meters, less the subsidy amount provided by DWA. Upon receipt of the meters, the water users were given 30 days to install the meters, after which the installations were checked and meter operation verified by an independent assessor.

No reaction (in the form of an order) was received from any of the water users after the order forms were sent out in November 2010. It was therefore decided that each water user should be visited in person to discuss their situation. These visits took place in December 2010 and January 2011, and order forms were amended to accommodate water users' financial situations, which was the most often cited reason for not ordering meters. Other water users rejected the water metering initiative because it was not compulsory or they felt that there were other users illegally using water, a situation which should first be addressed. The project team continued to follow up with the water users, and meetings with individual farmers were arranged. By the end of April, eight water users had ordered meters and of these, seven had paid the required 50% deposit.

The farms where meters were to be installed are listed in Table 5. Farm numbers left out are sites where farming businesses have gone bankrupt, or where no irrigation takes place.

DWA Steenkoppies Project order
Attention: Stuart / Rendani

Instrumentation (Pty) Ltd

P.O. Box 12245
Jacobs
4026
Ultimate House
152 Voortrekker Street
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http://www.uic.co.za

Quotation / Order		Date:	30 November 2010						http://www.uic.co.za
Addressed to:	**Address**	**Code**	**Contact Person**	**Contact number**	**Fax number**	**Cell number**	**VAT number**		**email address**
LJ Trust	PO Box 241 Tarlton	1749	Jan Marais	0833671546	011 952 2495		4501709442		janmarais@iafrica.com

Quotation / Order details

Item	Code	Description (meter size)	QTY	Unit Price (excluding VAT)		Amount
1	MT102	50 mm threaded body		R 16 880.80		R 0.00
2	MT102.5	65 mm threaded body		R 16 880.80		R 0.00
3	MT103	80 mm threaded body	1	R 16 880.80		R 16 880.80
4	MT104	100 mm threaded body		R 16 880.80		R 0.00
5	M0304	90 – 120 mm saddle type		R 16 880.80		R 0.00
6	M0306	125 – 165 mm saddle type	3	R 17 404.25		R 52 212.75
7	M0308	170 – 250 mm saddle type	1	R 18 532.85		R 18 532.85
8	HydroCom only	Modem / Comms unit		R 6 250.00		R 0.00
				Subtotal		R 87 626.40
				VAT @	14%	R 12 267.70
			5	Total		R 99 894.10

This quote is subject to the following terms and conditions:
1. The quote is valid for 30 days
2. Unit prices quoted excludes VAT
3. Terms of payment: 50% deposit required with order
Settlement of balance with delivery of equipment
4. All goods remain the property of UIC Instrumentation (Pty) Ltd until fully paid for.
5. UIC standard sale agreement terms and conditions available upon request
6. Delivery: 3 months

Acceptance of quote
I hereby accept the quote in accordance with the terms and conditions above
Name:
Signature:
Date: Client order nr:

Installation details

Meter nr	Longitude (approx.)	Lattitude (approx.)	Pipe material	Pipe size (OD) mm	Pipe wall mm	Horizontal / Vertical?	Reverse impeller?	Saddle / thread	Size if threaded	Type of water usage	Notes	Meter cost
16.1	S26˚03.682	E27˚36.487	steel	220	8.3	V	Y	S		irrigation/house		R 18 532.85
16.2	S26˚03.682	E27˚36.487	steel	165	5.1			S		irrigation/industry	Pipe work required, right angle meter?	R 17 404.25
16.3	S26˚03.682	E27˚36.487	steel	166	4.4	H	Y	S		irrigation/house		R 17 404.25
16.4	S26˚03.675	E27˚36.502	steel	165	4.8	H	Y	S		irrigation/house		R 17 404.25

Figure 8: Example of an order form for the water meters

16.1

16.2

16.3

16.4

Figure 9: Example of photos accompanying the order form

Table 5: Summary of water meter orders received

Farm nr	Number of boreholes used for irrigation	Total envisaged cost of flow meters (excluding VAT)	Number of meters ordered (or verbally undertaken to do so before 31 Jan. 2011)	Cost of flow meters ordered / to be ordered by 31 Jan. 2011	Reason for not ordering /ordering fewer than the total required / Notes
3	6	R 101 284.80	0	0	Finance
5	4	R 69 698.70	4	R 69 698.70	Finance
7	1	R 16 880.80	0	0	Finance
8	2	R 33 761.60	0	0	Finance
9	2	R 33 761.60	2	R 33 761.60	ORDER RECEIVED
10	5	R 84 404.00	0	0	Finance
11	3	R 51 689.30	0	0	Finance
14	6	R 101 284.80	4	R 67 523.20	Finance
15	Closed down				
16	5	R 87 626.40	Maybe 3	R 53 341.35	Finance
17	3	R 18 750.00	0	R 18 750.00	Previously installed – only modems
18	1	R 16 880.80	0	0	No response to order
19	2	R 33 761.60	0	0	Finance
21	1	R 16 880.80	0	0	Renting land out
26	11	R 339 128.90	11	R 107 178.50	Finance
28	1	R 16 880.80	1	R 16 880.80	N/A
30	2	R 33 761.60	0	0	Finance
31	20	R 350 760.35	20	R 350 760.35	N/A
32	2	R 33 762.60	2	R 33 761.600	N/A
34	12	R 203 616.50	0	0	Illegal users on the compartment should first be removed before he will install water meters
35	Industrial user				
36	2	R 33 761.60	0	0	Order referred to land owner
37	Closed down				
38	Closed down				

39	Closed down				
40	2	R 33 761.60	0	0	Not interested/finance
43	1	R 16 880.80	0	0	Finance
48	Closed down				
50	1	R 16 880.80	0	0	No response
51	Industrial user				
52	12	R 203 093.05	Maybe 2	R 33 761.60	Finance
53	1	R 16 880.80	1	R 16 880.80	N/A
54	8	R 168 658.70	4	R 69 698.70	Finance
Totals	**116**	**R 2 135 599.00**	**54**	**R 856 797.20**	

13.1.2.6 Delivery

The meters were received by the local suppliers from the manufacturer in the USA in June and July 2011, where after the GSM modems had to be fitted to each meter together with a SIM card to enable telemetric data collection via the cellular phone network. The project team facilitated the signing of the cell phone contracts by providing the SAMA members with information on different contracts available, and the meter supplier negotiated a special agreement with Vodacom on a R49 per month data contract (per modem).

Each meter was fitted with an identification tag that included the farm and borehole number according to the site survey that was done initially, and delivery notes were prepared for each water user to sign upon collection of the meters.

13.1.2.7 Installation process

An installation demonstration day was arranged for 27 September 2011, coinciding with the delivery of the first meters, and supporting documentation was prepared to assist water users with the installation process. The meters were all delivered by 4 November 2011, and it was arranged that the project team members would inspect the installations to verify the correct operation of the meters after 30 days.

However, by the end of January 2012 very few meters had in fact been installed, due to the intensive production season, the Christmas holidays, and rain. The project team commenced with the verification of the meter installation and a certificate was designed that could be signed by both parties upon completion of the installations (Figure 10).

By the completion of the WRC project, 80% of the meters purchased, had been installed, with the owners of the remaining 20% saying they will install it when required to do so by the responsible authority

Instrumentation (Pty) Ltd.

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Installation Certificate

Merchant Copy

Affidavit

I hereby confirm the installation of the McCrometer water meter at Site No. ___________, and that the meter was is working order on the date of the signing of this document.

By signing this document I verify that I have received a copy of the *McCrometer Installation, Operation & Maintenance Manual* and the calibration certificate of the meter.

Information:

Name of Farm____

Name of Farm representative__________________________________

Name of UIC representative___________________________________

McCrometer Serial number____________________________________

McCrometer Totaliser Value (m^3) ________________________________

Farm Representative Signature:	UIC Representative Signature:	Date:

Figure 10: Example of an installation certificate used at Steenkoppies

13.1.2.8 *Data collection system*

A website was developed for the collection of meter readings and presentation of data (Figure 11). The main screen uses a geographical background to display the meter locations, from where the user can zoom in closer to the specific area of interest (Figure 12). A specific meter can be identified and when selected, the website will display the number and critical information of the meter (battery and signal strength) as shown in Figure 13. The flow data of the specific meter can then be accessed via a password protected pop-up window, where the daily volumes transmitted by the meter's telemetry to the website can be seen (Figure 14).

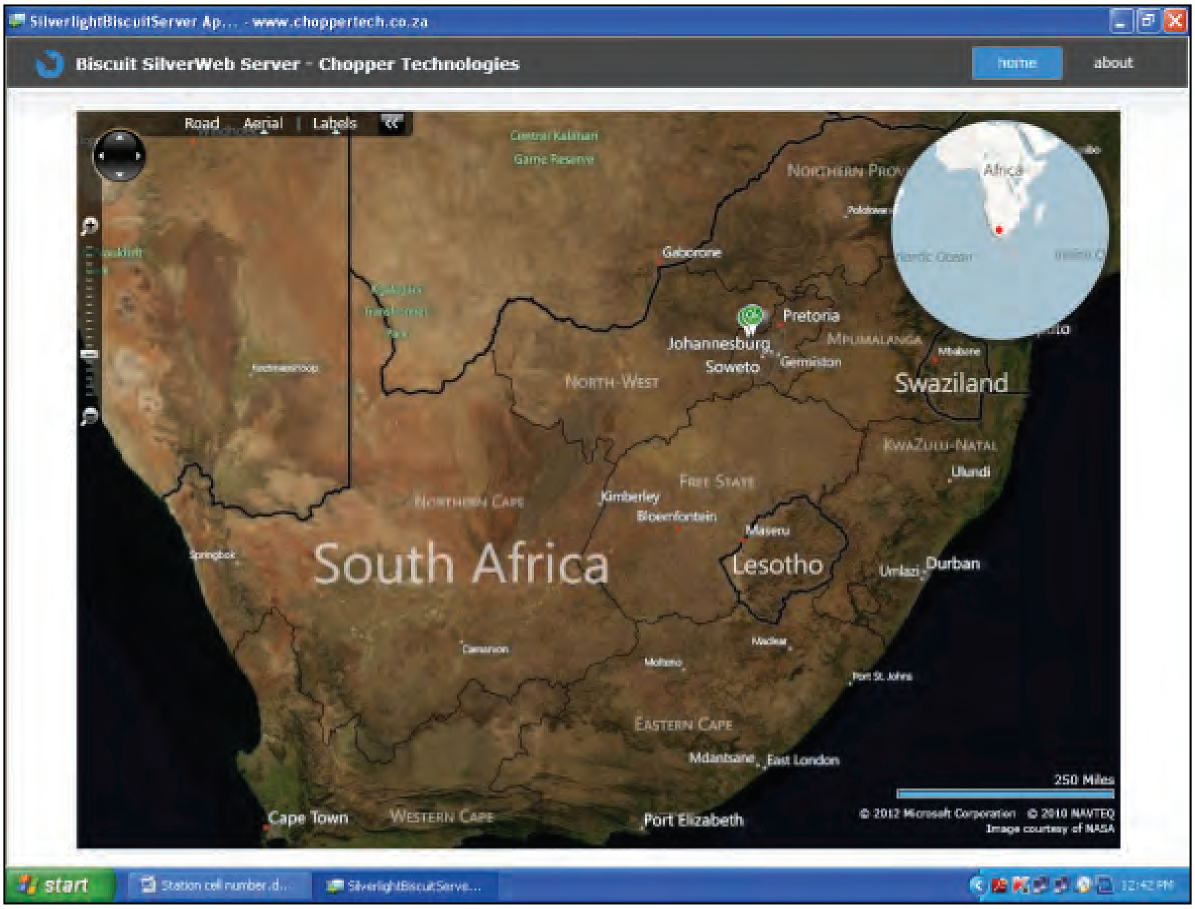


Figure 11: Steenkoppies water meter website main screen

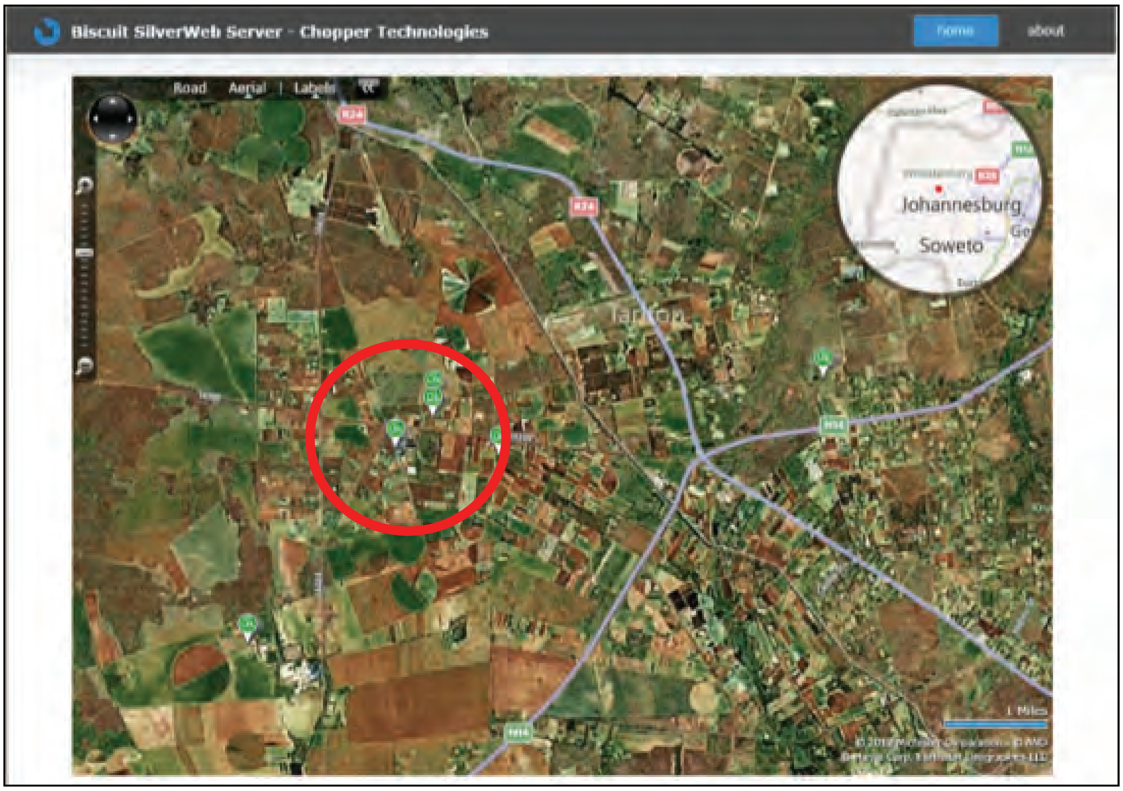


Figure 12: Steenkoppies water meter website main screen showing meter locations

Figure 13: Steenkoppies water meter website showing one selected meter

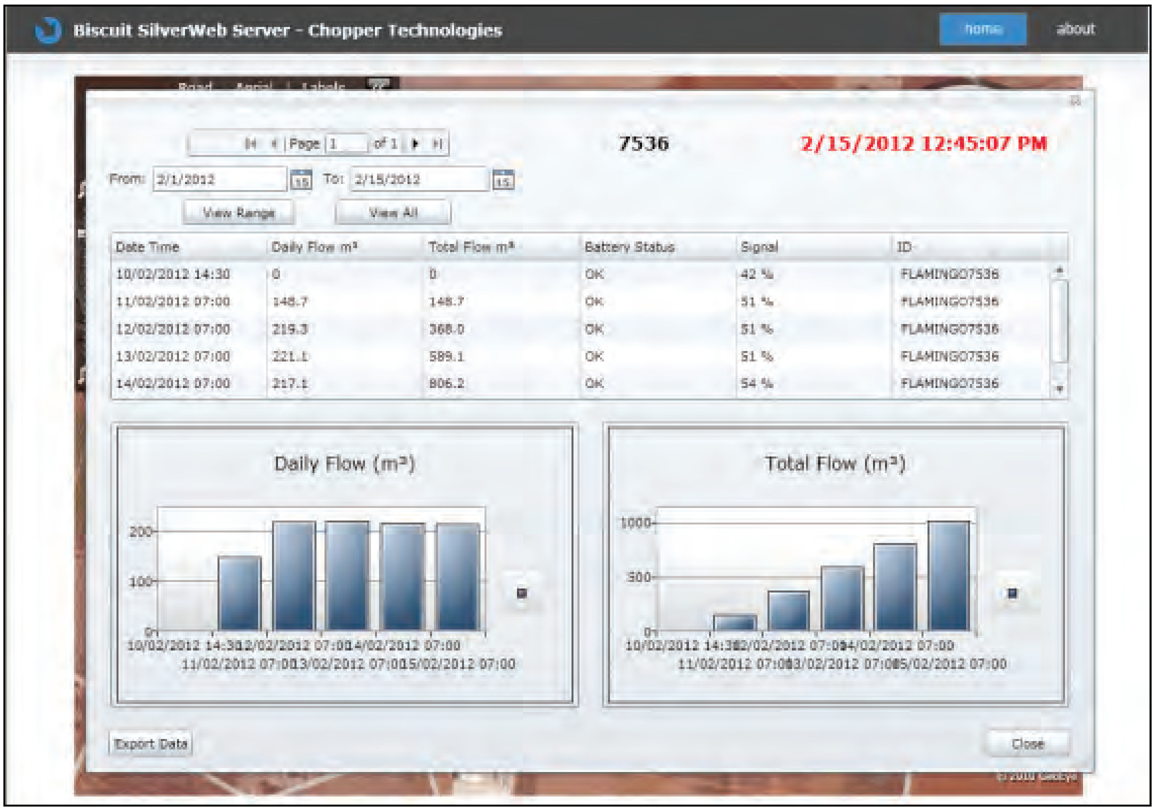


Figure 14: Steenkoppies water meter website showing data of selected meter

13.1.3. Case study activity summary

The actions that took place during the case study are presented in Table 6 as a timeline of events.

Table 6: Timeline of events for the Steenkoppies case study

Date	Events
March 2007	Eight of the nine springs at Maloney's Eye(the outflow of the Steenkoppies groundwater aquifer that feeds the Magalies River), stop flowing
May 2007	Farmers from the Tarlton area on the Steenkoppies compartment establish SAMA and appoint JT Vahrmeijer on a part time basis to start negotiations for the establishment of a WUA in the area. Verification of their registered water use was on-going at this time. Measurement of water abstracted from the aquifer is identified as a possible solution to proving their lawful water use.
October 2007	The Acting DG of DWA issues a notice that places restrictions on the amount of groundwater that can be withdrawn from the Steenkoppies dolomitic aquifer according to the flow rate measured from Maloney's Eye, following an instruction from the Magalies River Crisis Committee
November2007	The Tarlton farmers respond to the DWA notice through a report submitted on their behalf by their lawyers, requesting a partnership to be formed between DWA and all the water users affected.
January 2008	The farmers appoint a 3-person committee to investigate different water meter solutions. Suppliers are invited to make submissions and a short list of meters is compiled.
May 2008	The farmers approach consulting engineers to write a proposal for the implementation of water measurement on the aquifer. Funding is identified as a potential constraint to implementation.
July 2008	The Directorate: WUE submits a proposal to DWA to fund a project to implement water measurement and develop a WMP for the Steenkoppies dolomitic compartment. The Steenkoppies area is identified as a pilot study site for the WRC project on awareness creation, implementation plans and guidelines for management of sustainable on-scheme and on-farm water measurement.
March 2009	A survey of all the boreholes used for agricultural purposes in the compartment is undertaken as part of the WRC project.
August 2009	An implementation plan for water measurement on the Steenkoppies compartment is developed as part of the WRC project. Trial sites for the installation of a type of water meter selected from the short list compiled by the farmers are identified and meters ordered from the supplier (paid for by the farmers).
October 2009	Trial site meters are installed and monitoring commences. Manual data collection takes place until February 2009, during which automated data collection is identified as a definite requirement.
February 2010	The DWA project is approved and consultants are appointed to start with the project on 1 April 2010 (one year contract). Above average summer rainfall occurs, reducing the demand for irrigation water both on the Steenkoppies compartment and along the Magalies River.
April 2010	One of the trial sites is fitted with telemetry to test the proposed automatic data collection system. The DWA project consultant negotiates a discounted price for the meters and telemetry with the supplier.
June 2010	A proposal for the establishment of the Steenkoppies WUA is submitted to DWA by the members of SAMA.
July 2010	A meeting is held with the farmers to inform them of the meter procurement process and obtain their continued support for implementation.
October 2010	The water meter supplier undertakes a second borehole survey to collect detailed information for water meter orders. A draft WMP is compiled for the aquifer as part of the DWA project. An automatic weather station is installed to supplement available weather

	data for improved irrigation scheduling. DWA rejects the WUA application on the basis of lack of representivity of previously disadvantaged groups on the management committee of the proposed WUA.
November 2010	The borehole survey data is processed, and standardised specifications for meters to be ordered are compiled. A total of 116 boreholes are identified to be fitted with meters.
December 2010	Order forms and purchasing agreements are finalised and sent to water users.
January 2011	A follow-up process is started by visiting individual farmers to convince them to order the meters. Verbal undertakings are received from water users to order a total of 54 meters. SAMA and DWA RO takes steps to rectify the representivity of the management committee of the proposed WUA.
February 2011	The first water meter orders are received by supplier. Another year of above average summer rainfall occurs, reducing the pressure to restrict abstractions, but increasing contaminated surface run-off from the neighbouring Randfontein mine into the Rietfontein Spruit. Farmers report increasing water levels in boreholes and most of the springs in Maloney’s Eye are flowing again. A WRC/DWA project to determine the Reserve of the Steenkoppies compartment is started.
March 2011	About 80% of official water meter orders are still outstanding and are being followed up as part of the WRC project. DWA subsidies are paid to the meter supplier. Five water level sensors and 15 automatic rain gauges are installed across the compartment as part of the DWA project, to assist with data collection on aquifer recharge.
April 2011	All water meter orders and 50% deposits received by supplier.
June 2011	Water users who ordered meters are requested to sign cell phone contracts for the modem SIM cards used for data collection.
July 2011	Water meters are received from the manufacturer in the USA. Water users are in process of signing cell phone contracts.
Aug 2011	All water users have signed cell phoned contracts. Modems with SIM cards are fitted to meters by local supplier.
Sept 2011	Meters are fitted with identification tags and delivered to water users. An installation demonstration is arranged for the water users to coincide with the delivery of the first meters. Statements are sent out to water users for the balance of their accounts.
October 2011	A maintenance plan for the water meters and monitoring equipment is prepared in collaboration with SAMA
September 2012	80% of the meters delivered in 2011 are installed. Web-based data collection system is active.
Future	Undertake second round of meter orders – December 2012 to January 2013

The timeline shows that even though the farmers had agreed to implement measurement and were being supported in the process by a DWA and WRC project, they demonstrated a great deal of reluctance to place the orders. The farmers gave the following reasons for not supporting the water metering initiative:

- **Finance. The most common reason cited was lack of money to pay for the meters, especially by the smaller farmers. In most cases this is borne out by the general state of the properties, fields and roads, which reflect poor financial circumstances.**
- **Not a legal requirement. This was the second most common reason given. Some farmers commented that their water use is registered, and has been verified: As long as they do not expand their irrigated areas, their water use must be lawful. As the meters are not compulsory, they see it as an unnecessary expense.**
- **Not the most pressing water management issue. Some of the farmers recognised the usefulness of implementing metering, but felt that there were other issues that should be addressed first, such as illegal water use, over-abstraction and conveying groundwater to surface areas beyond the groundwater compartment: only once these problems were addressed would they consider installing meters.**
- **Fear that the meter readings will be used against them. Some farmers rejected the meter implementation initiative as they felt that accurate records of water use will be used by government to restrict their allocations or charge them more for the water they use.**

The project team and SAMA Chairperson highlighted various reasons and incentives to the farmers to implement water measurement at this stage, including:

- Protection against future legal action by the Magalies farmers. However, many people have already forgotten about the nearly R1 m in legal fees that had to be paid to protect their water resource in 2007. In some cases, there are new farmers on the properties who are not aware of the past problems.
- Protection of the groundwater aquifer through better management practices. From some farmers' reactions, it was clear that many of them had no understanding of the aquifer and perceived that there is "a lot of water". The fact that they have had a lot of rain during this summer season also reduces the threat of drought or water scarcity in their minds.
- Once-off subsidy from DWA. The subsidy is too little to change a farmer's mind about buying a meter now.

By the end of the WRC project period, the implementation process was still on-going, with 20% of the meters that had been delivered in 2011 still not yet installed. In general, the bigger farmers had complied with the implementation process while the smaller ones were struggling both to purchase and to install the meters.

The reasons provided by the farmers for non-compliance were mostly that they did not deem it necessary yet to install the meters they have purchased, as there is no official responsible authority that can force them to complete the installations. This is the result of the pending WUA application, which had been submitted in 2009 and was still not approved by DWA in 2012. The farmers had lost faith in the WUA process and DWA's ability to complete what they set out to do.

13.1.4. Lessons learnt

In order to relate the lessons learnt to the implementation plan (in view of future technology transfer or training interventions), the lessons learnt from the Steenkoppies case study are presented according to the heading structure of the implementation plan.

13.1.4.1 Measurement implementation planning

- *Background to the implementation area*

Understanding the situation is key finding an appropriate solution. It is important to collect as much information as possible at an early stage of the process, especially if consultants are used. Information on the physical (technical) elements of the area as well as the social and economic situation is needed to make the right decisions and approach the project correctly.

It was found to be nearly impossible to convince the water users at Steenkoppies to implement measurement unless it was the obvious solution to the problem they were facing, in which case no convincing was necessary: Other water management problems (or example, unlawful use) for which measurement was not the solution should be solved first. Water measurement as a management tool will only be adopted effectively if it solves the water management problem at hand.

- *Measurement trigger*

The trigger is the driver, and once measurement has been identified as the appropriate solution, it is important to move forward quickly. To maintain momentum with the implementation process, always make the trigger the focus, and explain measurement implementation in terms of the trigger.

- *Purpose of the proposed system*

This must be clear to the stakeholders, as well as the way in which the system will solve the problem that triggered the situation. It is important to remember that the different role-players each consider water management from the perspective of their management unit and its specific limitations. A management solution that may be clear to the IO (in terms of the irrigation scheme) may not be perceived as such by the water user (who thinks in terms of the productivity of their farm).

It is easy to lose focus during the implementation process: the purpose of the system should guide the implementers during the process, by providing a statement against which all decisions can be checked and tested.

- *Locations for measurement*

There should be agreement about the locations where measurement devices are to be installed before details about the locations are collected. Many hours and kilometers can be wasted if the locations are not selected carefully. The same is true for the collection of data on the locations. A checklist should be compiled of information to be collected at each location, train field workers properly to collect the data accurately and undertake quality control of the data on a daily basis so that mistakes or problems can be detected as early as possible. As many of the locations as possible should be visited in person by a trained worker, the locations numbered in an orderly way and photos taken for record purposes.

- *Benefits of measurement*

Stakeholders tend only to be interested in benefits that will solve their current problems: any others are "nice to haves" for which they are unlikely to be willing to pay. Stakeholders do not think of measurement all the time: they are confronted by it when they come into contact with water managers, and then it is usually when they are asked to pay for it.

- *Water user support and organisational arrangements*

Without a well organised management structure, implementation is near impossible. A WUA should, if possible, be formed before implementation, as this will give the role players a frame of reference and provide the person in charge with a support system. Water user support is a "have to have", without which implementation will fail.

13.1.4.2 The measurement system

- *Measuring device selection*

It is important that the best devices affordable are selected for implementation. The difference in cost between a reliable and a cheap system is relatively small but the cheap system may be more likely to fail.

It is advisable to install a small number of the selected devices as a trial, in order to experience the implementation process first hand and make changes before a large number of incorrect or inappropriate devices are ordered. It may also point out certain shortcomings with regard to the locations, such as different flow conditions, different climatic conditions, etc.

Details should be double-checked before ordering the devices, and a clear numbering system should be in place so that ordered devices can be correctly allocated to sites.

- *Installation*

Ideal hydraulic conditions can seldom be achieved when retrofitting devices on existing pipelines or in existing canals. There may have to be a compromise between cost of installation to modify existing pipelines and the degree of accuracy achieved.

Measuring devices should be clearly marked so that the site can be easily identified during field visits and the device matched to a data set.

- *Operation and maintenance*

If there is no dedicated person to collect data manually, it is recommended that an automatic system is installed, even if it is more expensive in terms of capital.

There must be a reference or benchmark to which the collected data can be compared, otherwise it will be meaningless. For results to be valued, it must be useful to the person paying for the measurement system. This often depends on the way it is presented and reported, so give attention to the structure of reports.

Data should be safeguarded and maintained: there should be a dedicated system and person to manage it.

Regular visits to the installation sites are needed, even if data is collected automatically. This is the only way in which preventative maintenance can be done effectively and money saved.

- *Monitoring and evaluation*

Regular reporting of progress should be undertaken by means of weekly reports during the implementation phase, after which the measurement results should be collected, processed and reported on a monthly basis. The monthly reports should include reference to any problems encountered with measuring devices during the reporting period, and the operational plan should make provision for how such problems should be handled

13.1.4.3 Implementing the plan

- *Budget and funding*

Measuring is expensive. Whatever device or system is selected, it must work: someone has to pay for it with hard-earned money. A phased approach can be taken to implementation to make it more affordable, or a payment plan can be structured that meets the water users' cash flow situations (i.e. around harvesting periods).

•	*Role players and responsibilities*

A respected local representative, who believes in the process and is driving it themselves, is very valuable. Without such a person, implementation is unlikely to be successful.

•	*Gantt chart*

Implementation often takes longer than initially envisaged. The better organised the stakeholders are, the quicker implementation will be.

•	*Invitation for inputs*

Communication is key: the same message should be conveyed in different ways or through different media. Water users are pre-occupied with their own responsibilities and concerns, and may not necessarily read and respond to notices as hoped.

13.2. Crocodile River Irrigation Boards

13.2.1 Case study background information

Three IBs in the Inkomati WMA were selected as case studies: the Komati River (KRIB), Lomati River (LRIB) and Crocodile River Main Irrigation Boards (CRMIB). They were selected because measurement systems have been in a process of implementation for nearly 30 years, and a great deal of knowledge and expertise has been accrued during this time. The majority of the work undertaken for the project however, took place along the Crocodile River as shown in Figure 15.

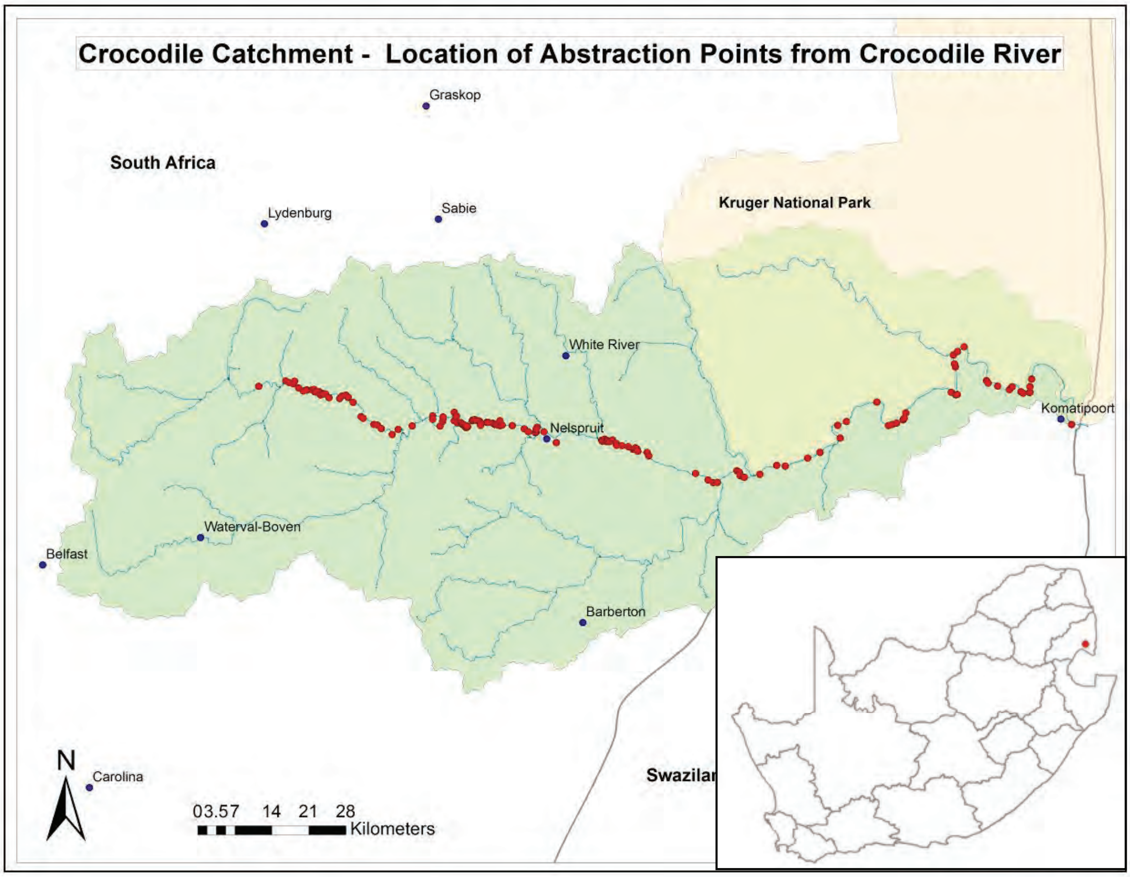


Figure 15: Locality map of the Crocodile River case study area

In order to obtain full benefit from this case study, the researchers asked the local stakeholders to draw up a timeline of events (Table 7) that led to the current status of water measurement in the catchment. It was interesting to find that implementation was already initiated in the 1980s.

Table 7: Timeline of events in the Crocodile River case study

Date	Lomati Catchment	Komati Catchment	Crocodile River Catchment
1980	Downstream farmers complain that they are not getting water. An evaluation is undertaken to assess pump sizes (abstraction capacity) of all users. Calculations are then done as to the number of hours that irrigators could pump to get their "fair share). A pumping schedule comes into operation		
1981-1994	In this period many negotiations, meetings and studies to get meters installed take place. Funding is a problem. The Land Bank grants a loan to irrigators to help fund the installation of meters and the smallholders receive a subsidy from DWA.		
1995		92 Magflow meters are installed over a 1 year period. The meters form part of a Water Allocation Management System (WAMS) with radio telemetry.	
1996	A WAMS is installed over a 1 year period. This system includes 75 water meters (mainly magflow meters and some ultrasonic meters), electronic control systems to turn pumps off and on, as well as radio transmission equipment. The meters have a flow rate indicator as well as a totaliser (total m^3 used). The weekly allocations are determined and radio transmitted from a control center to the various pumps. The pumps are turned off automatically when the allocation is met. Big problems are experienced with the telemetry (radio transmission). The system costs ±R 2.5 M (1996), and is financed by a Land Bank Loan	Meters are commissioned and become operational	The irrigators are notified by e-mail and SMS of restrictions of pump hours per day: e.g. to only pump between 12h00-18h00, five days per week. Neighbour to neighbour policing is used to ensure compliance. A water control officer (WCO) occasionally patrols the area. This form of water management is not very effective: largely due to the size of the farms, neighbour to neighbour policing is not easy. Realising the short-comings of the water management system (and policing), the CRMIB decides to survey all the irrigation abstraction points on the main stem of the Crocodile River in 1996 and again in 2003
1997	Meters are commissioned and become operational		
1998			
1999			

2000	Large floods wash many of the pumps away: they are later reinstalled. The telemetry is removed, and irrigators must phone through water meter readings daily to the control centre. The control centre communicates weekly water rights to the irrigators, which are programmed into the control systems on the pumps (which automatically turn the pumps off when the full quota is reached).	Large floods wash many of the pumps away: they are reinstalled and the telemetry replaced.	
2001			
2002	The new system becomes operational and is commissioned in mid-2003		
2003	A WCO is employed to help with water management. The WCO helps calculate the weekly allocations, communicates them to the water users, and captures details of actual water use in an Excel spreadsheet, as well as undertaking verification spot checks. The WCO also repairs faulty equipment.		A follow up survey of all irrigation pumps including the identification of all pump-stations and associated pump motor and pipe sizes is carried out. The information is captured electronically, and print-outs are made. The irrigators are asked to sign the print-outs pertaining to their farms, confirming that the survey had accurately captured details of their pumps and pipes. The survey provides useful information to water managers, enabling them to ascertain the pump abstraction capacities of the irrigators. However, even after completing the survey, there are short-comings in the management of the system, largely due to the inability of the system to appropriately deal with: Reserve flow rates, the International agreement with Mozambique, and the even distribution of available water to all legally entitled water users. A decision is taken to investigate the installation of water meters on all irrigators abstracting from the main stem of the Crocodile River. A consultant is employed to develop a management proposal associated with the installation and maintenance of the water meters, helping to guide choices about the type of water meter to be installed, how to capture and use the resulting information, and helping to explore how the water meters (purchase, installation and maintenance) could be funded.

2004		A WCO is employed to help with the management of water. The WCO helps calculate the weekly allocations, communicates them to the water users, captures details of actual water use in an Excel spreadsheet, undertakes verification spot checks, and repairs faulty equipment. It was decided to remove the telemetry and switch over to the same system as on the Lomati River.	
2005		Irrigators phone in water use to a control centre which works out weekly allocations and communicates them to irrigators. (Not sure if automated switch off occurs). The meters have a flow rate indicator as well as totaliser	
2006			
2007			
2008			180 predominantly magflow meters with a pump control system are installed at a cost of R6.5 Million, funded largely by Eskom to ensure that the pump does not work during peak hours. It is possible to manually override this during emergencies. The meters include a flow rate, totaliser, as well as the contact details of the WCO. Irrigators phone through their water use readings on a weekly basis. The control centre determines the water allocation per user, which the irrigator programmes into the unit attached to the meter. The WCO does spot checks weekly to confirm meter readings. The biggest problem is that electricity surges play havoc with the meter readings. The equipment manufacturer improves the design to accommodate these surges.
2009			A WCO is employed to help with the management of water. The WCO helps to calculate the weekly allocations to the various irrigators, communicates them to the water users, captures details of actual water use in an Excel spreadsheet, and undertakes verification spot checks. The WCO also repairs faulty equipment.

13.2.2 Case study aims and overview

As metering had already been implemented in all three areas, a new project was proposed in 2007 in conjunction with Eskom to telemetrically enable the installed meters on the Crocodile River, and link them to a web-based system which the irrigators could have used to easily track their water use. In addition, soil water content probes were to have been installed to monitor irrigation scheduling (with a view to using less water to produce the same or greater crop). This project would have been a one-year pilot project supported by DWA, but largely championed by Eskom. If successful, similar metering and information systems could have been rolled out to other catchments in South Africa. However, following the energy crisis at the beginning of 2008, the project was postponed indefinitely due to lack of funding from Eskom.

The WRC project team identified two monitoring activities that could be investigated in the catchment but which would require additional funding. The WRC obtained the required funding from the DAFF which was made available to the project team from July 2011, to undertake the following field work initiatives:

- The installation of basic GSM modems at three trial sites in order to assess the practicality of collecting the weekly flow meter readings via telemetry from the existing flow meters along the Crocodile River, and the development of a new function in the WAS program to accept flow meter readings via SMS sent by the modems. The initiative included the installation of a trial version of the WAS in view of possible future implementation on the whole of the Crocodile River (WAS is already used by the Komati Basin Water Authority (KOBWA) for the Komati River).
- The installation of additional measuring equipment (including power and pressure measurement) at two farms along the Crocodile River to assess the value of “smart metering”, a concept originating in Australia, that is aimed at monitoring the efficiency of the irrigation system through high frequency data logging and assessment. One of the farms selected for the smart metering installation is owned and managed by smallholders.
- Further, following a request from the Malelane Irrigation Board, (MIB) who receive their water from the Crocodile River, it was also agreed as part of the WRC project to undertake work aimed at assessing the accuracy of the measuring structures and devices used to deliver water to various points along the Malelane canal in view of possible recalibration or replacement, and the use of the devices to measure distribution losses in the canal, in view of maintenance or future upgrades. Approximately 40% of the water users along the canal are also smallholders that accessed the scheme through land claim farms.

The above timeline of events (Table 7) was obtained from discussions with the various stakeholders. It is clear from the time-line that the Lomati and Komati catchments in particular have been using water meters for a number of years now, and it is interesting to note the evolution that has taken place.

The three field work initiatives are discussed here.

13.2.2.1 Simple GSM modem application

The major functionality that CRMIBs requires from the telemetry is to collect the weekly readings from the nearly 300 water meters along the Crocodile River from Kwena Dam to Komatipoort (approximately 250 km). Currently, the water users submit the readings by SMS, but not all users comply. It is a great administrative burden to type in the readings, and it is easy to make mistakes.

The project team therefore identified an opportunity to expose the IB to the concept of a telemetric system where the installation of a simple GSM modem can facilitate the remote sensing of the totaliser value on the meter.

In addition, it was decided to also investigate using the WAS programme to administer the weekly meter readings as the current spreadsheet model had some limitations. Dr Nico Benadé agreed to do some additional programming in the WAS programme to accommodate this, as he has had similar requests from other users of the WAS programme.

It was decided to select three sites for modem installations, prioritising meters where there is a history of poor compliance with SMS data submission. The technical consultant responsible for managing the water meters was asked to identify the sites, and procure, install and program the modems. Figure 16 illustrates the data flow.

The modems were installed on 11 November 2011 and the WAS program was installed on the WCO's computer.

The simple modem installations were very successful, with the WCO reporting that the system of automatic SMSs was very reliable, and easier to work with than obtaining the readings from individual farmers. However, the WAS program was not adopted by the office to manage the meter readings. Four reasons were identified for this:

- The WC office does not use the WAS on a daily basis or for any other purpose: the staff therefore continued to use the existing database and spreadsheet to manage the readings rather than the WAS.
- Only three meter readings were received in a format suitable for importation into the WAS. It was easier for them to capture these three readings with the other nearly 300 in the existing format, than vice-versa.
- The WC office communicates on an ADSL line: the WAS import method requires the SMS sent by the modem at the meter to be received by a GSM modem and not an ADSL line. It was therefore a disruption of everyday routines to change internet connections to receive the three SMSs
- The WCO reported the import process to be cumbersome, and would like it to be more automatic, without any human intervention.

The problems were reported to Dr Benadé and it was decided that the WAS should be installed at the project team's office so that monitoring of the three modems can continue without losing any data, and so that suggestions for improvement can be made to him by the project team.

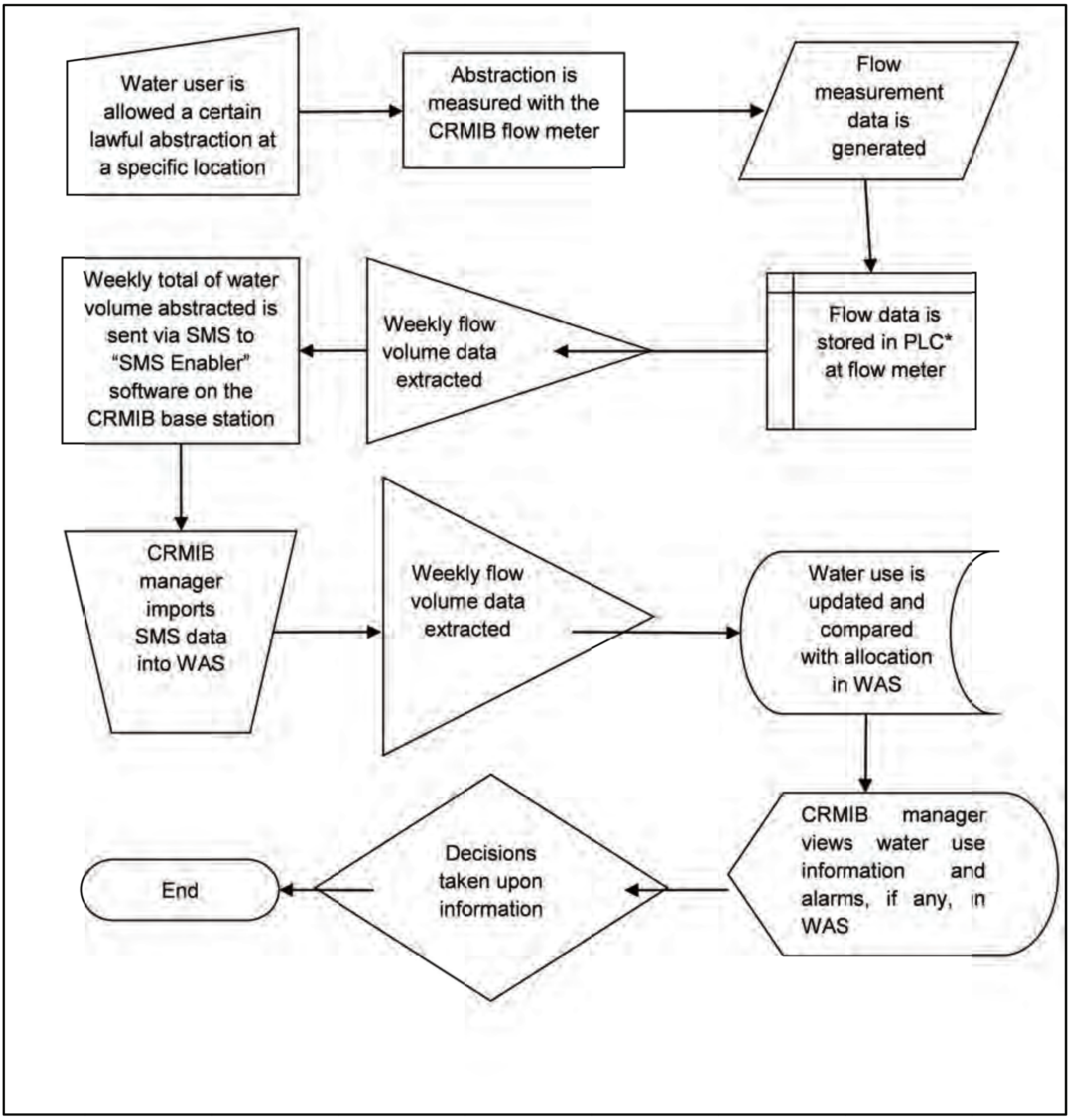


Figure 16: Process diagram for the simple telemetric system in the Crocodile River area

*Programmable Logic Controller

13.2.2.2 Smart metering application

The second telemetry application implemented on a trial basis was the installation of additional measuring equipment at two pump stations where flow meters are installed, and then to monitor a wider range of parameters at a higher frequency in order to assess the efficiency of the irrigation systems, improve system performance, achieve water and/or energy savings, reduce downtime of pumps and motors through early problem detection, and ultimately improving the skills and knowledge of irrigation managers and operators.

When this concept was tested in Australia, only flow rate was monitored, but in view of rising energy costs and deteriorating water quality in South Africa, it was decided to add power (kilowatt) and pressure measurement to the monitoring parameters.

Two river pump stations with filters were selected along the Crocodile River, with sand filters at one site and a screen filter at the other, which pump directly into the irrigation systems. One of the sites is a land claim farm that is now owned and operated by smallholders. The data collected at the two sites is shown in Table 8.

The equipment was commissioned in mid-November 2011. Pressure transducers and a Watt meter were added to the existing flow meters installed previously by the IB. Data was recorded onto a datalogger and sent to a website, where it could be viewed and downloaded. A reporting function with alarms was set up.

Some adjustments were made to logging intervals and other system parameters to find a balance between usefulness and quantity of data recorded. The longer the system can be monitored for, the more practical the solutions and improvements will become.

Table 8: Information of selected sites for smart metering in the Crocodile River area

Parameter	Site No. 1	Site No. 2
Co-ordinates	25°24.178'S 30°37.256'E	25°31.718'S 31°20.851'E
CRMIB nr	41.7R	147.0R
Suction Pipe	220 mm	273 mm (OD)
Suction Pipe Type	Steel	Steel
Foot Valve	Positive pressure	No
Eccentric Intake	Yes	Yes
Concentric Outflow	N/A	Yes
Outflow Pipe Type	Steel (to irrigation system)	Steel (to farm dam)
Outflow Pipe Diameter	115 mm	219 mm (OD)
Air Valve	Yes	No
Pump model	Rovatti 125/2	ETA 150-250
Motor power rating	45 kW	22 kW
Power Factor	0.89	0.89
Motor RPM	1475	1465

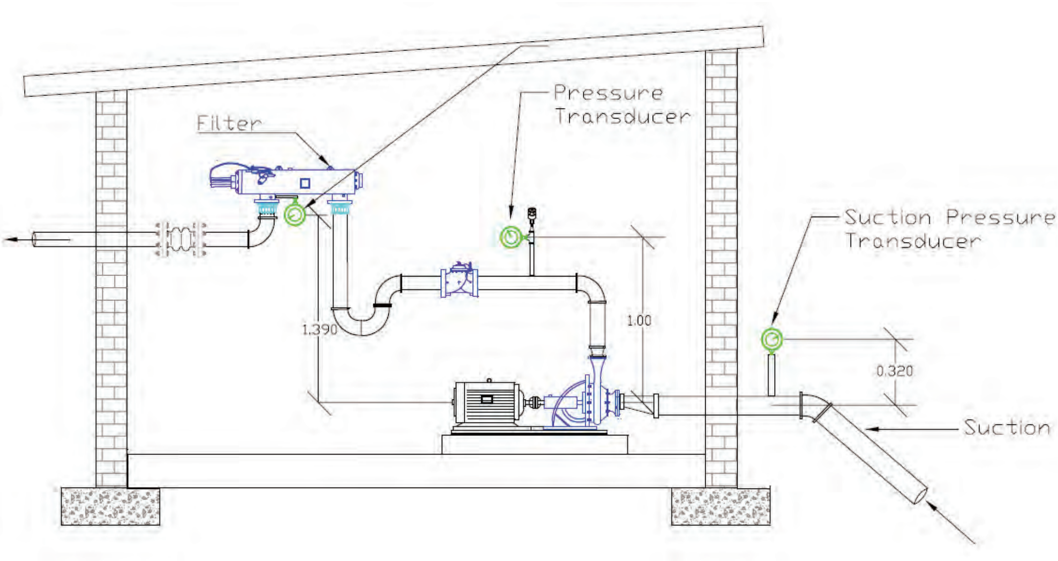
The following measurements were taken at each site. Each was totalised every 10 minutes and displayed for 24 hour periods, including minimum and maximum values recorded during those periods:

Flow (rate and volume, derived from the electromagnetic flow meter's pulse output).

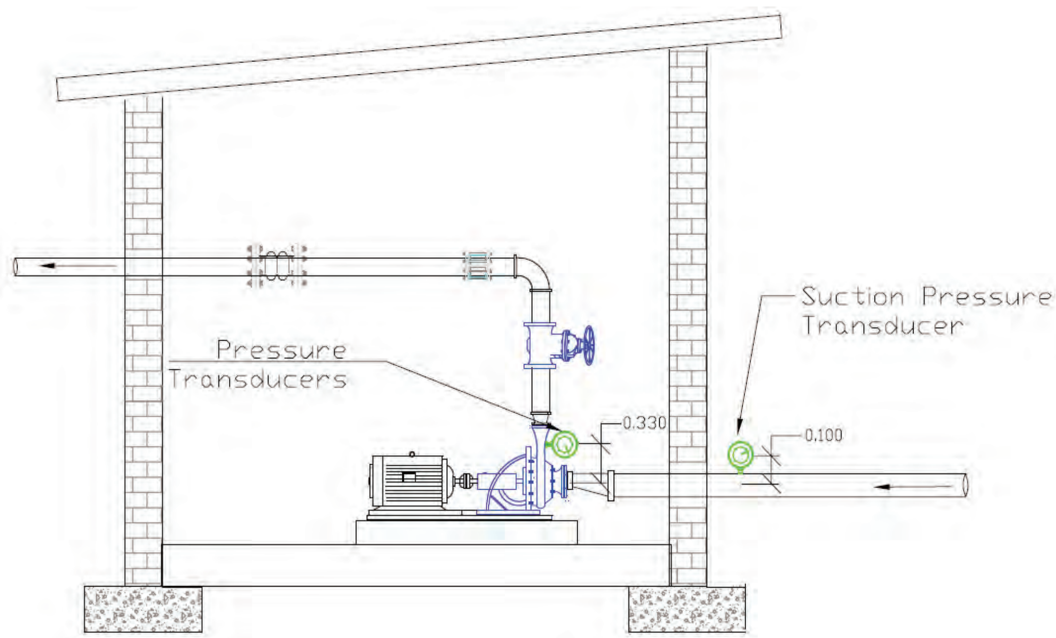
Pressure (before and after the pump, and after the filter bank, using pressure transducers).

Electrical power consumption (kWh, Volt, Amps, power factor, using a Watt meter).

The positions of the measuring locations relative to the pump, motor and filter are shown schematically in Figure 17.



i) (a) Site No. 1



ii) (b) Site No. 2

Figure 17: Schematic lay-out of measuring locations for smart metering sites

The measuring equipment installed at each site consisted of:

- WattNode power meter, together with three split-core current transducers to supply the electrical inputs for the power meter.
- Three piezo-electric pressure transducers.
- Campbell scientific CR200X datalogger.
- GSM modem and 5 DB dual band antenna.
- Back-up battery and trickle charger.

The pulse output from the existing flow meter was connected to the datalogger. Data was collected continuously and transmitted via a GSM modem to a base station. Data was displayed in a table on the project website (Figure 18). This was updated every 10 minutes (Figure 19), and summarised in a 24 hour table and also on graphs (Figure 20). The farmer had access to the website.

The data collected in the 10 minute table included flow rate, power, pressure (at two or three locations as per site), voltage, current, and the power factor. This information was used to calculate a combined pump and motor efficiency, as well the kilowatt-hour consumption per 10 minute interval. The instantaneous values were presented as the average over the 10 minute period.

The cost of installing the smart metering systems was approximately R30 000 per site.

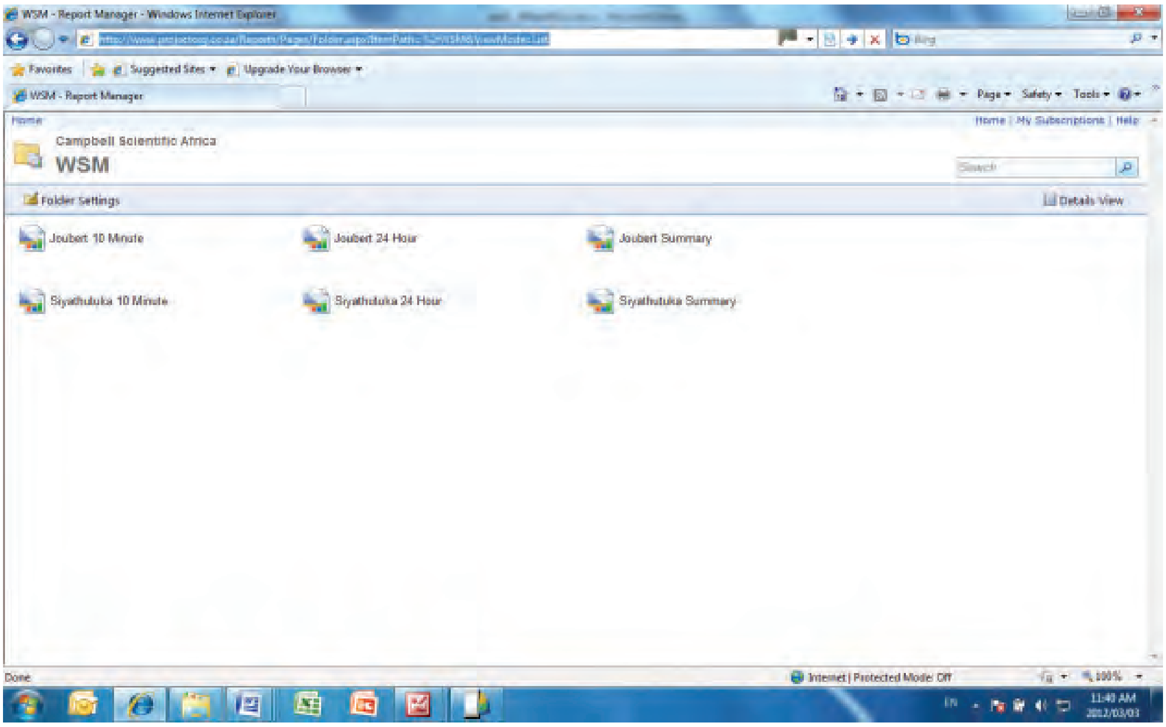
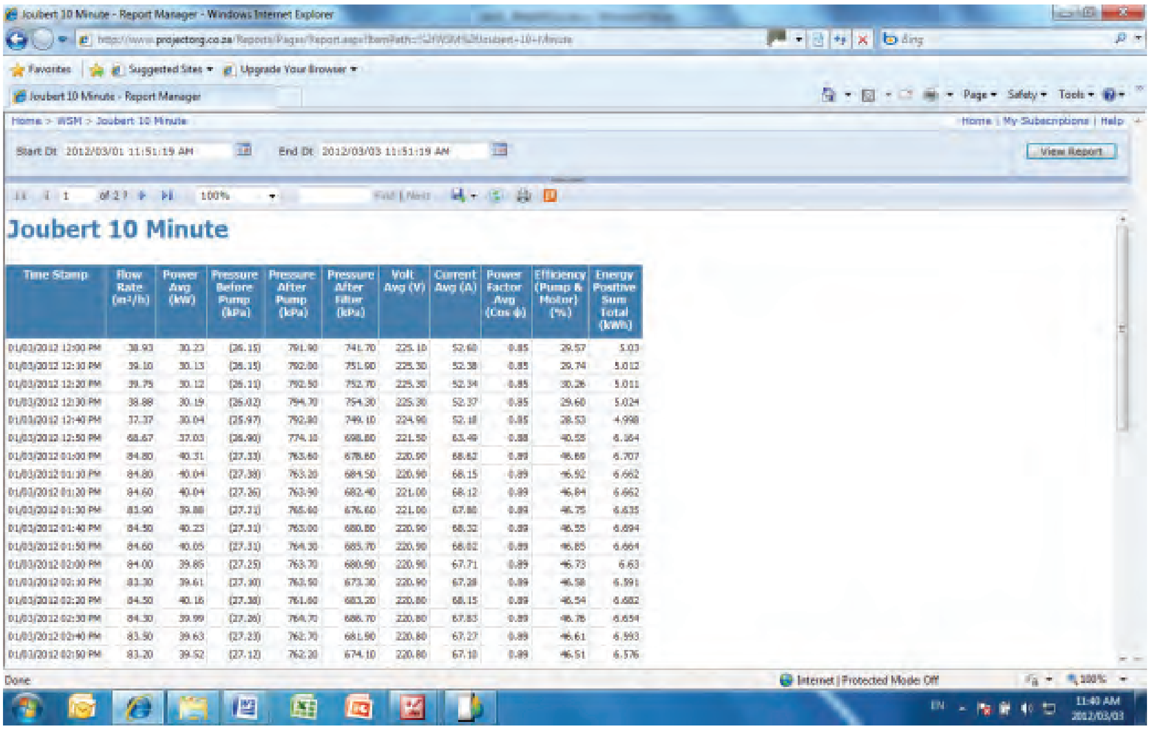


Figure 18: Smart metering website main screen



Time Stamp	Flow Rate (m^3/h)	Power Avg (kW)	Pressure Before Pump (kPa)	Pressure After Pump (kPa)	Pressure After Filter (kPa)	Volt Avg (V)	Current Avg (A)	Power Factor Avg (Cos ϕ)	Efficiency (Pump & Motor) (%)	Energy Positive Sum Total (kWh)
01/03/2012 12:00 PM	38.93	30.23	(26.15)	791.90	741.70	225.10	52.60	0.85	29.57	5.03
01/03/2012 12:10 PM	39.10	30.13	(26.15)	792.00	751.90	225.30	52.38	0.85	29.74	5.012
01/03/2012 12:20 PM	39.75	30.12	(26.11)	792.50	752.70	225.30	52.34	0.85	30.26	5.011
01/03/2012 12:30 PM	38.88	30.19	(26.02)	794.70	754.30	225.30	52.37	0.85	29.60	5.024
01/03/2012 12:40 PM	37.37	30.04	(25.97)	792.80	749.10	224.90	52.18	0.85	28.53	4.998
01/03/2012 12:50 PM	68.67	37.03	(26.90)	774.10	698.80	221.50	63.49	0.88	40.55	6.164
01/03/2012 01:00 PM	84.80	40.31	(27.33)	763.60	678.60	220.90	68.62	0.89	46.69	6.707
01/03/2012 01:10 PM	84.80	40.04	(27.38)	763.20	684.50	220.90	68.15	0.89	46.92	6.662
01/03/2012 01:20 PM	84.60	40.04	(27.26)	763.90	682.40	221.00	68.12	0.89	46.84	6.662
01/03/2012 01:30 PM	83.90	39.88	(27.21)	765.60	676.60	221.00	67.80	0.89	46.75	6.635
01/03/2012 01:40 PM	84.50	40.23	(27.31)	763.00	680.80	220.90	68.32	0.89	46.55	6.694
01/03/2012 01:50 PM	84.60	40.05	(27.31)	764.30	685.70	220.90	68.02	0.89	46.85	6.664
01/03/2012 02:00 PM	84.00	39.85	(27.25)	763.70	680.90	220.90	67.71	0.89	46.73	6.63
01/03/2012 02:10 PM	83.30	39.61	(27.30)	763.50	673.30	220.90	67.28	0.89	46.58	6.591
01/03/2012 02:20 PM	84.50	40.16	(27.38)	761.60	683.20	220.80	68.15	0.89	46.54	6.682
01/03/2012 02:30 PM	84.30	39.99	(27.26)	764.70	686.70	220.80	67.83	0.89	46.76	6.654
01/03/2012 02:40 PM	83.50	39.63	(27.23)	762.70	681.90	220.80	67.27	0.89	46.61	6.593
01/03/2012 02:50 PM	83.20	39.52	(27.12)	762.20	674.10	220.80	67.10	0.89	46.51	6.576

Figure 19: Smart metering website 10 minute update table

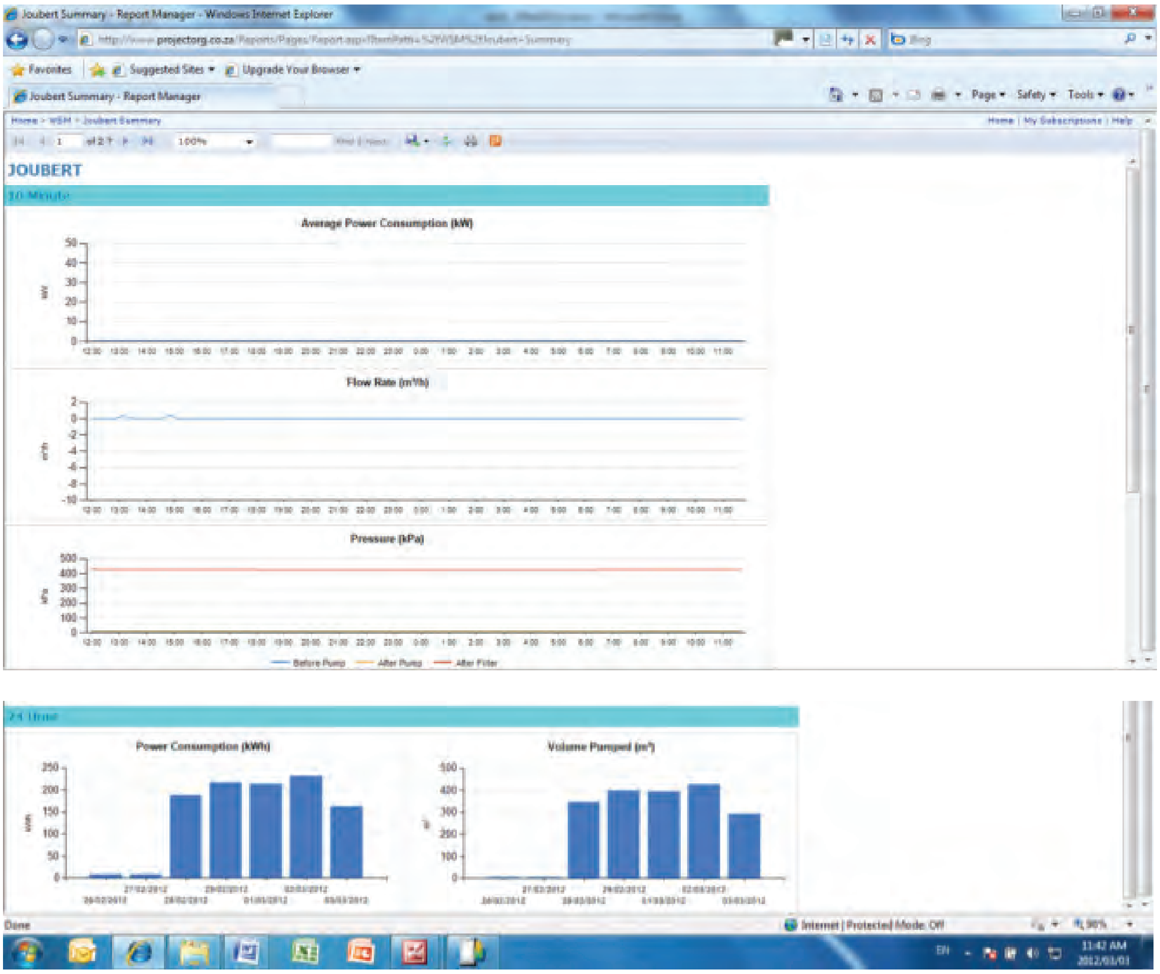


Figure 20: Smart metering website summary graphs

The smart metering site installations allowed the project team to gain a better understanding of how farmers perceive measurement, and the value of the measurements. The equipment was installed successfully and provided some interesting results, as shown by the typical values for Site No. 1 in Table 9.

Table 9: Typical results for the smart metering Site No. 1

Flow rate, (m^3/h)	Pressure (m)	Power (kW)	Current (Amps)	Power factor	Efficiency (calculated) (%)
40	81.6	30.8	55.3	0.88	30
82	78.3	40.5	72.3	0.90	45
112	73.5	47.3	84.3	0.90	49

It was found that the farmer operates the pump in an area of the pump curve where the pump is very inefficient: a combined pump and motor efficiency of less than 50% is always obtained. This means that the farmer getting less than half the benefit of the energy being paid for. The potential of the pump station if properly used and maintained is approximately 65%. Yet, when confronted with this information, the farmer did not seem particularly concerned about it, perceiving that the trouble and cost of changing the pump to one of a more appropriate size (that would operate in a more efficient area of its curve) not to be worth any saving that may be achieved. The results were valued more in terms of providing an accurate record of when irrigation took place and whether or not the workers were following instructions. The next step will therefore be for the project team to convert the percentage efficiency to a monetary value based on the amount invoiced to the farmer by Eskom for the specific transformer at the pump station.

The efficiency of the second smart metering site is constant, at approximately 52%, as the pump station supplies water to a fixed destination at the farm dam. The pump and motor combination have the potential to be 69% efficient, so improvement is also possible at this site.

The project team will continue monitoring these sites, especially during the high demand winter periods when the electricity tariffs increase, and undertake further analyses of the data for discussion with the farmers.

13.2.2.3 Malelane canal evaluations

The Malelane canal flows 40 km from the Crocodile River south-east to the Malelane area. The canal is 45 years old, and maintenance is now more important than ever.

The water supply system is a concrete canal that supplies water to different farms, each farm having an off-take that leads to an irrigation dam. The amount of water supplied to each farmer is measured by means of a Parshall flume. Some farmers have built sumps directly next to the Parshall flumes from which water is then pumped into the on-farm distribution networks, a practice that sometimes submerges the Parshall flumes. There are approximately 80 off-takes in operation.

The IB has recently installed six remotely sensed electronic water level sensors at strategic positions along the main canal to continuously monitor the water level at Parshall flumes, as shown in Figure 21. The data is collected on a website, in an attempt to manage the water better and monitor losses.

The water users that depend on the canal for irrigation water expressed the following two main concerns that needed investigation:

Significant losses occur along the canal due to its age and deteriorating condition.

The measuring structures through which water is delivered to individual users (Parshall flumes) are inaccurate, thereby resulting in incorrect deliveries.

This section covers the results of field work undertaken to address the second concern: the accuracy of the Parshall flumes.

The following specific objectives for the study were identified:

- To assess the accuracy of the measuring structures used to deliver water to various points along the canal.
- To measure the losses in the canal.

a) **Methodology:**

The evaluations took place during a field visit on 31 August and 1 September 2011.

i) Preparation

A meeting was held with W du Toit and R Radley on 10 August 2011 in Malelane, from which it emerged that the accuracy of the measuring devices on the Malelane canal needed to be determined, and the structures calibrated if necessary. Further, the newly installed remote sensing stations needed to be evaluated. It was decided that the conveyance efficiency of the main canal would be measured at a later stage through long term data collection over an upper section of the canal.

A sub-section of the canal was identified for the initial evaluation of the Parshall flumes and of one of the remote sensing stations. The sub-section receives water through Off-take No. 35 from the main canal, from where water flows via the secondary canal to seven farm sluice gates via Parshall flumes. The remote sensing station is also located at Off-take No. 35, measuring the amount of water that flows into the secondary canal. (Figure 21)

The following activities were undertaken to address the objectives:

- Assessing the accuracy of the Parshall flume and electronic level sensor installed at Off-take No. 35,
- Measuring the losses in the main conveyance section of the secondary canal, from the off-take to the point where the canal splits into three tertiary canals
- Assessing the accuracy of the Parshall flumes used to deliver water to individual farms along the secondary canal at Off-take No. 35

Figure 21: Locations of the off-takes from the main canal to the reservoirs.

ii) Equipment used

Three different types of measuring equipment were used:

- The standard Parshall flumes with gauging plate, which was installed when the canal was constructed;
- The newly installed remote sensing station installed on top of the stilling basin and consisting of a radar-type (non-contact) depth sensor and the web-based My City software to transmit the data continuously to a base station, using the Parshall flume to calculate the discharge, and
- The FlowTracker acoustic Doppler velocity meter, a portable instrument that measures velocity in combination with cross-sectional area information to calculate the discharge at the point of measurement.

The FlowTracker output was used as the reference for comparison with the data from the Parshall flume as well as the remote sensing station to determine the accuracy of the permanently installed devices.

b) Assessing the accuracy of the Parshall flume at Off-take No. 35

Measurement is at best an approximation and will always have a degree of error. Accuracy of measurement relates to the quality of the results and the maximum deviation of the meter indication and the true value of flow or the total flow, and is reported in terms of percentage error. The accuracy of water measurement devices is commonly expressed as an error percentage of the comparison standard discharge (or the actual discharge), as measured using another device of known accuracy.

The measurement error can be mathematically expressed as:

$$E_{\%CS} = \frac{100\,(Q_i - Q_{CS})}{Q_{CS}} \qquad \text{……………………(1)}$$

Where:

$E_{\%CS}$ = error in percent compared to the standard discharge,

Q_i = indicated discharge from device being tested and,

Q_{cs} = comparison standard discharge as measured with another device of known accuracy.

The results are often presented as an accuracy curve over the applicable discharge range, as shown in an example in Figure 22.

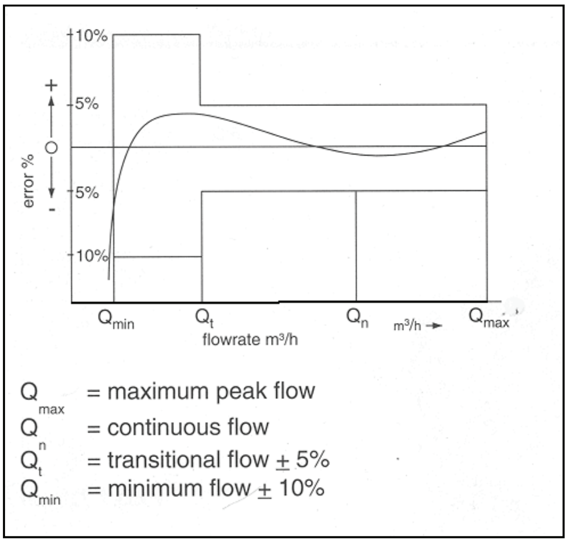


Figure 22: Example of a Meter Accuracy Curve (Mienecke & Laatzen, 2001)

The acceptable level of accuracy depends on the situation. Manufacturers test their meters in fully developed flow conditions where laminar flow is achieved. In the field, however, meters are more often subjected to less-than-perfect conditions, resulting in lower accuracy than the laboratory value. The more accurate the flow measurement, the more expensive the device will be.

The accuracy of measurement at Off-take No. 35 is very important as it is the entry point into the secondary canal. Being able to measure the right amount of water going through this Parshall flume means that the farmers can get a constant, reliable and accurate reading.

c) Measuring conveyance losses in the secondary canal at Off-take No. 35

In all water supply systems, some proportion of the water diverted from rivers or dams is lost in conveyance to the consumer. This is true of urban piped water supply systems and of irrigation delivery schemes. In the context of irrigation-water supply, conveyance losses are reported as the difference between the volume of water supplied to irrigation customers and water delivered to the system. Many factors influence the conveyance efficiency. Losses in the canal may be as a result of evaporation, seepage to groundwater and canal regulation, including the breaching of banks, flooding of backwaters, inaccurate meter reading or unrecorded consumption. The following steps were taken to establish the cause of losses in the secondary canal:

The quantity of water that enters the secondary canal was measured with the My City station, the FlowTracker, as well as with the Parshall flume gauge, in order to present a comparative assessment of the overall accuracy of the different measuring methods used (Figure 23). The accuracy of the Parshall flumes at the MIB was mostly influenced by the less-than-optimal installation conditions, the sedimentary nature of the water conveyed in the canals and the shifting of gauge plates over time.

The outflow at the end of the secondary canal was also measured with the FlowTracker to determine the amount of water that passes the bottom end of the canal/was discharged/delivered by the secondary canal. After measuring the quantity of water that passes the end of the secondary canal, calculations could be made to determine the conveyance losses along the canal.

Figure 23: Using the FlowTracker at the inlet of the secondary canal.

d) Assessing the accuracy of the Parshall flumes at the farm off-takes

The FlowTracker was used to determine the accuracy of the Parshall flumes. The discharge after each Parshall flume was measured with the FlowTracker and the readings were compared with the reading according to the existing gauge plates.

e) Results

i) Assessing the accuracy of the Parshall flume at Off-take No. 35

The results of the three measurement methods are shown in Table 10.

Table 10: Field data at Off-take No. 35

Position	Gauge plate Reading (ℓ/s)	Flow Tracker Reading (ℓ/s)	My City 4 Reading (ℓ/s)
My City 4	63.4	60.5	66
My City 4	77.3	74.5	79.4
My City 4	130.18	119.5	116

At minimum capacity discharge of 60.5 ℓ/s, the correlation between the Standard reading, the Flow Tracker reading and the My City reading is good. However, the greater the discharge, the greater the differences between the readings. At the maximum flow of the secondary canal (119.5 ℓ/s) the standard canal reading is very inaccurate and calibration is necessary.

The My City reading at Off-take No. 35 is a very good indication of the quantity of water entering the secondary canal if measured against the more accurate FlowTracker reading, and the standard canal reading can be calibrated according to the FlowTracker reading.

From the above information a Meter Accuracy Curve (Figure 24) could be plotted, to establish the percentage error of the Standard gauge and the My City devices as measured against the FlowTracker. Using Equation (1) the data could be used to calculate the percentage deviation of the gauge plate reading and the My City station (shown in Table 11).

Although the percentage errors varied over the discharge range, in most cases both the gauge plate and My City station provided a positive error, indicating that both devices over-estimate the flow, and that less water is actually flowing through the inlet than the canal operators are believing. In all cases, however, the measurement errors were less than 10%. This is acceptable for the gauge plate reading but a better value was expected from the My City station.

Table 11: Measurement errors of the devices at Off-take No. 35

FlowTracker Reading (ℓ/s)	Standard Reading (%)	My City Reading (%)
60.5	4.79	9.09
74.5	3.76	6.57
119.5	8.94	-2.93

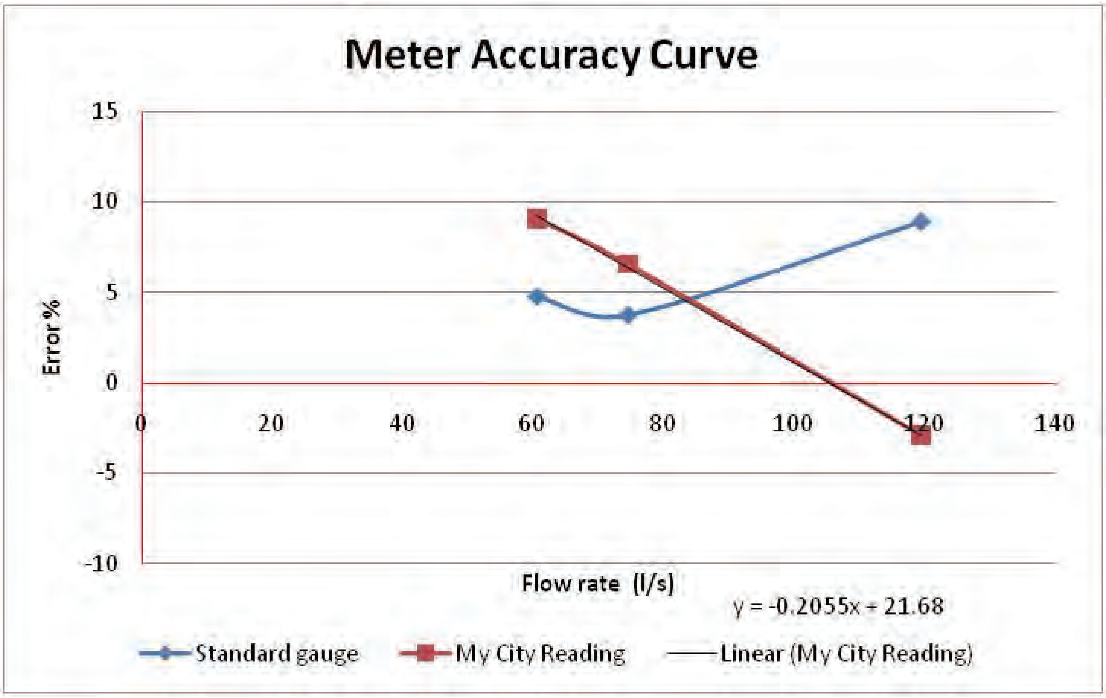


Figure 24: Meter accuracy curve

ii) Measuring conveyance losses in the secondary canal at Off-Take No. 35

Table 12: Data recorded for secondary canal at Off-take No. 35

Position 1 (Beginning of Secondary Canal) (ℓ/s)	Position 2 (End of Secondary canal) (ℓ/s)	Quantity losses (ℓ/s)	% Losses
90.5	79.1	11.4	12.6

From the Meter Accuracy Curve the following formula was generated to adjust the My City readings:

Y = -0.2055x + 21.68…………………… (2)

The data in Table 12 was rectified using the Meter Accuracy Curve to adjust the reading accordingly (Table 13). Using the modified reading, a more accurate value can be used to analyse the system (Table 14).

Table 13: Modified answer at Off-take No. 35

My City Reading (ℓ/s)	Formula (2)	Percentage correction	Rectified Answer (ℓ/s)
90.5 ℓ/s	Y= -0.2055(90.1) + 21.68	3.08	87.71

Table 14: Modified Data at Off-take No. 35

Position 1 (Beginning of Secondary Canal) Rectified Answer (ℓ/s)	Position 2 (End of Secondary canal) (ℓ/s)	Quantity losses (ℓ/s)	Percentage losses (%)
87.71	79.1	8.61	9.8

Over the 1.56 km long section of canal, 8.61 ℓ/s of water are being lost due to the age of the canal and associated deterioration. This section of canal conveys water at an efficiency of 90.2%. This value needs to be presented as discharge losses per 1 000 m^2 of wetted canal perimeter.

iii) Assessing the accuracy of the Parshall flumes at the farm off-takes

The results of the farm off-take Parshall flume measurements are shown in Table 15.

Table 15: Accuracy of farm off-take Parshall flumes

Parshall Flume Number	Standard canal reading (ℓ/s)	Flow Tracker reading (ℓ/s)	Percentage error
35 A	18.39	18.40	-0.10
35 B	7.36	8.20	-10.50
35 C	Not measured		
35 D	29.43	13.15	55.32
35 E	9.9	10.9	-9.17
35 F	7.07	8.89	-20.48
35 G	Not measured		

The error values varied greatly, from as good as -0.1% to as poor as 55.32%. Ideal measuring conditions for the use of the FlowTracker in the narrow tertiary canals could not always be found, but it is believed that a confidence interval of at least ±10% applies to the results.

f) Conclusion and recommendations

The following improvements were recommended to the IB:

- Accuracy of the Parshall flume at Off-take No. 35: a calibration curve of discharge against measured depth could be developed and programmed into the My City unit. After recalibration, the new accuracy could be checked with the FlowTracker.
- Losses in the secondary canal: the losses were higher than expected, but they should be checked again over a range of flow rates after recalibrating the My City unit.
- Accuracy of the Parshall flumes at the farm off-takes: as the results varied so greatly, it was recommended that alternative verification methods be investigated, and a standardised method then be used at a larger number (all?) of the off-takes to obtain a bigger data sample size from which trends could be established.

13.2.3 Case study activity summary

The actions that took place during the case study are presented as a timeline of events in Table 16 for the reporting period following the discussion on the granting of additional funds.

Table 16: Activities undertaken in the Inkomati case study area

Date	Description
21 June 2010	Meeting with Crocodile River managers to discuss telemetry implementation.
18 August 2010	Presentation of proposal for telemetry implementation to Crocodile River management.
January 2011	Request received from MIB to evaluate canal and measuring structures.
April 2011	Proposal on canal evaluation presented to MIB technical committee.
July 2011	Additional funding and project extension approved by WRC
August 2011	Activities planned in 2010 reviewed and adjusted in line with additional funding. Evaluation of Malelane canal measuring structures undertaken.
September 2011	Quotes for telemetry installations (basic GSM modems at 3 sites and smart metering at two sites) obtained. Implementation of WAS to collect telemetric data investigated.
October 2011	Sites for telemetry installations selected. Equipment for telemetry installations ordered. WAS SMS function developed. Feedback to MIB on canal evaluation results given.
November 2011	Telemetry equipment and WAS Installed and commissioned.
November 2011 to February 2012	Monitoring of telemetry sites, reporting and feedback to stakeholders.

13.2.4 Lessons learnt

During the field trip it became clear that almost all those interviewed felt that there were benefits associated with water metering, even though no definite numerically quantified benefit to cost calculations could be given. The following lessons were learnt.

- The MIB has improved their system management now that they know how much water is being taken by the various users, and when the water is used. They point out that they only became aware that they were in fact under-utilising their water allocations once they had the meters installed. They are now able to negotiate with the regulator i.e. DWA / Inkomati Catchment Management Agency (ICMA) from a stronger position, as they have hard facts and figures at their disposal. The MIB pointed out that it is not the water meters alone that improve matters, but rather the fact that the meters enable water managers to improve their management. Water meters can thus be seen as an essential enabler of improved management.

- An irrigator informed the project team that he uses the meter readings in combination with the electricity readings to monitor the performance of his irrigation systems. Water meter flow rate (ℓ/s) can quickly be used to ensure that the pump is drawing water as per the specifications (delivery capability) of the pump. If the flow rate is below the designed delivery capability of the pump, there could be wear on the impellor of the meter (reducing measuring performance), or there could be blockages in the irrigation pipe lines (reducing system performance). The irrigator felt that the potential benefits associated with identifying and addressing reductions in irrigation performance (made possible by the water meter) outweigh the costs of the meter. A suggestion was put forward to the WCO to add pump performance evaluation as an extra service, meaning that the WCO has access to the data required for this calculation and could track the performance of the irrigators' pumps. It makes more logistical and financial sense for the WCO to do this, rather than each farmer tracking their pump performance in isolation.
- The irrigators and water managers believe that there is an improved relationship and level of trust between irrigators, as they know that there is a fair and transparent system in place that ensures that users are complying with their water use allocations. They did acknowledge that there are some users who probably still do cheat the system, but by and large the majority are law abiding, and compliant with the regulations.
- Some of the irrigators felt that a water use charge based on actual water use should be introduced, which would help promote water conservation. This, therefore, is a potential benefit that will be realized if/when the water use charges are based on actual water use.

13.3 Orange-Riet Water User Association

13.3.1 Case study overview

The ORWUA is located on the border between the Free State and the Northern Cape Province, and includes a transfer scheme taking water from the Orange River via a canal into the Modder River catchment, eventually discharging into the Vaal River (Figure 25). The WUA is responsible for managing water supply to some 31 000 ha of irrigation.

When the scheme was developed during the 1940s, it was developed as a flood irrigation scheme with 25.6 ha farms on the sandy parts of the scheme and 17 ha on the clay parts, provided with water from the Kalkfontein Dam. The water distribution system was lined throughout, and designed to provide enough water to the irrigators. It was found that the water supply from the Kalkfontein dam was not secure enough, and after many years of farming with only a portion of water, a trans-basin scheme was built from the Orange River which transfers water to the Riet River irrigation scheme. Further expansion of the scheme then took place through identifying additional irrigable areas where farms of 60 ha were sold. A portion of the area of expansion was also used to allow for the consolidation of smaller units into bigger units, with 60 ha as the target size.

Water is supplied from the Orange River through a main canal of 15.6 m^3/s capacity and stored in four balancing dams from where it is distributed by lined canals to the irrigators. Measuring devices, mostly Crump weirs and some Parshall flumes are installed in the main canal and at the off-takes of secondary canals. Off-take at farm level is by means of sunken orifice sluice gates linked to long-crest weirs to stabilise flow height in the canals that serve farmers.

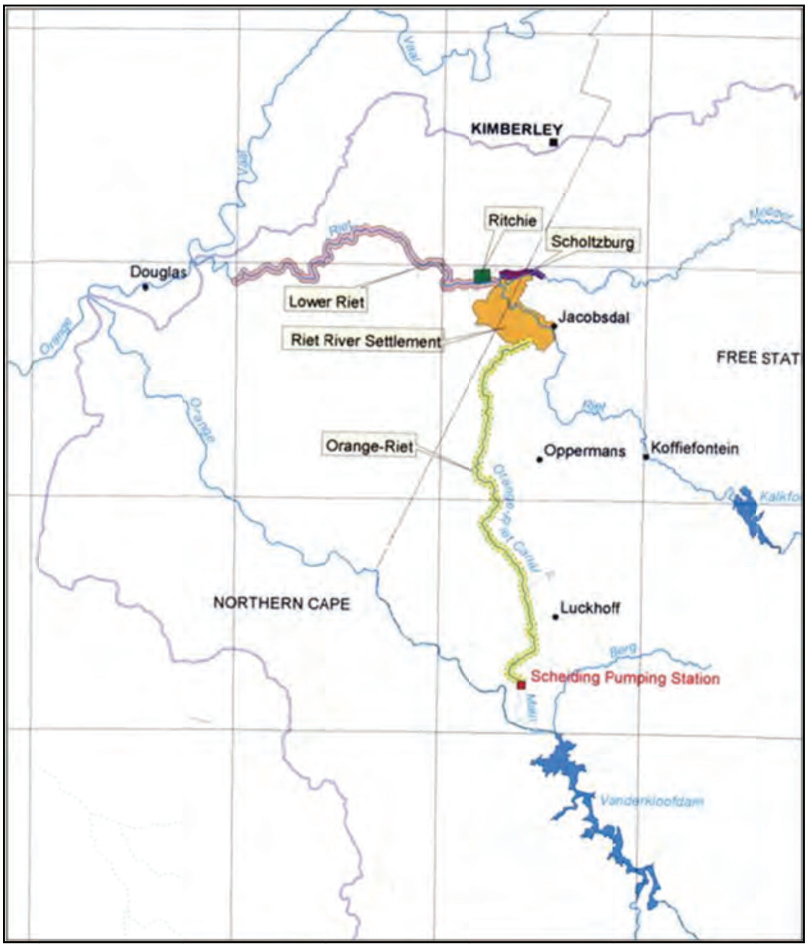


Figure 25: Water Management Areas in the Orange-Riet Region

The scheme has telemetric data capturing in place along the bigger canals (Figure 26), with the result that farmers can order their water as little as six to eight hours before they need it. Telemetric control of the sluices on the bigger canals is also used to ensure accurate water distribution and management (Figure 27). This results in a saving in manpower, because fewer WCOs are required. Required flow rates for the different canals are calculated on the basis of orders: the WCOs of the WUA open and close sluice gates accordingly. At farm level the irrigators are responsible for operating the sluice gates that service their farms. A water balance budget is kept for each user: users pay for water on a volumetric basis.

Figure 26: Telemetry station on the Orange-Riet scheme

Figure 27: Automated sluice gates on the Orange-Riet scheme

On-farm, the farmers have some leeway allowing irrigation to take place according to crop irrigation requirements. However, controlling water use by irrigators along the Orange-Riet canal and along the Lower Riet River has been difficult because water extraction in these areas was not metered.

When the GWS was transferred to a WUA in 1998, the WUA started a process of testing and evaluating a variety of measuring devices in order to find a solution to the water management problem along the Orange-Riet canal. The type of meter used on the canal off-takes has been standardised as a specific brand of mechanical meter (Figure 28), with the farmer responsible for purchase and installation. However, the WUA checks the accuracy of the meter with a clamp-on ultrasonic flow meter (Figure 29) and can adjust the calibration if necessary. The farmers must submit weekly water meter readings but the rate of abstraction from the canal is also limited to ensure that adequate flow reaches the Riet River scheme.

After nine years of experimenting with different solutions, the ORWUA now has a system in place that works for their specific situation and makes it possible to manage the water effectively.

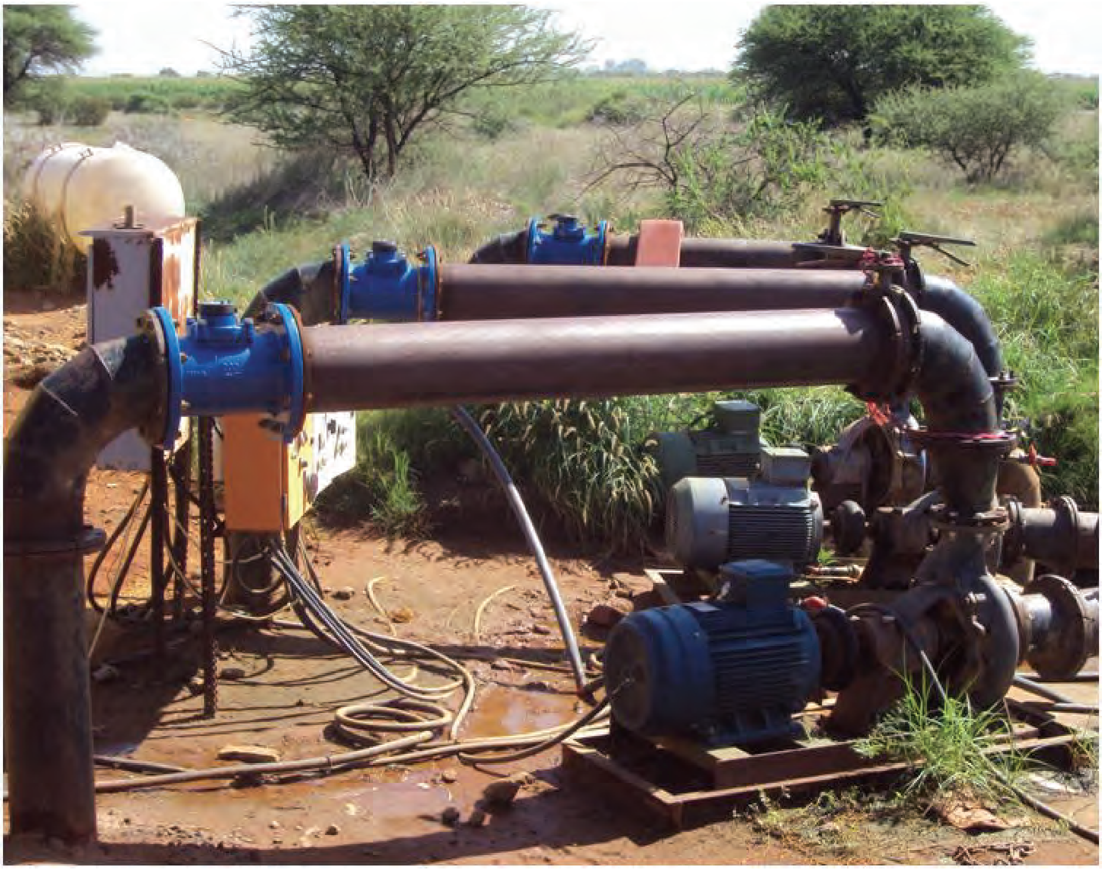


Figure 28: Mechanical water meters installed at off-takes on the Orange-Riet canal

Figure 29: Using a clamp-on ultrasonic meter to evaluate mechanical meters at the Orange-Riet Scheme

13.3.2 Lessons learnt

- Device selection and location: Trial and error showed that a suitable device can be found that will provide a solution even in the most complex of measuring locations: the meters that were finally selected address the main requirements (set by the ORWUA) of affordability, acceptable accuracy and suitability to the water quality and installation conditions.
- Operation and maintenance: By making provision for in-field calibration, the meters can be operated successfully. By receiving regular data, the meters can also be checked for consistency and early problem detection is possible.
- Organisational support: The importance of selecting appropriate technologies and training staff to use the technologies correctly can be clearly seen through the experiences of the ORWUA. Decisions were taken at management level to address the water management problems through a targeted approach of water measurement. By constantly addressing the problem and communicating a clear message to the water users, the ultimate solutions became acceptable to all the stakeholders involved.
- Funding: Finding appropriate solutions requires funding. Over the last 10 years, approximately R3.4 million has been spent on measurement-related infrastructure. Some of these funds were obtained externally, from Eskom and DWA, showing that it is possible to find solutions and implement changes.

13.4 Hereford Smallholder Irrigation Scheme

The Hereford Smallholder Irrigation Scheme's group of small-farmers were included in the project as a pilot area at the beginning of 2010, when the small-scale scheme initially selected in the Western Cape failed to materialise as an implementation site due to lack of funding.

13.4.1 Case study overview

The Hereford Irrigation Scheme is located near Groblersdal in the Limpopo province and consists of a canal distribution system supplying water to both commercial and smallholder farmers. The smallholders at the Hereford scheme receive water from the Olifants River via this canal. Water is diverted through a sluice gate (shown in Figure 30) without upstream control into an earth dam with an estimated capacity of 100 000 m^3, from where it is pumped into a pipe network. As there is no long-weir in the canal to regulate the upstream flow depth, sand bags are usually packed in the canal to raise the water level.

Figure 30: Sluice gate for the Hereford scheme small-scale farmers' water supply

A measuring point just after the sluice gate consists of a stilling basin and water level sensor, as shown in Figure 31. During a field visit to the scheme in 2011, it was not clear how the inflow to the dam was controlled as there was no lock on the sluice gate, but it seemed that the farmers were at the end of a secondary canal and received water on a rotational basis. According to a representative of the Hereford irrigation scheme, the technology at the measuring point was faulty and they would have liked to have replaced it after completing the canal lining project they were undertaking.

Figure 31: Canal between the sluice gate and the dam, showing the inlet to the stilling basin

The dam, together with the pump station and other in-field infrastructure, was constructed in 2003 by the Mpumalanga government. The area has very sandy soil and the earth dam was sealed with bentonite to some extent. However, it was quite obvious that the dam leaked, judging from the wet ground and reed growth below the wall, as shown in Figure 32.

The capacity of the dam had been reduced due to reeds growing inside it. The farmers used to allow the dam to dry out every winter and burn the dry reeds, but the last time this was done, two crocodiles were found living in the dam and the practice was subsequently stopped. From visual observation the reeds were covering about 40% of the dam's estimated 3 ha area, as shown in Figure 33.

There was also a great deal of algae and watergrass growing in the water, which reportedly caused problems in the pumps and in-field irrigation equipment.

Figure 32: Dam wall on the left and reeds growing on the right below the wall

Figure 33: Reed growth inside the dam

At the time of the visit, the water was pumped from the dam via an extremely long (approximately 50 m) suction pipe that had been laid over the dam wall. The pipe inlet was mounted on a float in the middle of the dam (Figure 34) in an attempt to reduce the amount of impurities being sucked into the pump, but during the field visit it was quite clear that the inlet was not well submerged and was sucking in air. The result of this was obviously audible cavitation at the pump station.

Figure 34: Float-mounted pump suction pipe withdrawing water from dam

The pump station consisted of two 100-200 single stage end suction centrifugal pumps driven by 45 kW motors. One of the pumps was out of order: the casing had cracked just below the outlet pipe. This apparently happened after serious cavitation occurred at the pump station as a result of farmers removing the sprinkler on their farms and using the water to flood irrigate their crops. The result would have been much higher flows and much lower pressures with the pumps running far towards the right hand side of the pump curve. On the right-hand side of the point of peak pump efficiency, the rise in losses is so rapid that it would, in the first place, become uneconomical to let the pump operate at that point (a very high current is required which can also lead to the motor burning out). The NPSH requirements of the pump would also rise exceedingly fast as soon as the duty point moves to the right of this point, which means the pump would need more pressure on the suction side, something which is hard to achieve with the long, siphon-like suction pipe.   All these conditions made cavitation more likely, increasing the likeliness of air in the water and leading to shock losses and waterhammer, which probably caused the pump casing to crack (Figure 35).   Continuously leaking air valves that were observed are also evidence of air in the water.

Figure 35: Cracked pump casing

From the pump station, water was fed into three pipelines that distributed the water amongst the 33 plots, which ranged in size from 2 ha to 9 ha. The pumps were switched on from 7:00 until 17:00 daily, and each farmer was supposed to pay R100 every month towards the electricity account. The payment was on a flat rate basis and not according to irrigated area. Out of the 32 farmers, 24 reportedly paid their contributions regularly. Both pumps were needed during peak irrigation times and with the one pump not working, demand could not be met.

Each farm received water through a hydrant of 50, 63 or 75 mm in size, depending on the size of the farm. The hydrant consisted of a butterfly valve and a mechanical water meter (Invensys WP Dynamic) as shown in Figure 36. According to the farmers, not all the meters worked and were not considered reliable because of the impurities in the water, and could therefore not be used to manage the water or the electricity account.

Figure 36: Farm hydrant with valve and water meter

Water was distributed on-farm with polyethylene pipes (mainlines and laterals), and applied with dragline sprinklers. The pipes did not stand up well to the constant moving and placing required by the cash crop rotations, and leaks developed due to cracks where the pipes bent. As part of the Comprehensive Agricultural Support Programme (CASP) programme of the Department of Agriculture, it was proposed that the whole scheme be converted to Floppy irrigation but the farmers did not agree to this and the process was halted. However, a bigger transformer (200 kVA) was already installed in anticipation of the changes but the farmers had to pay for the oversized installation.

As can be seen from the information above, the farmers were facing a number of problems regarding the water supply system that needed to be addressed:

- Accurate measurement was required at the inlet from the canal, to ensure that the farmers received their fair share of water.
- The condition of the dam needed to be improved: it was reed infested and had large (unmeasured) seepage losses.
- The dam's outlet works needed to be upgraded, as it made efficient operation of the pumps impossible.
- The cracked pump casing needed to be repaired, as it had effectively halved the capacity of the water supply system (and therefore irrigable area).
- There was insufficient pipeline and pump protection against high flows / low pressure and air problems.
- There was insufficient pre-treatment and/or filtration of the water entering the system, which affected the operation of the control and measuring infrastructure, and also limited the types of irrigation systems that could be used.
- The oversized electricity supply could not be fully utilised by the farmers.

Due to the nature of these problems, the correct operation of the water meters at farm level was not of great importance to the farmers at that stage. Their main concern was the leaking dam and the state of their in-field irrigation systems. However, improved measurement could definitely be beneficial to the scheme in order to:

- Monitor the amount of water pumped from the dam, allowing more accurate loss assessment. This would require the water to be filtered to some extent before entering the system, and repair or replacement of non-functional water meters.
- Divide the operational costs more fairly between large and small users.

It seems, however, that the social situation at the scheme and, inter alia the relationships between the farmers were rather fragile: farmers feared that any changes could upset the status quo, leading to hostility and vandalism. An extensive period of facilitation and capacity building would be required, that would probably have exceeded the project period.

Following the field visit, the project team contacted both the National and Provincial (Limpopo) departments of agriculture to find out whether there were any means by which the farmers could receive financial assistance to undertake the most urgent repairs. A consulting engineer was appointed in 2010 to undertake the improvements at the scheme, but during the feasibility study phase it became apparent that the conflict between the different factions within the group could become very serious. The consultants have requested the farmers to contact them when this has been resolved.

No further activities could be undertaken by the project team at this site before the end of the project period.

13.4.2 Lessons learnt

The time spent on the case study was not wasted as even though the water use measurement goals of the WRC project for this scheme could not be met, some lessons can be learnt.

The experiences of the project team at this small-scale irrigation scheme confirmed the lessons learnt at the commercial irrigation schemes:

- The purpose of the measuring system was not clearly defined and obvious to the water users, and therefore could not be fully utilised.
- Furthermore, implementation could not take place if, firstly, the farmers were not well organised, and secondly, if there were more pressing water management problems that needed to be addressed (and which would not be solved through measurement).
- The selection of inappropriate technology (in this case meters that were not suitable for raw water) led to technical failure of the system.
- In addition, the lack of a respected technically knowledgeable champion who was dedicated to driving water management changes hampered the process at Hereford, again confirming that skills development in water management is crucial to the irrigation sector.
- The lack of technical knowledge here however was secondary to the absence of a person who could provide leadership and guidance on the organisational issues hampering the success of the project.

13.5 Middle Komati River smallholder projects

Although no field work was undertaken by the project team at this scheme, it was included to broaden the knowledge base on recent activities at smallholder irrigation schemes regarding water measurement.

13.5.1 Case study overview

The Middle Komati River smallholder projects are located on the section of the Komati River between the Mananga border post (between South Africa and Swaziland), and the confluence of the Komati and Lomati Rivers near the town of Tonga (Figure 37).

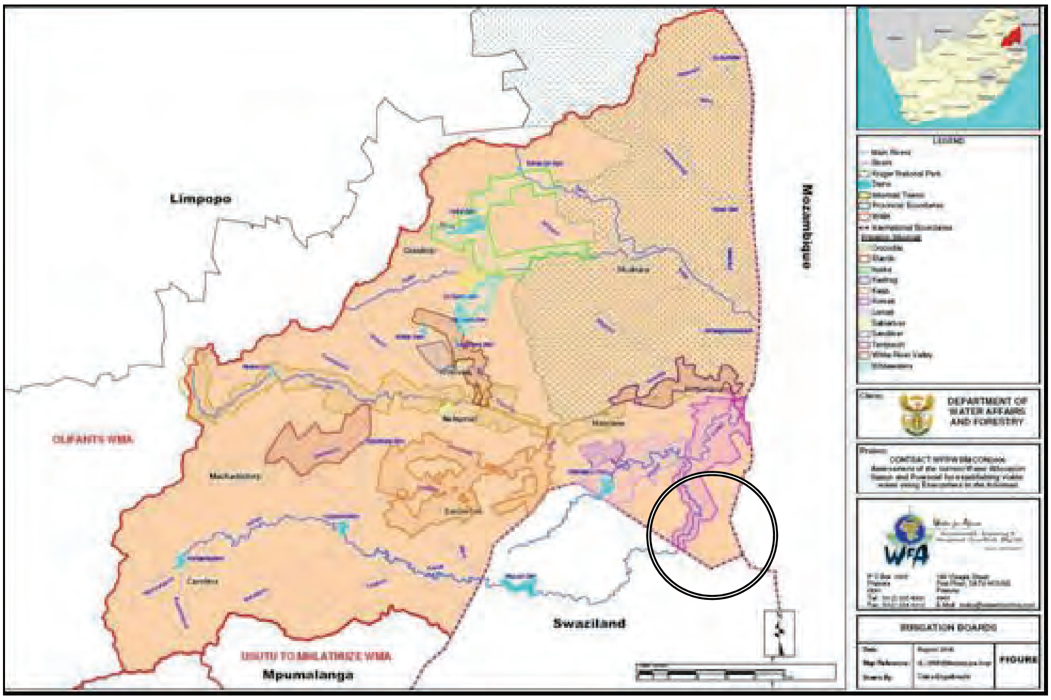


Figure 37: Location map of Middle Komati area

Approximately 1 200 smallholders are growing sugarcane in the Nkomazi east and west areas, and the cane is delivered to the Malelane and Komati mills, operated by TSB. There are 12 irrigation projects in the Malelane mill area and 22 in the Komati mill area. All sugarcane in the area is fully irrigated, and receive water from the two major rivers in the area. Water is allocated to individual growers but utilised collectively per project.

The Malelane projects abstracted water from the Lomati River, and the Komati growers abstract from the Komati River. Two storage dams have been constructed to stabilise the river systems and to store water for use during dry seasons. The Driekoppies dam was built in the Lomati River and the Maguga dam in the Komati catchments area. The water quota on the Lomati River is 8 500 m^3/ha/annum and 9 950 m^3/ha/annum for the Komati River.

Water restrictions are constantly imposed during times of drought, depending on dam levels. Irrigation water is abstracted directly from rivers and none of the projects had any storage dams. Some projects have small balancing dams with booster pumps.

These irrigation projects fall within the LRIB and KRIB areas, which are managed on behalf of the IBs by an appointed technical consultant in conjunction with KOBWA and DWA. Every abstraction point on the rivers was fitted with an electromagnetic flow meter, and farmers are provided with pumping schedules on a weekly basis to control abstraction volumes.

Farmers then submit their actual abstraction volumes as measured with the flow meter on a weekly basis for comparison with their allowance.

However, the smallholder projects on the Middle Komati River refused to allow the installation of flow meters when installation in the rest of the IB area took place from 1995 to 2000. The reported reason was that they feared that the meters could be used to cut off their water supply: possibly a belief coming from the old WAMS system that was installed in the area in the 1990s but subsequently damaged by floods and removed. A summary of the smallholder projects is shown in Table 17.

Table 17: Middle Komati Smallholder projects

Project name (Komati)	Area (hectares)	Number of growers	Average field size
Figtree A (Hoyi)	245.4	13	14.59
Figtree B	233.0	18	12.13
Figtree C	423.1	56	7.42
Figtree D	384.7	71	4.75
Lugedlane	326.5	24	15.34
Mangane	98.0	16	8.66
Mfumfane	310.6	47	6.89
Mbunu B	386.9	59	5.92
Mbunu C	150.0	25	6.16
Mzinti	258.3	38	6.98
Magudu	402.0	46	7.81
Madadeni	417.6	56	7.59
Mangweni	123.1	8	7.63
Ntunda	305.9	48	6.43
Phiva	239.8	38	5.00
Shinyokana	188.7	17	12.68
Sikhwahlane	388.6	62	6.22
Spoons 7 A	235.0	30	8.39
Spoons 7 B	77.4	5	7.74
Spoons 8	561.9	79	7.24
Sibange	378.0	51	7.20
Walda	823.9	79	9.93
Total area	**6958.7**	**886**	**7.82**

There is no abstraction data available for the Middle Komati area, making it difficult to manage the Komati and Lomati river systems effectively, especially in terms of honouring the international requirements of water that should be released to Mozambique at Komatipoort.

Since their establishment in 2004, the ICMA has been working on a catchment management strategy (CMS) to improve water management. The installation of water meters in the middle Komati area was identified by the ICMA as a major output of the strategic plan that needs to be achieved, and consultants were appointed to drive the process in 2011.

In a 2012 progress report, the consultants reported that progress was slow at the beginning of the project, with farmers demanding the installation of meters at individual farms (requiring a total of approximately 1100 meters) rather than at the points of bulk abstraction (requiring a total of 22 meters), as well as the provision of off-channel storage facilities to retain unused water to prevent the loss of this allocation to neighbouring countries. These additional demands of course implied much higher costs for the project.

The farmers eventually gave permission for the consultants to commence with a survey of all the river abstraction points in the area as part of a feasibility study, following a public participation process to obtain support. Support was provided by TSB and KOBWA to explain to the farmers that the meters are necessary to manage the water, and are not a threat to their water allocations (PD Naidoo & Associates, 2012).

The process included the identification of all stakeholders such as DWA, Komati and Lomati Irrigation Boards, KOBWA, the cane growers association, TSB Sugar, Nkomazi Local Municipality and the relevant farmers' associations. Once the stakeholders were identified, meetings / awareness workshops were arranged that outlined the various benefits of fitting a water meter, and reasons for their need as well as the history and current situation in the region.

The data gathering survey could only begin once the stakeholders were in agreement with the project and would allow the survey to commence without interference. The survey consisted of the following activities:

- Identifying all abstraction points using existing maps, aerial photography and inputs obtained from the stakeholders;
- Visiting each abstraction point in order to collect all the relevant data such as pump type and size, delivery and suction pipe sizes, motor size, source of power etc.
- Undertaking an on-site investigation of each abstraction point to obtain the following information:
    - GPS coordinates of each abstraction point;
    - Digital photos of each abstraction point;
    - Confirmation of ownership of the equipment;
    - All existing data related to water users and their water use rights;
    - A flow diagram of each abstraction point indicating the existing infrastructure and a proposed position of the new water meter that is to be installed;
- Allocating a unique identification number for each abstraction point;
- Compiling a detailed cost estimate for the installation of the water meters;
- Recommending appropriate measurement devices for each abstraction point taking into account cost, accuracy and durability.

The survey was followed by data analysis that resulted in recommendations for installations and cost estimates at 58 pump stations, with a total project cost in excess of R4m.

Should the meters be installed, their management and the collection of data will be critical, and the KRIB WCO has indicated that telemetry will be necessary to ensure sustainability. A system similar to the simple modems installed at the three sites along the Crocodile River will be suitable.

13.5.2 Proposals for effective implementation

The WCO and the management of the KRIB have extensive experience with the installation and management of water meters. The IB standardised the type of meters to be used as well as their installation practices, and also found a suitable telemetric solution for data collection.

The implementation challenges in the Middle Komati area will be of a social rather than technical nature, including:

Access challenges to farms and pump stations to undertake the bulk water abstraction point survey: farmers may refuse them access even though a decision was taken at a meeting held between the stakeholders and the consultants.

Further demands by the farmers for individual meters and off-channel storage facilities before implementation of the bulk water meters can commence.

Obstruction by the farmers of the installation of the bulk water meters by refusing contractors access to pump stations.

Vandalism and damage to the meters after they have been installed.

Lack of compliance to submit the meter readings after installation, should telemetry not be available.

Disregard of water allocations by abstracting more water than allowed once meter readings become available.

The provision of a regulation by the DWA or the ICMA imposing the installation of water meters as a pre-requisite to water use would support the implementation action required. However, even a regulation may be disregarded by the small-scale farmers.

This case study illustrates the importance of education in, and understanding of water management principles. Water users should understand that they do not operate in isolation; that water is a shared resource; and that responsibility comes with the lawful use of water. Further, as new structures under new legislation are put in place, all water users should be treated equally regardless of their history, and legislation and regulation should be applied to and respected by all.

13.6 Thabina Smallholder Irrigation Scheme

13.6.1 Case study overview

Although no field work was undertaken by the project team at this scheme, it was included in the project to broaden the knowledge base on recent activities at smallholder irrigation schemes regarding water measurement.

The scheme is located in the Mopani District of the Limpopo Province. The Thabina Smallholder Irrigation Scheme lies about 20 km South-East of Tzaneen on the Lydenburg road. The coordinates for Thabina are S 23.93183, E 30.2836 and it lies in the B81D quaternary catchment (Figure 38).

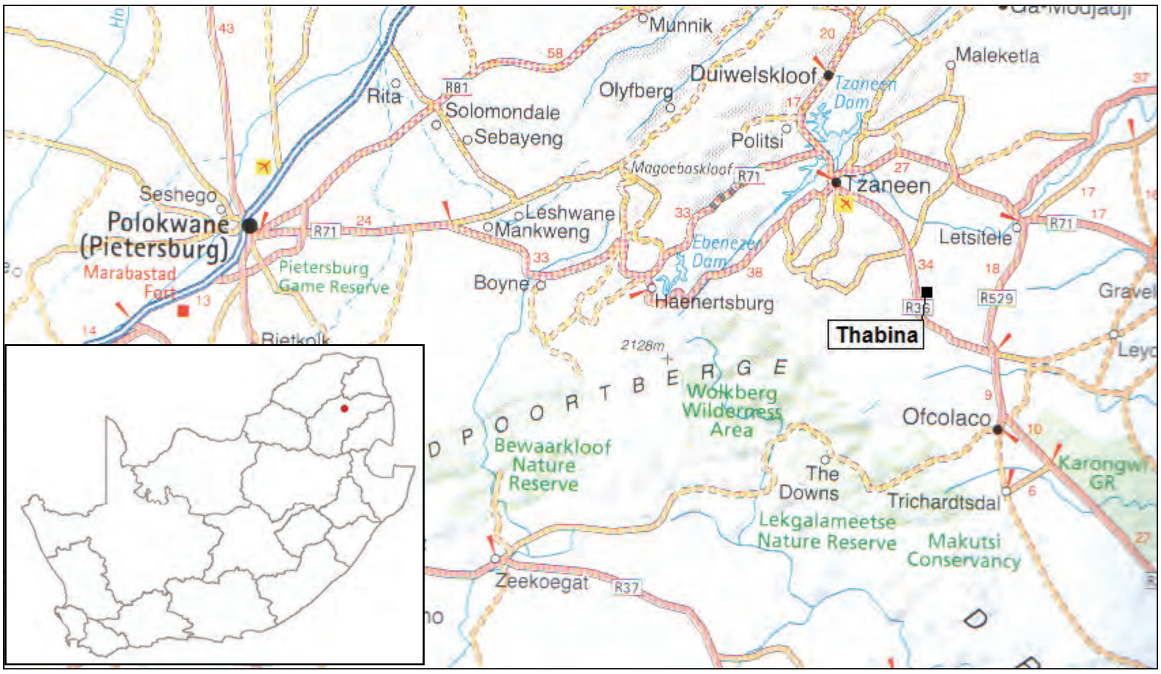


Figure 38: Location map of the Thabina Smallholder Irrigation Scheme

Water is supplied to the scheme from two weirs in the Thabina River, the second of which has been the subject of a revitalisation project. Originally the whole scheme was irrigated by short-furrow irrigation, but the revitalisation project added a pump station to supply water to three centre pivots and a section of drip irrigation.

The existing fenced area is approximately 350 ha with an irrigable area of 266 ha. This information was derived from a detailed topographical survey and a soil survey. The 2009 registered water allocation with the DWA was 393 750 m³ per year, which was equivalent to the supply of 63 ha of irrigation. The peak monthly flow required to irrigate 63 ha was estimated at 86 310 m^3 during December and the total annual estimated requirement was 308 700 m^3 spread over 10 months. With careful water management 80 ha of irrigation should be possible with this allocated volume of water.

The water supply from the river is not constant: it varies from year to year, and consecutive months of low or no flow could occur, which highlights the risk in terms of water supply. This risk had to be taken into account when planning areas to be irrigated at a certain stage or month. Since the water allocation for Thabina is only from run-off-river flow, and not from dam storage, the risk due to fluctuation in water supply is accentuated.

After an extensive public participation process, the farmers accepted that sufficient water was available for only 63 ha. They indicated that they would like to continue with their current cropping patterns, which were maize (grain and green mealies), tomatoes, cabbage and green beans. The farmers agreed that 3 x 21 ha centre pivots would be erected, and that provision would be made for 20 ha of drip irrigation for vegetables. About 100 ha dryland production was also envisaged, but the LDA did not approve the inclusion of this production area.

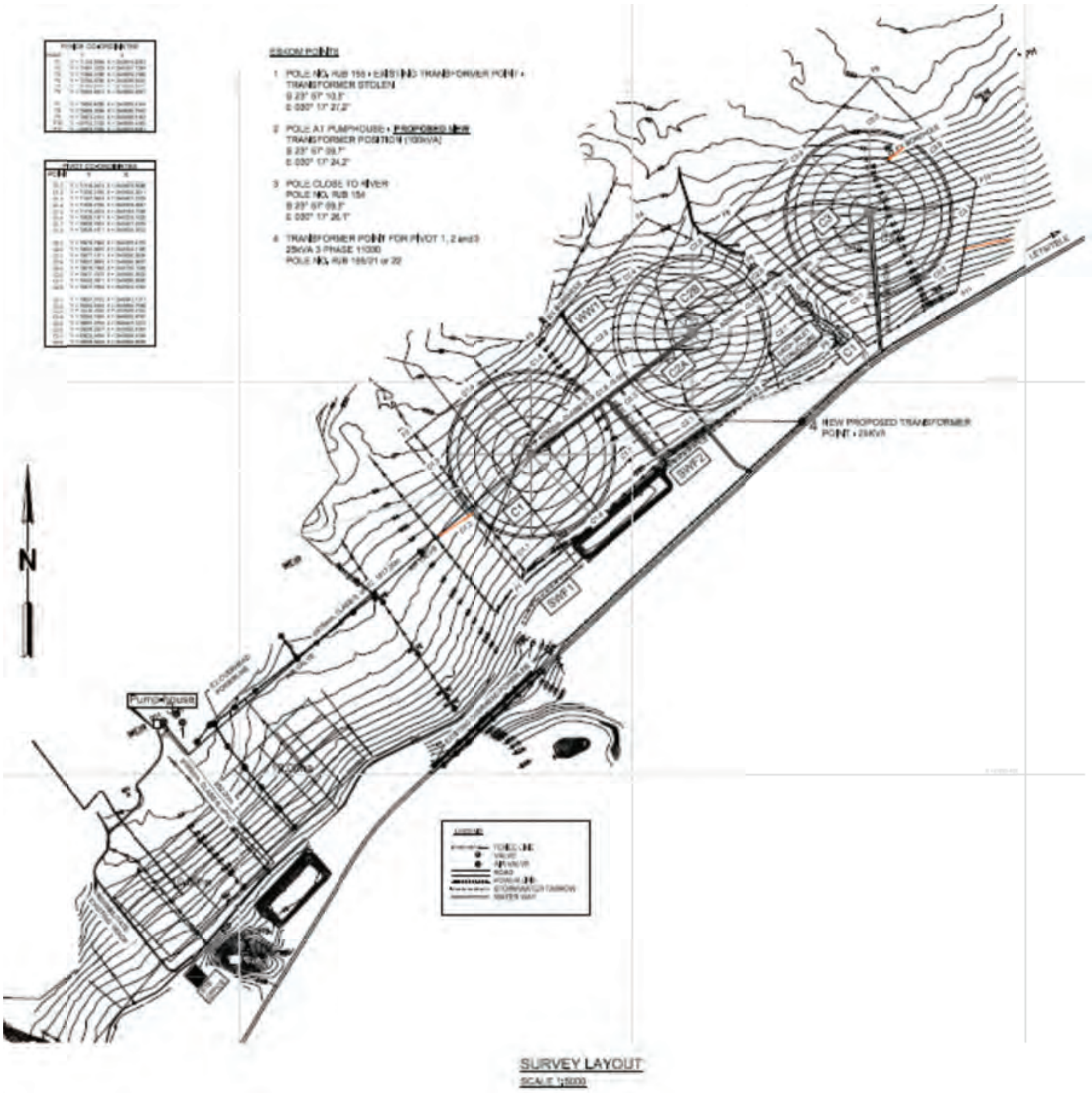


Figure 39: Lay-out of irrigation infrastructure at the Thabina Smallholder Irrigation Scheme

The lay-out of the irrigation infrastructure is shown in Figure 39. Water for the centre pivots and planned drip fields is pumped from the Thabina River (Weir 2) directly into the irrigation system, while farmers also irrigate parts of the scheme with short furrow irrigation on the area supplied with water from the first weir.

The establishment of irrigation systems only took place on irrigation potential Class 2 soils and a six day irrigation schedule was proposed. Centre pivots can be operated for 20 hours a day but the system was designed for supplementary irrigation in the summer months as Thabina is situated in an area with above-average summer rainfall.

The lay-out of the new pump station is shown in Figure 40. A common suction pipe supply water to four centrifugal pumps, three of which are dedicated to the centre pivots while the fourth pump was installed for the future development of drip irrigation, with a filter bank for this purpose.

Figure 40: The new pump station at the Thabina Smallholder Irrigation Scheme

Paddle-wheel type mechanical flow meters are installed on the two main lines. They are fitted with pulse output mechanisms (Figure 41) to allow the flow meters to be read on a display unit mounted in the pump house with the electrical control box (Figure 42), as the meters are located in an inspection chamber outside the pump house.

Figure 41: Flow meters installed at the Thabina Smallholder Irrigation Scheme

Figure 42: Display unit of the flow meters at Thabina Smallholder Irrigation Scheme

The new pivots were installed and commissioned. The farmers formed a cooperative, but initially had no funds available to commence production, and no implements or tractors to prepare the fields. They applied to the Department of Rural Development for funds, but with many of the Province's departments having been placed under administration due to management irregularities, no funds have been made available. In the meantime, the farmers successfully negotiated with a commercial farmer who has a contract with Freshmark to plant the areas under the pivots for them, and this agreement was implemented in 2012, a certain improvement from the grass was growing under the pivots at the time of the project team's visit in 2011 (Figure 43).

Figure 43: Centre pivot at Thabina Smallholder Irrigation Scheme

The upper part of the scheme where short furrow irrigation was still practiced receive its water from a smaller weir (Figure 44) which is poorly maintained and situated in an urban area.

The main canal supplied by Weir 1, which was outside the boundaries of the scheme, runs through Maake, (a residential area) where water has been used for domestic purposes by this community for at least four decades. Eighteen secondary canals are supplied from the main canal, as well as a night storage dam at the end. In March 2010 it was estimated that about 40ha was irrigated from this canal.

Figure 44: First weir at the Thabina Smallholder Irrigation Scheme

The decision was taken to transfer this canal to the local municipality to be utilised for food security projects. The LDA will thus not do any repairs on Weir 1. It is strongly recommended that an arrangement is developed between the LDA and the municipality to stipulate boundaries for the use of the canal and the land.

According to the local extension officer, DWA visited the first weir in 2010 and indicated that they will install a measuring device and silt trap at the first weir, but no action was taken.

13.6.2 Proposals for effective management

The new irrigation infrastructure at Thabina has been fitted with water meters that should be used not only as management tools to assist the farmers with their crop production but also to protect their water allocation of 393 750 m³ per year. To ensure that the meters can be used effectively, the following recommendations are made:

Records should be kept of the type and model of the meters that were installed, the supplier and their contact details, as well as any documentation that was received with the meters (such as the calibration certificates).

The pump house operator should be trained to read the meters on both the remote display as well as on the mechanical registers.

A system should be put in place whereby the meters are regularly read (for example once a week) and the readings recorded with the dates.

The scheme manager or extension officer should be tasked with the responsibility of checking the readings at least once a month to ensure the meters are in working order, and against the annual allocation to ensure the farmers do not exceed this.

With only one water meter for all three pivots, it will be difficult to use it as a scheduling aid. However, the extension officer can be trained to use the meter to check the general condition of the irrigation systems, by comparing actual flow rates with the design values.

A system should be put in place for action to be taken in case of suspected malfunctioning of the meters. A suitable contractor or technician's contact details should be available.

It is unfortunate that although new infrastructure was provided, the farmers were unable to commence production. As a result, the use and maintenance of the flow meters was not a priority for them: obtaining funds for production inputs, managing the crop once it has been planted, and securing a market for the harvest was of much greater importance and in fact critical to the survival of the scheme. Only once the production cycle has been established will water users be able to focus their attention on the finer detail of managing their water resource with the aid of the water meters.

13.7 Conclusion

The case studies presented the project team with opportunities to assess the usefulness of measuring irrigation water use in a number of situations. In some cases, it was found that measurement could not be implemented successfully, indicating that the benefits thereof were often not clear to the people who needed to drive the process. The activity of measurement is seemingly simple but its role in water management is not always fully understood. A significant amount of knowledge dissemination is still required to convince the average water user or IO of the value of measurement in terms of being essential for water loss control and on-farm savings.

Especially in the case of smallholder irrigation schemes, the potential of flow measurement as a management tool is still largely under-estimated (Denison & Manona, 2007). International experiences in irrigation revitalisation, focused on collapsed or largely dysfunctional schemes, have shown that investment in infrastructure alone is likely to fail. This includes the simplistic repair of existing systems and "upgrading" of infield irrigation technology. It is clearly important in almost all cases that irrigation initiatives need parallel elements addressing the complex of activities and functions as discussed in detail in earlier sections of the report.

Recent South African experiences have been documented earlier (e.g. Ncora scheme) where infrastructure degradation is observed on a scheme at the same time as new infrastructure rehabilitation initiatives are being undertaken. This demonstrates a disturbing lack of awareness of options on the part of the agencies funding infrastructure-centred approaches, or demonstrates that other expenditure or political motivations for these interventions are at play.

Provincial policies, where they exist, are characterised by an emphasis on capital expenditure and infrastructure development (i.e. irrigation hardware and technology) and a heavy reliance on the concept of commercial partnerships for the production component. Given South African and international experiences in smallholder irrigation (Denison & Manona, 2007), provincial policies need to be reviewed to accommodate more diverse solutions in acknowledgement of the widely differing technical, social and historical situations of schemes. The adoption of generic strategies applied to widely different schemes is unlikely to meet the diverse opportunities, smallholders' needs and operational realities of schemes in any one province. The links between irrigation scheme operation, management and engineering design present an opportunity in the revitalisation initiative to make water apportionment, management and policing more equitable and with lower transaction costs. At its simplest level, the engineering team must not only consider rehabilitation of existing infrastructure but also think about adding new engineered components (such as division boxes, gates, flow meters, etc.) that will change the behaviour of water users.

Technology is an instrument of social change in this sense and small technical interventions can greatly reduce conflict and time spent dealing with water. Redesigning schemes for easier group management can be achieved by installing flow-meters in key places in pipelines, or easy to read flow-control structures in carefully selected locations in canal systems. This will have the effect of reducing the size of hydraulic units and therefore the size of the water management group that must collaborate with each other on a daily basis. Redesign may involve inclusion of new secondary and tertiary canals to offset the imbalance between top and tail-end users and make water management and apportionment easier and has potential to reduce transaction costs and water conflict. Engineers are generally practical and sensible but in irrigation design this is of limited use unless they interrogate water management issues and are thoroughly informed by scheme users to develop appropriate solutions to these problems. It will amount to a case of really listening to farmers and jointly developing creative changes to the water system (Denison & Manona, 2007).

Where implementation of flow measurement has failed, it has more often than not been the soft issues that were the obstacles: organisations, individuals and the institutions that determine their behaviour are more difficult to change in order to achieve a desired outcome, than technical challenges.

Of great importance in this regard is the parts played by the different role players and the way these contribute to the success of a project. Failure of one role-player to accept the responsibilities associated with the position they hold can jeopardise implementation. DWA, the IO, the water users, local government, equipment suppliers and other organisations all have roles to play and should be made aware of the importance thereof in the context of the whole project.

Finally, any project should be planned and implemented as simply and practically as possible: unnecessary complication is a threat to successful project implementation. This can only be achieved if knowledgeable implementing agents manage the project through careful planning and in-depth assessment of the situation presenting itself, as every project will be different in its own right and therefore require site-specific solutions, an outcome that will hopefully be achieved through the careful application of the proposed implementation guidelines and plan.

PART E: AWARENESS CREATION

14 Technology transfer initiatives

Various activities were undertaken during the course of the project to obtain inputs and to disseminate information on water measurement to a wider audience. These activities included workshops, popular articles, presentations, demonstrations, interviews with the media and the development of a project website.

14.1 DWA workshop

Parallel to the WRC project, the Directorate Water Use Efficiency (DIR: WUE) of DWAF embarked in 2007 on a process to develop a strategy and implementation guidelines for measurement of irrigation water. A discussion document was drawn up, a workshop was held on 31 July 2007 at Roodeplaat Dam where approximately 40 DWAF representatives attended, and subsequently consultants were appointed to complete the strategy and guideline documentation for the Directorate by June 2008.

During the course of the two projects, it was found that in addition to the overlap between the two projects' objectives, there were a number of other initiatives being undertaken by DWA Directorates, the successful implementation of which relied on the availability of accurate information regarding the actual abstraction and consumption of irrigation water use in South Africa.

As a result, it was recognised that there is an urgent need for the parties involved with all of these projects to meet and coordinate their efforts, to ensure that the projects' output complement each other rather than creating duplication within DWA. It was therefore decided to organise a workshop where the parties could be brought together to discuss the implementation of irrigation water measurement.

The workshop took place on 12 March 2008 at the Agricultural Research Council Institute for Agricultural Engineering (ARC-IAE) in Silverton, Pretoria.

In addition to providing a unique opportunity for the representative of the different DWAF directorates to talk to each other about water measurement, representatives raised various important issues and expressed opinions including:

- Projects are being initiated by different Directorates of DWAF with slightly different purposes to meet slightly different line function needs whilst satisfying overall requirements of NWA. It is difficult for outside users to navigate their way around the different Directorates, and also the water use figures seem to be inaccurate.
- Water management should be effective at all levels, not only within an irrigation scheme. What about water users outside schemes who are not being measured? Nothing is known of their water use, their water use efficiency, or even about the potential illegal water use. Farmers will want to know the answer to these questions. For example, in the Limpopo area there are only three target areas, which is only a small part of the whole irrigation area.
- The RO/ CMA focuses on the unregulated users (those outside the government control areas and outside the WUA). CMAs are "wall to wall" and will catch up those areas of currently unregulated users. The responsibility for measurement lies with the RO/CMA and could later be rolled out WUAs.
- Regardless of all the problems with registration, verification and validation, the aim is to put the means to measure in place, so that control can be undertaken. The problems need to be

solved as soon as possible, but meanwhile measurement/metering needs to be implemented in any case. A policy decision is required that will give some relief/incentive to those who are measuring e.g. by reducing their water services management charges.

- There is a clear need for measuring and monitoring. Why then is water use measuring/metering not already happening? Is it due to lack of a lead Directorate or clear champion organisation leading the way?

The DWAF representatives expressed their appreciation to the WRC project team for providing an opportunity to discuss technical and practical requirements of water measurement. The workshop was followed the next year by a project funded by the Directorate: WUE to develop a water measuring strategy, and in 2009 the regulations were proposed for water measurement implementation.

14.2 Stakeholder workshop

As part of the WRC project's implementation phase, a workshop was arranged to engage with key stakeholders on the topic of irrigation water measurement and to provide feedback on work undertaken during the project and the state of the art of irrigation water measurement. The objectives of the workshop were, therefore:

a) To inform all the identified stakeholders of the available water measurement technologies, their applications and benefits, and the regulatory environment for irrigation water measurement.

b) To discuss the outcomes of the WRC project within the context of the different case studies undertaken.

The workshop took place on 8th March 2012 at ARC-IAE Silverton, Pretoria.

14.2.1 Proceedings

The programme followed during the workshop is shown in Figure 45. A significant part of the programme was devoted to energy use. This had become a major focus point by this stage of the project due to rising electricity costs, and because water measurement can help to identify inefficient energy use.

One of the attendees noted that whilst measuring water is not a new idea in a water scarce country, it is important to measure energy costs in addition to water as a production cost. Energy costs for riparian irrigation farmers have risen from R2 000 to R5 000 per hectare, thus water measurement links to energy costs and productivity, giving an important reason to measure.

It was noted that in order to optimise water use and increase efficiency it is necessary to know what resources one has, and to use them better. Further, it was noted that although metering is one method of providing information, the data recording time-step is important, together with information about the area that is metered. There may also be adjunct forms of measurement such as telemetry, water pressures, satellite imagery, etc. that form other pieces of the information-gathering puzzle.

It was agreed that whilst accuracy of metering is important, it should not be allowed to distract attention from the main issues: appropriate and acceptable levels of accuracy would be determined and agreed by stakeholders for various scenarios, and technology will improve over time. It was also noted that proper installation and maintenance of water meters is as important as accuracy, and that operations and maintenance costs must be both expected and built in to water measurement implementation planning.

Mr Walther van der Westhuizen from DWA presented an overview of the regulations requiring the taking from a water resource for irrigation purposes to be limited, monitored, measured and recorded. This was received with great interest from the workshop delegates.

WATER RESEARCH COMMISSION

Stakeholder Workshop:

Sharing Experiences in Irrigation Water Measurement in South Africa

ARC – ILI, Silverton, Pretoria

8 March 2012

AGENDA

08:30	ARRIVAL AND TEA / COFFEE	
09:00	WELCOME AND INTRODUCTION	A Pott
09:05	OBJECTIVES OF THE WORKSHOP	I van der Stoep
09:15	OVERVIEW: IRRIGATION MEASUREMENT TECHNOLOGIES • Options, Costs, Skills and Knowledge	I van der Stoep
09:45	DISCUSSION	All / A Pott
10:00	OVERVIEW: DWA PROPOSED REGULATIONS REQUIRING THE TAKING OF WATER FROM A WATER RESOURCE FOR IRRIGATION PURPOSES BE LIMITED, MONITORED, MEASURED AND RECORDED	W van der Westhuizen
10:30	DISCUSSION	All / A Pott
11:00	TEA / COFFEE / SANDWICH BREAK	
11:30	OVERVIEW: VALUE-ADDING THROUGH ADDITIONAL MEASUREMENTS AND EFFECTIVE DATA MANAGEMENT • Data collection and reporting	I van der Stoep
12:00	Scheduling Energy and Water Use in Irrigation	Dr Roy Mottram
12:30	Improved efficiency using variable speed drives	Werner Scheepers
13:00	DISCUSSION	All
14:00	WORKSHOP SUMMARY AND CLOSURE	A Pott

THANK YOU FOR YOUR ATTENDANCE AND INPUTS!

Figure 45 Workshop programme

The following points were captured during the discussions which followed on from the presentations given at the workshop:

- The need for regulations was initially triggered by the illegal water use situation in the Upper Vaal River in 2005, the volume of which was exceeding the capacity of the Mohale Dam, but it was seen over time that there was a national need for irrigation water use regulations. There is a particular problem with illegal abstraction from "conveyance" rivers.
- Undertaking the above actions contributes to good irrigation practice, and brings irrigation water use in line with all other water uses, which are measured. The regulations are aimed at limiting users to their lawful allocation rather than introducing curtailments, although Compulsory Licensing will complement the regulations in some situations.

- There were no stipulations in the old permits or proclamations that required irrigators to undertake measurement. However, licenses issued under the NWA do stipulate that measuring must take place. There is a measurement “loophole” with regard to ELU. Compliance cannot be maintained without measurement.
- The above actions are stated in the regulations, but it is not the intention is to force every user to install a meter. Monitoring preferably needs to be undertaken in terms of volumes used rather than only the traditional method of hectares irrigated.
- Each farmer will pay for their own water use monitoring, which can be undertaken using a cheaper method (such as remote sensing, an electricity meter or an hour meter), but where there is flagrant violation they will be required to install a water meter.
- Broader, cheaper (less accurate but adequate) means of measurement such as SAPWAT data combined with satellite imagery, in-field verification using GPS, etc. may be used in the first instance, with metering being imposed on persistent and flagrant transgressors. DWA may also install its own meter.
- Whilst there no detailed specifications for the format of data storage and transmission are described in the regulations, farmers are obliged to keep records, and to transmit them to DWA on request (where, for example, there is suspicion of gross over-abstraction).
- It was stressed that both the volume abstracted and the flow rate are to be monitored. The volume per annum refers to the lawful allocated amount. The abstraction rate is an important factor: users may not take all their water at once!
- Pumping hours, the characteristics of the pumping equipment, and the irrigated area will be recorded by the farmer. Where a suspected transgressor is detected, then a meter may need to be installed. Irrigators who are subject to the regulations go all the way down to subsistence level: it is not realistic to expect a minor user to install a flow meter as a first step in the regulatory process.
- DWA will monitor the area, first and foremost, and WCOs will from time to time take spot-check measurements with clamp-on meters. This may not require extra staff – there are sufficient WCO posts that must be filled, and WCOs and must be trained.
- The response to non-compliance will depend on the extent and persistence of the transgression. Ultimately the entitlement can be withdrawn for persistent abuse.
- Measurements will be undertaken using the most appropriate method for the system characteristics, rather than stipulating a single particular method. There is no minimum requirement for accuracy in the current draft of the regulations, although if the public consultation process reveals a need, it may become a recommendation.
- Energy measurement may also be used to determine water volumes and rates. The regulations override the Eskom privacy clause currently in place, allowing DWA to access farmers’ electricity usage records. People do tamper with electricity meters: whilst the extent of an irrigated area is plain to see from satellite imagery, up to 90% of electricity meters are found to have been tampered with. However, an immediate answer comes from the use of a clamp-on flow rate meter.
- In terms of the development of the regulations and the process of promulgation, the regulations have been discussed with Agri SA, TAU and with WUAs, and their recommendations have already been included. Currently they are with the State legal advisor. They require more discussion and input from other entities and organs of state, after which they will be published in the Government Gazette for public comment. They are expected to be promulgated a year from now.

- There could be region-specific requirements, but these are not currently in the draft. Further, it is expected that each region will target its priority areas during national roll-out of the regulations.
- Leading up to the roll-out of the regulations, the WC/WDM directorate could undertake advocacy and build awareness of how measuring can benefit farmers.
- Whilst Compulsory Licensing closes certain loopholes in water allocation, this regulation applies to ALL users, even if they are currently licensed.
- The concept of energy savings linking to increased water use efficiency has given much food for thought: Whilst water measurement is not big news, there is an increasing need for new devices to be more accurate. The topic of energy savings is important to help with inefficiencies.
- Although it is on the periphery of these discussions, in future the issue of carbon credits will become increasingly important and the strong energy links and incentives that have been highlighted today could have implications in terms of this; it could be an additional area of incentives.
- When this project is concluded and implementation has begun, it will be necessary to reach a wider audience and emphasise the energy/water link, and bring in key new technologies to better inform water managers in the field. Plans are already there for a new project, which must now be followed through.
- At this workshop, only one component was examined in terms of energy efficiency. Optimally one needs to combine all components, including VSD, and adopt a systems approach.
- DWA have been aware of this study, and see the need to work closer together with this study to promote the regulations and irrigation water use measurement to increase efficiency. At this stage, however, the input from the DWA colleagues concerning the regulations was reassuring and pragmatic.
- More clarity is required regarding the right meter/measuring tool for the right application: in line, clamp on, magnetic, etc. Also more information on the percentage accuracy differences between the various means of measuring, because this will have an influence on the baseline that is being developed by Eskom.
- It was noted in response to this comment that inaccuracies can even vary between one device and another of the same make and model, depending on a variety of factors such as installation, working environment, etc. General information is however available on the project website and in WRC report TT 248/05.
- The starting point for irrigation decision making is SAPWAT, which shows people when they are over-irrigating. However, there is a need to relate SAPWAT and satellite imagery to on-the-ground measuring to show farmers that these information sources are accurate and trustworthy.
- The general impression given by workshop delegates was encouraging and positive: hopefully this applies to the wider farming public. With sufficient energy and money-saving incentives, the regulations might almost not be necessary.
- The workshop gave a deeper insight into the complexities of metering in the agricultural sector. Solutions can very across the board: there is a need for “horses for courses”, i.e. the right meter for the right application.
- With the huge potential for major savings it is amazing that there is still so much inefficiency. Electricity integrates across the system and focuses the savings. The cost of current levels of inefficiency in terms of electricity use is illustrated by the fact that Eskom have calculated

that they currently need to generate 640 mw electricity to drive the nation's centre pivots If the measures discussed today were implemented, about half of that: i.e. about 300 mw, could be saved.

- A survey of 500 farmers in Mpumalanga revealed that fewer than 10% have done scheduling or water measurement. Of these, even fewer knew about the importance of proper maintenance for irrigation efficiency. For example, 90% of centre pivot nozzles have never been inspected or changed since installation. It should be noted, however, that this has now changed in certain areas where better capacity building and monitoring is going on, and that it makes a difference if the crop is irrigation dependent or if irrigation is supplementary.
- Farmers will do things and change things only if it is easy and convenient to do so. However, since golf courses for example have automated irrigation systems that require only a few small adjustments to be made once they are up and running, the same should be possible on-farm.
- The adoption of scheduling has been poor in the past, because triggers such as the low cost of water have been weak: even though the opportunity cost of wasted water may be higher, water cannot trigger scheduling and saving – it seems that energy saving is the trigger.
- There are variations in practice and a range of views around the table: a win-win message is that efficiency translates into water savings leaving more water available on the farm, or for expansion in agriculture or other areas. All stakeholders need to work together to support efficiency gains that translate into savings.

It was concluded that packaging and marketing water use efficiency are the big challenges: water users need to increase beneficial consumptive use and reduce the non-beneficial consumptive portion, and work together to translate efficiency gains into water savings. This is cooperative rather than confrontational and something everyone wants to achieve.

14.3 Popular articles

Three popular articles were published in South African magazines during the course of the project.

- "Irrigation water measurement: One size does not fit all!" SABI Magazine, August/September 2010
- "Water meters for irrigation" Farming SA magazine, December 2010
- "Implementation plans for sustainable measurement of irrigation water" SABI Magazine, April/May 2012

14.4 Presentations / Demonstrations

Presentations regarding the project activities and outputs were presented during the following events:

- Boegoeberg irrigation scheme, 30 October 2007
- South African Association of Water User Associations (SAAFWUA) AGM, Worcester, 31 October 2007
- DWA area office, Clanwilliam, 11 November 2007
- DWA area office, Uitkeer, 4 December 2007
- DWA area office, Worcester, 6 February 2008
- SAILI CPD Event for agricultural engineers, Pietermaritzburg, 23 September 2008
- SANCID Symposium, Club Mykonos, 19 November 2008

- DWA meeting on water measurement implementation at the Steenkoppies groundwater compartment, Pretoria, 29 June 2009
- Sandveld Farmer's Day, Redelinghuys, 25 November 2010
- WRC 40th Celebration conference, Emperor's palace, 31 August 2011
- Steenkoppies demonstration day, Tarlton, 27 October 2011

14.5 Website

The website was developed to assist with communication between the research team and the stakeholders during the course of the project. The website performed certain functions at various stages of the project, specifically to inform, persuade and remind the stakeholders of their involvement in the project.

During the preparatory phase of the project (deliverables 1 to 4), the website was used to inform the stakeholders about the WRC project, and specifically about the survey amongst irrigation water users regarding the current status of and needs for measurement of irrigation water. The information page was used to show that the project team had adequate knowledge of the subject and its environment, to refer to past research and consulting experiences that the stakeholders could relate to, and to present a positive attitude about the subject and project.

The website was also used to re-enforce the idea of involvement by reminding the stakeholders to become and stay involved, and by giving them instructions on how to complete the questionnaire, how to obtain information and how to contact the project team. An image of the main website page is shown in Figure 46.

Figure 46 Project website main page

14.6 Interviews

Interviews with the following media groups took place to distribute information on the project outputs:

- AgriTV
- Radio Elsenburg

14.7 Future Initiatives

The technology transfer actions initiated during this WRC project should be taken further with knowledge dissemination activities and mechanisms such as posters, pamphlets and advertising to convey a set message to the wider irrigation water use community. This is discussed in more detail in Chapter 15.

15. Conclusion

Although progress is being made towards regulating measurement implementation, the importance of irrigation water measurement is still largely disregarded, despite the fact that the implementation thereof makes good business sense from a management perspective.

The focus therefore remained on the practical, rather than the institutional, side of implementation for the duration of this project, building on the technical foundation that was laid in the first two WRC funded projects undertaken from 2001 to 2007.

Engagement with DWA during the preparatory phase of the project showed that measurement implementation will benefit a number of Directorates through the improved water management that is made possible by water use data collection. However, the survey on the current status of water measurement revealed that the knowledge and skills associated with implementation is vested in the IOs, rather than with DWA.

Those organisations that have implemented measurement successfully have taken a practical approach to addressing the challenges presented by their specific situations and made use of the most advanced technologies that they could afford. Their experiences have led to the development of the necessary skills amongst their staff to implement and manage the measuring devices successfully.

The following constraints hindering successful implementation of irrigation water use measurement were identified:

- An incomplete and inaccurate register of water users and points of use, making implementation of water measurement and enforcement of allocations difficult.
- Lack of useful benchmarks against which to judge the actual use figures, should measurement be implemented, due to inaccurate water use registrations captured in the Water Use Authorisation and Registration Management System (WARMS) data base.
- The relatively low cost of water, combined with a history of flat rate billing leading to uneconomic water use and a lack of consideration for WUE.
- Fragmented and ambiguous organisational arrangements for water management across the country. Dissimilar management structures apply to water users, making uniform implementation of a strategy by the regulator very difficult.
- A shortage of skilled staff at various levels in the water management hierarchies, from hands-on technical level (for installations, etc.) up to management level (to develop WMPs, etc.).
- The lack of a standardised approach across Water Management Areas (WMAs) and well as within them, when advice is given regarding what measuring device should be installed where, and by whom.
- The remoteness of locations where measurement must take place, both in terms of the management of the measurement locations as well as actually installing the devices.
- Lack of guidance on the type of device that is acceptable to the regulator for monitoring water use, if required for the purposes of compliance monitoring.
- Lack of guidance on operational practices for water measuring devices in terms of a standardised approach to data collection methods and data storage formats.
- Little information on funding options for implementation, e.g. possible rebates from DWA or partners (such as Eskom) that can be approached for financial assistance.

- Poor communication between IOs and DWA regarding aspects such as resource management and the application of water resource management (WRM) levies
- Confusion regarding organisational issues amongst the water users, such as the establishment of WUAs and CMAs, and the roles and responsibilities of these organisations (in general, but especially regarding water measurement).
- Inequality in policy application: any policy on water measurement should be fair, and applicable to all raw water users. Other sectors (mining and domestic were named specifically) are reputed to use water and manage resources indiscriminately, especially where water quality is concerned. This causes major problems for agricultural water use for food production.
- Socio-political issues: many farms are subject to land claims which need to be finalised before major investment in management infrastructure can be made. New farmers should also comply with water use conditions and cannot be exempted.

Many of these constraints refer to challenges in water management in general, and not to water measurement specifically. They do however represent some of the obstacles to successful measurement implementation. If the social, political, organisational and environmental issues are not addressed, technical solutions cannot be implemented successfully, no matter how technologically appropriate or advanced they are.

DWA is in the process of developing regulations with regard to measurement of water in the irrigation sector which will address some of the constraints identified during the project. Entitled "*Proposed regulations requiring the taking of water from a water resource for irrigation purposes be limited, monitored, measured and recorded*", the latest version of the document puts forward a process to monitor water use by irrigation farmers using remote sensing applications as a starting point, with direct measurement of water only recommended as a final solution in the case of confirmed transgressors. The regulations are still under development, with an extended stakeholder engagement process still to take place before being introduced into practice.

Until the regulations have been approved, the advantages of water measurement from an on-farm water or business management perspective should be pointed out, specifically relating to:

- The potential to make more profit, and/or
- The potential to help improve the convenience to the farmer.

Emerging trends suggest that water meters are becoming increasingly important, as they provide irrigators with vital information (often with other sets of complementary information) to help improve or protect profits, and water meters and associated technologies and products are offering information to irrigators in a convenient, affordable and reliable format.

The cost of water meters is easily quantified, with the capital cost of a meter usually insignificant compared with the capital costs of the pumps, pipes, filters and other components that comprise the irrigation system itself. It is more difficult to quantify the benefits of metering as clearly as the costs; however, water meters can and do offer significant value to irrigators in South Africa as described in this report and given this fact, it is in the interests of irrigators to invest in water meters sooner than later.

Key profit-related considerations in the South African context include the rapid rise in electricity costs, and the threat of curtailments to existing lawful water use in over-allocated catchments. An analysis of trends in irrigation suggests that due to rising electricity costs there is a growing need for irrigators to consider more energy-efficient irrigation options. Energy usage is strongly correlated to water usage. The financial returns to an irrigator are in turn strongly correlated with the volume and pattern of irrigation water application. The water scarcity situation in South Africa may result in some irrigators being restricted, which will result in them making do with less water.

The net result is that there is significant pressure on irrigators to improve their irrigation practices. Decision support may be required. Water meters have a role to play in helping irrigators remain financially viable. New technologies and support services are emerging, largely supported by the internet platform which can assist irrigators with making improved decisions in a convenient and cost effective manner.

The installation of water meters with dataloggers will also assist irrigators to comply with legislation in a manner that is more convenient than manually recording pumping hours and other sets of information that would otherwise be required.

The project has led to the development of a suggested implementation plan to be used when considering water measurement to be implemented at irrigation scheme level. The plan covers the following aspects:

- Measurement implementation planning
    - Background to the implementation area
    - Measurement trigger
    - Purpose of the proposed system
    - Locations for measurement
    - Benefits of measurement
    - Water user support and organisational arrangements
- The measurement system
    - Measuring device selection
    - Installation
    - Operation and maintenance
    - Monitoring and evaluation
- Implementing the plan
    - Budget and funding
    - Role players and responsibilities
    - Gantt chart
    - Invitation for inputs

Guidelines have also been developed to provide the implementing agent with information on the different aspects and how they should be addressed when developing the implementation plan for a specific situation.

During the implementation phase when the plan and guidelines were tested, it was found that in some cases the benefits of measurement implementation is often not clear to those persons who must be the drivers of the process. The activity of measurement is seemingly simple but its role in water management is not always fully understood. A significant amount of knowledge dissemination is still required to convince the average water user or IO of the value of measurement in terms of being essential for water loss control and on-farm savings.

Where implementation has failed, it is more often than not the soft issues that were the obstacles – organisations, individuals and the institutions that determine their behaviour are more difficult to change to achieve a desired outcome than technical issues. Of great importance in this regard are the parts played by the different role players and how these contribute to the success of a project. Failure of one role-player to accept the responsibilities associated with the position they hold can jeopardize implementation. DWA, the IO, the water users, local government, equipment suppliers and other organisations all have roles to play and should be made aware of the importance thereof in the context of the whole project.

15.1 Key messages

The outcomes of the implementation phase of the project can be summarised into four key messages for potential users of measuring devices for irrigation water:

15.1.1 Assign the responsibility for implementation to a skilled person

A knowledgeable and skilled person employed by the WUA or IB is required if water measurement is to be implemented successfully. Such a person should preferably have a technical background and be involved with the process of implementation right from the start, to ensure that they share all the experiences in the process of finding a sustainable measurement solution for the area under consideration. This person must be able to develop a measurement system for the specific situation and also be able to see to the day-to-day operation and maintenance of the measuring devices (with assistance if necessary).

15.1.2 Preparation is key

In order to find the best solution, it is recommended that any possible technology that is being considered for wide-scale implementation must first be evaluated on a trial basis to obtain first-hand experience with its installation, operation and maintenance requirements. It is better to try out as many technologies as possible on a small scale before making a final selection, as this can prevent inappropriate, costly systems from being purchased that may become redundant after a short while of operation. The cost of single units of a few different technologies is money well-spent in view of selecting the best solution.

15.1.3 Commit to an implementation plan

Any project should be planned and implemented as simply and practically as possible – unnecessary complication is a threat to successful project implementation. This can only be achieved if knowledgeable implementing agents manage the project through careful planning and in-depth assessment of the situation presenting itself, as every project will be different in its own right and therefore require site-specific solutions, an outcome that will hopefully be achieved through the careful application of the proposed implementation guidelines and plan.

15.1.4 Install the most appropriate technology that can be afforded

Research work undertaken over the last 10 years has shown that suitable technologies and devices are available for the measurement of irrigation water, even in challenging situations with regards to aspects such as water quality and installation conditions. Failure of measuring devices or systems can usually be blamed on incorrect selection, application, installation or maintenance rather than on the technology itself. Under demanding conditions, it is imperative that the best technology or device available and affordable is obtained, to ensure a sustainable system that will serve the purpose that the owners of the system intended it for. The benefits of a suitable system will pay for itself within a short period of time but an unreliable system will only cause frustration and lead to unnecessary expenses and an additional work load on the water managers of a scheme.

15.2 Recommendations

The project has provided the project team with opportunities to evaluate and improve the water measurement guidelines developed during the preceding WRC project. The project activities have resulted in a range of case study material being available for further use in to support and promote the use of water measuring devices in irrigation for improved water management.

The following recommendations are made regarding future use and application of the project output:

- Crocodile River case study area:

  The recently installed energy monitoring equipment should be transferred to the new directed WRC project entitled "The optimisation of electricity and water use for sustainable management of irrigation farming systems" that is due to commence in April 2013. It would provide the new project team with accurate and recent historical data of water and energy use at easily accessible sites.

- Short term project on knowledge dissemination:

  It is recommended that a knowledge dissemination project be undertaken to implement the project outcomes through the distribution of results by means of pamphlets, brochures, posters or other forms of promotional material. The project should entail the development of the material, based on the lessons learnt and the documentation generated during the projects undertaken from 2001 until 2012, as well as the distribution thereof.

  In order to ensure long-term use and achieve greater impact of the project output, it is recommended that a non-commercial entity with a vested interest in irrigation water measurement, such as the South African Association for Water User Associations (SAAFWUA) be targeted as the primary partner of the project team to create a credible point of entry into the target group. This organisation should take ownership of the tools that have been developed – guidelines, implementation plan, project website and other promotional material – and promote it as wide as possible. If necessary, the tools should be aligned with the DWA regulations (once approved) and DWA regional offices targeted for capacity building too.

  The project approach should be one where partnerships are formed with other organisations such as the South African Irrigation Institute (SABI), the South African Committee on Irrigation and Drainage (SANCID), and meter manufacturers, to distribute the promotional material.

  The project should also explore additional funding mechanisms that can be used to promote measurement technology. Options such as the Technology Innovation Agency (TIA) which was established in terms of the TIA Act, 2008 (Act No. 26 of 2008) with the objective of stimulating and intensifying technological innovation in order to improve economic growth and the quality of life of all South Africans by developing and exploiting technological innovations.

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Appendix A:

Results of the survey amongst irrigation organisations

A Survey amongst WUAs

A1 Introduction

Aim 2c of the project requires interaction with stakeholders "to determine the current status and to synthesise the available knowledge on water measurement in practice at irrigation scheme level on a national basis with an appropriate survey technique". In order to collect this baseline information on the current status, and to collect data for the analysis phase to determine the needs of the users, a questionnaire has been developed. The questionnaire was sent out to 297 WUAs and IBs, from all 19 WMAs. The questionnaire is attached in Appendix C and covers the following sections:

1. Irrigation organisation
2. Water source/s from which the water users have irrigation water rights:
3. Quotas and scheduled areas (per source per water year)
4. Water control infrastructure – Dam, river, canal and pipeline schemes
5. Water control infrastructure – Groundwater schemes
6. Water control infrastructure – On-farm dams
7. Water quality
8. WUA management

A total of 73 completed questionnaires were received. The data were collected electronically by e-mail as far as possible, while mailed and faxed submissions were also received. The format shown in Appendix C is the e-mail submission form which can be filled in electronically.

NB: Some of the optional answers are drop-down menus from which possible answers can be selected; Not all the options show on this printed version.

The data were captured into an Excel spreadsheet for analysis, and the results are presented graphically below in Figures 9 to 53. The results will also be published on the project website (www.watermeter.co.za).

A2 Results

A2.1 Responses

Responses were received on the understanding that the confidentiality of the IOs would be maintained: IOs would not be named nor would responses be linked directly to any particular IO. 73 of the 297 irrigation organisations (IOs) that were contacted submitted responses to the questionnaire survey. Of these, the majority were IBs, followed by WUAs, as shown in Figure 3.

It is important to note, however, that the majority of irrigation water users do not belong to *any* IO, and are administrated by DWAF ROs. These irrigation water users were not included and are not covered by this questionnaire.

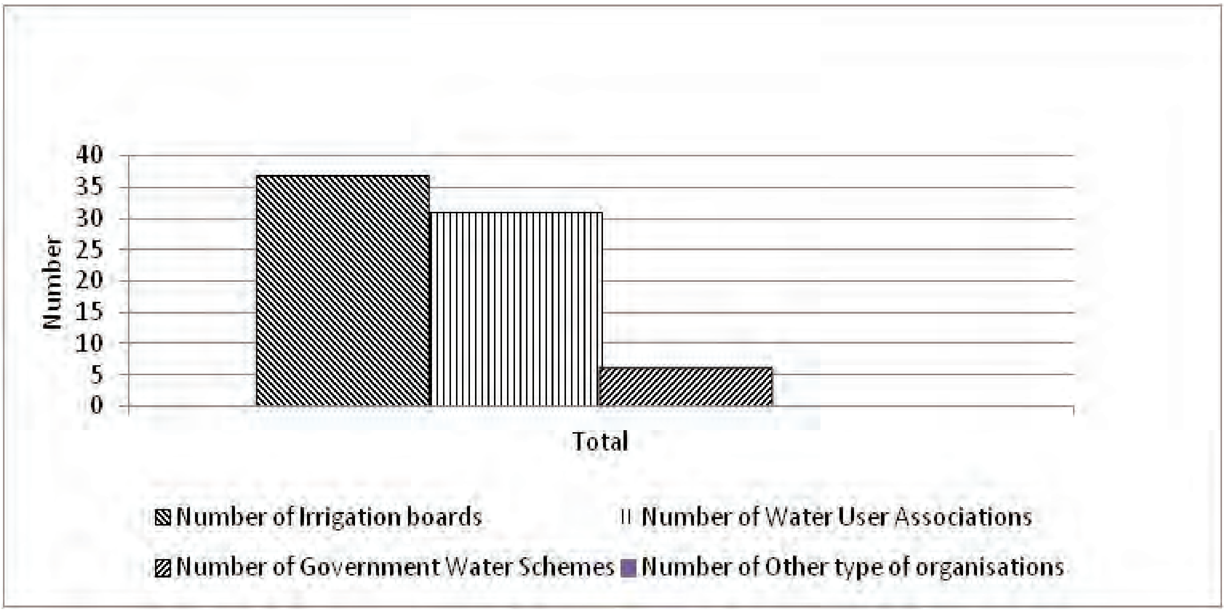

Figure 47: Organisation types that took part in the survey

Organisations from across all nine provinces responded to the questionnaire. The most (>20) responses per province were received from the Western Cape (possibly due to the high number of small schemes in this Province) whilst fewest (<5) responses were received from KwaZulu-Natal, Free State and Gauteng Province. The majority of provinces returned between 5 and 15 questionnaires, as shown in Figure 4.

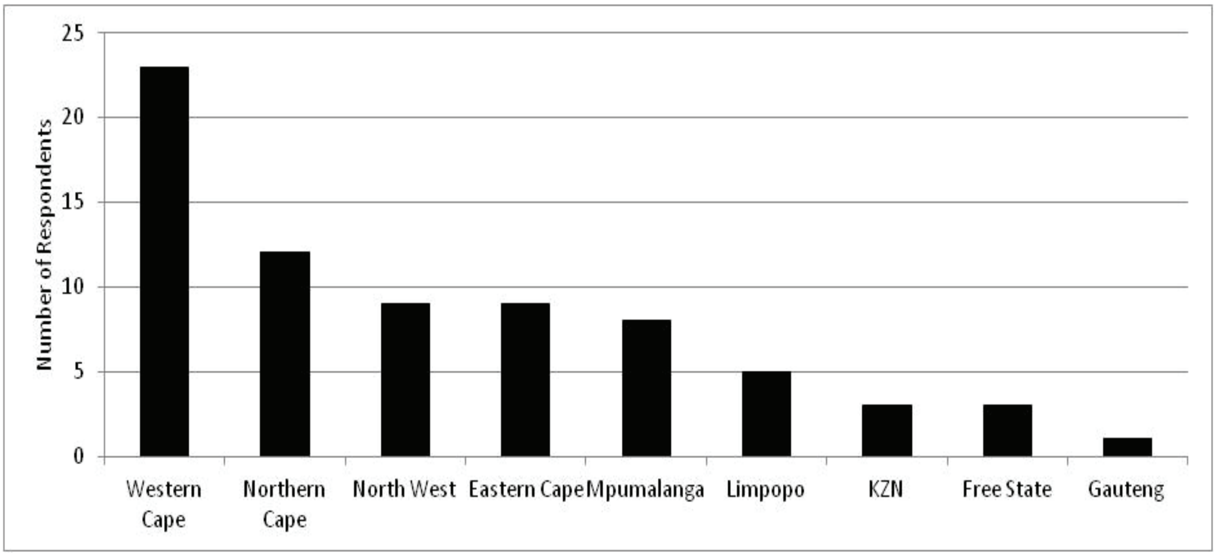

Figure 48: Number of organisations that responded per province

Questionnaires were received from ios in 15 out of 19 WMAs, as shown in Figure 5. The high number of responses received from the Breede WMA was due to the large number of small IBs in that WMA.

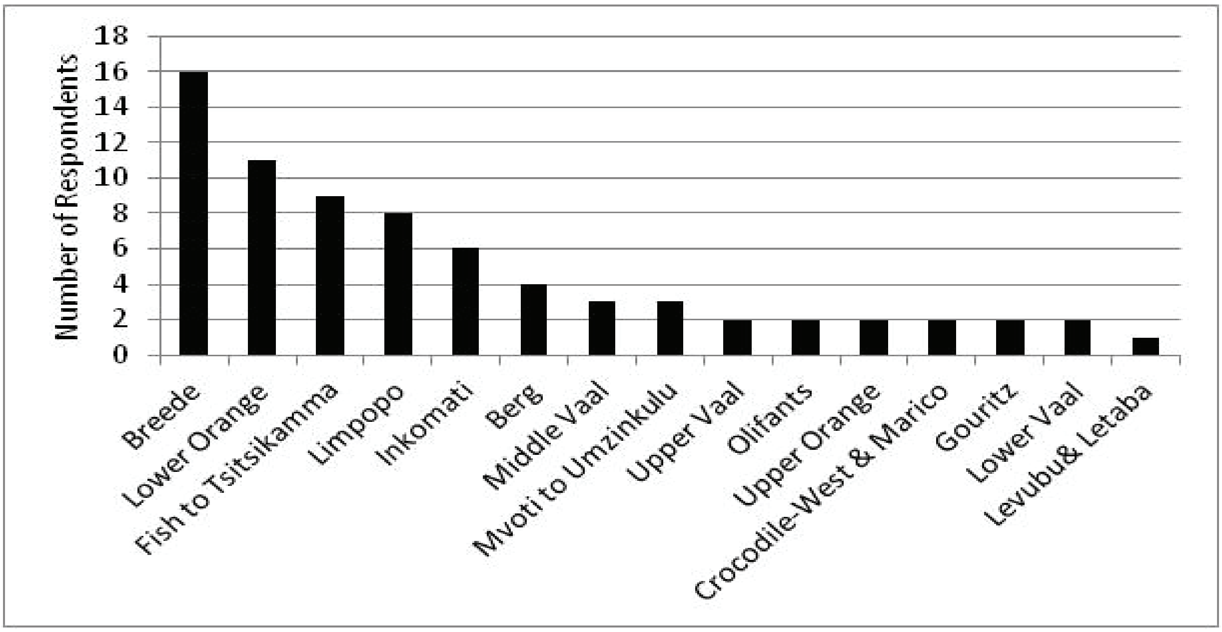

Figure 49: Responses per WMA

A2.3 About the irrigation water use organisations

Figure 6 shows that IOs are by far the dominant type of management authority of water sources across all water source types for the responding organisations.

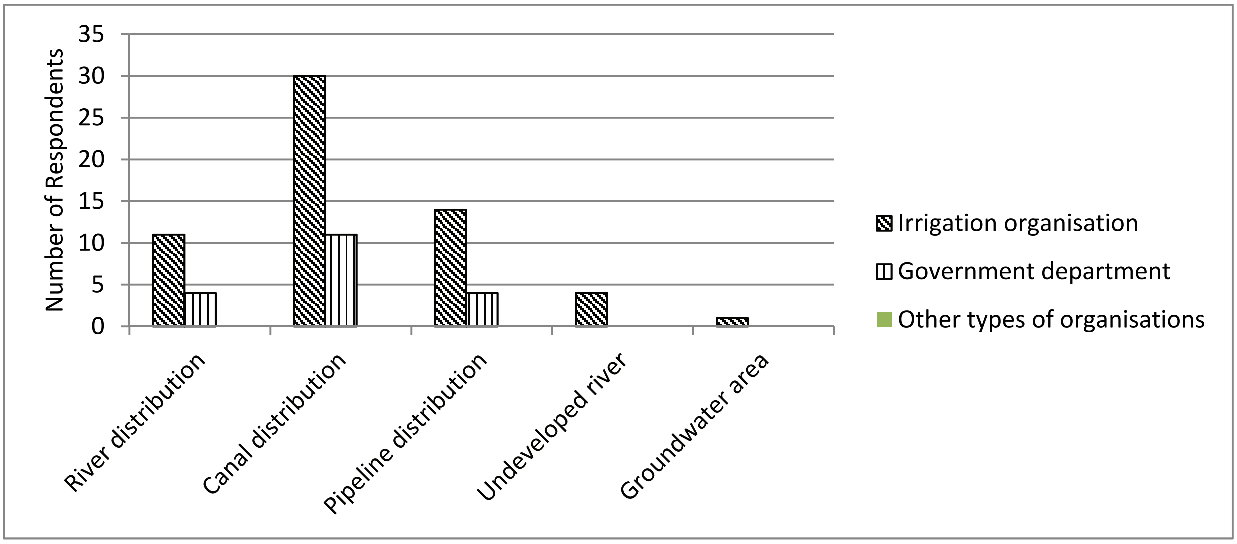

Figure 50: Management authority of water source

Figure 7 shows that the number of water users per IO ranged from almost 1000 to only 4.

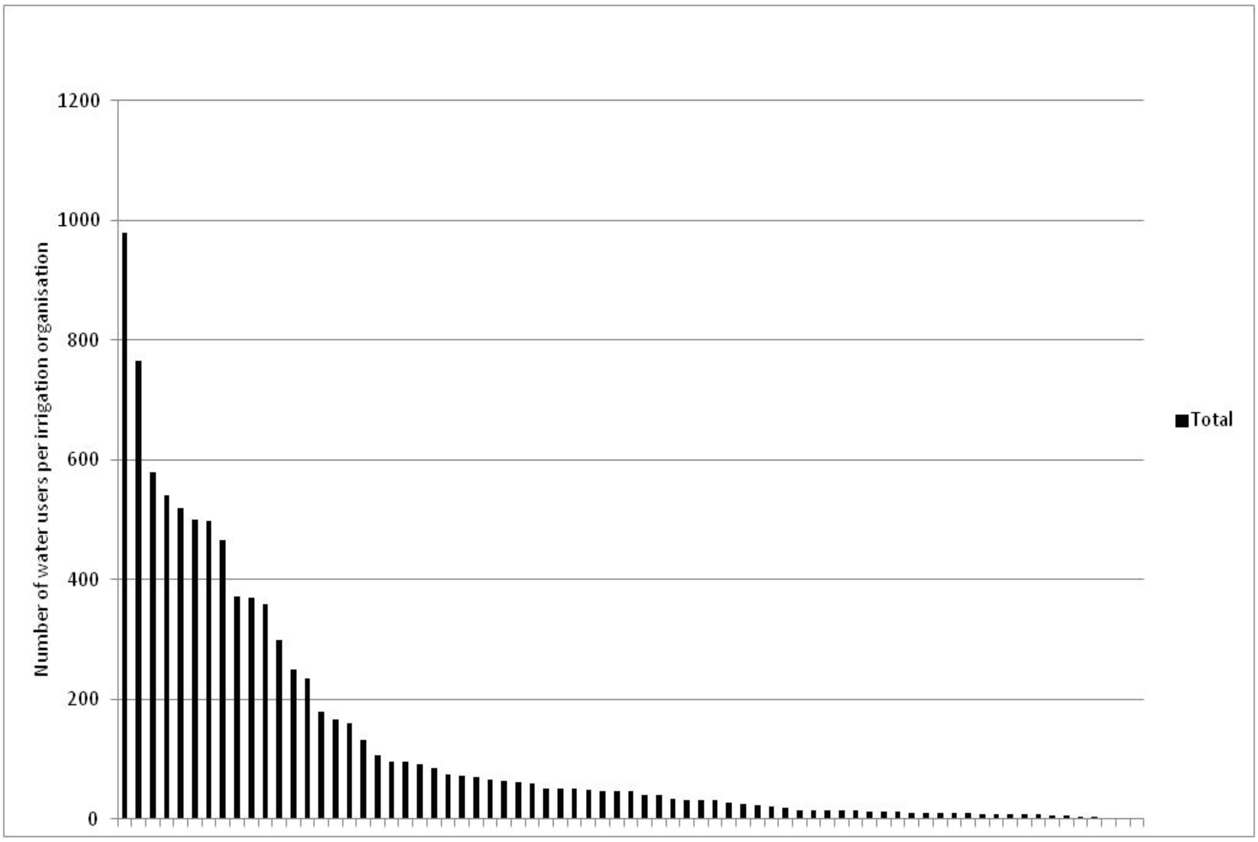

Figure 51: Number of water users per organization

A2.3 Water distribution systems

This section of the questionnare aimed to find out more about the water distribution systems by which the IOs distribute water to the water users. (An IO may use more than one type of distribution system.)

Responses covered the whole spectrum of situations found in the field. Figure 8 demonstrates the variety of situations encountered for which measurement solutions must be found. 41 respondents reported that they distribute water via canals. IOs who use pipelines numbered 17, whilst 15 used rivers. Only five IOs used undeveloped rivers, whilst two respondents represented groundwater areas and only one IO reported on-farm dams as the main source of irrigation water.

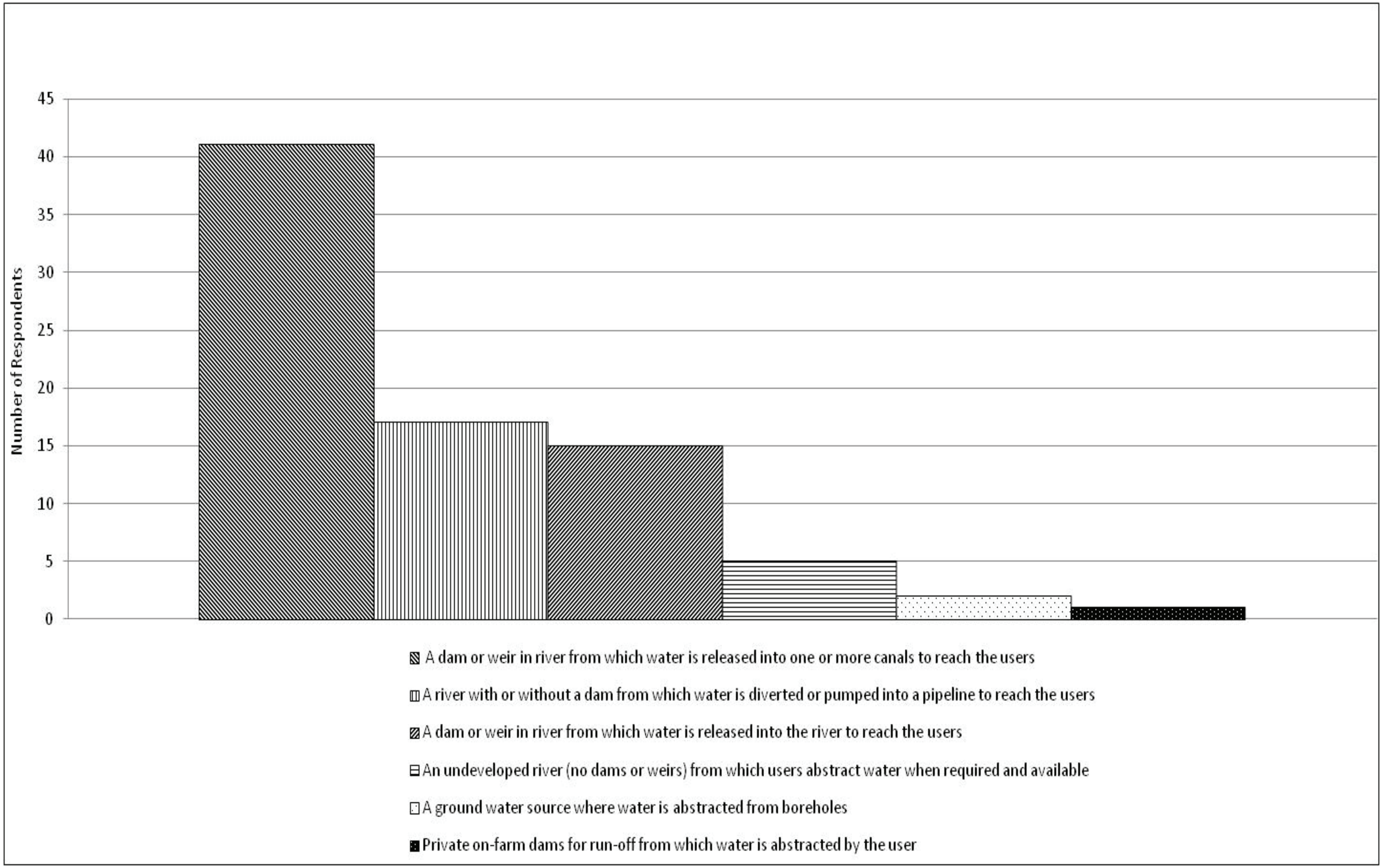

Figure 52: Water supply infrastructure used by respondents.

Of the 41 IOS using canal distribution systems, the majority (30) reported that the canals were lined, as shown in Figure 9. This is a good response in terms of WUE considerations. Only four in this group are using unlined canals.

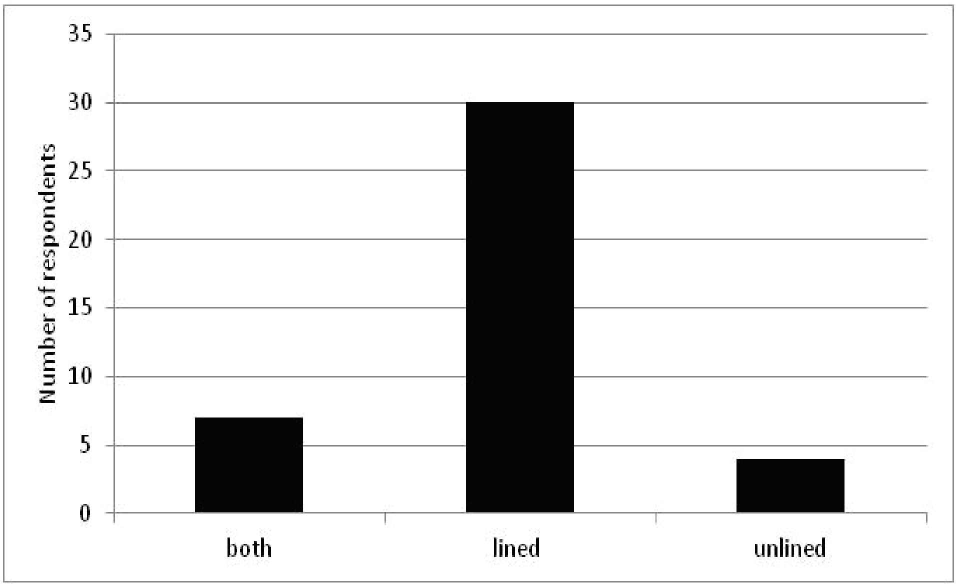

Figure 53: Type of canals used by respondents

A2.4 Water use allocations per water year

Water charges per ha

Figures 10 to 13 compare the water charges/ha for users of rivers, canals, pipelines and undeveloped rivers respectively. Figure 10 shows that water charges for users abstracting from rivers are generally below R400/ha, although in one WMA they are R2629/ha.

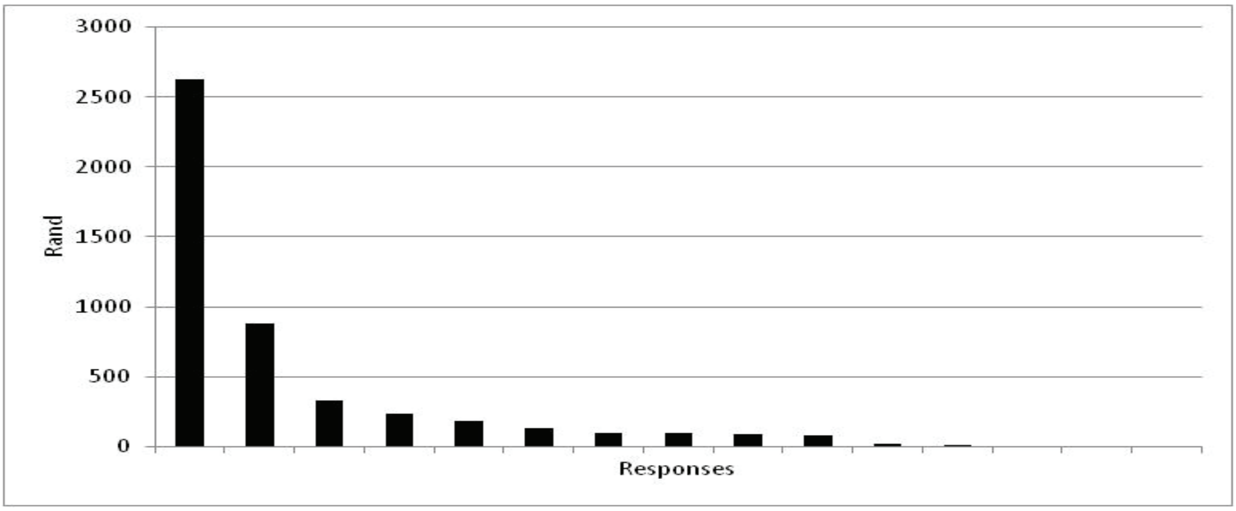

Figure 54: Water charges: River distribution

Figure 11 shows that for canal distribution water charges per ha are nearly all below R1000/ha, with most between R100/ha and R800/ha.

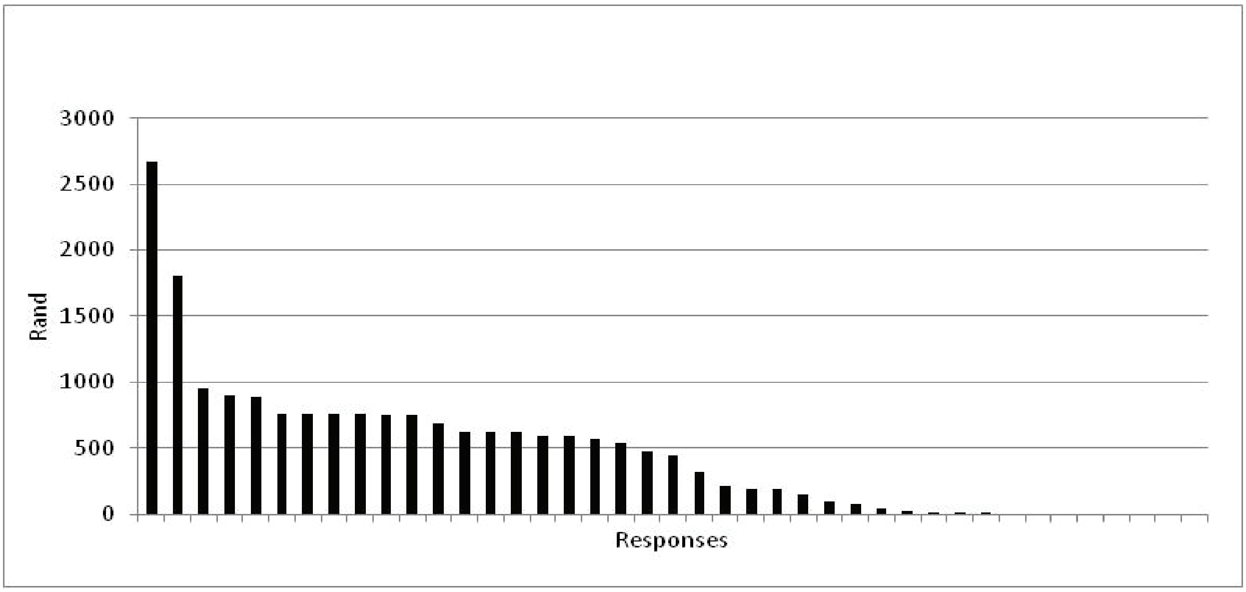

Figure 55: Water charges: Canal distribution

Figure 12 shows that most water charges are below R500/ha for those distributing their water via pipeline, although in one WMA they are R2500/ha.

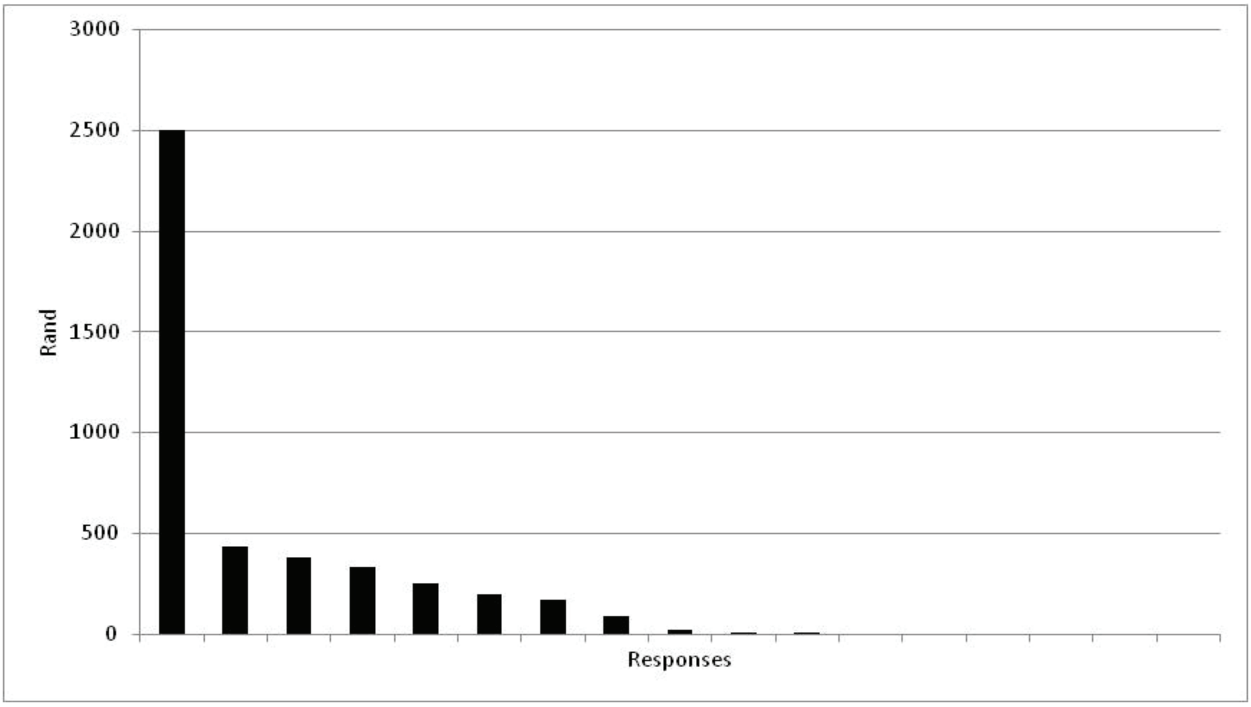

Figure 56: Water charges: Pipeline distribution

The size of the sample represented by Figure 13 is small, but nevertheless it is apparent that water charges for those distributing their water from undeveloped rivers lies between R350 and R150 per ha

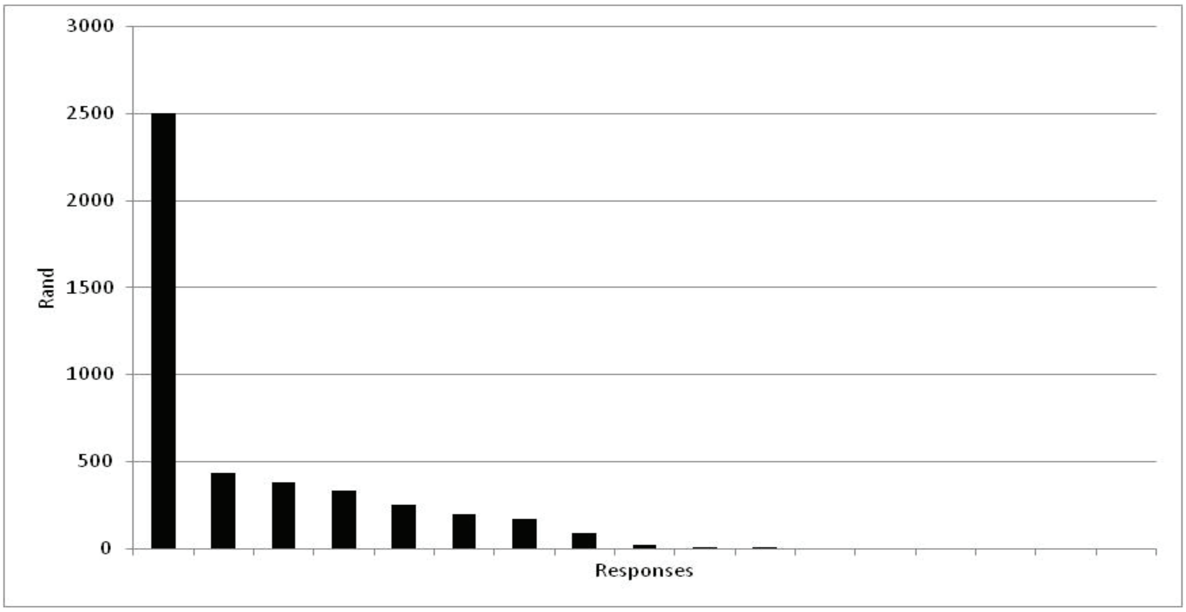

Figure 57: Water charges: Undeveloped river distribution

Figure 14 again represents a small sample, in which water charges in groundwater areas are under R100/ha

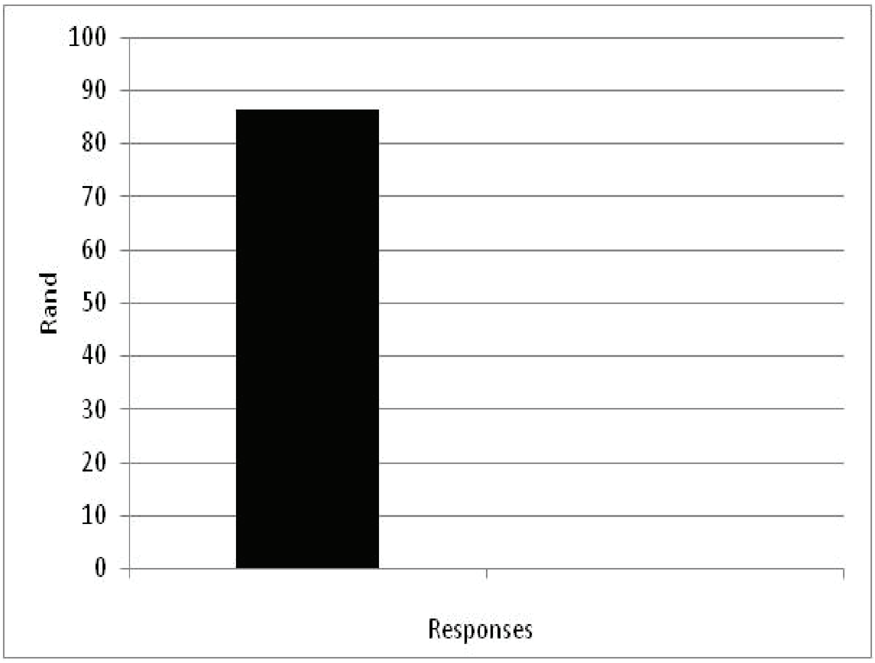

Figure 58: Water charges: Groundwater area distribution

From Figure 15 it can be seen that the majority of water users have to pay for their full quota regardless of the amount of water they actually use. There is, therefore, the potential to provide incentives for users to convert to paying for actual use only, but this is difficult to implement due to budget implications for the IO in terms of reduced revenue.

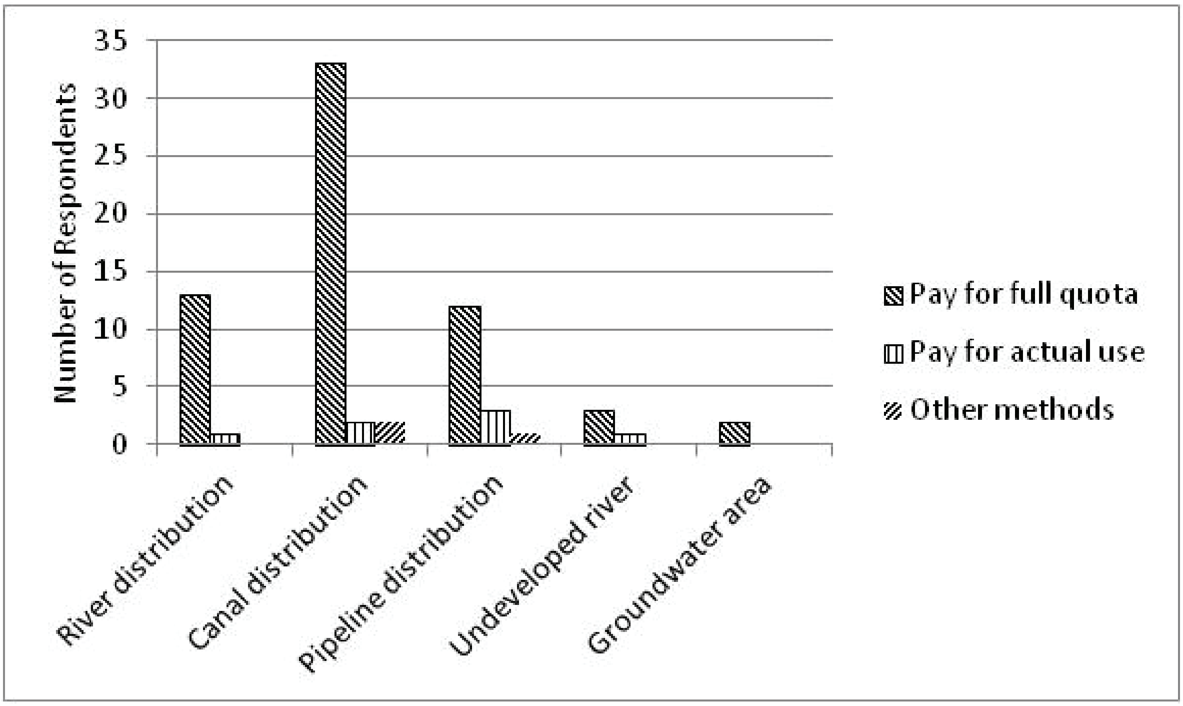

Figure 59: Water charge basis

A2.5 Water control infrastructure

Operating rules

Figures 16 to 19 depict the operating rules employed by IOs distributing water to their users by means of rivers, canals, pipelines and undeveloped rivers, respectively. It is important to note that one IO may a range of operating rules.

Figure 16 shows that of the 15 IOs using river distribution, 5 reported that they use the control of pumping rates as an operational rule, and 2 reported that they control pumping time. Limiting the hectares irrigated, releasing water only on request, and applying fixed pumping schedules were among the other operating rules reported by the respondents

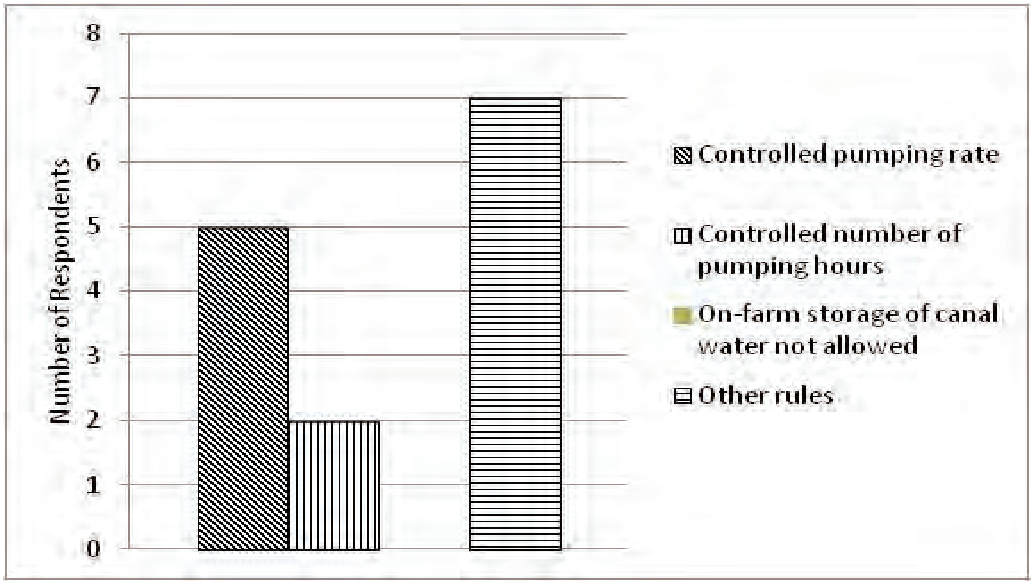

Figure 60: Operating rules: River distribution

Amongst those distributing water by canal, 24 reported that they operate according to a water request system, 11 reported that they use rotational supply, whilst 5 allow water to be available on demand, as shown in Figure 17. Other reported operating rules included the use of calibrated sluice gates, fixed sluice gate settings, and allowable withdrawals depending on water availability (continuous supply system).

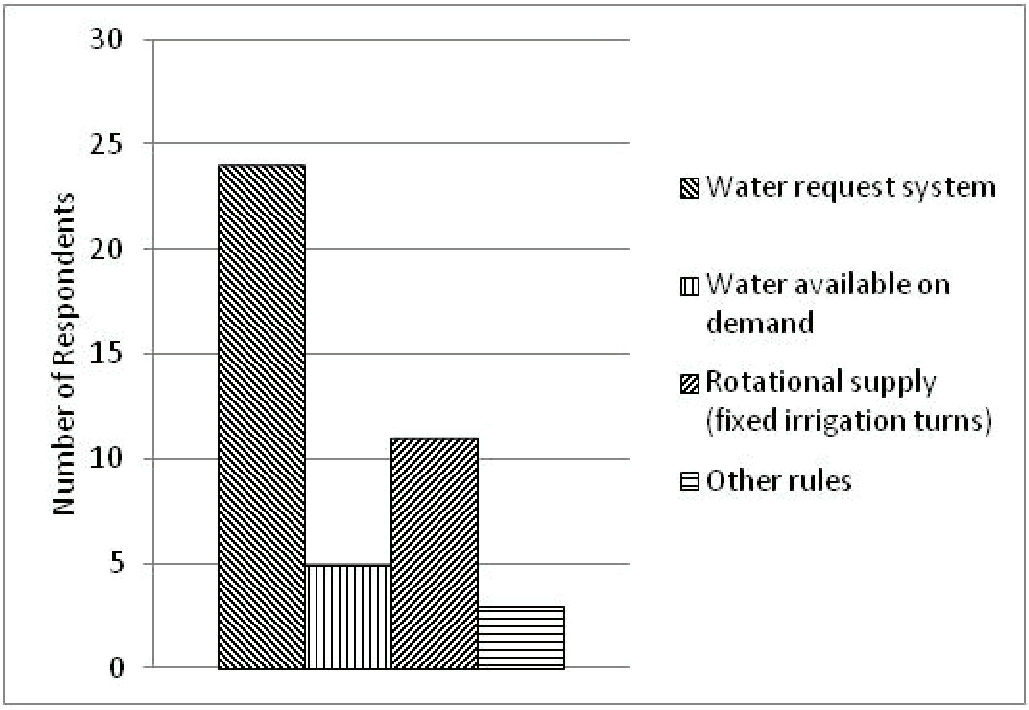

Figure 61: Operating rules: Canal distribution

Figure 18 shows the operating rules employed by the IOs who distribute their water by pipeline. Eight use the control of abstraction rates whilst the control of pumping hours was only reported once. Other reported operating rules included rotational supply, allowing abstractions according to the limited capacity of the infrastructure, or distribution according to crop water requirements.

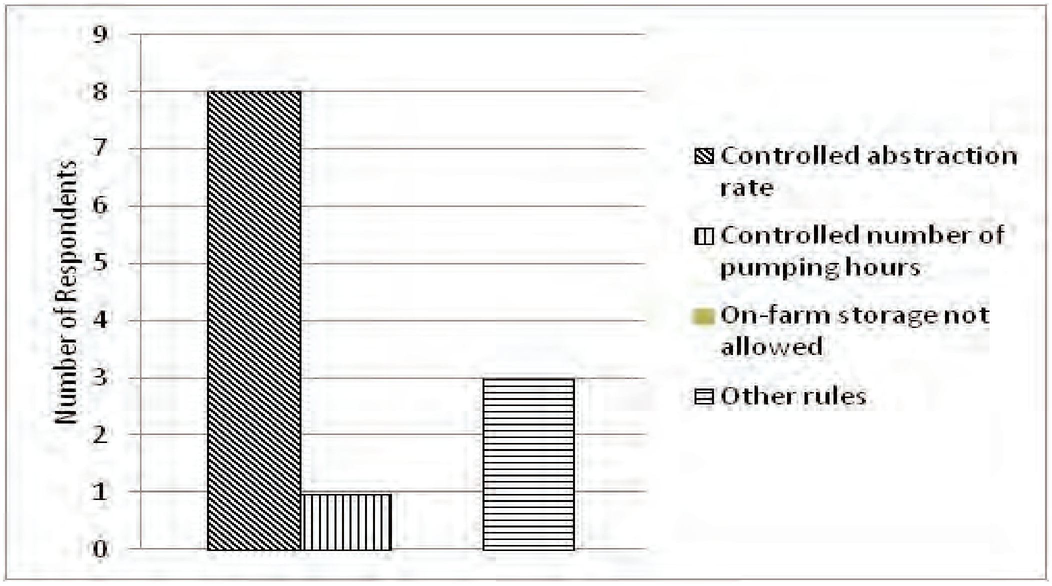

Figure 62: Operating rules: Pipeline distribution

Operating rules employed by those IOs distributing via undeveloped rivers are shown in Figure 19. The other reported operating rules included the imposition of rotational supply (fixed irrigation turns).

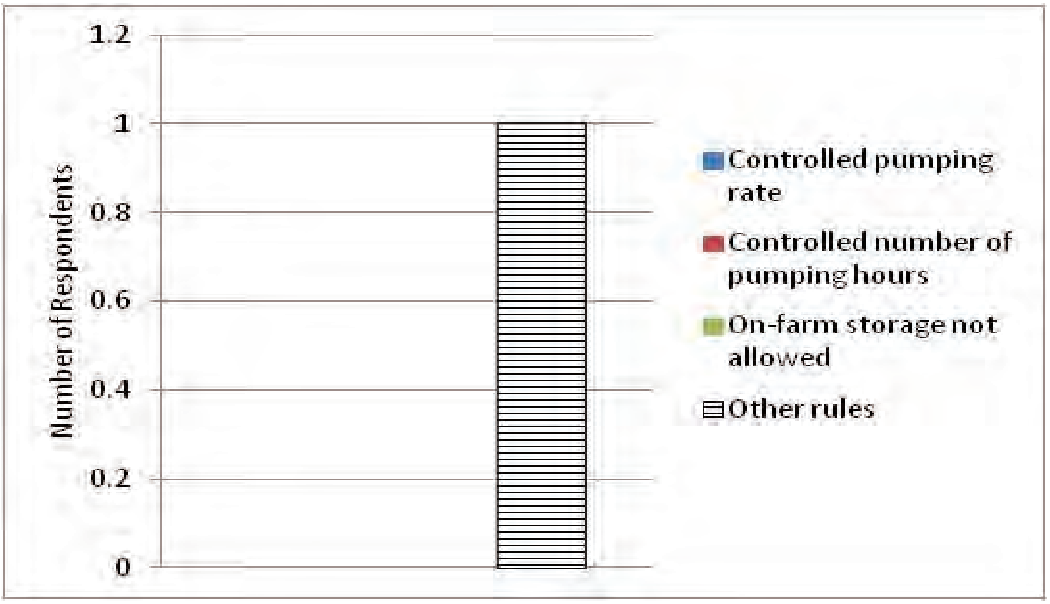

Figure 63: Operating rules: Undeveloped river distribution

Measurement of main inflows

Figure 20 shows that measurement take place at the majority of inflows. The lower figures for pipeline schemes is probably due to the high cost of flowmeters for large diameter pipelines.

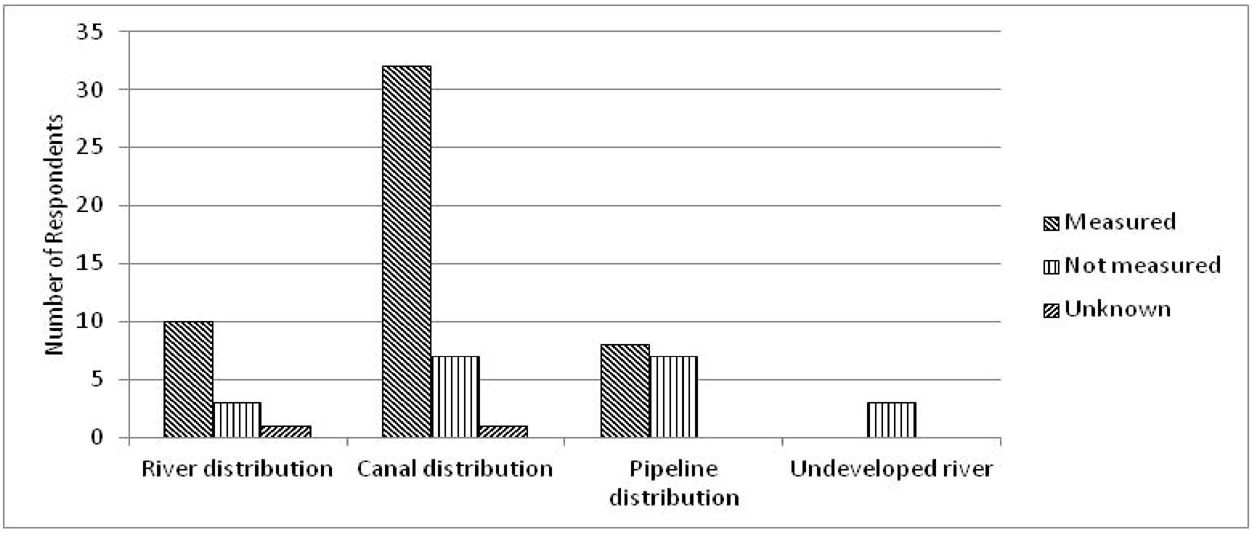

Figure 64: Measurement at main distribution inflow

Type of measuring device at main inflow

Figures 21 to 24 compare the types of measuring device used at the main inflow for rivers, canals, pipelines and undeveloped rivers respectively. Figure 21 shows that though there is no preferred device for measuring inflows to river distribution systems, weirs are more common than Parshall flumes, probably due to the greater range of flow rates that can be handled by a single structure.

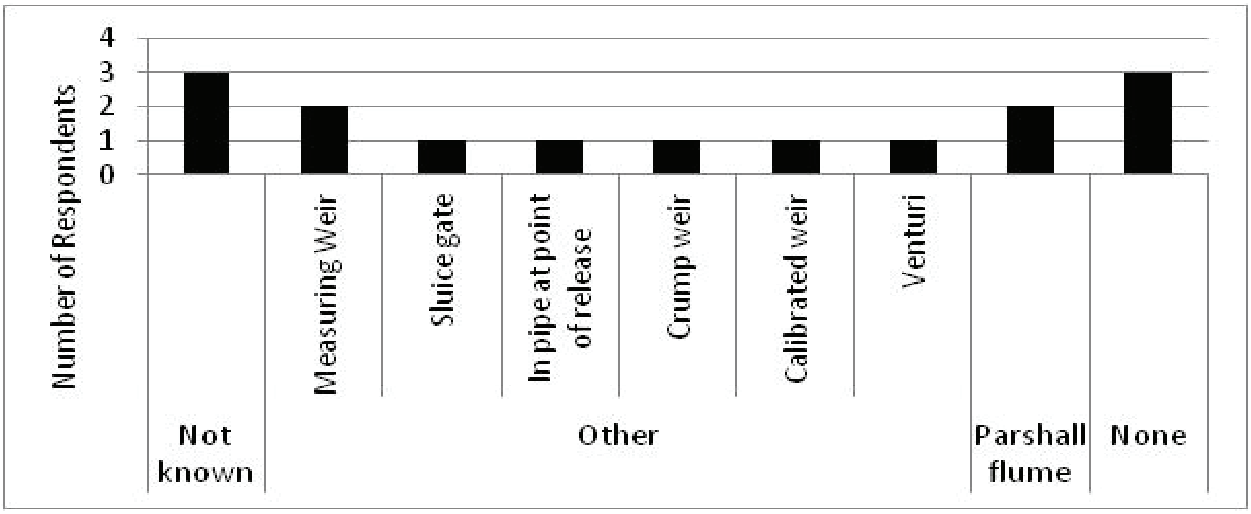

Figure 65: Type of device used at main inflow: River distribution

Figure 22 shows that Parshall flume by far the most common type of measuring device used at the main inflow to canal systems, due to the age of most of the canal systems in the country. Modern scheme managers consider Crump weirs to be more user friendly, as they are easier to install and can handle a greater range of flow rates than Parshall flumes.

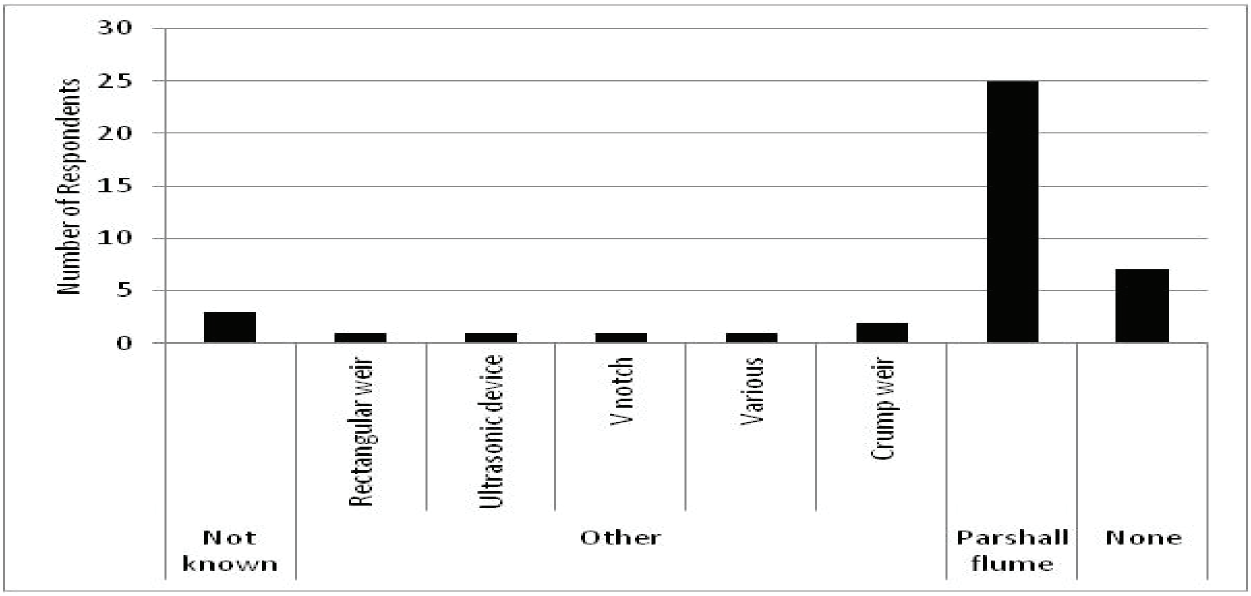

Figure 66: Type of device used at main inflow: Canal distribution

It is interesting to note from Figure 23 that no respondents reported the use of ultrasonic devices on large pipelines, despite the fact that they offer cost effective measuring options that can easily be attached to a telemetric system. This is probably due to the perception that this technology is expensive – however, considering the ease of installation, lack of moving (serviceable) parts and high accuracy of the devices, the benefits are considerable and the cost realistic.

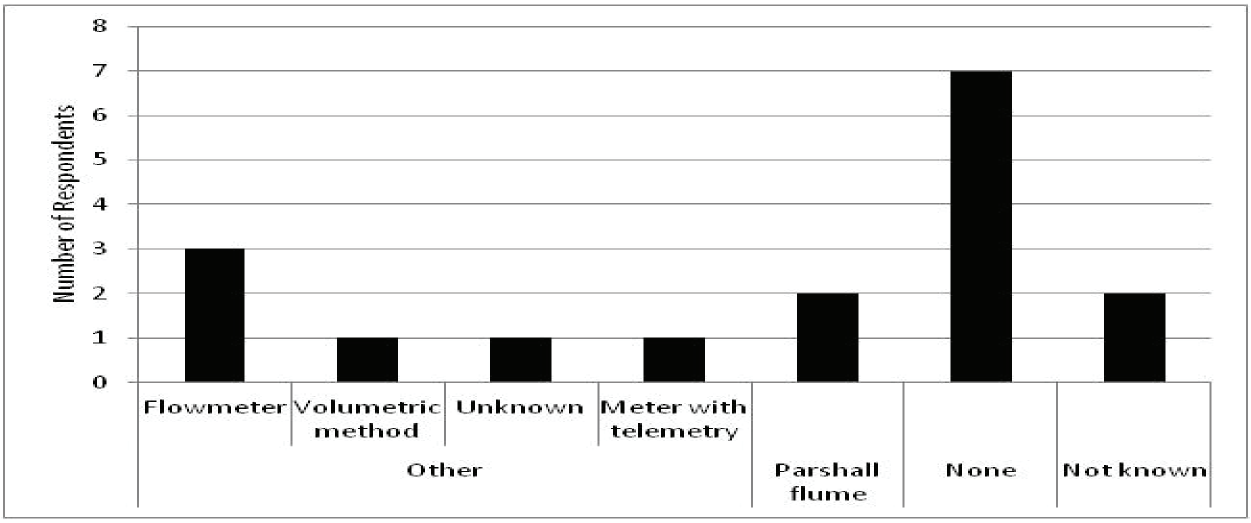

Figure 67: Type of device used at main inflow: Pipeline distribution

No measuring device was used at the inflows to undeveloped river distribution systems in three cases, (Figure 24) whilst electromagnetic devices and Parshall flumes were each reported once.

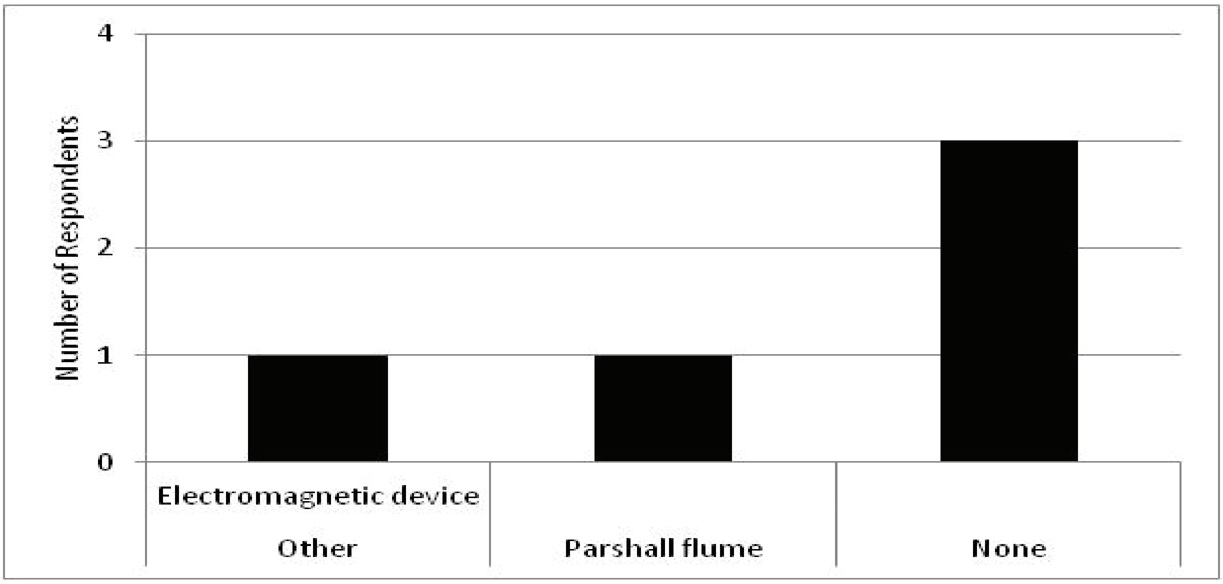

Figure 68: Type of device used at main inflow: Undeveloped river distribution

User abstraction points

It can be seen from Figure 25 that the IOs with canal systems are the most aware of the number of abstraction points through which they deliver water to users, and that they also have the highest number of measured abstraction points (Figure 26).

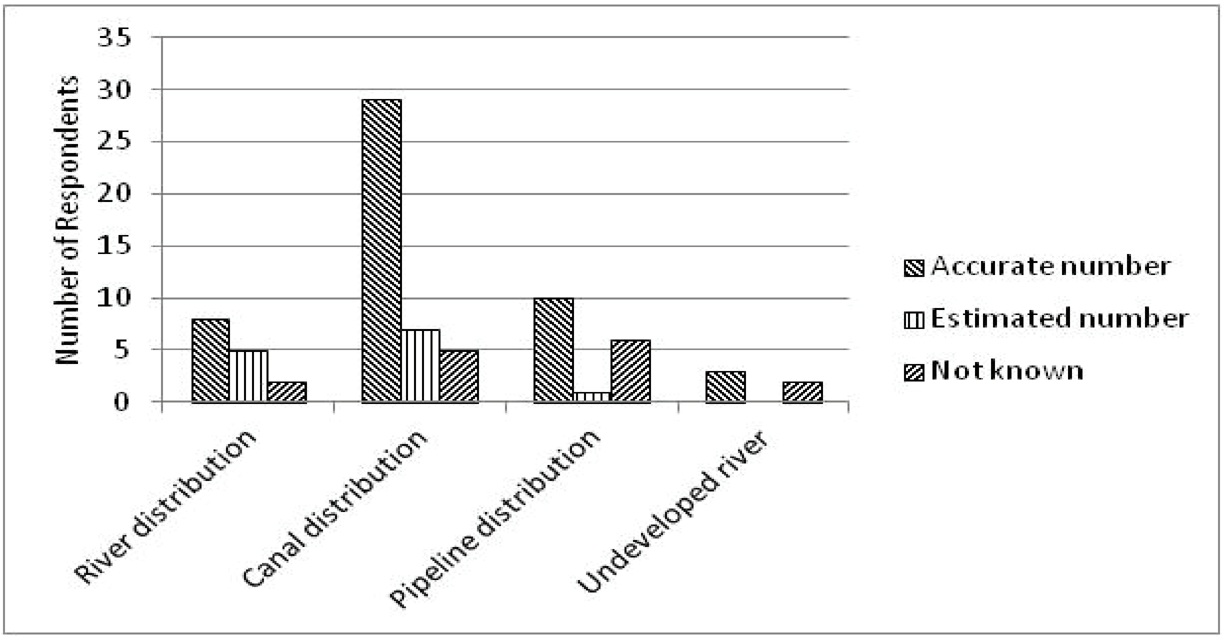

Figure 69: Number of abstraction points known

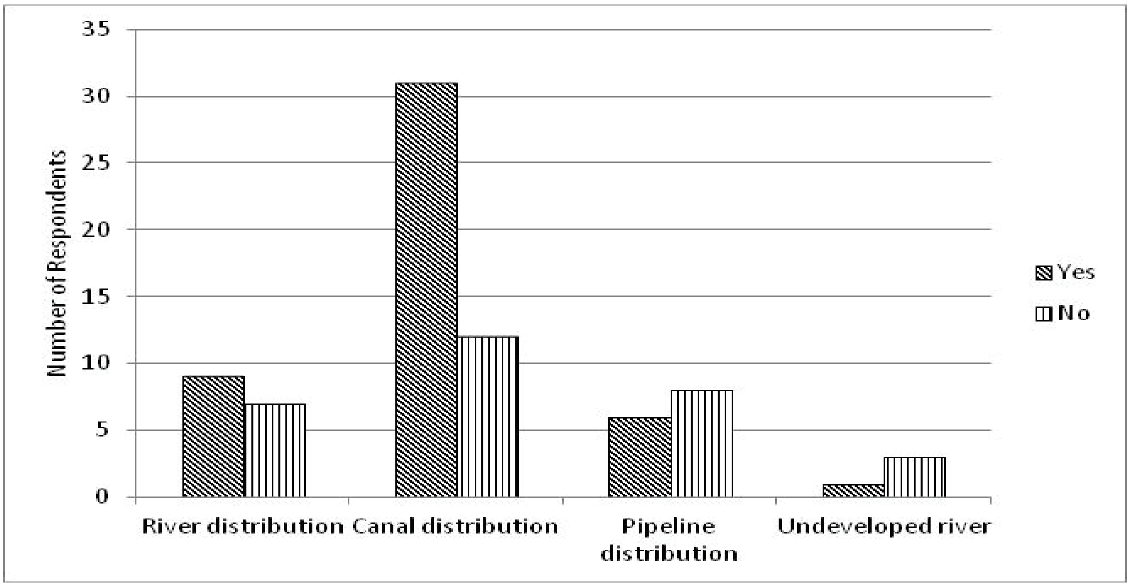

Figure 70: Number of organisations with measuring devices installed at abstraction points

It is interesting to note from Figure 26 that (in contrast to the results for rivers and canals), the majority of pipeline abstraction points are not measured.

Abstraction method by user

Figures 27 to 30 show the types of infrastructure found at the abstraction points where water is taken by individual users from the main distribution systems for rivers, canals, pipelines and undeveloped river system respectively. The respondents in this category reported a total number of 3212 abstraction points present in river systems, the majority of which are privately owned pump stations along the river banks as shown in Figure 27.

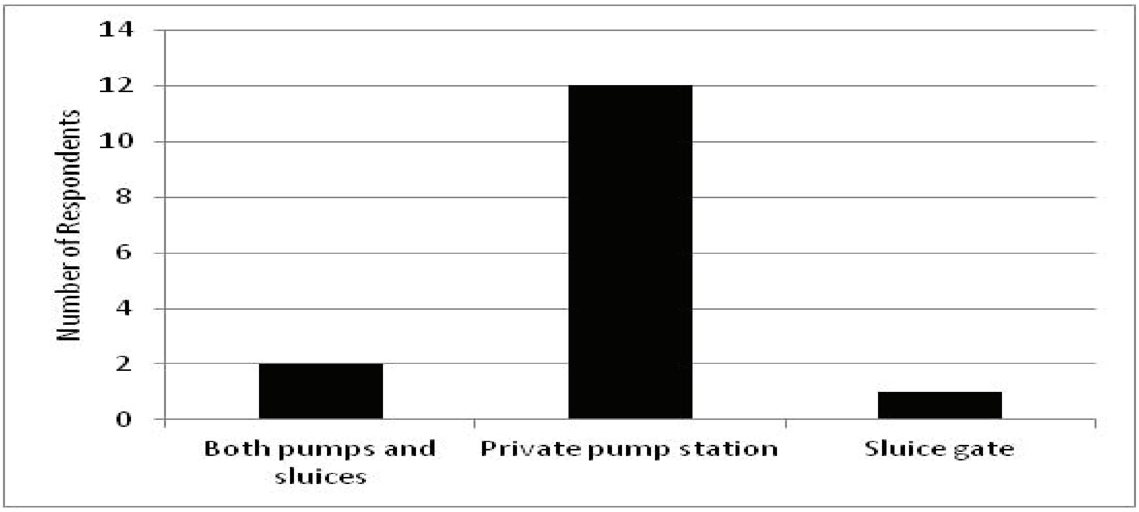

Figure 71: Abstraction types from river distribution

The majority of water users from the canal systems receive water through a sluice gate, as shown in Figure 28, while other infrastructure configurations are found to a lesser extent. The respondents reported a total of 8422 abstraction points on their canal distribution systems.

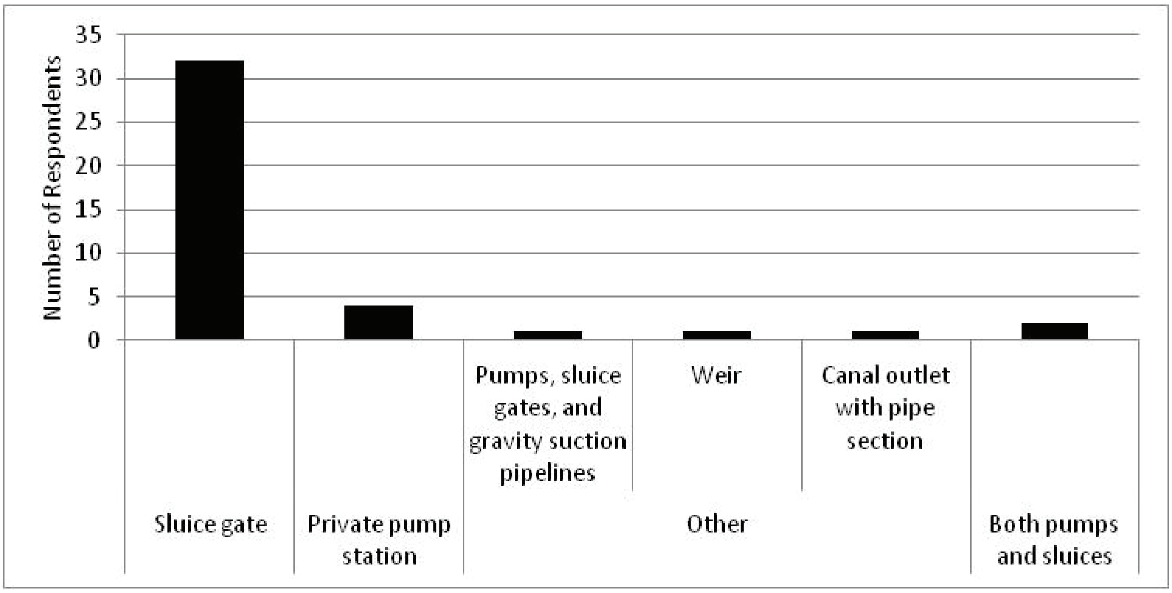

Figure 72: Abstraction types from canal distribution

Two possible situations can occur in pipeline systems; Water can either be supplied under pressure to the user through a valve, for use directly into their irrigation system, or water is delivered under gravity into a farm dam or to the farmer's own pump station. A total number of 1110 abstraction points from pipeline distribution systems were reported by the responding IOs, with the majority receiving water under pressure through a valve, as shown in Figure 29.

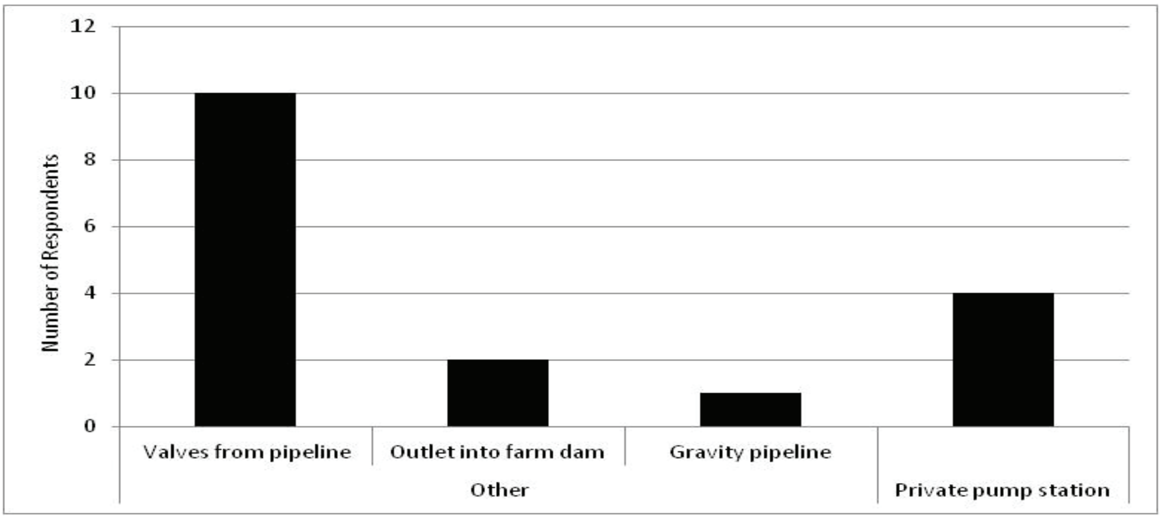

Figure 73: Abstraction types from pipeline distribution

Water can be diverted in a number of ways from an undeveloped river, as shown in Figure 30. Only 50 abstraction points on this type were reported by the respondents.

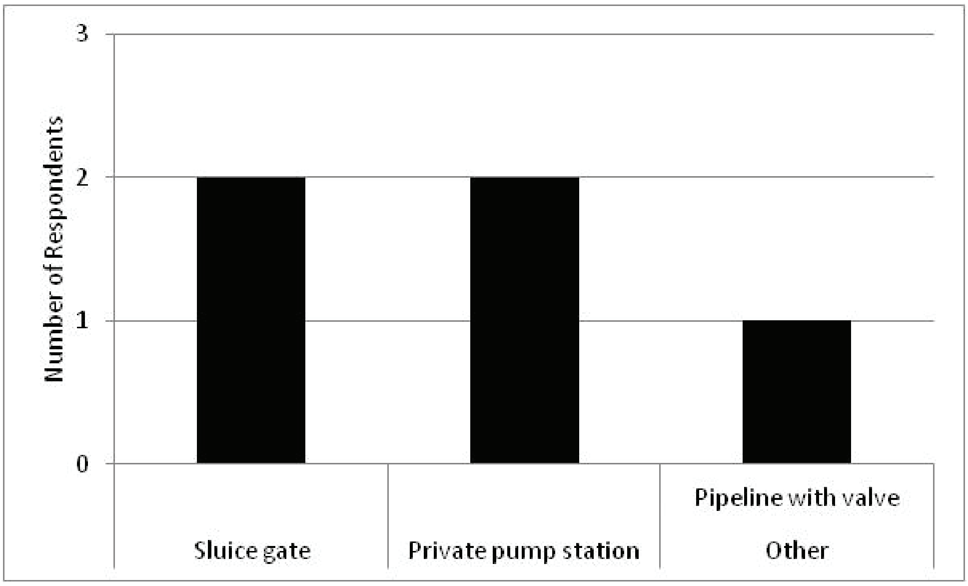

Figure 74: Abstraction types from undeveloped river distribution

Types of measuring devices at abstraction points

Figures 31 to 34 show the variety of measuring devices reported by the respondents at user abstraction points on rivers, canals, pipelines and undeveloped rivers respectively.

Figure 31 shows that most of the measuring devices encountered on river abstractions are flowmeters, mostly on systems where water is pumped from a river, while sluice gates, Crump weirs and Parshall flumes are used where water is diverted under gravity from a river.

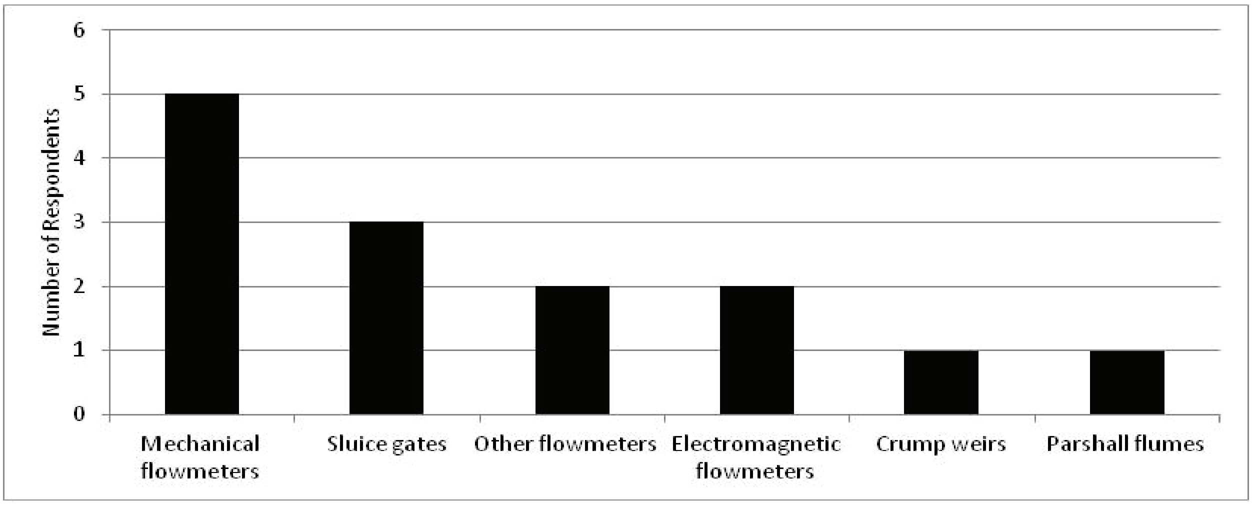

Figure 75: Types of measuring devices at abstraction points from rivers

Parshall flumes are most commonly found on canal schemes, as shown in Figure 32, whilst the number of Crump weirs is relatively low. Sluice gates with long weirs (for upstream pressure control) can be set to allocate water accurately but without the long weir, delivery through the sluice gate will vary as the water level in the canal fluctuates. A small number of schemes also reported using flowmeters at the canal off-takes.

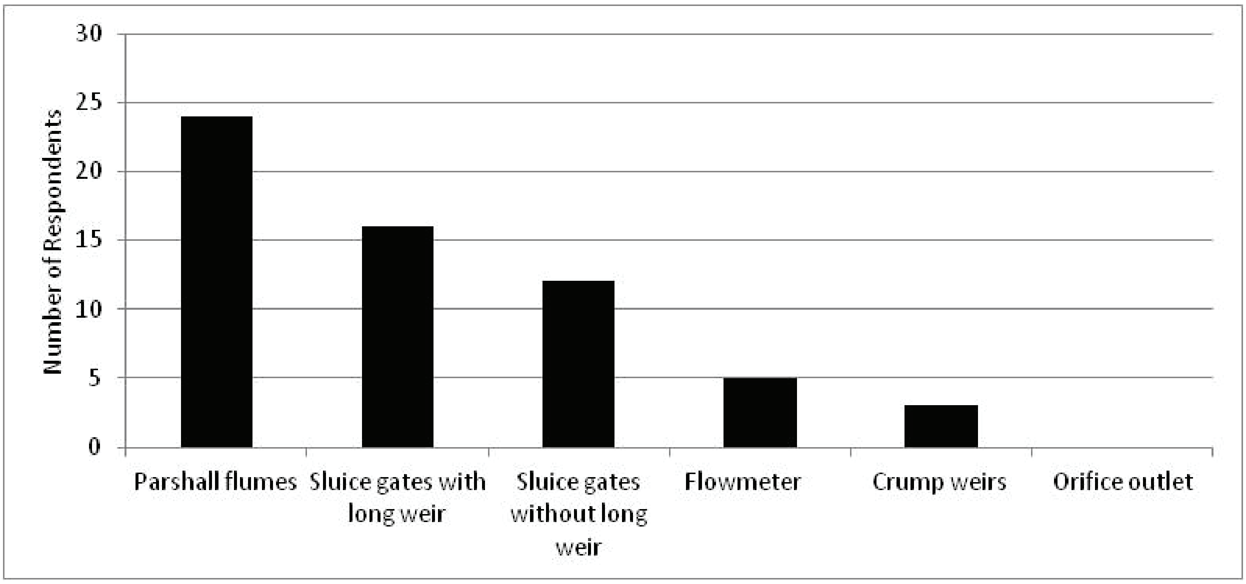

Figure 76: Types of measuring devices at abstraction points from canals

Mechanical flowmeters were the only measuring devices reported to be used by pipeline schemes, as shown in Figure 33.

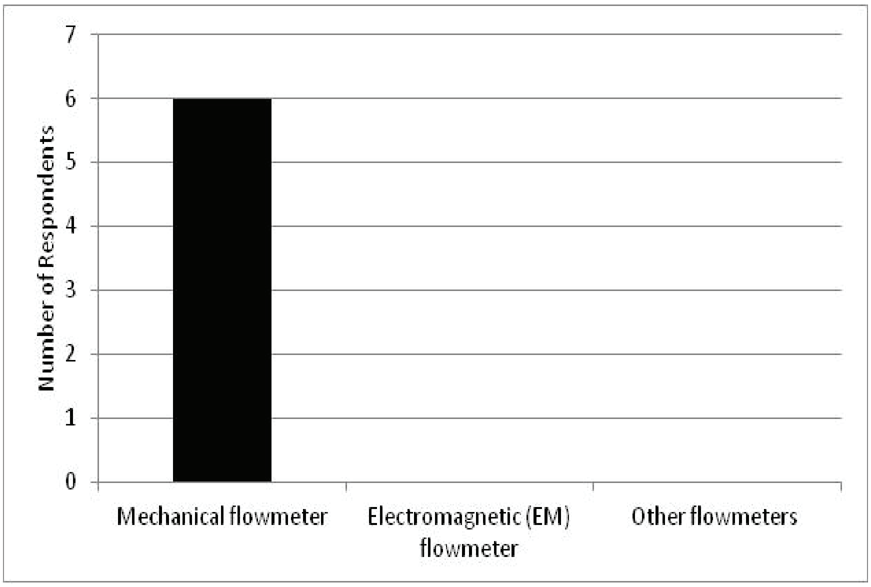

Figure 77: Types of measuring devices at abstraction points from pipelines

Water delivered under gravity from undeveloped rivers is reported to be measured by structures such as sluice gates (upstream control not specified) and Parshall flumes, as shown in Figure 34.

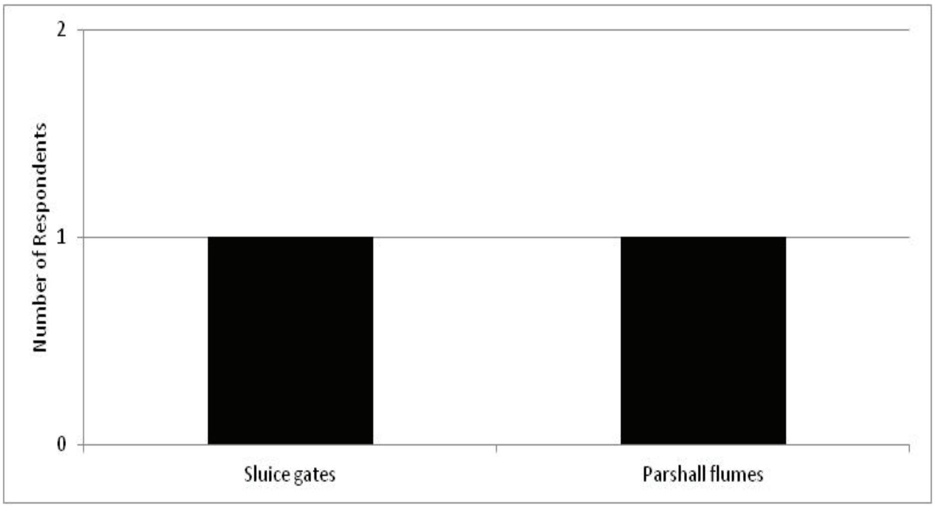

Figure 78: Types of measuring devices at abstraction points from undeveloped rivers

Data collection

Both river and canal based IOs reported more continuous than periodical data recording at abstraction points, as shown in Figure 35. This is probably due to the operational requirements of these systems to ensure water reaches all the abstraction points when required. Periodical data recording is more common at pipeline schemes. It is important to note that the IO, not the user, is responsible for the collection of data at user abstraction points.

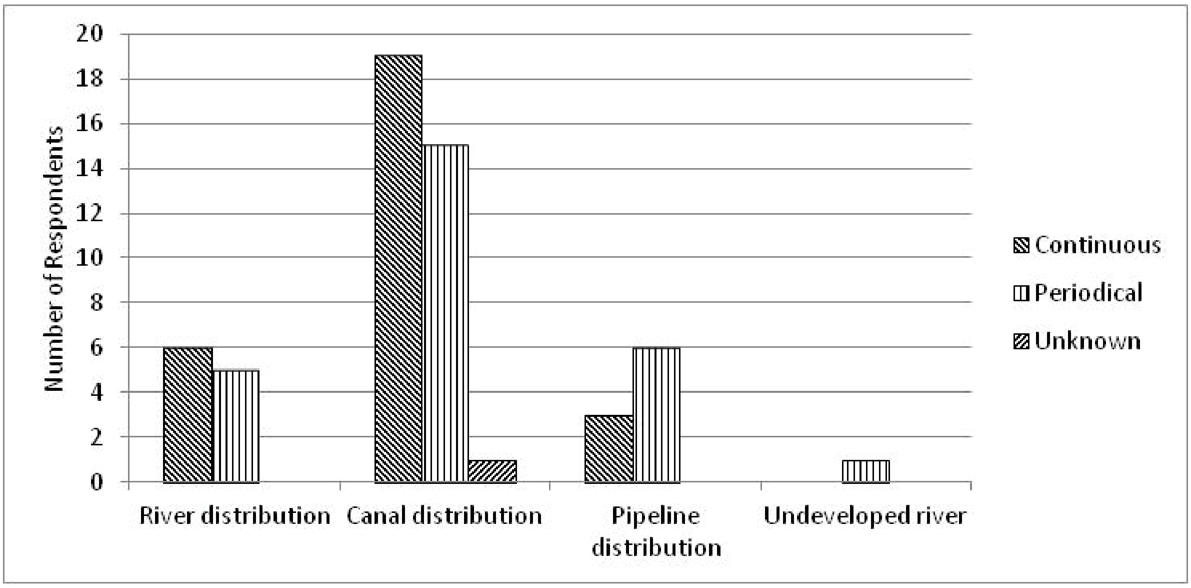

Figure 79: Data collection interval at abstraction point

Figure 36 shows the percentage of responding IOs using telemetry to collect data. IOs with river-based systems (both developed and undeveloped) are making best use of this modern technology to manage water, probably due to the remoteness of monitoring points in their areas. Interestingly enough, the canal-based IOs reported the lowest percentage of telemetry use of all systems, even though their abstraction point management was reportedly better (see Figures 25 and 26).

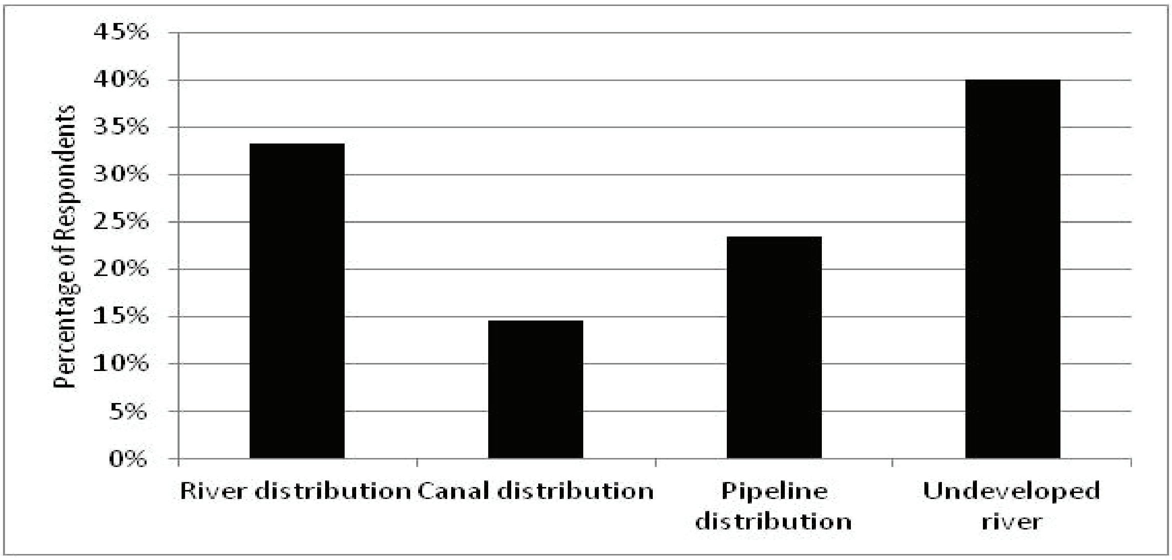

Figure 80: Number of IOs using telemetry

As shown in Figure 37, the river-based IOs were the only group of which the majority considered measurement to be an effective management tool, possibly due to the fact that they cannot manage without it, and therefore the benefits are perceived to be greater. In pipeline systems, where the bulk of the water is well controlled by the distribution infrastructure, one third of the respondents considered measurement to be an ineffective management tool.

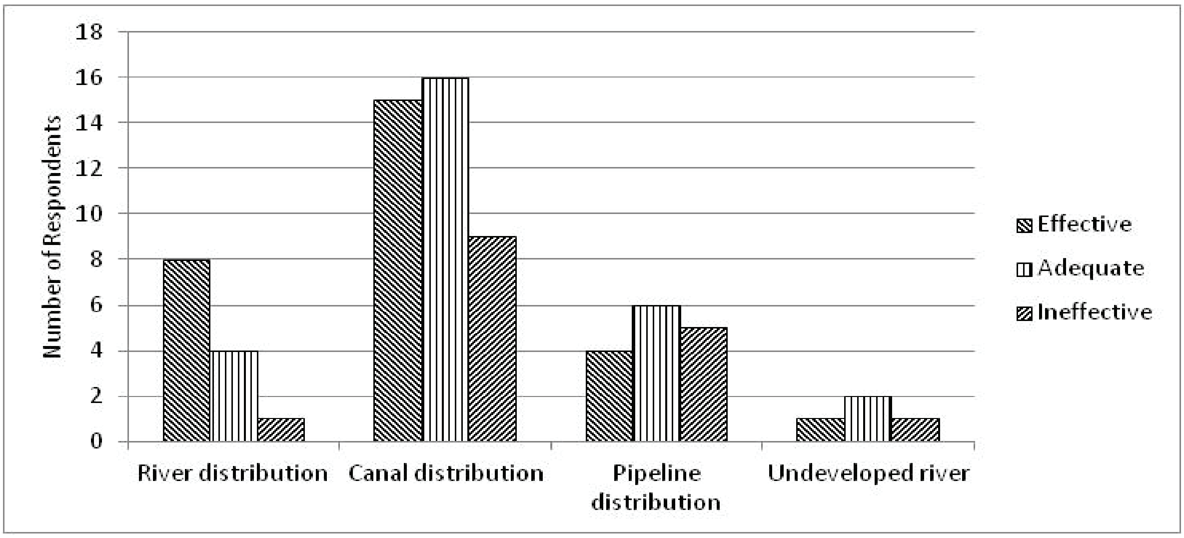

Figure 81: Perceived effectiveness of measurement devices

A2.6 Groundwater

Although based on a small sample size, Figure 38 shows that 50% of the IOs that use groundwater extensively reported that they monitor groundwater levels. However, no measurement of individual abstractions from boreholes is reportedly taking place (Figure 39)

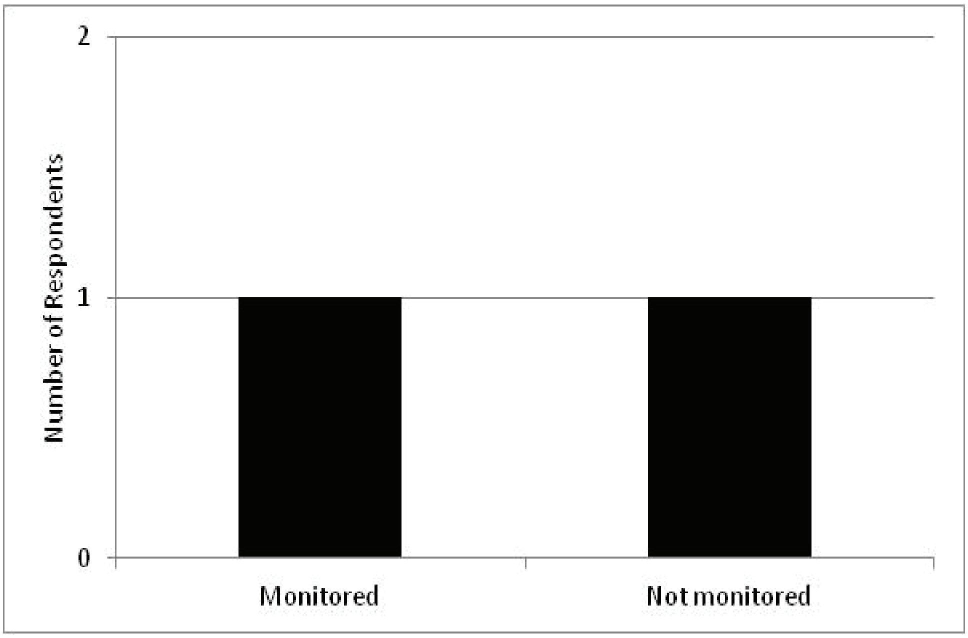

Figure 82: Groundwater level monitoring

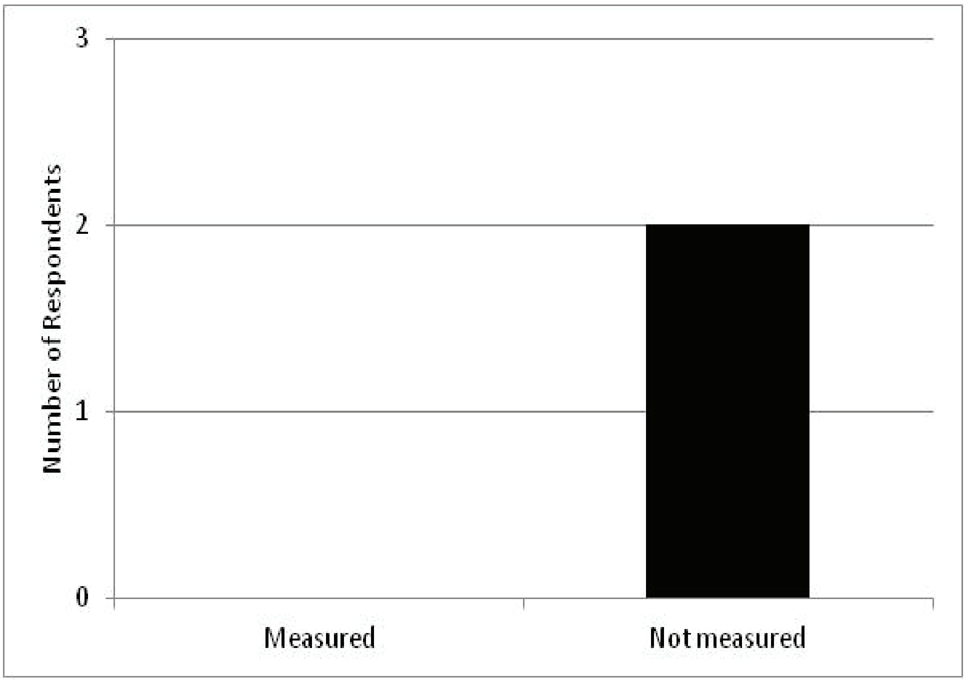

Figure 83: Groundwater abstraction measuring

A2.7 On-farm dams

Only one IO using farm dams as a source of irrigation water responded; they reported that abstractions from the dams are being monitored (Figure 40), and in this case not with in-line flowmeters (Figure 41) but specifically using kilowatt-hour meter readings from the power supply to farmers' pump stations.

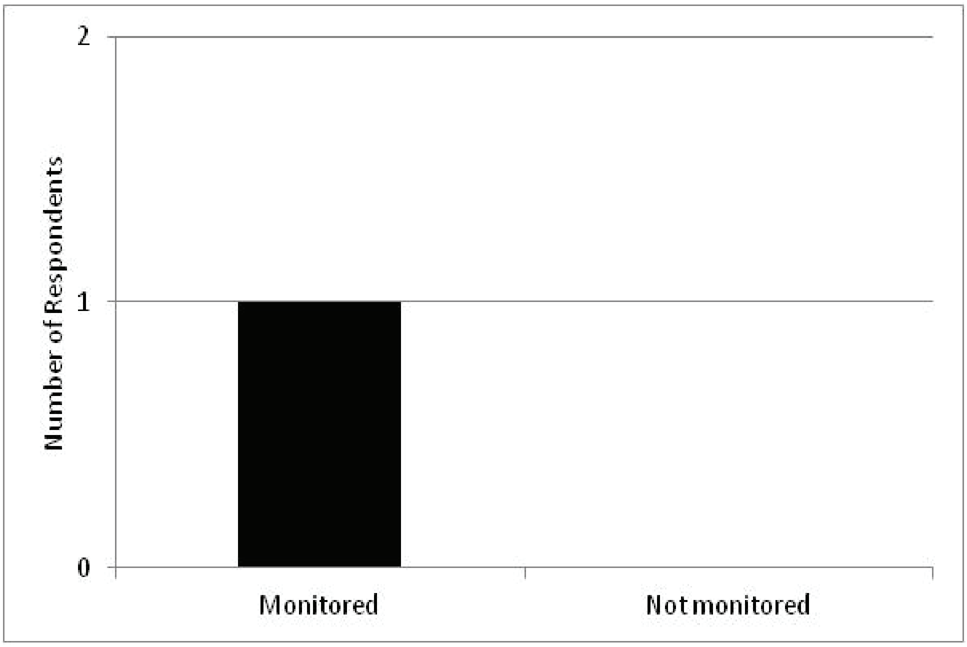

Figure 84: On-farm dam monitoring

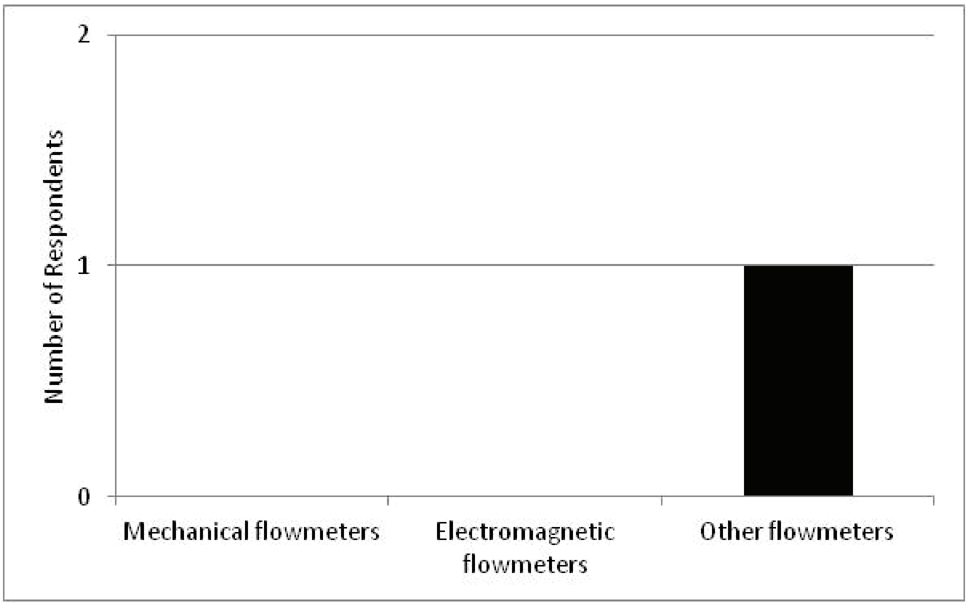

Figure 85: Types of devices used for on-farm dam measurement

A2.8 Water quality

The responses to the questions on water quality are shown in Figure 42. The graph shows which percentage of the organisations with different types of distribution systems reported the various water quality problems listed in the legend.

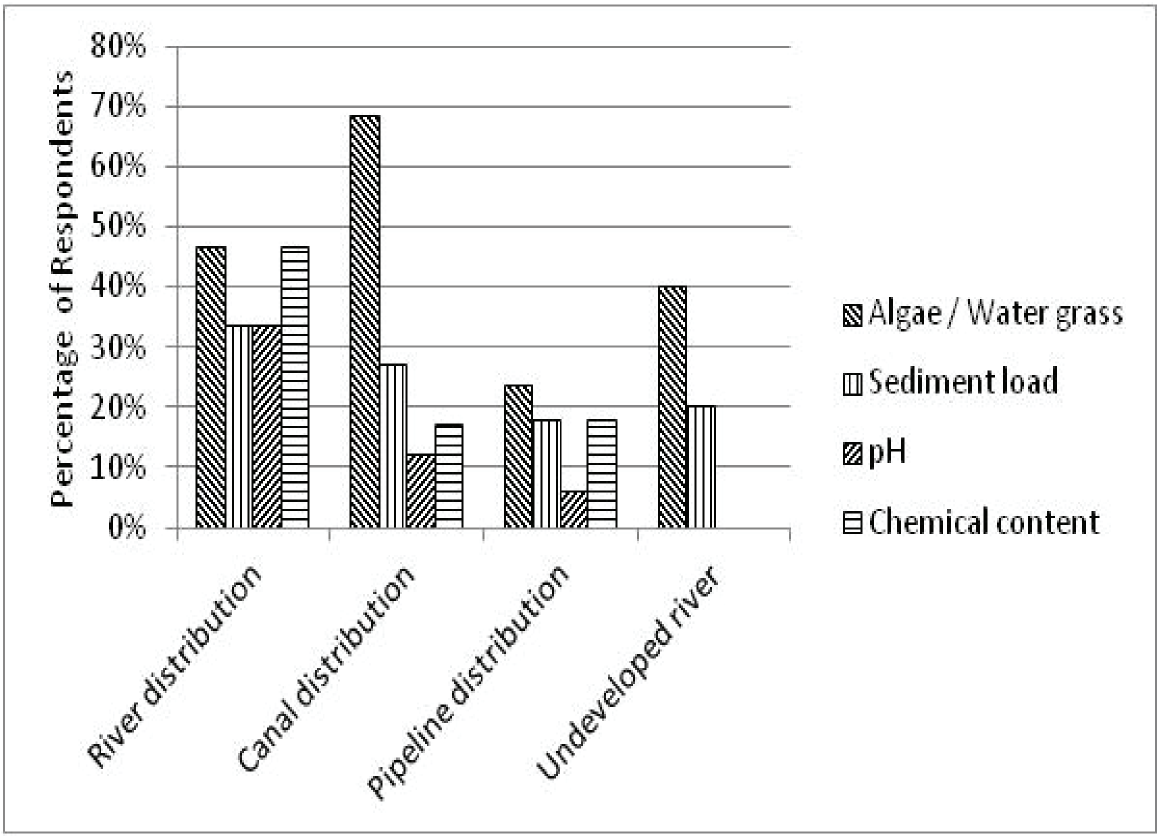

Figure 86: Water quality problems

The results confirm increasing concerns in the water sector regarding the management of our water resources by various stakeholders. Algae and unacceptable chemical content of the water were the most commonly reported problems by all IOs, increased algae also being the results of poor chemical water quality. Other specific problems reported by the organisations include:

- Salinity
- Erosion (causing excessive sediment loads)
- Water hyacinths
- Sewage spills into rivers from municipal water treatment works, industries or private houses on the river banks (6 reports)

A2.9 Management aspects

Human resources

The majority of responding organisations reported that they have adequate human resources to implement and/or operate the measurement systems in their areas (Figure 43). However, this situation may be quite different in the case of emerging farmer irrigation schemes, which were not included in the surve.

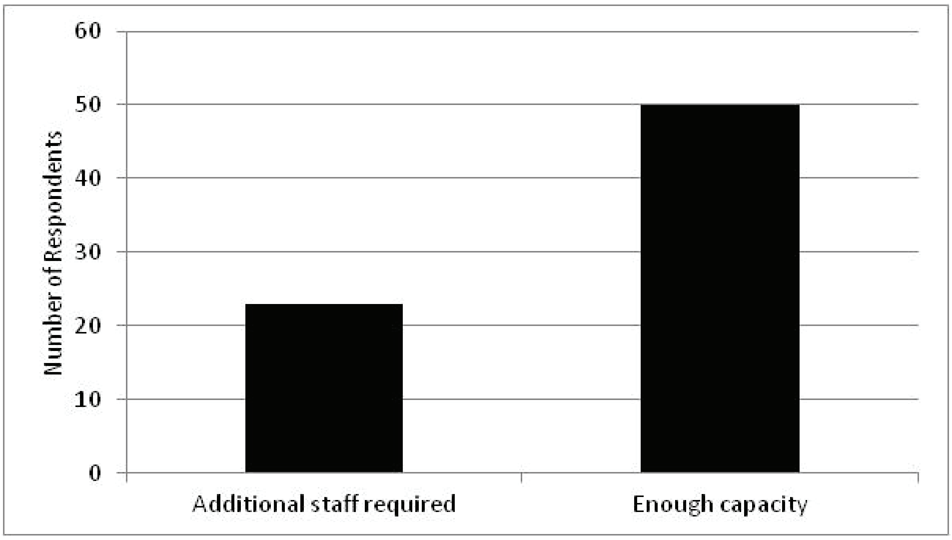

Figure 87: Human resources capacity of IOs

Only 24 out of the 73 responding IOs reported that they employ full time technical staff (Figure 44). This is probably due to the need to keep operating costs low, rather than to a shortage of skilled technical persons, although that has also been reported to be a problem.

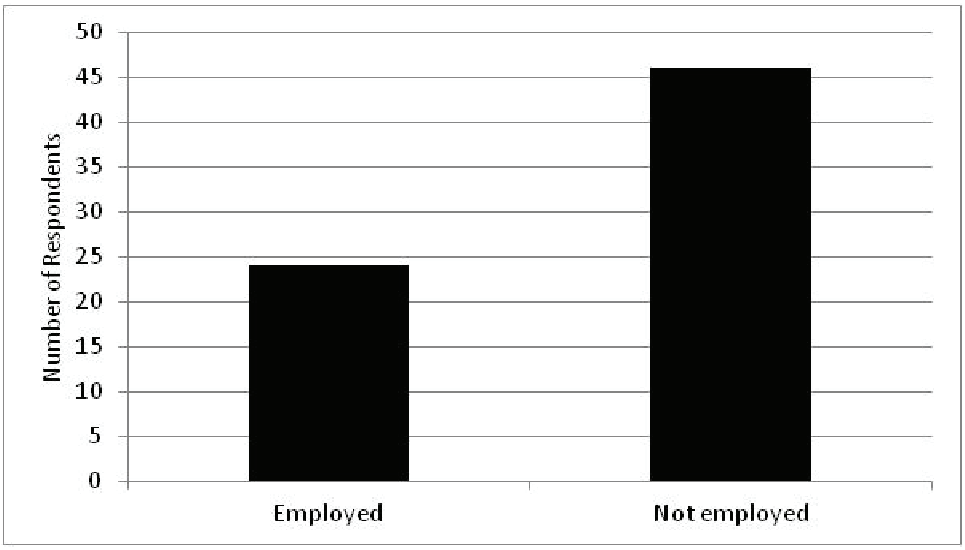

Figure 88: Full time technical staff employed by IOs

The majority of organisations with full time technical staff reported that their staff had received training in water control from DWAF, as shown in Figure45.

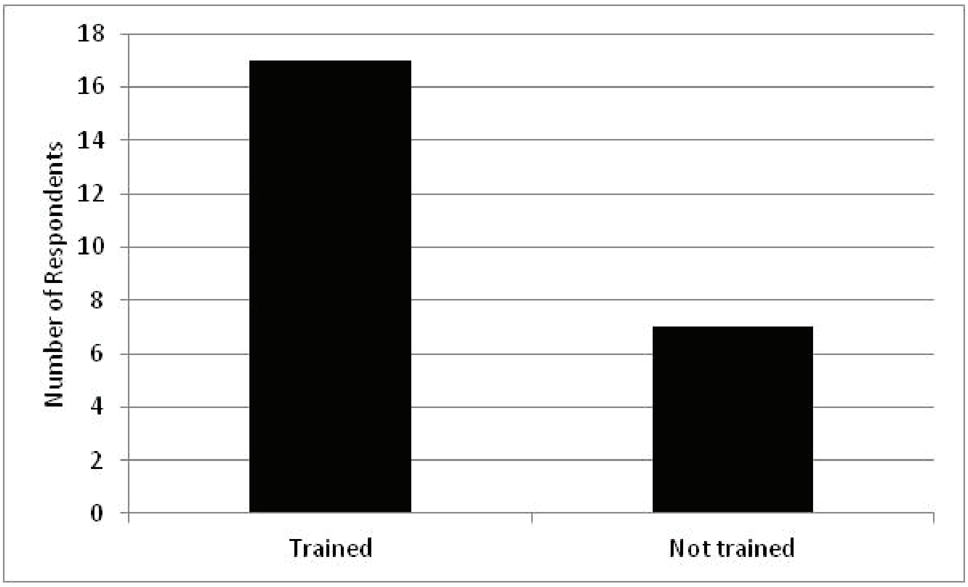

Figure 89: Water control training of IO staff

Financial resources

By far the majority of organisations indicated that they would require financial support to implement measurement in their areas, as shown in Figure 46. This accentuates the need for clear policy from DWAF regarding incentives and rebates for organisations and/or water users that are willing to improve their water management.

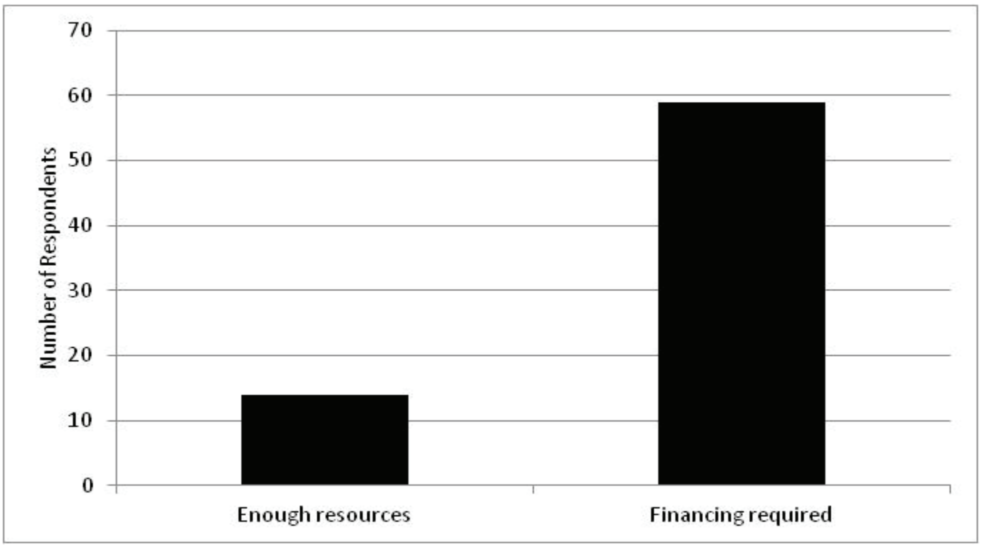

Figure 90: Financial resource availability for measurement implementation

A2.10 Unutilised water

As shown in Figure 47, the majority of IOs, regardless of the type of distribution system they were operating, considered the amount of water leaving their area unutilised to be of little value to other users further downstream in the catchment.

The results also accentuate the fact that in South Africa, in the case of canal systems specifically, our canals are managed to deliver only the water required and many systems are run on a request basis. Only in the case of the river systems was the unutilised outflow considered to be of significant value, by just more than one third of the responding organisations.

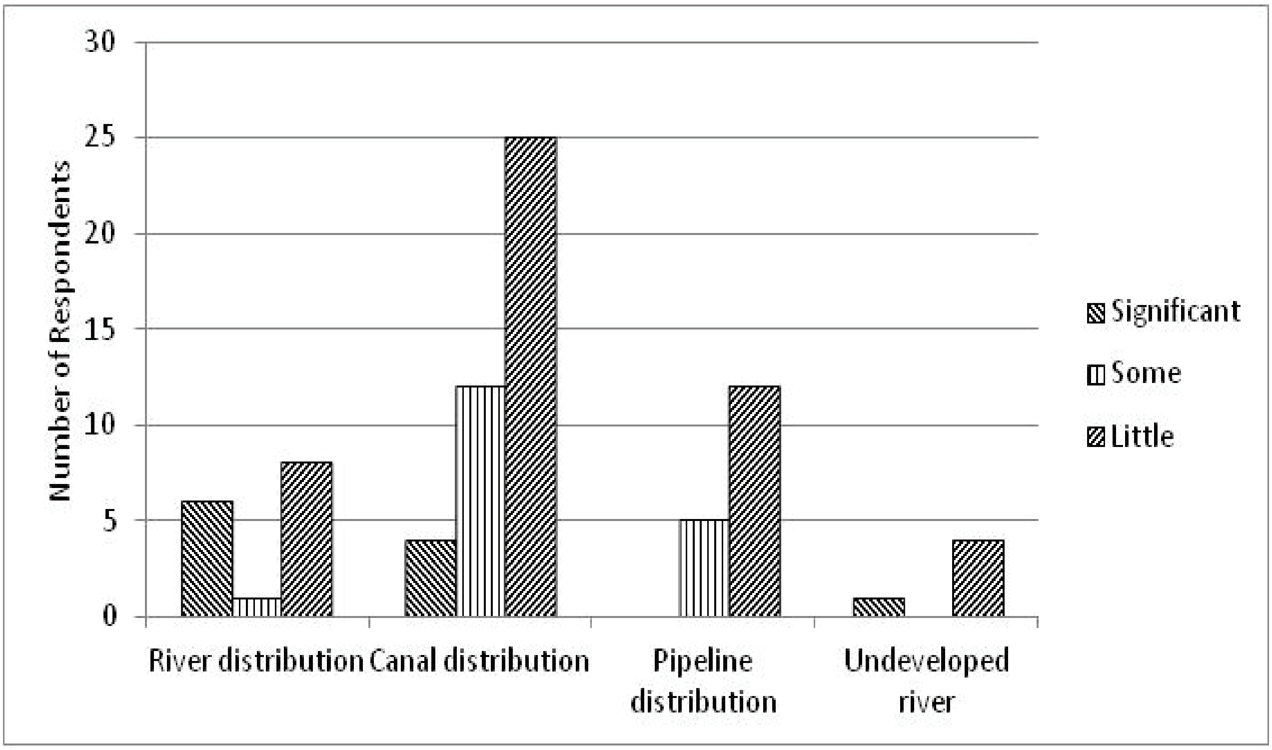

Figure 91: Unutilised water leaving the IO's area

Appendix B:

Proposed regulations requiring the taking of water from a water resource for irrigation purposes be limited, monitored, measured and recorded

DEPARTMENT OF WATER AFFAIRS

NATIONAL WATER ACT, 1998

PROPOSED REGULATIONS REQUIRING THE TAKING OF WATER FROM A WATER RESOURCE FOR IRRIGATION PURPOSES BE LIMITED, MONITORED, MEASURED AND RECORDED

Definitions

1. In these Regulations any word or expression to which a meaning has been assigned in the Act shall have the meaning so assigned and unless the context otherwise indicates─

"field hectares" means the maximum physical area that is irrigated by a single water user in terms of the Act during any time of the year in respect of a single crop or more than one crop on the same field;

"the Act" means the National Water Act, 1998 (Act No 36 of 1998);

"the table" means the table contained in the Annexure to these Regulations;

"water measuring device" includes but is not limited to a device─

(a) that measures and records directly or indirectly the flow in an open channel or a closed conduit to a tolerance of not higher than plus or minus 10% (per centum) of─
(i) the actual flow volume;
(ii) the actual flow rate; or
(iii) the actual time duration of such flow.

(b) that measures and records the energy consumption of the abstraction pump to a tolerance of not higher than plus or minus 5% (per centum) of the actual energy consumption of such pump; or

(c) that measures the actual field area irrigated at any given time to a tolerance of not higher than plus or minus 10% (per centum) of the actual field area;

"water measuring method" includes but is not limited to─

(a) a method of reading from a water measuring device and the applicable calculations needed to determine either─
(i) the actual flow volume;
(ii) the actual flow rate; or
(iii) the actual time duration of such flow;

(b) a method whereby the actual field area irrigated at any given time can be measured to a tolerance of not higher than plus

or minus 10% (per centum) of the actual field area;

(c) a method of calculating the irrigation requirement during any month to a tolerance of not higher than plus or minus 10% (per centum) of the actual irrigation requirement during such month; or

(d) a method of calculating the actual abstracted volume or the actual abstraction flow rate by using the energy consumption of an abstraction pump.

"water use" means the taking of water from a water resource for the purpose of irrigation.

Application

2. These Regulations apply to water use on the properties in the Republic of South Africa included in the quaternary drainage regions set out in column 1 of the Table

Limit on water use

3. (1) Subject to any condition or obligation relating to the abstraction rate, a water use must take place within the parameters specified in columns 2 and 3 of the Table.

(2) *(a)* The flow rates in litres per second per field hectare shown in column 2 of the Table are calculated on a total irrigation time of 120 hours per week and must be calculated for any other irrigation time by dividing the 120 hours per week by the water user's actual irrigation hours per week and the result multiplied by the value given in column 2 of the Table.

(b) The values of cubic metres per field hectare per day given in column 3 are not affected by the number of hours irrigated per week.

(3) The total volume of water abstracted from a water resource may not exceed the authorised volume during any relevant period of time.

Monitoring the taking of water

4. (1) As contemplated in regulations 5 and 6, water use must be accurately monitored by a water measuring device or method.

(2) The responsible authority may, where there is no acceptable water measuring device or method being applied, direct that a water measuring device be installed or a method be applied, as the case may be, by the water user within three months of the written directive by the responsible authority to do so.

(3) The responsible authority may, where there is no acceptable water measuring device or method being applied, install a temporary water measuring device to monitor the water use, to ascertain whether it is within the parameters specified in columns 2 and 3 of the Table.

(4) If the responsible authority is of the opinion that a water measuring device or method is not monitoring the water use accurately, the responsible authority may, until an appropriate water measuring device is installed or method applied, direct the water user to limit─

(a) the abstraction volume;

(b) the abstraction rate;

(c) irrigated area; or

(d) the time periods when the abstraction may take place.

Water measuring device

5 (1) Where a water measuring device is to be installed, the water user must─

(a) install a self registering water measuring device approved by the responsible authority;

(b) operate and maintain the water measuring device in accordance

with the operational requirements of the supplier; and

(c) must record the data pertaining to such water use.

(2) The water measuring device must be calibrated at least once every five years or when the water user is instructed to do so by the responsible authority by a person, an institution, service provider or organisation acceptable to the responsible authority.

(3) A water measuring device must be installed with a measuring mechanism that is sealed and secured, in order to be free from damage or vulnerability to tampering or sabotage.

(4) Certified proof of the calibration under subregulation (2) must be submitted to the responsible authority within 30 days upon request of such calibration.

Prior approval for water measuring method

6. Where a water measuring method is to be applied, the water user must obtain prior written approval from the responsible authority to ensure that the method to be used, complies with the specified tolerances.

Recording water use

7. (1) The data referred to in regulation 5(1)*(c)* must be recorded on official forms obtained from the Department or on forms approved by the responsible authority.

(2) The forms referred to in subregulation (1) must be submitted to the responsible authority at time intervals stated on the form.

Offences and penalties

8. Any person who contravenes or fails to comply with any provision of these Regulations is guilty of an offence and is liable on conviction to a fine or imprisonment not exceeding a period of five years.

Short title

9. These Regulations shall be called the Regulations Requiring the Taking of Water for Irrigation be Limited, Monitored, Measured and Recorded

ANNEXURE

NOTE: Information regarding the quaternary drainage regions referred to in Column 1 of the Table can be obtained from the Department, upon written request.

TABLE

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
A10A	1,40	121,0
A10B	1,40	121,0
A10C	1,40	121,0
A21A	1,20	103,7
A21B	1,20	103,7
A21C	1,20	103,7
A21D	1,20	103,7
A21E	1,20	103,7
A21F	1,30	112,3
A21G	1,30	112,3
A21H	1,30	112,3
A21J	1,40	121,0
A21K	1,40	121,0
A21L	1,40	121,0
A22A	1,20	103,7
A22B	1,20	103,7
A22C	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
A22D	1,30	112,3
A22E	1,40	121,0
A22F	1,40	121,0
A22G	1,30	112,3
A22H	1,40	121,0
A22J	1,40	121,0
A23A	1,20	103,7
A23B	1,30	112,3
A23C	1,40	121,0
A23D	1,30	112,3
A23E	1,30	112,3
A23F	1,30	112,3
A23G	1,30	112,3
A23H	1,40	121,0
A23J	1,40	121,0
A23K	1,40	121,0
A23L	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
A24A	1,40	121,0
A24B	1,40	121,0
A24C	1,40	121,0
A24D	1,40	121,0
A24E	1,40	121,0
A24F	1,40	121,0
A24G	1,30	112,3
A24H	1,40	121,0
A24J	1,40	121,0
A31A	1,20	103,7
A31B	1,30	112,3
A31C	1,30	112,3
A31D	1,40	121,0
A31E	1,40	121,0
A31F	1,40	121,0
A31G	1,40	121,0
A31H	1,40	121,0
A31J	1,40	121,0
A32A	1,40	121,0
A32B	1,40	121,0
A32C	1,40	121,0
A32D	1,40	121,0
A32E	1,40	121,0
A41A	1,40	121,0
A41B	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
A41C	1,40	121,0
A41D	1,40	121,0
A41E	1,40	121,0
A42A	1,30	112,3
A42B	1,30	112,3
A42C	1,30	112,3
A42D	1,30	112,3
A42E	1,30	112,3
A42F	1,40	121,0
A42G	1,40	121,0
A42H	1,40	121,0
A42J	1,40	121,0
A50A	1,30	112,3
A50B	1,30	112,3
A50C	1,30	112,3
A50D	1,30	112,3
A50E	1,30	112,3
A50F	1,40	121,0
A50G	1,40	121,0
A50H	1,40	121,0
A50J	1,40	121,0
A61A	1,30	112,3
A61B	1,30	112,3
A61C	1,30	112,3
A61D	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
A61E	1,30	112,3
A61F	1,20	103,7
A61G	1,30	112,3
A61H	1,30	112,3
A61J	1,30	112,3
A62A	1,30	112,3
A62B	1,30	112,3
A62C	1,30	112,3
A62D	1,30	112,3
A62E	1,20	103,7
A62F	1,30	112,3
A62G	1,30	112,3
A62H	1,20	103,7
A62J	1,30	112,3
A63A	1,30	112,3
A63B	1,40	121,0
A63C	1,40	121,0
A63D	1,40	121,0
A63E	1,40	121,0
A71A	1,20	103,7
A71B	1,10	95,0
A71C	1,20	103,7
A71D	1,20	103,7
A71E	1,20	103,7
A71F	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
A71G	1,20	103,7
A71H	1,20	103,7
A71J	1,30	112,3
A71K	1,40	121,0
A71L	1,40	121,0
A72A	1,30	112,3
A72B	1,30	112,3
A80A	1,10	95,0
A80B	1,10	95,0
A80C	1,10	95,0
A80D	1,10	95,0
A80E	1,10	95,0
A80F	1,20	103,7
A80G	1,30	112,3
A80H	1,20	103,7
A80J	1,40	121,0
A91A	1,10	95,0
A91B	1,10	95,0
A91C	1,10	95,0
A91D	1,10	95,0
A91E	1,10	95,0
A91F	1,20	103,7
A91G	1,20	103,7
A91H	1,30	112,3
A91J	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
A91K	1,40	121,0
A92A	1,20	103,7
A92B	1,30	112,3
A92C	1,30	112,3
A92D	1,40	121,0
B11A	1,20	103,7
B11B	1,10	95,0
B11C	1,10	95,0
B11D	1,20	103,7
B11E	1,20	103,7
B11F	1,20	103,7
B11G	1,20	103,7
B11H	1,20	103,7
B11J	1,20	103,7
B11K	1,20	103,7
B11L	1,30	112,3
B12A	1,10	95,0
B12B	1,20	103,7
B12C	1,20	103,7
B12D	1,20	103,7
B12E	1,20	103,7
B20A	1,20	103,7
B20B	1,20	103,7
B20C	1,20	103,7
B20D	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
B20E	1,20	103,7
B20F	1,20	103,7
B20G	1,20	103,7
B20H	1,20	103,7
B20J	1,20	103,7
B31A	1,20	103,7
B31B	1,20	103,7
B31C	1,30	112,3
B31D	1,30	112,3
B31E	1,40	121,0
B31F	1,40	121,0
B31G	1,30	112,3
B31H	1,30	112,3
B31J	1,40	121,0
B32A	1,30	112,3
B32B	1,20	103,7
B32C	1,30	112,3
B32D	1,40	121,0
B32E	1,20	103,7
B32F	1,30	112,3
B32G	1,20	103,7
B32H	1,30	112,3
B32J	1,40	121,0
B41A	1,10	95,0
B41B	1,10	95,0

Column 1	**Column 2**	**Column 3**
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
B41C	1,10	95,0
B41D	1,20	103,7
B41E	1,20	103,7
B41F	1,00	86,4
B41G	1,10	95,0
B41H	1,20	103,7
B41J	1,30	112,3
B41K	1,30	112,3
B42A	1,00	86,4
B42B	1,00	86,4
B42C	1,10	95,0
B42D	1,00	86,4
B42E	1,10	95,0
B42F	1,00	86,4
B42G	1,10	95,0
B42H	1,20	103,7
B51A	1,30	112,3
B51B	1,40	121,0
B51C	1,40	121,0
B51E	1,40	121,0
B51F	1,20	103,7
B51G	1,30	112,3
B51H	1,30	112,3
B52A	1,40	121,0
B52B	1,20	103,7

Column 1	**Column 2**	**Column 3**
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
B52C	1,20	103,7
B52D	1,30	112,3
B52E	1,20	103,7
B52F	1,10	95,0
B52G	1,20	103,7
B52H	1,00	86,4
B52J	1,10	95,0
B60A	1,00	86,4
B60B	1,10	95,0
B60C	1,10	95,0
B60D	1,10	95,0
B60E	1,00	86,4
B60F	1,10	95,0
B60G	1,10	95,0
B60H	1,10	95,0
B60J	1,30	112,3
B71A	1,00	86,4
B71B	1,10	95,0
B71C	1,00	86,4
B71D	1,10	95,0
B71E	1,20	103,7
B71F	1,20	103,7
B71G	1,20	103,7
B71H	1,30	112,3
B71J	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
B72A	1,20	103,7
B72B	1,30	112,3
B72C	1,30	112,3
B72D	1,30	112,3
B72E	1,20	103,7
B72F	1,10	95,0
B72G	1,30	112,3
B72H	1,30	112,3
B72J	1,30	112,3
B72K	1,30	112,3
B73A	1,20	103,7
B73B	1,30	112,3
B73C	1,30	112,3
B73D	1,30	112,3
B73E	1,30	112,3
B73F	1,30	112,3
B73G	1,40	121,0
B73H	1,40	121,0
B73J	1,40	121,0
B81A	1,00	86,4
B81B	1,00	86,4
B81C	1,20	103,7
B81D	1,20	103,7
B81E	1,20	103,7
B81F	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
B81G	1,30	112,3
B81H	1,30	112,3
B81J	1,30	112,3
B82A	1,10	95,0
B82B	1,20	103,7
B82C	1,20	103,7
B82D	1,20	103,7
B82E	1,10	95,0
B82F	1,20	103,7
B82G	1,30	112,3
B82H	1,30	112,3
B82J	1,40	121,0
B83A	1,40	121,0
B83B	1,40	121,0
B83C	1,40	121,0
B83D	1,40	121,0
B83E	1,40	121,0
B90A	1,40	121,0
B90B	1,40	121,0
B90C	1,30	112,3
B90D	1,40	121,0
B90E	1,40	121,0
B90F	1,30	112,3
B90G	1,40	121,0
B90H	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C11A	1,10	95,0
C11B	1,10	95,0
C11C	1,20	103,7
C11D	1,20	103,7
C11E	1,20	103,7
C11F	1,10	95,0
C11G	1,20	103,7
C11H	1,20	103,7
C11J	1,20	103,7
C11K	1,20	103,7
C11L	1,30	112,3
C11M	1,30	112,3
C12A	1,30	112,3
C12B	1,30	112,3
C12C	1,30	112,3
C12D	1,20	103,7
C12E	1,20	103,7
C12F	1,20	103,7
C12G	1,20	103,7
C12H	1,30	112,3
C12J	1,30	112,3
C12K	1,30	112,3
C12L	1,30	112,3
C13A	1,20	103,7
C13B	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C13C	1,30	112,3
C13D	1,30	112,3
C13E	1,30	112,3
C13F	1,30	112,3
C13G	1,30	112,3
C13H	1,30	112,3
C21A	1,10	95,0
C21B	1,20	103,7
C21C	1,30	112,3
C21D	1,20	103,7
C21E	1,20	103,7
C21F	1,20	103,7
C21G	1,20	103,7
C22A	1,20	103,7
C22B	1,20	103,7
C22C	1,20	103,7
C22D	1,20	103,7
C22E	1,20	103,7
C22F	1,20	103,7
C22G	1,30	112,3
C22H	1,20	103,7
C22J	1,20	103,7
C22K	1,30	112,3
C23A	1,30	112,3
C23B	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C23C	1,30	112,3
C23D	1,20	103,7
C23E	1,20	103,7
C23F	1,20	103,7
C23G	1,30	112,3
C23H	1,30	112,3
C23J	1,30	112,3
C23K	1,30	112,3
C23L	1,40	121,0
C24A	1,40	121,0
C24B	1,40	121,0
C24C	1,20	103,7
C24D	1,30	112,3
C24E	1,30	112,3
C24F	1,30	112,3
C24G	1,40	121,0
C24H	1,40	121,0
C24J	1,40	121,0
C25A	1,40	121,0
C25B	1,50	129,6
C25C	1,50	129,6
C25D	1,40	121,0
C25E	1,50	129,6
C25F	1,50	129,6
C31A	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C31B	1,40	121,0
C31C	1,40	121,0
C31D	1,40	121,0
C31E	1,40	121,0
C31F	1,50	129,6
C32A	1,50	129,6
C32B	1,50	129,6
C32C	1,50	129,6
C32D	1,50	129,6
C33A	1,50	129,6
C33B	1,60	138,2
C33C	1,60	138,2
C41A	1,40	121,0
C41B	1,40	121,0
C41C	1,40	121,0
C41D	1,40	121,0
C41E	1,40	121,0
C41F	1,50	129,6
C41G	1,40	121,0
C41H	1,50	129,6
C41J	1,50	129,6
C42A	1,30	112,3
C42B	1,40	121,0
C42C	1,40	121,0
C42D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C42E	1,40	121,0
C42F	1,40	121,0
C42G	1,40	121,0
C42H	1,40	121,0
C42J	1,40	121,0
C42K	1,40	121,0
C42L	1,50	129,6
C43A	1,50	129,6
C43B	1,50	129,6
C43C	1,50	129,6
C43D	1,50	129,6
C51A	1,50	129,6
C51B	1,40	121,0
C51C	1,50	129,6
C51D	1,40	121,0
C51E	1,50	129,6
C51F	1,50	129,6
C51G	1,50	129,6
C51H	1,50	129,6
C51J	1,50	129,6
C51K	1,60	138,2
C51L	1,60	138,2
C51M	1,60	138,2
C52A	1,40	121,0
C52B	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C52C	1,50	129,6
C52D	1,50	129,6
C52E	1,50	129,6
C52F	1,50	129,6
C52G	1,50	129,6
C52H	1,50	129,6
C52J	1,50	129,6
C52K	1,60	138,2
C52L	1,60	138,2
C60A	1,30	112,3
C60B	1,30	112,3
C60C	1,30	112,3
C60D	1,40	121,0
C60E	1,30	112,3
C60F	1,40	121,0
C60G	1,40	121,0
C60H	1,40	121,0
C60J	1,40	121,0
C70A	1,30	112,3
C70B	1,30	112,3
C70C	1,30	112,3
C70D	1,30	112,3
C70E	1,30	112,3
C70F	1,40	121,0
C70G	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C70H	1,40	121,0
C70J	1,40	121,0
C70K	1,40	121,0
C81A	1,30	112,3
C81B	1,30	112,3
C81C	1,30	112,3
C81D	1,30	112,3
C81E	1,30	112,3
C81F	1,20	103,7
C81G	1,20	103,7
C81H	1,30	112,3
C81J	1,30	112,3
C81K	1,30	112,3
C81L	1,30	112,3
C81M	1,30	112,3
C82A	1,30	112,3
C82B	1,30	112,3
C82C	1,30	112,3
C82D	1,30	112,3
C82E	1,30	112,3
C82F	1,30	112,3
C82G	1,30	112,3
C82H	1,30	112,3
C83A	1,30	112,3
C83B	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
C83C	1,30	112,3
C83D	1,30	112,3
C83E	1,30	112,3
C83F	1,30	112,3
C83G	1,30	112,3
C83H	1,30	112,3
C83J	1,30	112,3
C83K	1,30	112,3
C83L	1,30	112,3
C83M	1,30	112,3
C91A	1,50	129,6
C91B	1,50	129,6
C91C	1,60	138,2
C91D	1,60	138,2
C91E	1,60	138,2
C92A	1,60	138,2
C92B	1,60	138,2
C92C	1,60	138,2
D11A	1,00	86,4
D11B	1,10	95,0
D11C	1,10	95,0
D11D	1,10	95,0
D11E	1,20	103,7
D11F	1,30	112,3
D11G	1,10	95,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
D11H	1,20	103,7
D11J	1,30	112,3
D11K	1,30	112,3
D12A	1,50	129,6
D12B	1,40	121,0
D12C	1,40	121,0
D12D	1,50	129,6
D12E	1,50	129,6
D12F	1,50	129,6
D13A	1,30	112,3
D13B	1,30	112,3
D13C	1,30	112,3
D13D	1,30	112,3
D13E	1,40	121,0
D13F	1,40	121,0
D13G	1,40	121,0
D13H	1,40	121,0
D13J	1,40	121,0
D13K	1,40	121,0
D13L	1,50	129,6
D13M	1,50	129,6
D14A	1,50	129,6
D14B	1,40	121,0
D14C	1,40	121,0
D14D	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
D14E	1,50	129,6
D14F	1,50	129,6
D14G	1,50	129,6
D14H	1,50	129,6
D14J	1,50	129,6
D14K	1,50	129,6
D15A	1,30	112,3
D15B	1,40	121,0
D15C	1,40	121,0
D15D	1,40	121,0
D15E	1,50	129,6
D15F	1,50	129,6
D15G	1,50	129,6
D15H	1,50	129,6
D16A	1,10	95,0
D16B	1,20	103,7
D16C	1,20	103,7
D16D	1,20	103,7
D16E	1,20	103,7
D16F	1,10	95,0
D16G	1,20	103,7
D16H	1,20	103,7
D16J	1,20	103,7
D16K	1,20	103,7
D16L	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
D16M	1,20	103,7
D17A	1,30	112,3
D17B	1,30	112,3
D17C	1,30	112,3
D17D	1,30	112,3
D17E	1,30	112,3
D17F	1,30	112,3
D17G	1,20	103,7
D17H	1,20	103,7
D17J	1,20	103,7
D17K	1,20	103,7
D17L	1,30	112,3
D17M	1,30	112,3
D18A	1,40	121,0
D18B	1,30	112,3
D18C	1,40	121,0
D18D	1,40	121,0
D18E	1,30	112,3
D18F	1,40	121,0
D18G	1,30	112,3
D18H	1,40	121,0
D18J	1,50	129,6
D18K	1,40	121,0
D18L	1,50	129,6
D21A	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
D21B	1,20	103,7
D21C	1,30	112,3
D21D	1,20	103,7
D21E	1,30	112,3
D21F	1,30	112,3
D21G	1,40	121,0
D21H	1,40	121,0
D21J	1,30	112,3
D21K	1,30	112,3
D21L	1,40	121,0
D22A	1,40	121,0
D22B	1,40	121,0
D22C	1,40	121,0
D22D	1,40	121,0
D22E	1,40	121,0
D22F	1,40	121,0
D22G	1,40	121,0
D22H	1,40	121,0
D22J	1,40	121,0
D22K	1,40	121,0
D22L	1,40	121,0
D23A	1,40	121,0
D23B	1,50	129,6
D23C	1,40	121,0
D23D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D23E	1,40	121,0
D23F	1,50	129,6
D23G	1,50	129,6
D23H	1,40	121,0
D23J	1,50	129,6
D24A	1,50	129,6
D24B	1,50	129,6
D24C	1,50	129,6
D24D	1,40	121,0
D24E	1,40	121,0
D24F	1,50	129,6
D24G	1,50	129,6
D24H	1,40	121,0
D24J	1,50	129,6
D24K	1,40	121,0
D24L	1,50	129,6
D31A	1,50	129,6
D31B	1,50	129,6
D31C	1,60	138,2
D31D	1,60	138,2
D31E	1,60	138,2
D32A	1,40	121,0
D32B	1,50	129,6
D32C	1,50	129,6
D32D	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D32E	1,40	121,0
D32F	1,50	129,6
D32G	1,50	129,6
D32H	1,50	129,6
D32J	1,50	129,6
D32K	1,60	138,2
D33A	1,60	138,2
D33B	1,60	138,2
D33C	1,60	138,2
D33D	1,60	138,2
D33E	1,60	138,2
D33F	1,60	138,2
D33G	1,60	138,2
D33H	1,70	146,9
D33J	1,60	138,2
D33K	1,70	146,9
D34A	1,50	129,6
D34B	1,50	129,6
D34C	1,50	129,6
D34D	1,50	129,6
D34E	1,50	129,6
D34F	1,50	129,6
D34G	1,50	129,6
D35A	1,50	129,6
D35B	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D35C	1,50	129,6
D35D	1,50	129,6
D35E	1,50	129,6
D35F	1,50	129,6
D35G	1,50	129,6
D35H	1,50	129,6
D35J	1,50	129,6
D35K	1,50	129,6
D41A	1,40	121,0
D41B	1,50	129,6
D41C	1,60	138,2
D41D	1,60	138,2
D41E	1,60	138,2
D41F	1,60	138,2
D41G	1,60	138,2
D41H	1,60	138,2
D41J	1,50	129,6
D41K	1,60	138,2
D41L	1,50	129,6
D41M	1,70	146,9
D42A	1,70	146,9
D42B	1,70	146,9
D42C	1,70	146,9
D42D	1,70	146,9
D42E	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D51A	1,50	129,6
D51B	1,50	129,6
D51C	1,60	138,2
D52A	1,50	129,6
D52B	1,50	129,6
D52C	1,60	138,2
D52D	1,50	129,6
D52E	1,60	138,2
D52F	1,60	138,2
D53A	1,70	146,9
D53B	1,70	146,9
D53C	1,70	146,9
D53D	1,70	146,9
D53E	1,70	146,9
D53F	1,70	146,9
D53G	1,70	146,9
D53H	1,70	146,9
D53J	1,70	146,9
D54A	1,60	138,2
D54B	1,60	138,2
D54C	1,70	146,9
D54D	1,70	146,9
D54E	1,70	146,9
D54F	1,70	146,9
D54G	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D55A	1,40	121,0
D55B	1,50	129,6
D55C	1,40	121,0
D55D	1,50	129,6
D55E	1,60	138,2
D55F	1,60	138,2
D55G	1,60	138,2
D55H	1,60	138,2
D55J	1,60	138,2
D55K	1,60	138,2
D55L	1,60	138,2
D55M	1,60	138,2
D56A	1,50	129,6
D56B	1,50	129,6
D56C	1,50	129,6
D56D	1,60	138,2
D56E	1,50	129,6
D56F	1,50	129,6
D56G	1,60	138,2
D56H	1,60	138,2
D56J	1,60	138,2
D57A	1,70	146,9
D57B	1,70	146,9
D57C	1,70	146,9
D57D	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D57E	1,70	146,9
D58A	1,60	138,2
D58B	1,60	138,2
D58C	1,60	138,2
D61A	1,50	129,6
D61B	1,50	129,6
D61C	1,60	138,2
D61D	1,60	138,2
D61E	1,50	129,6
D61F	1,50	129,6
D61G	1,60	138,2
D61H	1,60	138,2
D61J	1,60	138,2
D61K	1,60	138,2
D61L	1,60	138,2
D61M	1,70	146,9
D62A	1,60	138,2
D62B	1,70	146,9
D62C	1,50	129,6
D62D	1,60	138,2
D62E	1,60	138,2
D62F	1,60	138,2
D62G	1,70	146,9
D62H	1,70	146,9
D62J	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D71A	1,60	138,2
D71B	1,50	129,6
D71C	1,70	146,9
D71D	1,60	138,2
D72A	1,70	146,9
D72B	1,70	146,9
D72C	1,70	146,9
D73A	1,60	138,2
D73B	1,60	138,2
D73C	1,60	138,2
D73D	1,70	146,9
D73E	1,70	146,9
D73F	1,70	146,9
D81A	1,70	146,9
D81B	1,70	146,9
D81C	1,70	146,9
D81D	1,70	146,9
D81E	1,70	146,9
D81F	1,70	146,9
D81G	1,70	146,9
D82A	1,70	146,9
D82B	1,60	138,2
D82C	1,60	138,2
D82D	1,60	138,2
D82E	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
D82F	1,70	146,9
D82G	1,60	138,2
D82H	1,50	129,6
D82J	1,50	129,6
D82K	1,60	138,2
D82L	1,40	121,0
E10A	1,10	95,0
E10B	1,20	103,7
E10C	1,30	112,3
E10D	1,30	112,3
E10E	1,30	112,3
E10F	1,40	121,0
E10G	1,40	121,0
E10H	1,10	95,0
E10J	1,40	121,0
E10K	1,40	121,0
E21A	1,10	95,0
E21B	1,20	103,7
E21C	1,20	103,7
E21D	1,20	103,7
E21E	1,30	112,3
E21F	1,30	112,3
E21G	1,30	112,3
E21H	1,20	103,7
E21J	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
E21K	1,10	95,0
E21L	1,50	129,6
E22A	1,50	129,6
E22B	1,60	138,2
E22C	1,40	121,0
E22D	1,60	138,2
E22E	1,50	129,6
E22F	1,60	138,2
E22G	1,60	138,2
E23A	1,60	138,2
E23B	1,60	138,2
E23C	1,70	146,9
E23D	1,70	146,9
E23E	1,60	138,2
E23F	1,70	146,9
E23G	1,60	138,2
E23H	1,60	138,2
E23J	1,70	146,9
E23K	1,70	146,9
E24A	1,00	86,4
E24B	1,30	112,3
E24C	1,60	138,2
E24D	1,70	146,9
E24E	1,70	146,9
E24F	1,70	146,9

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
E24G	1,70	146,9
E24H	1,70	146,9
E24J	1,50	129,6
E24K	1,50	129,6
E24L	1,50	129,6
E24M	1,50	129,6
E31A	1,60	138,2
E31B	1,60	138,2
E31C	1,70	146,9
E31D	1,60	138,2
E31E	1,60	138,2
E31F	1,60	138,2
E31G	1,50	129,6
E31H	1,50	129,6
E32A	1,50	129,6
E32B	1,60	138,2
E32C	1,60	138,2
E32D	1,60	138,2
E32E	1,60	138,2
E33A	1,50	129,6
E33B	1,60	138,2
E33C	1,60	138,2
E33D	1,50	129,6
E33E	1,50	129,6
E33F	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
E33G	1,40	121,0
E33H	1,40	121,0
E40A	1,50	129,6
E40B	1,60	138,2
E40C	1,50	129,6
E40D	1,50	129,6
F10A	1,60	138,2
F10B	1,70	146,9
F10C	1,40	121,0
F20A	1,70	146,9
F20B	1,70	146,9
F20C	1,70	146,9
F20D	1,20	103,7
F20E	1,20	103,7
F30A	1,40	121,0
F30B	1,40	121,0
F30C	1,40	121,0
F30D	1,50	129,6
F30E	1,50	129,6
F30F	1,60	138,2
F30G	1,40	121,0
F40A	1,30	112,3
F40B	1,50	129,6
F40C	1,50	129,6
F40D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
F40E	1,50	129,6
F40F	1,30	112,3
F40G	1,50	129,6
F40H	1,40	121,0
F50A	1,40	121,0
F50B	1,40	121,0
F50C	1,50	129,6
F50D	1,50	129,6
F50E	1,40	121,0
F50F	1,50	129,6
F50G	1,40	121,0
F60A	1,40	121,0
F60B	1,50	129,6
F60C	1,50	129,6
F60D	1,50	129,6
F60E	1,40	121,0
G10A	1,30	112,3
G10B	1,20	103,7
G10C	1,40	121,0
G10D	1,40	121,0
G10E	1,40	121,0
G10F	1,40	121,0
G10G	1,10	95,0
G10H	1,50	129,6
G10J	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
G10K	1,40	121,0
G10L	1,30	112,3
G10M	1,20	103,7
G21A	1,10	95,0
G21B	1,20	103,7
G21C	1,40	121,0
G21D	1,40	121,0
G21E	1,30	112,3
G21F	1,20	103,7
G22A	0,90	77,8
G22B	1,00	86,4
G22C	1,20	103,7
G22D	1,00	86,4
G22E	1,20	103,7
G22F	1,30	112,3
G22G	1,30	112,3
G22H	1,20	103,7
G22J	1,20	103,7
G22K	1,20	103,7
G30A	1,40	121,0
G30B	1,50	129,6
G30C	1,50	129,6
G30D	1,50	129,6
G30E	1,40	121,0
G30F	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
G30G	1,30	112,3
G30H	1,40	121,0
G40A	1,10	95,0
G40B	1,10	95,0
G40C	1,20	103,7
G40D	1,20	103,7
G40E	1,20	103,7
G40F	1,30	112,3
G40G	1,00	86,4
G40H	1,00	86,4
G40J	1,20	103,7
G40K	1,30	112,3
G40L	1,10	95,0
G40M	1,20	103,7
G50A	1,10	95,0
G50B	1,30	112,3
G50C	1,10	95,0
G50D	1,30	112,3
G50E	1,20	103,7
G50F	1,10	95,0
G50G	1,30	112,3
G50H	1,30	112,3
G50J	1,10	95,0
G50K	1,20	103,7
H10A	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
H10B	1,20	103,7
H10C	1,30	112,3
H10D	1,00	86,4
H10E	1,10	95,0
H10F	1,40	121,0
H10G	1,40	121,0
H10H	1,20	103,7
H10J	1,00	86,4
H10K	1,10	95,0
H10L	1,40	121,0
H20A	1,30	112,3
H20B	1,20	103,7
H20C	1,10	95,0
H20D	1,20	103,7
H20E	1,00	86,4
H20F	1,20	103,7
H20G	1,20	103,7
H20H	1,50	129,6
H30A	1,40	121,0
H30B	1,40	121,0
H30C	1,20	103,7
H30D	1,20	103,7
H30E	1,40	121,0
H40A	1,10	95,0
H40B	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
H40C	1,40	121,0
H40D	1,30	112,3
H40E	1,40	121,0
H40F	1,40	121,0
H40G	1,30	112,3
H40H	1,40	121,0
H40J	1,40	121,0
H40K	1,30	112,3
H40L	1,40	121,0
H50A	1,30	112,3
H50B	1,40	121,0
H60A	1,20	103,7
H60B	1,20	103,7
H60C	1,20	103,7
H60D	1,30	112,3
H60E	1,40	121,0
H60F	1,30	112,3
H60G	1,30	112,3
H60H	1,40	121,0
H60J	1,30	112,3
H60K	1,30	112,3
H60L	1,30	112,3
H70A	1,40	121,0
H70B	1,30	112,3
H70C	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
H70D	1,40	121,0
H70E	1,40	121,0
H70F	1,30	112,3
H70G	1,30	112,3
H70H	1,20	103,7
H70J	1,30	112,3
H70K	1,20	103,7
H80A	1,50	129,6
H80B	1,40	121,0
H80C	1,40	121,0
H80D	1,30	112,3
H80E	1,30	112,3
H80F	1,30	112,3
H90A	1,30	112,3
H90B	1,50	129,6
H90C	1,40	121,0
H90D	1,30	112,3
H90E	1,20	103,7
J11A	1,60	138,2
J11B	1,60	138,2
J11C	1,50	129,6
J11D	1,60	138,2
J11E	1,50	129,6
J11F	1,40	121,0
J11G	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
J11H	1,30	112,3
J11J	1,40	121,0
J11K	1,50	129,6
J12A	1,30	112,3
J12B	1,40	121,0
J12C	1,40	121,0
J12D	1,40	121,0
J12E	1,30	112,3
J12F	1,30	112,3
J12G	1,20	103,7
J12H	1,40	121,0
J12J	1,30	112,3
J12K	1,40	121,0
J12L	1,40	121,0
J12M	1,50	129,6
J13A	1,50	129,6
J13B	1,40	121,0
J13C	1,40	121,0
J21A	1,50	129,6
J21B	1,60	138,2
J21C	1,60	138,2
J21D	1,50	129,6
J21E	1,60	138,2
J22A	1,60	138,2
J22B	1,60	138,2

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
J22C	1,60	138,2
J22D	1,60	138,2
J22E	1,60	138,2
J22F	1,50	129,6
J22G	1,50	129,6
J22H	1,50	129,6
J22J	1,60	138,2
J22K	1,50	129,6
J23A	1,50	129,6
J23B	1,50	129,6
J23C	1,40	121,0
J23D	1,40	121,0
J23E	1,30	112,3
J23F	1,40	121,0
J23G	1,40	121,0
J23H	1,30	112,3
J23J	1,00	86,4
J24A	1,60	138,2
J24B	1,50	129,6
J24C	1,50	129,6
J24D	1,50	129,6
J24E	1,50	129,6
J24F	1,20	103,7
J25A	1,20	103,7
J25B	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
J25C	1,30	112,3
J25D	1,40	121,0
J25E	1,40	121,0
J31A	1,30	112,3
J31B	1,20	103,7
J31C	1,30	112,3
J31D	1,30	112,3
J32A	1,40	121,0
J32B	1,40	121,0
J32C	1,50	129,6
J32D	1,50	129,6
J32E	1,40	121,0
J33A	1,10	95,0
J33B	1,10	95,0
J33C	1,20	103,7
J33D	1,30	112,3
J33E	1,40	121,0
J33F	1,40	121,0
J34A	1,10	95,0
J34B	1,00	86,4
J34C	0,90	77,8
J34D	1,00	86,4
J34E	1,00	86,4
J34F	1,20	103,7
J35A	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
J35B	1,30	112,3
J35C	1,30	112,3
J35D	1,40	121,0
J35E	1,50	129,6
J35F	1,40	121,0
J40A	1,40	121,0
J40B	1,30	112,3
J40C	1,20	103,7
J40D	1,20	103,7
J40E	1,00	86,4
K10A	0,90	77,8
K10B	1,00	86,4
K10C	1,20	103,7
K10D	1,00	86,4
K10E	1,10	95,0
K10F	0,90	77,8
K20A	0,90	77,8
K30A	0,90	77,8
K30B	0,90	77,8
K30C	0,90	77,8
K30D	0,90	77,8
K40A	0,90	77,8
K40B	0,90	77,8
K40C	0,90	77,8
K40D	0,90	77,8

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
K40E	0,90	77,8
K50A	1,00	86,4
K50B	0,90	77,8
K60A	1,00	86,4
K60B	1,10	95,0
K60C	1,10	95,0
K60D	1,10	95,0
K60E	1,10	95,0
K60F	1,00	86,4
K60G	0,90	77,8
K70A	1,10	95,0
K70B	1,20	103,7
K80A	1,20	103,7
K80B	1,20	103,7
K80C	1,20	103,7
K80D	1,10	95,0
K80E	1,00	86,4
K80F	0,90	77,8
K90A	1,20	103,7
K90B	1,20	103,7
K90C	1,20	103,7
K90D	1,10	95,0
K90E	0,90	77,8
K90F	1,00	86,4
K90G	1,10	95,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
L11A	1,50	129,6
L11B	1,50	129,6
L11C	1,60	138,2
L11D	1,40	121,0
L11E	1,50	129,6
L11F	1,50	129,6
L11G	1,60	138,2
L12A	1,60	138,2
L12B	1,60	138,2
L12C	1,50	129,6
L12D	1,50	129,6
L21A	1,60	138,2
L21B	1,60	138,2
L21C	1,40	121,0
L21D	1,30	112,3
L21E	1,50	129,6
L21F	1,60	138,2
L22A	1,60	138,2
L22B	1,60	138,2
L22C	1,60	138,2
L22D	1,60	138,2
L23A	1,60	138,2
L23B	1,60	138,2
L23C	1,50	129,6
L23D	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
L30A	1,50	129,6
L30B	1,50	129,6
L30C	1,50	129,6
L30D	1,50	129,6
L40A	1,50	129,6
L40B	1,50	129,6
L50A	1,40	121,0
L50B	1,50	129,6
L60A	1,50	129,6
L60B	1,50	129,6
L70A	1,30	112,3
L70B	1,50	129,6
L70C	1,40	121,0
L70D	1,50	129,6
L70E	1,50	129,6
L70F	1,30	112,3
L70G	1,30	112,3
L81A	1,20	103,7
L81B	1,20	103,7
L81C	1,20	103,7
L81D	1,30	112,3
L82A	1,10	95,0
L82B	1,20	103,7
L82C	1,20	103,7
L82D	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
L82E	1,30	112,3
L82F	1,30	112,3
L82G	1,30	112,3
L82H	1,30	112,3
L82J	1,20	103,7
L90A	1,20	103,7
L90B	1,20	103,7
L90C	1,20	103,7
M10A	1,30	112,3
M10B	1,30	112,3
M10C	1,30	112,3
M10D	1,20	103,7
M20A	1,10	95,0
M20B	1,30	112,3
M30A	1,30	112,3
M30B	1,30	112,3
N11A	1,30	112,3
N11B	1,40	121,0
N12A	1,20	103,7
N12B	1,30	112,3
N12C	1,40	121,0
N13A	1,50	129,6
N13B	1,50	129,6
N13C	1,50	129,6
N14A	1,60	138,2

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
N14B	1,60	138,2
N14C	1,50	129,6
N14D	1,60	138,2
N21A	1,60	138,2
N21B	1,40	121,0
N21C	1,60	138,2
N21D	1,60	138,2
N22A	1,60	138,2
N22B	1,60	138,2
N22C	1,60	138,2
N22D	1,50	129,6
N22E	1,60	138,2
N23A	1,50	129,6
N23B	1,50	129,6
N24A	1,60	138,2
N24B	1,60	138,2
N24C	1,60	138,2
N24D	1,60	138,2
N30A	1,40	121,0
N30B	1,50	129,6
N30C	1,50	129,6
N40A	1,50	129,6
N40B	1,40	121,0
N40C	1,40	121,0
N40D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
N40E	1,40	121,0
N40F	1,30	112,3
P10A	1,30	112,3
P10B	1,30	112,3
P10C	1,40	121,0
P10D	1,40	121,0
P10E	1,30	112,3
P10F	1,30	112,3
P10G	1,20	103,7
P20A	1,10	95,0
P20B	1,20	103,7
P30A	1,30	112,3
P30B	1,20	103,7
P30C	1,00	86,4
P40A	1,20	103,7
P40B	1,20	103,7
P40C	1,00	86,4
P40D	1,00	86,4
Q11A	1,50	129,6
Q11B	1,50	129,6
Q11C	1,50	129,6
Q11D	1,50	129,6
Q12A	1,50	129,6
Q12B	1,50	129,6
Q12C	1,50	129,6

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
Q13A	1,50	129,6
Q13B	1,50	129,6
Q13C	1,50	129,6
Q14A	1,50	129,6
Q14B	1,50	129,6
Q14C	1,50	129,6
Q14D	1,50	129,6
Q14E	1,50	129,6
Q21A	1,20	103,7
Q21B	1,50	129,6
Q22A	1,40	121,0
Q22B	1,50	129,6
Q30A	1,20	103,7
Q30B	1,40	121,0
Q30C	1,40	121,0
Q30D	1,40	121,0
Q30E	1,40	121,0
Q41A	1,20	103,7
Q41B	1,30	112,3
Q41C	1,40	121,0
Q41D	1,40	121,0
Q42A	1,40	121,0
Q42B	1,40	121,0
Q43A	1,50	129,6
Q43B	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
Q44A	1,40	121,0
Q44B	1,50	129,6
Q44C	1,50	129,6
Q50A	1,40	121,0
Q50B	1,40	121,0
Q50C	1,50	129,6
Q60A	1,30	112,3
Q60B	1,30	112,3
Q60C	1,50	129,6
Q70A	1,50	129,6
Q70B	1,40	121,0
Q70C	1,40	121,0
Q80A	1,20	103,7
Q80B	1,30	112,3
Q80C	1,30	112,3
Q80D	1,40	121,0
Q80E	1,50	129,6
Q80F	1,50	129,6
Q80G	1,40	121,0
Q91A	1,40	121,0
Q91B	1,40	121,0
Q91C	1,40	121,0
Q92A	1,30	112,3
Q92B	1,40	121,0
Q92C	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
Q92D	1,40	121,0
Q92E	1,50	129,6
Q92F	1,40	121,0
Q92G	1,50	129,6
Q93A	1,40	121,0
Q93B	1,30	112,3
Q93C	1,30	112,3
Q93D	1,20	103,7
Q94A	1,30	112,3
Q94B	1,40	121,0
Q94C	1,40	121,0
Q94D	1,40	121,0
Q94E	1,40	121,0
Q94F	1,40	121,0
R10A	1,20	103,7
R10B	1,20	103,7
R10C	1,20	103,7
R10D	1,30	112,3
R10E	1,30	112,3
R10F	1,20	103,7
R10G	1,30	112,3
R10H	1,40	121,0
R10J	1,40	121,0
R10K	1,30	112,3
R10L	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
R10M	1,20	103,7
R20A	1,20	103,7
R20B	1,20	103,7
R20C	1,20	103,7
R20D	1,20	103,7
R20E	1,20	103,7
R20F	1,20	103,7
R20G	1,00	86,4
R30A	1,00	86,4
R30B	1,10	95,0
R30C	1,20	103,7
R30D	1,10	95,0
R30E	1,20	103,7
R30F	1,00	86,4
R40A	1,00	86,4
R40B	1,30	112,3
R40C	1,10	95,0
R50A	1,20	103,7
R50B	1,10	95,0
S10A	1,40	121,0
S10B	1,40	121,0
S10C	1,40	121,0
S10D	1,40	121,0
S10E	1,50	129,6
S10F	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
S10G	1,50	129,6
S10H	1,50	129,6
S10J	1,40	121,0
S20A	1,40	121,0
S20B	1,40	121,0
S20C	1,30	112,3
S20D	1,30	112,3
S31A	1,40	121,0
S31B	1,50	129,6
S31C	1,50	129,6
S31D	1,50	129,6
S31E	1,50	129,6
S31F	1,50	129,6
S31G	1,50	129,6
S32A	1,20	103,7
S32B	1,40	121,0
S32C	1,40	121,0
S32D	1,20	103,7
S32E	1,20	103,7
S32F	1,30	112,3
S32G	1,30	112,3
S32H	1,50	129,6
S32J	1,50	129,6
S32K	1,40	121,0
S32L	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
S32M	1,40	121,0
S40A	1,30	112,3
S40B	1,20	103,7
S40C	1,30	112,3
S40D	1,30	112,3
S40E	1,30	112,3
S40F	1,30	112,3
S50A	1,30	112,3
S50B	1,40	121,0
S50C	1,30	112,3
S50D	1,30	112,3
S50E	1,30	112,3
S50F	1,30	112,3
S50G	1,30	112,3
S50H	1,30	112,3
S50J	1,30	112,3
S60A	1,20	103,7
S60B	1,20	103,7
S60C	1,20	103,7
S60D	1,20	103,7
S60E	1,20	103,7
S70A	1,20	103,7
S70B	1,20	103,7
S70C	1,30	112,3
S70D	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
S70E	1,20	103,7
S70F	1,10	95,0
T11A	1,30	112,3
T11B	1,30	112,3
T11C	1,30	112,3
T11D	1,20	103,7
T11E	1,30	112,3
T11F	1,30	112,3
T11G	1,30	112,3
T11H	1,30	112,3
T12A	1,30	112,3
T12B	1,30	112,3
T12C	1,30	112,3
T12D	1,30	112,3
T12E	1,30	112,3
T12F	1,30	112,3
T12G	1,30	112,3
T13A	1,30	112,3
T13B	1,30	112,3
T13C	1,30	112,3
T13D	1,30	112,3
T13E	1,20	103,7
T20A	1,20	103,7
T20B	1,20	103,7
T20C	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
T20D	1,20	103,7
T20E	1,30	112,3
T20F	1,30	112,3
T20G	1,20	103,7
T31A	1,30	112,3
T31B	1,30	112,3
T31C	1,30	112,3
T31D	1,30	112,3
T31E	1,30	112,3
T31F	1,40	121,0
T31G	1,30	112,3
T31H	1,30	112,3
T31J	1,30	112,3
T32A	1,30	112,3
T32B	1,30	112,3
T32C	1,20	103,7
T32D	1,30	112,3
T32E	1,30	112,3
T32F	1,30	112,3
T32G	1,30	112,3
T32H	1,30	112,3
T33A	1,30	112,3
T33B	1,40	121,0
T33C	1,40	121,0
T33D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
T33E	1,30	112,3
T33F	1,30	112,3
T33G	1,30	112,3
T33H	1,30	112,3
T33J	1,30	112,3
T33K	1,30	112,3
T34A	1,30	112,3
T34B	1,40	121,0
T34C	1,40	121,0
T34D	1,30	112,3
T34E	1,30	112,3
T34F	1,30	112,3
T34G	1,30	112,3
T34H	1,30	112,3
T34J	1,30	112,3
T34K	1,30	112,3
T35A	1,30	112,3
T35B	1,30	112,3
T35C	1,20	103,7
T35D	1,30	112,3
T35E	1,30	112,3
T35F	1,20	103,7
T35G	1,20	103,7
T35H	1,20	103,7
T35J	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
T35K	1,20	103,7
T35L	1,20	103,7
T35M	1,30	112,3
T36A	1,30	112,3
T36B	1,20	103,7
T40A	1,20	103,7
T40B	1,20	103,7
T40C	1,20	103,7
T40D	1,20	103,7
T40E	1,10	95,0
T40F	1,00	86,4
T40G	1,00	86,4
T51A	1,20	103,7
T51B	1,20	103,7
T51C	1,20	103,7
T51D	1,20	103,7
T51E	1,20	103,7
T51F	1,20	103,7
T51G	1,20	103,7
T51H	1,30	112,3
T51J	1,30	112,3
T52A	1,30	112,3
T52B	1,20	103,7
T52C	1,30	112,3
T52D	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
T52E	1,20	103,7
T52F	1,20	103,7
T52G	1,20	103,7
T52H	1,20	103,7
T52J	1,10	95,0
T52K	1,10	95,0
T52L	1,00	86,4
T52M	1,00	86,4
T60A	1,10	95,0
T60B	1,30	112,3
T60C	1,20	103,7
T60D	1,10	95,0
T60E	1,30	112,3
T60F	1,30	112,3
T60G	1,10	95,0
T60H	1,10	95,0
T60J	1,20	103,7
T60K	1,20	103,7
T70A	1,20	103,7
T70B	1,20	103,7
T70C	1,30	112,3
T70D	1,10	95,0
T70E	1,20	103,7
T70F	1,20	103,7
T70G	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
T80A	1,10	95,0
T80B	1,20	103,7
T80C	1,30	112,3
T80D	1,10	95,0
T90A	1,20	103,7
T90B	1,20	103,7
T90C	1,20	103,7
T90D	1,20	103,7
T90E	1,20	103,7
T90F	1,10	95,0
T90G	1,10	95,0
U10A	1,20	103,7
U10B	1,20	103,7
U10C	1,20	103,7
U10D	1,20	103,7
U10E	1,20	103,7
U10F	1,20	103,7
U10G	1,20	103,7
U10H	1,20	103,7
U10J	1,20	103,7
U10K	1,20	103,7
U10L	1,20	103,7
U10M	1,10	95,0
U20A	1,10	95,0
U20B	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
U20C	1,20	103,7
U20D	1,20	103,7
U20E	1,20	103,7
U20F	1,30	112,3
U20G	1,20	103,7
U20H	1,20	103,7
U20J	1,20	103,7
U20K	1,20	103,7
U20L	1,10	95,0
U20M	1,00	86,4
U30A	1,10	95,0
U30B	1,00	86,4
U30C	1,20	103,7
U30D	1,10	95,0
U30E	1,20	103,7
U40A	1,20	103,7
U40B	1,30	112,3
U40C	1,20	103,7
U40D	1,20	103,7
U40E	1,20	103,7
U40F	1,20	103,7
U40G	1,20	103,7
U40H	1,20	103,7
U40J	1,20	103,7
U50A	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
U60A	1,10	95,0
U60B	1,20	103,7
U60C	1,10	95,0
U60D	1,00	86,4
U60E	1,00	86,4
U60F	1,00	86,4
U70A	1,10	95,0
U70B	1,20	103,7
U70C	1,10	95,0
U70D	1,10	95,0
U70E	1,00	86,4
U70F	1,00	86,4
U80A	0,90	77,8
U80B	1,10	95,0
U80C	1,00	86,4
U80D	1,00	86,4
U80E	1,20	103,7
U80F	1,00	86,4
U80G	1,10	95,0
U80H	1,10	95,0
U80J	1,20	103,7
U80K	1,10	95,0
U80L	1,10	95,0
V11A	1,30	112,3
V11B	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
V11C	1,40	121,0
V11D	1,60	138,2
V11E	1,40	121,0
V11F	1,60	138,2
V11G	1,20	103,7
V11H	1,40	121,0
V11J	1,60	138,2
V11K	1,60	138,2
V11L	1,60	138,2
V11M	1,50	129,6
V12A	1,40	121,0
V12B	1,40	121,0
V12C	1,40	121,0
V12D	1,50	129,6
V12E	1,50	129,6
V12F	1,50	129,6
V12G	1,40	121,0
V13A	1,30	112,3
V13B	1,50	129,6
V13C	1,50	129,6
V13D	1,50	129,6
V13E	1,50	129,6
V14A	1,50	129,6
V14B	1,50	129,6
V14C	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
V14D	1,50	129,6
V14E	1,50	129,6
V20A	1,20	103,7
V20B	1,20	103,7
V20C	1,20	103,7
V20D	1,20	103,7
V20E	1,20	103,7
V20F	1,20	103,7
V20G	1,30	112,3
V20H	1,40	121,0
V20J	1,40	121,0
V31A	1,20	103,7
V31B	1,30	112,3
V31C	1,30	112,3
V31D	1,40	121,0
V31E	1,40	121,0
V31F	1,30	112,3
V31G	1,40	121,0
V31H	1,30	112,3
V31J	1,40	121,0
V31K	1,40	121,0
V32A	1,30	112,3
V32B	1,40	121,0
V32C	1,40	121,0
V32D	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
V32E	1,40	121,0
V32F	1,30	112,3
V32G	1,30	112,3
V32H	1,30	112,3
V33A	1,30	112,3
V33B	1,30	112,3
V33C	1,20	103,7
V33D	1,30	112,3
V40A	1,20	103,7
V40B	1,20	103,7
V40C	1,20	103,7
V40D	1,20	103,7
V40E	1,10	95,0
V50A	1,20	103,7
V50B	1,10	95,0
V50C	1,20	103,7
V50D	1,20	103,7
V60A	1,30	112,3
V60B	1,40	121,0
V60C	1,50	129,6
V60D	1,40	121,0
V60E	1,40	121,0
V60F	1,40	121,0
V60G	1,40	121,0
V60H	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
V60J	1,40	121,0
V60K	1,30	112,3
V70A	1,20	103,7
V70B	1,20	103,7
V70C	1,30	112,3
V70D	1,30	112,3
V70E	1,30	112,3
V70F	1,30	112,3
V70G	1,40	121,0
W11A	1,20	103,7
W11B	1,30	112,3
W11C	1,30	112,3
W12A	1,20	103,7
W12B	1,20	103,7
W12C	1,30	112,3
W12D	1,30	112,3
W12E	1,30	112,3
W12F	1,20	103,7
W12G	1,30	112,3
W12H	1,30	112,3
W12J	1,10	95,0
W13A	1,20	103,7
W13B	1,30	112,3
W21A	1,30	112,3
W21B	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
W21C	1,30	112,3
W21D	1,30	112,3
W21E	1,20	103,7
W21F	1,20	103,7
W21G	1,10	95,0
W21H	1,20	103,7
W21J	1,20	103,7
W21K	1,30	112,3
W21L	1,30	112,3
W22A	1,20	103,7
W22B	1,20	103,7
W22C	1,20	103,7
W22D	1,20	103,7
W22E	1,20	103,7
W22F	1,20	103,7
W22G	1,30	112,3
W22H	1,20	103,7
W22J	1,30	112,3
W22K	1,30	112,3
W22L	1,30	112,3
W23A	1,30	112,3
W23B	1,30	112,3
W23C	1,20	103,7
W23D	1,20	103,7
W31A	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
W31B	1,20	103,7
W31C	1,20	103,7
W31D	1,20	103,7
W31E	1,30	112,3
W31F	1,30	112,3
W31G	1,40	121,0
W31H	1,40	121,0
W31J	1,40	121,0
W31K	1,40	121,0
W31L	1,40	121,0
W32A	1,30	112,3
W32B	1,30	112,3
W32C	1,40	121,0
W32D	1,30	112,3
W32E	1,30	112,3
W32F	1,30	112,3
W32G	1,30	112,3
W32H	1,20	103,7
W41A	1,30	112,3
W41B	1,30	112,3
W41C	1,30	112,3
W41D	1,30	112,3
W41E	1,30	112,3
W41F	1,30	112,3
W41G	1,30	112,3

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
W42A	1,20	103,7
W42B	1,30	112,3
W42C	1,30	112,3
W42D	1,30	112,3
W42E	1,30	112,3
W42F	1,30	112,3
W42G	1,30	112,3
W42H	1,20	103,7
W42J	1,30	112,3
W42K	1,20	103,7
W42L	1,20	103,7
W42M	1,30	112,3
W43A	1,20	103,7
W43B	1,20	103,7
W43C	1,30	112,3
W43D	1,40	121,0
W43E	1,40	121,0
W43F	1,40	121,0
W44A	1,30	112,3
W44B	1,40	121,0
W44C	1,40	121,0
W44D	1,40	121,0
W44E	1,40	121,0
W45A	1,40	121,0
W45B	1,40	121,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
W51A	1,20	103,7
W51B	1,20	103,7
W51C	1,20	103,7
W51D	1,30	112,3
W51E	1,20	103,7
W51F	1,20	103,7
W51G	1,20	103,7
W51H	1,20	103,7
W52A	1,20	103,7
W52B	1,20	103,7
W52C	1,20	103,7
W52D	1,20	103,7
W53A	1,20	103,7
W53B	1,20	103,7
W53C	1,20	103,7
W53D	1,20	103,7
W53E	1,20	103,7
W53F	1,20	103,7
W53G	1,20	103,7
W54A	1,20	103,7
W54B	1,20	103,7
W54C	1,20	103,7
W54D	1,10	95,0
W54E	1,20	103,7
W54F	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
W54G	1,30	112,3
W55A	1,20	103,7
W55B	1,20	103,7
W55C	1,20	103,7
W55D	1,20	103,7
W55E	1,10	95,0
W56A	1,20	103,7
W56B	1,20	103,7
W56C	1,20	103,7
W56D	1,20	103,7
W56E	1,20	103,7
W56F	1,30	112,3
W57A	1,30	112,3
W57B	1,40	121,0
W57C	1,40	121,0
W57D	1,20	103,7
W57E	1,40	121,0
W57F	1,30	112,3
W57G	1,40	121,0
W57H	1,40	121,0
W57J	1,40	121,0
W57K	1,40	121,0
W60A	1,10	95,0
W60B	1,10	95,0
W60C	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
W60D	1,40	121,0
W60E	1,40	121,0
W60F	1,40	121,0
W60G	1,30	112,3
W60H	1,40	121,0
W60J	1,40	121,0
W60K	1,30	112,3
W70A	1,30	112,3
X11A	1,10	95,0
X11B	1,20	103,7
X11C	1,10	95,0
X11D	1,10	95,0
X11E	1,10	95,0
X11F	1,10	95,0
X11G	1,20	103,7
X11H	1,20	103,7
X11J	1,10	95,0
X11K	1,20	103,7
X12A	1,20	103,7
X12B	1,20	103,7
X12C	1,20	103,7
X12D	1,20	103,7
X12E	1,20	103,7
X12F	1,20	103,7
X12G	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	litres per second per field hectare (120h/week)	Cubic metres per field hectare per day
X12H	1,20	103,7
X12J	1,10	95,0
X12K	1,20	103,7
X13A	1,10	95,0
X13B	1,10	95,0
X13C	1,10	95,0
X13D	1,20	103,7
X13E	1,30	112,3
X13F	1,20	103,7
X13G	1,30	112,3
X13H	1,30	112,3
X13J	1,30	112,3
X13K	1,30	112,3
X13L	1,30	112,3
X14A	1,10	95,0
X14B	1,10	95,0
X14C	1,10	95,0
X14D	1,20	103,7
X14E	1,30	112,3
X14F	1,20	103,7
X14G	1,30	112,3
X14H	1,30	112,3
X21A	1,00	86,4
X21B	1,10	95,0
X21C	1,10	95,0

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
X21D	1,10	95,0
X21E	1,00	86,4
X21F	1,10	95,0
X21G	1,10	95,0
X21H	1,10	95,0
X21J	1,10	95,0
X21K	1,00	86,4
X22A	1,00	86,4
X22B	1,00	86,4
X22C	1,10	95,0
X22D	1,00	86,4
X22E	1,00	86,4
X22F	1,10	95,0
X22G	1,00	86,4
X22H	1,10	95,0
X22J	1,20	103,7
X22K	1,20	103,7
X23A	1,10	95,0
X23B	1,20	103,7
X23C	1,10	95,0
X23D	1,20	103,7
X23E	1,10	95,0
X23F	1,20	103,7
X23G	1,20	103,7
X23H	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
X24A	1,20	103,7
X24B	1,20	103,7
X24C	1,20	103,7
X24D	1,30	112,3
X24E	1,30	112,3
X24F	1,30	112,3
X24G	1,30	112,3
X24H	1,30	112,3
X31A	1,00	86,4
X31B	1,00	86,4
X31C	1,00	86,4
X31D	1,10	95,0
X31E	1,10	95,0
X31F	1,00	86,4
X31G	1,10	95,0
X31H	1,00	86,4
X31J	1,10	95,0
X31K	1,20	103,7
X31L	1,30	112,3
X31M	1,30	112,3
X32A	1,20	103,7
X32B	1,20	103,7
X32C	1,30	112,3
X32D	1,20	103,7
X32E	1,20	103,7

Column 1	Column 2	Column 3
Quaternary drainage region	**litres per second per field hectare (120h/week)**	**Cubic metres per field hectare per day**
X32F	1,30	112,3
X32G	1,30	112,3
X32H	1,30	112,3
X32J	1,40	121,0
X33A	1,40	121,0
X33B	1,40	121,0
X33C	1,40	121,0
X33D	1,30	112,3
X40A	1,40	121,0
X40B	1,40	121,0
X40C	1,30	112,3
X40D	1,40	121,0