KNOWLEDGE FOR IMPACT

Research for successful service delivery at the local government level

WATER RESEARCH COMMISSION

SP No. 96/16

Obtainable from:
Water Research Commission
Private Bag X03
Gezina
0031

Disclaimer
The Water Research Commission (WRC) has approved this book for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Author: Kim Trollip
Editor: Lani van Vuuren
Design and layout: Anja van der Merwe

ISBN 978-1-4312-0820-3
Printed in the Republic of South Africa

Contents

Abbreviations and acronyms

AMD	Acid mine drainage
CEO	Chief Executive Officer
CECs	Contaminants of emerging concern
COGTA	Department of Co-operative Governance and Traditional Authorities
DPR	Direct potable reuse
DSS	Decision support system
DWS	Department of Water and Sanitation
eWQMS	Electronic Water Quality Measurement System
IPR	Indirect potable reuse
IWRM	Integrated water resources management
LFM	Low-flow meter
MBI	Municipal Benchmarking Initiative
NAEBP	National Aquatic Ecosystem Biomonitoring Programme
NWA	National Water Act
NWRS	National Water Resource Strategy
O&M	Operations and maintenance
R&D	Research and development
RTS	return-to-service (power stations)
SALGA	South African Local Government Association
SASS	South African Scoring System
SRFA	Sanitation Research Fund for Africa
SU	Stellenbosch University
SuDS	Sustainable Drainage Systems
UCT	University of Cape Town
UP	University of Pretoria
VIP	Ventilated improved pit (latrines)
WDM	Water demand management
WISA	Water Institute of Southern Africa
W2RAP	Wastewater risk abatement plan
WRC	Water Research Commission
WRM	Water Resource Management
WSA	Water services authority
WSP	Water safety planning
WSUD	Water sensitive urban design
WWTW	Wastewater treatment works

Back to top

Foreword

Local government is the sphere of government closest to the people. They are elected by citizens to represent them and are responsible to ensure that services are delivered to the community.

In recognition of this important responsibility the Water Research Commission (WRC) – South Africa's primary funder of water and sanitation research – has taken it upon itself to support municipalities in their responsibility to make sure that all citizens are provided with services to satisfy their basic needs.

There is recognition of the enormity of the task of serving all of the country's citizens, especially in light of the gross imbalanced access to infrastructure our municipalities inherited when apartheid ended in 1994. Rather than letting our municipal officials face this task alone, entities such as the WRC and its research partners have joined forces to come up with science-based solutions to allow for better decision-making in the management of water at a local level and the implementation of sustainable solutions in the roll-out of water and sanitation services.

The road to creating cities, towns and villages where people cannot only live healthily and safely but thrive economically is a rocky, uphill one. The everyday challenge of providing potable water and safe sanitation to communities is compounded by South Africa's inherent water scarcity, increasing population, rising urbanisation and climate change.

It is the hope of the WRC that this publication, which sets out the solutions developed by the Commission for local government, will inspire municipalities to seek out innovation as a way of overcoming some of these challenges towards meeting their mandate to serve the people of South Africa.

Dhesigen Naidoo
WRC CEO

Introduction

South Africa relies on water engineers and municipal managers to help the nation secure water for people and food, protect vital ecosystems and deal with variability and uncertainty of water in space and time. This is particularly important at a time when Parliament has declared the 2015/2016 drought one of the worst in 30 years, a national disaster.

The governance of water is defined as the competence of government at a national level, while the function of providing water and sanitation services is the primary competence of local government, with national government's role being one of regulation and support. In these circumstances, cooperative governance between the Department of Water and Sanitation, local government, and other line agencies, in close consultation with communities, is especially important to achieve sustainable development.

Research, undertaken by the Water Research Commission (WRC) and its network of partners and experts, has informed many water management successes in South African local government. This publication highlights some of the current contributions and serves to remind municipal managers and local government decision-makers how the WRC can assist them in the all-important work of managing our most precious resource – water.

Meeting the service delivery challenge

The WRC strives to help in sustainably servicing those who are still without safe water and sanitation, while ensuring existing services remain sustainable. Our motto *Olwazi Amandla Awethu* means the *Power of Knowledge to the People*.

"The achievement of a higher level to water security and the expansion of the frontiers of dignity through accessible safe sanitation will require us as the water science and technology community to up the game. We need to accelerate our efforts to bring Knowledge to Action. This requires us to more actively package scientifically derived knowledge in a form that brings a much larger group of people into the conversation in a manner that strongly empowers participation and influences decision-making."

– Dhesigen Naidoo, WRC Chief Executive Officer

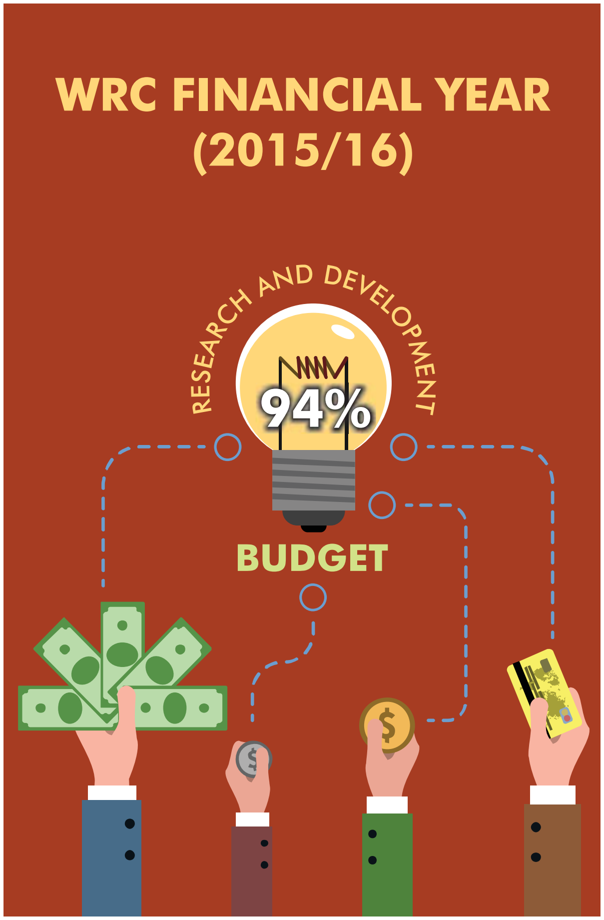
This document would like to encourage the municipal managers of South Africa to:

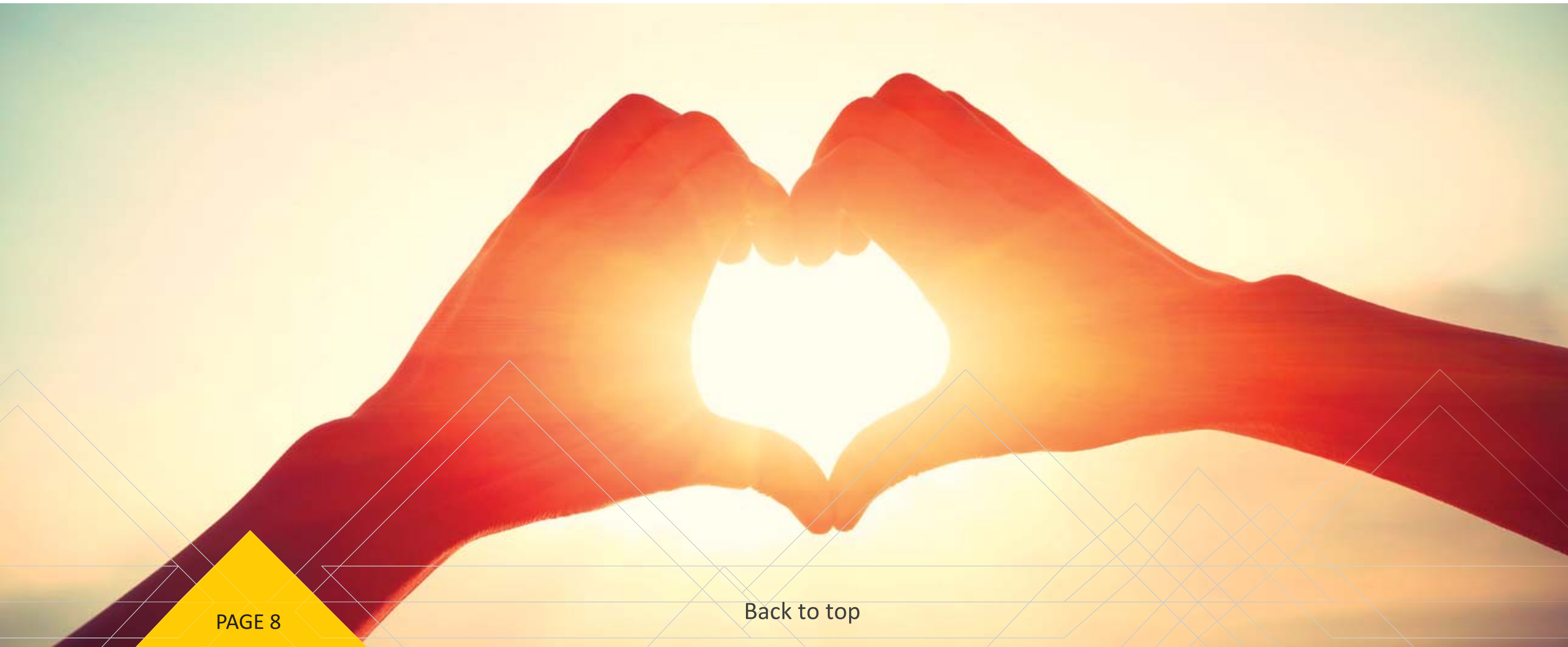
- Continue to embrace scientifically developed tools and guidelines for policy development and decision-making;
- Support the implementation of these tools and guidelines on the ground for the benefit of their municipalities;
- Use the scientifically derived knowledge the WRC provides to bring about action;
- Remember the need to promote holistic continuous improvement;
- Embrace capacity building and training;
- Listen to the input of the communities they service to help address their aspirations while overcoming the logistical challenges of working responsibly within the limits of South Africa's water resources; and
- Practice good performance management to maintain, improve and extend municipal water services delivery in South Africa.

Municipalities need to choose technical options that, in the long term, are affordable and sustainable. Municipal managers, particularly those in the water-scarce regions of the country, are encouraged to implement sanitation technologies that require less water and are acceptable to and embraced by the communities they serve.

This publication is designed to bring that conversation to the municipal decision makers across the country and to the municipal technical managers on the ground, who are facing the challenges of providing clean water and sanitation to rural and urban communities across South Africa on a daily basis.

The WRC has celebrated 20 years of serving democratic South Africa with water and sanitation research. Watch a video on the Commission's achievements here.





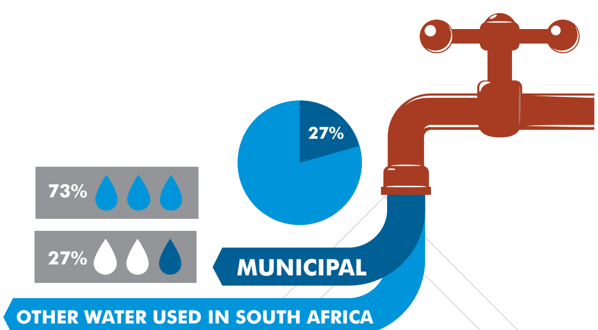
01

Using drinking water wisely and efficiently

South Africa is a semi-arid country, and has less water per person than countries widely considered much more arid, such as Namibia and Botswana. Many parts of the country are fast approaching the point at which all of the easily accessible freshwater resources are fully utilised. Extreme climatic conditions, such as drought and flood, exacerbate our water challenges.

Increasing urbanisation, a growing population and industrialisation place enormous pressure on our scarce water resources in terms of management and allocation. Ensuring a sustainable water balance requires a multitude of strategies, including water conservation and water demand management, further utilisation of groundwater, desalination, water reuse, rainwater harvesting and reuse of treated acid mine drainage; etc.

The wise and efficient use of drinking water has a profound impact on our water environment, resources and investments. Drinking water and commercial activities have a high cost and assurance attached to them, as well as growing competitive demands. Thus, the Water Research Commission (WRC) supports research, demonstration and development of innovative ideas, technologies and processes that enhance the efficient use, reuse and conservation of our precious water. Over the years, the organisation has had a constant focus on initiatives to improve the drinking water quality standards in municipalities.



The WRC aims to proactively and effectively lead and support the advancement of technology, science, management and policies relevant to water supply and waste and effluent management. It also supports studies on institutional and management issues, with special emphasis on the efficient functioning of water service institutions and their viability. Research on infrastructure for both water supply and sanitation is included. A further focus is on water supply and treatment technology serving the domestic sector. Finally, it focuses on waste and effluent as well as reuse technologies that can support the municipal sector and improve management with the aim of improving productivity and supporting economic growth while minimising the negative effect on human and environmental health.

This publication reminds the municipal managers and local government decision-makers of South Africa to:

- Practice good risk governance for sustainability and operational resilience of water utilities
- Follow an integrated approach to risk management that considers water as a business
- Ensure planning across all functions of the municipality and consider regulatory, financial, operational, technical, and political needs
- Proactively and effectively lead and support the advancement of WRC-recommended tools and technologies
- Embrace the WRC's proven reuse technologies that can support the municipal sector, improve productivity and support economic growth, while minimising the negative effect on human and environmental health
- Elevate water safety planning in terms of water quality control and assurance
- Strengthen water quality surveillance and monitoring activities
- Pursue adaptive climate change technologies and approaches
- Strengthen improved conservation and efficiency technologies to minimise water loss and enhance recycling options.

In the past, risk management focused on operational aspects – the water safety planning approach – which ensures water quality integrity from source to tap. However, there is a need for an integrated approach that considers water as a business that requires synergetic planning across all functions of the municipality i.e. regulatory, financial, operational, technical and political.

"Good risk governance is an essential requirement for sustainability and operational resilience of water utilities. A holistic approach to the management of risk is a fundamental requirement for the effective and efficient delivery of water and sanitation services."

– Dr Nonhlanhla Kalebaila, WRC Research Manager

The WRC is cognisant of the challenges facing municipal managers, including the lack of resources (particularly skilled human resources and finance) to implement strategies and technologies, but urges them to consult widely, benchmark and make use of the many useful guidelines and proven tools that are available to them.

The following factors are crucial to success:

- Managing drinking water quality
- Operational resilience
- Financial viability
- Infrastructure management
- Communications and customer care
- Planning for water supply
- Performance measurement and continual improvement

In order to properly manage drinking water quality in South Africa's municipalities, **water safety planning** has to be elevated in terms of water quality control and assurance. A number of emerging and persistent contaminants (chemicals) and pathogens have been detected in source waters used for drinking water production. There is a need for strengthening water quality surveillance and monitoring activities. This is very important in the context of water reuse (both planned and unplanned). There is more comprehensive information about direct reclamation of municipal wastewater for drinking purposes in the chapter below where we outline some success stories where water reuse is being successfully applied. Technologies and systems for the reuse, recycling and reclamation of water in South Africa have matured to the point where there are no longer any health concerns if the quality control and assurance is top notch.

While proper water safety planning is the first step towards long-term success, **operational resilience** is only achieved through the addition of proper wastewater risk abatement planning and emergency response planning. In addition, water security and safety planning is essential to prepare for and respond to emergencies. The implementation of adaptive climate change technologies and approaches for local governments are also important ingredients in the achievement of long term operational resilience.

Wastewater treatment services are one of the core business responsibilities of a municipality. Legislation in South Africa **ensures access to water services, affordably and effectively, to all consumers in an economic and sustainable manner**. The approach for setting an effective wastewater treatment tariff is often challenging because it requires coordination of activities across multiple municipal departments and setting effective tariffs requires a genuine long-term perspective. Fundamentally, a municipality needs to issue a tariff that covers all wastewater treatment costs and recover all these costs from the clients that it serves.

At the time of writing the WRC was placing the final touches on a new strategy and technical guideline document that sets out a roadmap towards the setting of accurate charges. This training guideline will assist municipalities in setting effective (cost-reflective) charges. The guideline is divided into key strategic thrusts and goals to allow municipalities to gradually improve their cost accounting, ring-fencing, asset management, human resources and knowledge of the client base.

Municipal water and wastewater infrastructure are important contributors to communal health and well-being.

Increased scientific knowledge and innovative technologies have radically improved the ability of water authorities to **manage water and wastewater infrastructure**. These assets are the lifeblood of the community, since they protect public health and ensure that local economies continue to run. These assets also have an operational life and effective and efficient use of these components impacts the ability of water utilities to continue to provide high quality, high assurance water and sanitation services reliably and affordably.

"Mounting evidence internationally suggests that the integrity of drinking water and wastewater infrastructure is at risk without a concerted effort to improve the management of key assets: pipelines, treatment plants, and other facilities - and a significant investment in maintaining, rehabilitating and replacing these assets."

– Jay Bhagwan, WRC Executive Manager: Water Use and Waste Management

In addition, the reduction of water loss, improved water management, improved distribution management and water meter management all play a crucial role in **good infrastructure management practices**.

The WRC recommends a two-pronged approach to **communications and customer care**, namely the ongoing monitoring and communication of water quality data and the use of ICT as a way of engaging customers. In recent years, water management practice has shifted away from a 'technicist' approach, with its focus on building dams and laying pipes, to a broader approach which includes people as well other natural resources like land. This change has come about through understanding that it is not possible to manage water without knowing what people need, how they understand their water resource, and what role they have in managing it.

Customer care is an integral part of municipal service delivery.

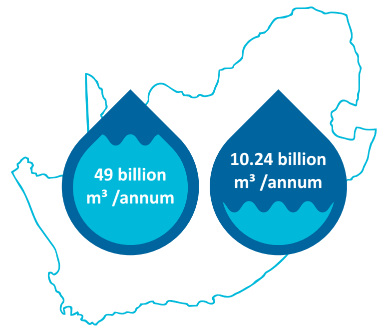
Planning for water supply, almost without exception, has to involve the use of alternative sources of water to meet demand. This may include water reclamation, groundwater development, desalination (seawater and brackish) and water harvesting, among others. Lessons from desalination and water reclamation projects in South Africa indicate a clear need for long term planning, water supply strategies and proper operations and maintenance (O&M) arrangements.

Ongoing **performance measurement and continual improvement** assist in improving service delivery and operational management, as well as contribute to institutional effectiveness through detailed performance measurement and assessment. This assessment can be based on learning from the best performance by peers. National Treasury defines service delivery as a by-product of effective, efficient and economical processes that are informed by strategic direction, resource planning and implementation. This compels municipalities to improve their operational and business processes.

Water use and waste management in South Africa is a key factor for social and economic growth, as well as for our environment. The way we think about and use water is thus an important factor in determining our future.

Alternative water supplies

Water scarcity is recognised as a major challenge in many countries around the world. Water resource managers and planners are forced to look at other, unconventional water sources such as desalination (of seawater and brackish groundwater), water reuse and rainwater harvesting. Water reuse has become an attractive option for water augmentation due to improvement in efficiency of treatment processes, reduced costs and the fact that this water source is readily available and in close proximity to the point of application.



South Africa has a mean annual runoff (MAR) of about **49 billion m³ /annum**, however only some **10.24 billion m³ /annum** of this is available at high assurance.

The most important drivers for water reuse are rapid population growth, urbanisation and unpredictability of conventional water source sustainability (due to climate change and source pollution). In South Africa, there has also been a lot of interest recently in direct water reclamation (direct potable reuse), for a number of reasons. Being an arid region, southern Africa faces serious challenges with availability of conventional water sources. Already the effects of prolonged droughts in the sub-continent are evident, necessitating the implementation of contingency plans in the short term, and the rethinking of the water supply systems in the medium and long term.

South Africa has a limited supply of water with an uneven geographic distribution thereof, in regions which range from semi-desert to tropical. The rainfall is also highly variable, with frequent severe water shortages. Intensive industrial, mining and urban development aggravate this problem, creating a vital need for water reuse in the country.

It is estimated that the population growth is 2.4% per year. This means that the water demand is likely to exceed available water resources in selected water management areas in the short to medium term. Water reuse and recycling are thus an undeniably necessary supplement to fresh water use.

This may entail reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, or for replenishing a ground water basin (referred to as ground water recharge). Recycled water can satisfy most water demands, as long as it is adequately treated to ensure water quality appropriate for the use. Water recycling can therefore also entail water reclamation for drinking purposes.

"Reuse, recycling and reclamation of water in South Africa has matured to the point where it can really be used now. The technology and systems have been refined and have matured to the point where there are no longer any health concerns. In addition, the municipal engineer has access to comprehensive WRC monitoring guidelines and training aids, which are freely available for use."

– Chris Swartz, consulting engineer and chair of the Water Institute of Southern Africa's water reuse division

As water energy demands and environmental needs grow, water reuse and reclamation will play a greater role in our overall water supply and can help municipalities to sustainably manage their vital water resource.

In addition to providing a dependable, locally-controlled water supply, water reuse provides tremendous environmental benefits. By providing an additional source of water, water recycling can help us find ways to decrease the diversion of water from sensitive ecosystems. Other benefits include decreasing wastewater discharges and reducing and preventing pollution. Recycled water can also be used to create or enhance natural habitats.

In response to the 2015/2016 drought, Minister of Water and Sanitation, Nomvula Mokonyane, has revealed government's plans to buffer the impact of recurrent droughts in the medium to long-term future. A key component of the plan is the large-scale development of desalination plants along the coastal regions. These plans are designed to ensure that the country is climate change resilient.

To confront recurrent droughts, the country needs to step up its water management efforts by making scientifically-informed decisions about how to best use its limited water resources. The challenge is to save enough water for use during periods of recurrent droughts. We need long-term research to implement and learn from instructive global lessons. By exposing these global lessons, South Africa is poised to build a foundation for a drought resilient society.

Water reuse success stories

South Africa's inherent water scaraty is driving interest in water reclamation and reuse of wastewater as alternative water supply sources. Several water reclamation plants have been constructed as a result of this water shortage in: Beaufort West (direct potable reuse or DPR), George (indirect potable reuse or IPR) and Mossel Bay (reuse for industrial purposes). Direct potable reuse options in Durban (eThekwini Municipality), Port Elizabeth, Cape Town and Hermanus are at an advanced planning stage. In this regard, water reuse for potable purposes involves the reclamation of wastewater for drinking purposes, after it has been extensively treated, to produce water that is safe for human consumption and human use.

Direct water reuse involves the reuse of treated wastewater or effluent by direct transfer from the site where it was produced, to the site of the new or different beneficial application, whereas indirect water reuse comprises the reuse of treated wastewater from a surface water or groundwater body where it was discharged to with the intention of reuse, before being abstracted for reuse at a new or different site of beneficial application.

Beaufort West – the largest town in the arid Great Karoo region of the Western Cape – is the site of South Africa's first DPR plant, where treated wastewater effluent is conveyed directly to a water treatment facility for further treatment to drinking water standard.

It was built in 2010 when the town's main water supply, the Gamka Dam, dried up during a drought. Emergency relief funding from National Treasury covered the R24 million construction costs, and the plant came on stream in January 2011. In June of that year, the drought was broken and the Gamka Dam began refilling, reaching 100% capacity by September, but the DPR plant continued operating nevertheless.

Chris Swartz

The low level of the Gamka Dam illustrates the importance of alternative water resources, such as reclaimed water

The plant blends no more than 30% reclaimed water with either surface water or borehole water, or a mix of the two. Even when the dam fills, the reclaimed water component is kept at about the same level. The area has a very low annual rainfall, and in March 2015 the dam was back down to only 9% full, so the reclaimed water is definitely still needed.

The towns of George and Mossel Bay also built water reclamation plants during the drought, but each took a different approach.

The George plant is an IPR plant, where the treated wastewater effluent is discharged to the Garden Route Dam for dilution and storage before it is piped to the water treatment plant for further treatment. In this case the reclaimed water replenishes the surface water supply, but it can even be used to recharge groundwater that is subsequently extracted and treated to drinking water standard. The discharge of treated effluent from wastewater works into rivers, followed by diversion of river water to water treatment plants downstream, represents 'unplanned' indirect potable reuse – a practice that occurs the world over.

The Mossel Bay plant involves water reclamation for industrial purposes only. Final effluent from the regional wastewater works is treated further to provide the high-quality water needed for the PetroSA refining process. A similar scheme had already proved successful for the eThekwini Municipality, where the Durban Water Recycling Project was undertaken as a public-private partnership. The treatment plant was commissioned in May 2001, and to date the two largest customers for its high-quality but lower-cost water are the Mondi Paper Mill in Merebank and the Sapref Refinery owned by Shell and BP.

Many other towns and cities recycle the final effluent from wastewater treatment works by making it available for industrial purposes or for irrigation of agricultural crops, golf courses, sports fields and public open spaces. This water is generally not treated further to bring it to a higher standard, but many of the advantages of water reclamation still apply. It conserves the available water supply, which reduces the need to abstract more water from surface or groundwater sources, or build new dams or inter-basin transfer schemes, all of which have environmental and financial costs. It also reduces the volume of treated effluent discharged back into aquatic systems, where it may degrade natural water quality and cause the ripple-effect of ecological changes associated with nutrient enrichment.

Watch Chris Swartz talk about the potential of water reuse here.

Water reuse guidelines and tools from the WRC:

- Investigation into the cost and operation of Southern African desalination and water Reuse plants Volume 1 (Overview of desalination and water reuse) (**Report No. TT 636/15**)
- Investigation into the cost and operation of Southern African desalination and water reuse plants Volume 2 (Current status of desalination and water reuse in southern Africa) (**Report No. TT 637/15)**
- Investigation into the cost and operation of Southern African desalination and water reuse plants Volume 3 (Best practices and cost and operation of desalination and water reuse plants) (**Report No. TT 638/15**)

Water reclamation for drinking purposes

But while recycling of wastewater effluent and advanced treatment for industrial purposes are often cheaper alternatives than using the normal potable water supply, water reclamation for drinking purposes is considerably more expensive. Australia's much lauded Western Corridor Recycled Water Scheme, which collected effluent from six wastewater treatment plants in Brisbane and processed it at three advanced water treatment plants to augment the city's main drinking water reservoir, was mothballed in August 2013 because it was costing so much to operate. Authorised by the previous state government during a drought, the scheme was labelled an 'unmitigated disaster' by the then Water Minister. It is costing Queensland Aus$150 million per year in interest repayments. The cost of installing new pipelines and pumps is just one of the many factors to take into account when considering the implementation of direct or indirect potable reuse systems. Another is the quality of the feed water, because this will determine whether the more advanced treatment technologies are required, resulting in higher capital and operating costs.

In a recently completed WRC-funded project, a decision-support model aimed at assisting municipalities and water boards to evaluate, compare and select appropriate reuse systems was developed. Since cost is inevitably one of the most important selection criteria, a costing model called REUSECOST was developed in addition to the main REUSEDSM.

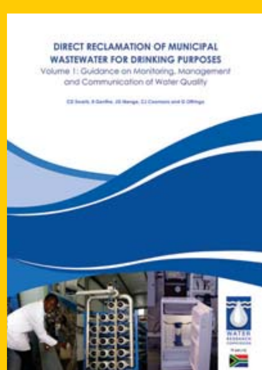
Potable reuse plants employing reverse osmosis as a treatment method have high energy costs, because the process relies on high-pressure pumping to overcome osmotic pressure. The Beaufort West DPR plant uses reverse osmosis as part of a multiple-barrier approach that also incorporates rapid sand filtration, ultrafiltration, UV-hydrogen peroxide and final chlorination. Reverse osmosis also pushes up costs because the highly concentrated brine produced as a by-product is difficult to dispose of. "If the plant is near the coast it can be discharged into the sea, but there are environmental impacts associated with that," says Swartz, who headed up the project. "If it's inland the options are very limited – it needs to be contained in evaporation ponds that are lined and have a large surface area. It's quite expensive, so that has a big impact on the capital cost of the plant."

Chris Swartz

The water reclamation plant in Beaufort West.

"At Beaufort West there were some extra ponds available at the wastewater treatment works, and fortunately the volumes are reasonably low, but for a bigger plant the cost can be a problem." The membranes needed for reverse osmosis are also expensive, although prices are coming down all the time as the technology is more widely used. The Beaufort West DPR plant includes a pretreatment stage to reduce the loading on the membranes and hence limit the fouling rate, which helps ensure that the membranes last longer before needing costly cleaning or replacement. But if there are so many negatives associated with reverse osmosis, why use it? The New Goreangab Reclamation Plant in Windhoek – commissioned in 2002 to replace the world's first, but less sophisticated, DPR plant that began operating in 1968 – certainly manages without it, and its capacity is ten times that of the Beaufort West plant. It just employs more 'treatment barriers' to bring the water to potable quality, including a number of ozonation and chemical dosing steps, dissolved air flotation, biological and granulated activated carbon filters, ultrafiltration and chlorination.

The advantages of using reverse osmosis in potable reuse plants are that pathogens, dissolved salts and some dissolved organics can be removed using less chemicals and labour (since the process is fully automated) on a smaller footprint of land. Reverse osmosis is also believed to be more effective in removing so-called contaminants of emerging concern (CECs). These include chemical compounds from pesticides, flame retardants, plasticisers, pharmaceuticals and personal care products.



Water reclamation guidelines and tools from the WRC:

- Islamic jurisprudence and conditions for acceptability of reclamation of wastewater for potable use by Muslim users (**Report No. 2360/1/15**)
- Monitoring management and communication of water quality in the direct reclamation of municipal wastewater for drinking purposes (**Report No. TT 641/15**)
- Decision-support model for the selection and costing of direct potable reuse systems from municipal wastewater (**Report No. 2119/1/14**)

Empowering local communities through water quality monitoring

Another WRC project has resulted in the development of guidelines for water quality monitoring, management and communication for direct potable water reuse in South Africa.

The main aim of this project was to empower local communities by providing guidance on the health-based targets, water quality monitoring, and communication of water quality data for direct potable water reuse in order to ensure successful implementation and long-term sustainability of such projects. The resultant guideline document outlines recommended terminology, water quality monitoring programmes (from catchment to final water), health-based water quality targets, water quality analysis information (laboratories and associated costs), as well as communication programmes and incident management protocols. The proposed water quality targets for reclaimed water are more stringent than the current SANS 241 standard.

Public perceptions and community acceptance of direct re-use of treated wastewater remain a challenge to direct re-use. The WRC launched a programme on the monitoring, management and communication of water quality and public acceptance in the direct reclamation of municipal wastewater for drinking purposes.

"Water reclamation is well recognised as an alternative to conventional water supply strategies," says Dr Kalebaila, "However, its wide implementation in South Africa needs to be fast-tracked by building the required technical capacity in the water sector, and providing clear institutional leadership and financial incentives towards water recycling, reclamation and reuse. In addition to these specific factors, there is a need to educate, raise awareness and involve the public in water reuse decision-making, in order to change their perceptions and circumvent challenges with recycled water acceptance."

Indeed, the 'yuck factor' – consumer resistance to drinking what was once domestic wastewater – is the major challenge to overcome. But implementing a comprehensive monitoring programme, effectively communicating the results, and raising awareness about the benefits of water reclamation can go a long way towards building the public's trust in water service providers and allaying fears about health risks.

The promise of groundwater

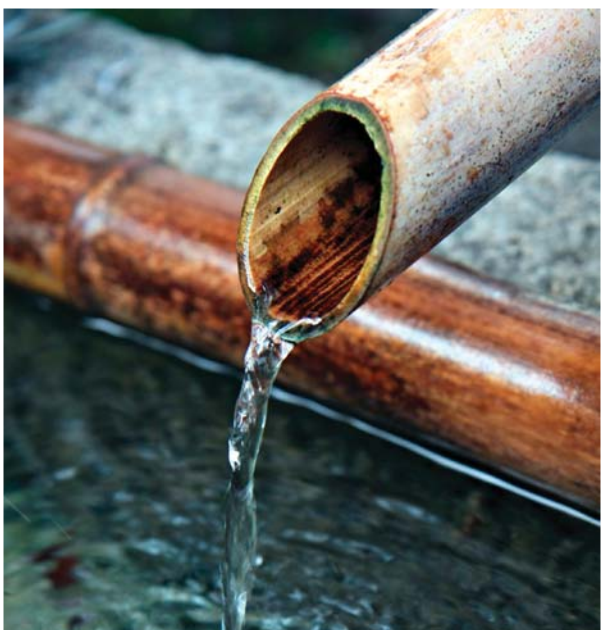
With opportunities of surface water development increasingly scarce in South Africa, groundwater will and needs to play a bigger role in meeting the country's growing water requirements. Groundwater is a significant source and has been instrumental in South Africa jumping from just little over 60% of population having access to safe water in 1994 to 95% today. The majority of these supplies (50% to 90% of communities served, depending on province) have been served from groundwater sources.

Although only 15% of the country's total water consumption is obtained from groundwater, very often those communities dependent upon it have no other viable sources of supply. This is true for some urban and many rural communities in South Africa. Groundwater has moved from an ignored resource to within the top three options for many areas and even in South Africa's towns and cities, it is becoming increasingly important. Around 22% of towns use groundwater as a sole source while 34% use groundwater in combination with surface water.

As South Africans we often underestimate groundwater – in fact about two-thirds of South Africans rely on groundwater for their domestic needs. The big metros of Tshwane and Johannesburg use groundwater for part of their water requirements and the city of Mahikeng is 100% reliant on groundwater, sourced from dolomite aquifers to the east.

Other cities such as Port Elizabeth and Cape Town are currently investigating its potential. Atlantis, Beaufort West, De Aar, Jamestown, Victoria West and several other towns rely mainly on groundwater. Although most large-volume water users now rely on surface water, the majority of small water supplies, which are critical to livelihoods, health and dignity, depend on groundwater.

Considering its potential, groundwater in South Africa is underutilised and often neglected – it offers a substantial source of unallocated water, albeit one that is distributed over a large area. Groundwater is a "proximal resource" – although yields from individual boreholes in South Africa are often modest, groundwater is distributed much more evenly across the country compared with surface water, making it often suitable for small-scale water supplies in rural areas and for smaller municipalities. The total volume of available, renewable groundwater in South Africa is estimated to be about 7 500 million cubic metres per year, even in a dry year, and we currently use less than half of this. In contrast, the assured yield of our surface water resources is about 12 000 million cubic metres per year – but most of this is already allocated.



You can watch the importance of groundwater to the city of Tshwane here.

About 15% of the country's total water consumption is obtained from groundwater.

Few people are aware that large South African cities, such as Pretoria, are also partly supplied by groundwater.

Back to top

The lead times for developing groundwater resources are far shorter than typically found in big surface water development projects, which allows for delivery of the benefits far sooner. There is also scope for substantial cost savings in developing local decentralised groundwater-based schemes, instead of big regional surface water schemes with major pipelines conveying water from distant impoundments.

The WRC invests generously in groundwater research to better understand this important yet still somewhat poorly understood and managed resource.

> *"About 9% of the WRC's total research investment over the last two decades has been in groundwater research. Greater use of groundwater sources does indeed hold great promise for accelerating sustainable access to improved water services and augmenting supply in many parts of the country."*
>
> *– Dr Shafick Adams, WRC Executive Manager: Water-linked Ecosystems*

Groundwater's huge potential in South Africa, particularly for poor and rural communities, is still being unlocked. The resource also has important functions in improving food security, maintaining ecosystems, and insuring us against drought and climate change. Improved scientific understanding and management is necessary to further unlock groundwater's benefits.

Study reiterates importance of a scientific approach

A WRC study has examined the reliability or sustainability of groundwater-based domestic water supplies, and concluded that the issue of O&M is the single biggest factor in ensuring long-term success.

Normally the responsibility of the municipal water services provider, or its appointed professional services provider, O&M is often underfunded or overlooked altogether. Better O&M not only ensures much higher levels of reliability and continuity of water supply, it has been proven to actually save money in the long term. A study carried out in 2012 by researchers in the United States found that a 3- to 5-fold increase in net value is realised with the implementation of an O&M programme for groundwater supplies in rural areas. Groundwater cannot usually be seen in the same way as a dam or river, and many misconceptions about the resource still persist, such as that groundwater flows in "underground rivers", that it is mysterious and unreliable, or that water diviners are needed to locate it. In fact, groundwater can be understood and managed in much the same way as other natural resources but this does require specific techniques and expertise.

Advice to municipal managers:

- Misconceptions about the physical resource are often amplified by poor choices of technology (e.g. unsuitable pumps) and a lack of appropriate O&M
- A qualified hydrogeologist should be involved with planning of any groundwater schemes intended for domestic use – even where the resource is easy to find and the quantities needed are small, there are many additional issues that need expert assistance
- A professional approach to groundwater supply installation, including appropriate O&M recommendations, will save resources in the long term
- The plan for ongoing O&M must be financially and logistically sustainable
- The O&M plan also benefits from professional groundwater advice, since the choice of technology can be matched not only to the existing resource but also to the envisaged O&M regime

O&M costs for surface water supplies and groundwater supplies in rural South Africa were broadly the same over the life of the assets.

Costing of groundwater schemes must realistically estimate the costs of O&M, and if necessary set those against the costs of neglecting O&M, leading to premature replacement of assets. Mechanisms for the monitoring of asset management (including O&M of water supply systems) at local government level should be supported.

The WRC study argues that neither absolute shortage of water nor shortage of funds is the cause of domestic water supply backlogs in South Africa, and that adequate and professional O&M of water supply systems (including groundwater) is in fact the key to sustainable water supplies.

There is a danger that failures to adequately operate and maintain groundwater supplies in South Africa will result in the resource itself being characterised as unreliable or undesirable, and that more expensive options such as desalination or long pipelines to bring surface water will be chosen instead.

Alternatively, domestic water supply failures will be characterised in terms of the "discourse of shortage" – South Africa is a dry country, and therefore it is no surprise that water supplies fail or are inadequate. Both of these outcomes have already happened in parts of South Africa. There is an urgent need to shift away from a narrow focus on technical hydrogeological factors to a wider appreciation of the varied strands related to O&M that really determine whether domestic water supplies from groundwater are reliable or not. We need to move away from the discourse of shortage, and focus on the local-level institutions and mechanisms for O&M.

Correctly maintained, groundwater schemes have been found to be just as reliable as surface water schemes in the same area.

Groundwater governance, protecting our hidden treasure

Today, in terms of the National Water Act, South Africa's groundwater is recognised as a common asset, whose ownership is vested in the state and which is subject to all the stipulations of the Act. Groundwater has now been included in a variety of policies, strategies and regulations, and is recognised as a crucial link in the integrated water resource management chain. Groundwater is increasingly recognised as a strategic water resource. It plays a pivotal role in ensuring both water security and extension of access to safe water. At the current utilisation rate of less than 50% in South Africa and even less in Sub-Saharan Africa, groundwater holds large promise as a 'new' water resource.

"In terms of volumes it represents a very small portion of the overall water supplied, but in terms of the national objective of development and the elimination of poverty and inequality, it represents major progress," explains Dr Adams.

While it now has a strategic importance – groundwater's role, occurrence and behaviour is not yet properly understood. The WRC is investing in rectifying this situation. The research focus is on understanding the catchment processes and land-use activities that influence the quality and quantity of our water resources. In addition we have further challenges to the integrity and quality of groundwater with the threats from anthropological activity that, in some cases, pose a major threat to aquifer quality e.g. acid mine water and further potential threats such as shale gas exploration through hydraulic fracturing. An important part of the solution is the appropriate groundwater governance model(s). The WRC has recently participated in the Sub-Saharan Africa diagnostic as part of a larger global project in this domain.

"While our aquifers have faithfully supplied us with water for hundreds of years, we have not always appreciated their value. It is now vital that groundwater protection and management features strongly in national and regional policy, planning and management agendas to overcome its past neglect and lay a foundation for its increasingly important role in ensuring national water security."

– Water and Sanitation Minister Nomvula Mokonyane

The state of groundwater resources and the health of the aquifers that supply human uses of groundwater are closely linked to the state of groundwater governance – the local arrangement that directly impacts groundwater use and aquifer pollution.

A very important function of groundwater is maintaining ecosystems and 'environmental goods and services'. Without groundwater baseflow, many rivers would only flow after heavy rain. Springs, wetlands, pans and many lakes – and the associated plants and animals- are also dependent on groundwater. This is area that has not received enough attention in the past, particularly in South Africa, although researchers are now catching up and recognising links to the "green economy" and associated opportunities envisaged for the future.

Trends in groundwater governance

The recently concluded Regional Diagnosis for the Sub-Saharan Africa Region on groundwater governance, part of an international project, namely ***Groundwater Governance – A Global Framework for Action (2011-2014)***, highlights important recommendations for the improved management of the region's groundwater resources. The intention is to identify and promote best practices in groundwater governance as a way to

Back to top

achieve the sustainable management of this resource. An integral part of the project has been regional consultation to acquire first-hand knowledge of regional issues from local groundwater experts. The WRC has been involved in the sub-Saharan African regional consultation process along with other South African organisations. This regional consultation has identified several principles that can improve the way in which groundwater is governed.

Groundwater's unseen and little understood functioning within the hydrological environment, as well as its common property resource nature continue to contribute to its poor management. While groundwater management is to be institutionalised as part of integrated water resource management (IWRM), which has been adopted as the water governance framework throughout the region, its management performance continues to be hamstrung by many impediments towards a more sustainable utilisation.

The concerns include:

- A serious lack of capacity at national, river basin and local level
- Inadequate resource monitoring and assessment
- Lack of institutional development at the all-important local level
- A general lack of awareness and appreciation of the role of groundwater

Only a systematic, but flexible, long-term process, driven within a multi-stakeholder-agreed framework, can turn groundwater's present poorly utilised and governed situation around. This transformation must lead to a top down facilitation of multiple local actions, thus requiring attention on many implementation levels, in particular, local, aquifer, basin, national and regional levels. The process needs to be knowledge-driven and capable of building widespread community support for courses of action across sectors and administrative jurisdictions. Catchment management organisations should play a major role in making groundwater a fully integrated part of IWRM.

Governance priorities

Systematic groundwater monitoring needs to be implemented in South Africa. This should include the status of the resource in terms of quantity and quality as well as its use by the various economic sectors. Knowledge management should be introduced as ongoing contribution from the groundwater science sector to the water sector. This would include sharing, archiving and effective communication of knowledge products.

Capacity building is a long-term, continuing process and the WRC believes the rollout of an information thrust should be strategically anchored in existing initiatives, e.g. institutional capacity building, local government support and disaster management. Existing bodies and networks, such as the NEPAD Water Centres of Excellence and Africa Groundwater Net, will be a key part of the science structures providing regional support.

Because of its ubiquitous nature and relative ease of local access, there are widely distributed and generally dispersed abstraction points and many stakeholders, who are involved in groundwater development, use, as well as misuse. This complicates the traditional national approaches to resource regulation and requires a very high degree of participative management. It also requires novel approaches to the systematic planning, financing and implementation of hundreds and even thousands of small, locally dispersed groundwater schemes.

The actual management on the ground of hundreds of these small groundwater schemes supplying dispersed communities has emerged as a major new challenge which is just starting to be addressed. The WRC continues to play a science leadership role, harnessing the private and academic sector to address this challenge and help build new capacity into local level groundwater management institutions.

In 2015, the WRC released a report *20 Years of Groundwater Research, Development and Implementation in South Africa 1994-2014*. The authors of the report are Eberhard Braune of the University of the Western Cape, the WRC's Dr Adams and Fanus Fourie of the Department of Water and Sanitation.

Meeting current priorities and future needs

As South Africa puts in place new policies and strategies for growth and jobs, and reinforces its commitment to the poorest in society, there is no doubt that the importance of groundwater will continue to grow. According to the National Development Plan (NDP), by 2030 all South Africans should have access to clean running water in their homes.

Many other development outcomes, including health, education, dignity, and gender equality also rely on clean, safe and reliable water supplies – many of them from groundwater. Better use of our groundwater resources, linked to scientific development and adequate O&M, will help to realise our plans.

The NWA explicitly requires the establishment of a water resources information system and regular monitoring and assessment of resources. A unique feature of South Africa's groundwater occurrence is the predominantly fractured rock environment. Through systematic and increasingly integrated work these systems are now well understood in terms of modes and emplacement, fracture development and hydraulic behaviour.

The systematic countrywide quantification of South Africa's groundwater resources followed a national groundwater mapping programme of the then Department of Water Affairs and Forestry, launched jointly with the WRC in 1992. Its first output was a series of national maps and explanatory documents published in 1995. In parallel, the department published a set of 21 hydrogeological maps covering the country at a scale of 1:500 000.

For Fourie, the latter is a significant highlight for the sector as it was a national attempt to characterise the country's groundwater. This eventually led to the Groundwater Resource Assessment Phase 2 (GRA2) project, the key findings of which were eventually included in the fourth iteration of the ***Surface Water Resources of South Africa***, or WR2005.

The South African groundwater sector is supported by a small, but productive research community, to which the WRC readily contributes. "The WRC has been strategically funding projects to meet both current priorities and future needs. It has a strong groundwater portfolio, even with limited funds available," reports Dr Adams. "At the same time, the WRC has been partnering with the Groundwater Division of the Geological Society of South Africa in creating awareness of the resource and providing training and knowledge sharing platforms."

The current research portfolio speaks to both current and anticipated future issues. For example, the WRC is funding several projects around the issue of unconventional gas mining. The latter projects are designed in such a way that the knowledge gleaned from them can be applied much wider than just the unconventional gas industry. At the local level, where groundwater is mostly used, the Commission is also developing the required tools and capabilities to manage groundwater resources optimally.

Much of this research has found its way through the various stages of policy and strategy formulation into implementation. A sterling example is the ***Artificial Recharge Strategy***. South Africa is the second country in the world to develop such a strategy in addition to all the practical guidelines, tools and information.

Dr Adams has much praise for South Africa's groundwater professionals.

Back to top

"South Africa certainly does not have a skills or capability shortage [in this sector] and most groundwater problems can be solved by local professionals. The challenge we do have is that most of these skills sit within the private sector. This does not necessarily bode well for implementation and enforcement. We have hundreds of local municipalities using groundwater – sometimes as a sole source – but they rarely have groundwater professionals in their employ. This is something that must change and is of great concern, especially if we want to unlock more groundwater for drinking water supplies and economic development."

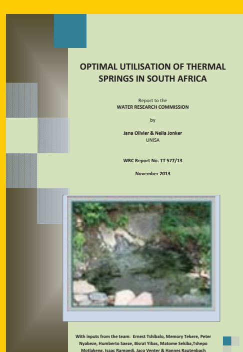
– Dr Shafick Adams, WRC Executive Manager: Water -linked Ecosystems

The failure of some groundwater schemes has caused many municipalities to distrust this resource. However, investigations of failed groundwater supply schemes show that while the blame is often placed on the resource the real cause is almost always either due to failure of infrastructure (e.g. blocked borehole screen) or unsuitable pumping regimes that are related to lack of monitoring.

Groundwater-based systems are typically used in small scattered settlements – which are precisely the areas where the institutional resources capable of supporting reliable delivery of fuel and spares, quick dispatch of spares and ready access to skilled maintenance personnel are least likely to be found. This is an issue which must be addressed going into the future.

There is no doubt that groundwater still has much to offer South Africa. If managed correctly our aquifers can go a long way to ensuring South Africa's water secure future. As Minister Nomvula Mokonyane concludes in the foreword to the WRC book ***20 Years of Groundwater Research***, "All of South Africa's citizens have a role to play in ensuring the legacy of our underground treasure remains for generations to come."

Groundwater will continue to play a bigger role in meeting the country's growing water requirements into the future. In the last three years groundwater developments have grown faster than surface water developments in the context of total water use in South Africa. This is not surprising if you consider that 40% of all groundwater in South Africa has not yet been used or developed.



Groundwater guidelines and tools from the WRC:

- Key interventions to improve local groundwater governance (**Report No. 2238/1/15**)
- An appraisal of diverse factors influencing long-term success of groundwater schemes for domestic supplies, focusing of priority areas in South Africa (**Report No. 2158/1/14**)
- Optimal utilisation of thermal springs in South Africa (**Report No. TT 577/13**)
- Groundwater Resource Directed Measures (2012 Edition) (**Report No. TT 506/12**)

Benchmarking success

Good performance management by water services authorities is crucial to measuring, maintaining, improving and extending municipal water services delivery in South Africa. Better performance measurement is crucial, and municipal services benchmarking can take the sector forward towards achieving this. Effective benchmarking is a key tool to improve service quality, expand service networks and optimise operations.

The Municipal Benchmarking Initiative (MBI), a programme of the WRC and the South African Local Government Association (SALGA) in association with the Institute of Municipal Engineering of South Africa, has made significant strides towards improving water management at the local level since its establishment in 2011.

Benchmarking guides and supports effective performance assessment and continuous performance improvement. Specific progress has been made through the initiative in module and material development; municipal engagement, support and events/forums; development of a database and web tool; and business analysis and intelligence as well as business management and leadership.

The benchmarking focuses on core organisational and operational management parameters that are essential for good, sustainable services delivery, while building awareness within municipalities of why they matter.

Optimising fog water harvesting

The idea of harnessing fog as a source of drinking water has been studied for decades. The first experiments were conducted in 1901, on Table Mountain. Today fog harvesting in low rainfall areas could enhance water security in water-scarce parts of South Africa, particularly in rural communities. To this end, studies undertaken by the WRC since 1995 have established the feasibility of using fog to supplement existing water supplies. The studies focus on the process of designing, erecting and operating fog water collection systems in rural communities.

Fog harvesting is an unconventional source of water that can be used to supplement supplies in high elevation areas i.e. mountainous regions – stretching from Cape Town, along the escarpment of the Western and Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo all the way up to the Soutpansberg in the north.

It is ideal for small communities living in fog-prone areas where other sources are not economically viable. For instance, where the water table is very low and sinking boreholes or piping water from dams would be too expensive. Many such communities are located on hilltops in the Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo where the fog is denser than coastal fog and hence provides more water. It is ideal for use for homes, community centres, schools, clinics, lodges etc. located in misty areas.

Benefits of fog water harvesting:

- Environmentally friendly
- Relatively cost-effective (after initial outlay, only maintenance costs are necessary, fog collection nets last for a number of years and can be replaced at minimal cost)
- Water quality is excellent
- Fog collectors can be erected at places without electricity
- Collectors are usually erected at a high point and thus water drains downwards from the nets by means of gravity and can be piped to storage facilities or homes
- In addition to domestic consumption, the water can be used for small-scale agriculture

Professors Jana Olivier and Johan van Heerden from the Department of Geography, Geoinformatics and Meteorology at the University of Pretoria (UP) have been involved in fog harvesting research for the WRC, together with Prof Hannes Rautenbach, former Director of the UP Water Institute.

One of the WRC's fog harvesting testing sites.

Prof Olivier says the amount of fog water that can be harvested is often related to altitude and sites in high mountains usually deliver the highest yields. However, such places must be accessible so that structures can be erected. "The amount of water harvested can vary considerably over short distances and it is imperative that a suitable site be identified for the erection of a fog water harvesting system. For this reason it is recommended that some research is conducted before costs are incurred for the erection of a large fog water harvesting system," she adds. This will involve the erection of a small pilot collector and weather station. Data should be collected for a period of at least six to nine months. It is strongly recommended that an expert in the field of fog water harvesting be consulted to identify the most suitable sites for the pilot study.

"The amount of water that can be harvested is limited. Maximum yields of around 10 litres per square meter of collecting surface per day were obtained from a site near Woodbush and Hanglip (Makhado) in Limpopo. The size of the system would thus be dependent on the volume required by the community."

– Prof Jana Olivier, Geography, Geoinformatics and Meteorology, UP

Fog water harvesting is variable over time and adequate provision should be made for water storage during times of low fog incidence. However, fog water collection is nevertheless more reliable than rainfall and occurs even during droughts. Ideally it should be implemented together with a rainfall harvesting system to maximise the amount of water that can be collected from alternative sources.

Extracting water from thin air: SA case studies

In 1999, a prototype system under the leadership of Prof Olivier was set up at Tshanowa Junior Primary School, on the Soutpansberg in Limpopo. The only water sources the children had before the erection of the fog nets were a non-perennial spring 2 km away, and a dam, 5 km away.

Permission was obtained from the relevant local and tribal leaders to erect a fog water collection system on vacant land adjacent to the school. Construction commenced in 1999 and local inhabitants were employed to assist. The system intercepts droplets during foggy conditions on large nets. The droplets then trickle towards gutters at the bottom of the net. From there the water is channelled to a filter and eventually to storage tanks. An automatic weather station was also installed to record rainfall, wind speed and wind direction. Within four days of completion, learners and members of the local community were drinking water collected by the fog screen.

The same system was later also set up by Prof Van Heerden at Lepelfontein, a small missionary station about 400 km from Cape Town. Although groundwater here is abundant, it is of such poor quality that it is considered a health risk. The fog screens were installed in 1999, and the overflow from one of the 10 kl tanks is now being used to supplement the water from the desalination plant. At least 80 per cent of the water collected at this site is from fog alone, as the region receives very little rain. While Lepelfontein's water initially showed high levels of sodium – possibly due to the proximity of the ocean and wind-blown spray –

Prof Olivier says that water quality at both sites is good, with no disease-forming organisms present in samples.

"In fact, at Tshanowa, water was rated as Class 0 – ideal quality," she says. "Since the water is used for drinking purposes, quality is tested regularly." She adds that experiments conducted at other high elevation sites around the country have yielded more than 10 per square meter of collecting surface per day. "This shows that in terms of quality and magnitude of yield, fog harvesting could go a long way to alleviating water shortage problems in the fog-prone mountainous regions of the country. "The costs are low, the technology is simple and the source is sustainable for hundreds, even thousands of years."

In 2010, the WRC approved a new project worth R2,4 million to expand fog harvesting in areas where applicable. Two nine-panel systems have been erected at Cabazana near Kokstad in the mountains of the Eastern Cape, and one nine-panel system at Lamberts Bay and Doringbaai on the West Coast. These systems are robust and have withstood numerous storms. Additional research has resulted in a method to grade different fog water system sites – while research dealing with a wide range of features relevant to fog water extraction, including design features and water yield, is ongoing.

An additional element that researchers investigated was whether climate change will have an impact on the frequency of fog and thus on the volume of fog water that can be harvested in the long term.

Researchers from UP have developed two WRC innovations on fog harvesting. The first is a measuring instrument for low and intermittent water flow. Since the volume of fog varies considerably – from hundreds of litres per day to less than one, water collection is also intermittent. A lot of water is collected during wet conditions but it may be that none is collected during sunny periods. Conventional water flow meters invariably fail during these conditions.

Prof Van Heerden has built a low-flow meter (LFM) that can measure such flows. It is based on a tipping bucket principle, but can measure 1 to 1.5 per tip. The LFM is made from perspex to enable easy identification of blockages. The system has been tested under field conditions and has been found to be robust and accurate.

The second innovation, the Whirly, can be used to harvest fog water during near-windless conditions. Previous systems – and those used worldwide – are static nets that rely on fog-bearing winds to blow through the system, depositing tiny fog droplets of water on the screen. These droplets then coalesce, become heavier and trickle downwards. They drip into a gutter attached to the bottom of the screen.

To see how the Whirly works, watch here

The Whirly enables the collection of fog even during near windless conditions.

From there it is channelled to storage tanks. The new invention consists of a vertical shaft with three nets attached. An electronic system has been attached that cause a rotor to turn- thereby rotating the nets when the relative humidity reaches 98% (as it does during foggy conditions). The system switches off when the fog ceases. The batteries that drive the system are charged by means of solar power. This system allows the capture of water during near windless conditions – a situation that often occurs on the West Coast.

The main findings of the research are that numerous factors affect the water harvesting potential of fog water collection systems. Geographic factors appear to be the most important of these, especially altitude, since this influences both the liquid water content of the air and the wind speed.

However, topographic factors such as aspect, steepness of slope and the presence of large topographic obstructions in the vicinity of a site may impact on water harvesting potential. The most suitable sites have high elevation and are located on seaward-facing terrain so as to be exposed to moisture-laden winds. The liquid water content of the air and wind speeds are the most important climatic controls with the latter controlling the volume of moist air passing through the nets. Highest water collection occurs during rain-events. The most optimal net design was found to consist of nine panels arranged in the shape of four equilateral triangles to form the basic nine panel system of 396 m^2. Additional nine panel systems can be linked to this, allowing the expansion of the system to the space available. The individual mesh panels of the system are 11 m x 4 m in size, suspended by three individual 6 mm-diameter galvanized cables anchored to ground with brackets.

The researchers also showed that the type of material used as fog collectors and the design of the system can influence the amount of water collected. Fortunately these can be controlled and water harvesting potential increased using appropriate design and materials. In addition, the quality of the water collected at the two experimental sites was extremely good and found to be suitable for human and animal consumption.

Advice to municipal managers:

- South Africa remains at the forefront of fog water harvesting research and municipalities are urged to consider fog as a viable and affordable alternative source of water for small communities in high elevation areas. Prof Olivier says if such a community is identified and fog harvesting is being considered, then it is very important that they first conduct a pilot study to identify the most suitable sites. If a suitable site is found and the project is viable, then fog water collection should be included formally in the municipality's water provision strategies and general resource development plans.
- It is further recommended that, in view of the environmental benefits and potential (albeit limited) for job creation and rural development, municipalities should be encouraged to take note of this alternative source of water, and implement the technology and knowledge gained from this project, in suitable areas. As with other systems and technologies, it is important, as early as possible, to get community buy-in on such projects.
- Finally, decision-makers need to make adequate plans for the control to access of fog water and for the continuous maintenance of the system.

Recent developments

In 2015, the WRC published a report on optimising fog water harvesting. The report details research that was conducted to at two experimental sites, one in the mountains near Avontuur in the south-eastern Cape and the other located at the Lamberts Bay site mentioned earlier. The objectives were to understand the physical and chemical characteristics of fog, to optimise the fog harvesting process, and from the latter, to develop novel products to measure and capture fog water.

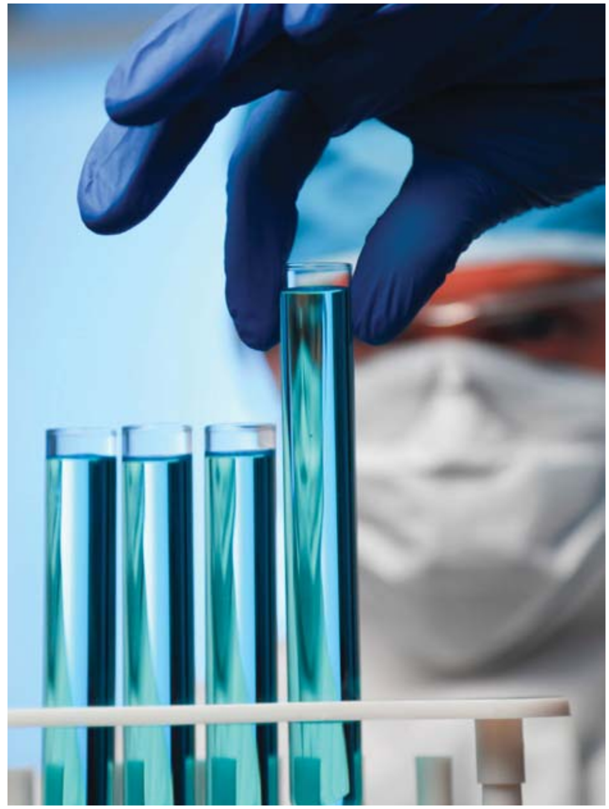
Various designs and materials were tested for their efficacy; problems related to construction of the fog water collection systems that were encountered during previous projects were solved; chemical analyses of the water were conducted to determine portability of the water; the impact of the systems on the environmental determined; and predictions made of the effect of climate change on fog water harvesting potential given specific climate change scenarios.

A delegation from the KwaZulu-Natal Provincial Government has had discussions with the fog researchers and has subsequently visited the experimental site at Avontuur in the Western Cape. Swakopmund, on the coast of Namibia, enjoys a cool climate – in striking contrast to the hot inland deserts – brought about by the Benguela current flowing out of the Antarctic. A side-effect of this geography is that the town experiences persistent periods of coastal fog. A group of Namibian architects have decided to make the most of this and have designed a green building for the Namibian Ministry of Mines and Energy that features an entire wall composed of a fog net. The building features many renewable energy technologies and an entire boundary wall is dedicated to water collection through fog harvesting.

The fog harvesting boundary wall can be seen on the far side of the courtyard.

Integrated water safety planning

Past and recent studies in South Africa have shown that it is apparent that for a significant proportion of municipalities, sustained provision of service and quality are under threat due to failing infrastructure. The Department of Water Affairs and Sanitation reported that there has been significant improvement



in terms of water quality monitoring within Water Service Authorities, however there still needs to be improvement until all Water Services Authorities are monitoring as per current South African National Standard (SANS) 241 water quality requirements.

In order to take proper action, the existing situation has to be analysed and required corrective measures must be identified and implemented.

A previous WRC project aimed to establish a methodology to identify and manage the risks of water services infrastructure and the means by which Water Services Institutions (WSIs) are better able to identify and manage these through use of Water Safety Planning.

The Water Safety Plan tool developed through this study is a desktop electronic-based tool that requires detailed knowledge of the water-supply system. Some

Back to top

of the required information is available within the municipality, whereas other information can only be obtained via site visits. Site visits are therefore an essential part of the process and should be conducted prior to using the tool.

Water Safety Planning is a systematic process that aims to consistently ensure acceptable drinking water quality that does not exceed the numerical limits in the SANS 241 water quality requirements. The process entails implementing an integrated water quality management plan, which includes a risk assessment and risk management approach from catchment to point of delivery.

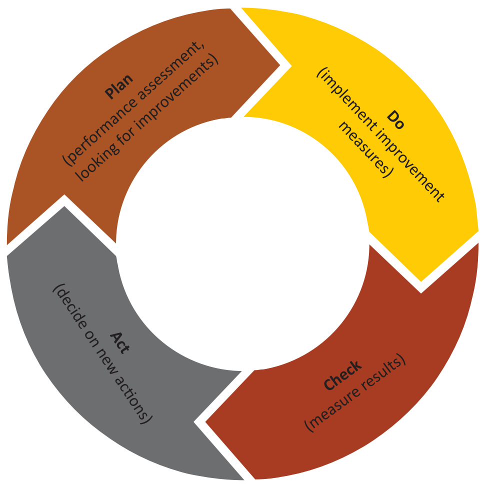
Waterborne disease remains a major health concern around the world. Ensuring the safety of drinking water is dependent upon a comprehensive risk assessment based on sound science and a risk management approach that encompasses all steps in water supply from catchment to consumer.

The process needs to identify systems by which these measures are implemented and monitored. Management plans describing actions taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes, should be included.

Key components of Water Safety Planning include:

- **System assessment** – determine whether the supply system can deliver safe water, and is meeting SANS 241 targets.
- **Identifying control measures** – conduct a risk assessment to collectively control identified risks and hazardous events and ensure that SANS 241 targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance is rapidly detected in a timely manner.
- **Management plans and risk management** – to develop plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes.

The Water Safety Planning process assists the user in developing a water safety plan, which is a guiding plan with respect to managing, avoiding, minimising/reducing chances of contamination in the water supply system. The process requires development of the plan, implementation of the plan, review of performance and amendment or modification to the plan to ensure that it remains relevant.



The WRC's Water Safety Plan tool should also be used in conjunction with the current SANS 241 water quality requirements (i.e. link current SANS 241 determinants to identified risks). This is explained further in the guide. The tool is also available on the WRC website: www.wrc.org.za

The tool assists in developing an integrated water safety plan and assists with the implementation thereof, e.g. taking required actions, implementing corrective actions, as well as developing and implementing management and communication procedures.

Advice to municipal managers (shade/box)

- Water safety planning goes beyond simply adhering

to the Department of Water and Sanitation's Blue Drop and Green Drop programmes
- Planning must be integrated
- Undertake ongoing risk management in order to identify and manage risks
- Address the issue of poor management of functions such as drinking water quality, water use efficiency and O&M, Water & Wastewater Treatment and customer care, among other
- Water safety plans are not static documents, they have to be reviewed and updated on a regular basis
- Water safety planning success is being hampered by a lack of stakeholder involvement

Unathi Jack of Emanti Management – who is a water engineer with a chemical engineering background – helped design and develop the WRC's electronic Water Safety Plan Tool says one of the biggest challenges that municipalities face is insufficient implementation due to a lack of resources. This includes a lack of both people and finance.

Nevertheless, since the launch of the Water Safety Plan Tool, progress has been made.

The purpose of the WRC water safety planning tools is to highlight key steps to be considered when conducting water safety planning and to provide step-by-step guidance as to how to develop and implement a water safety plan. The tools also allow the user to manage and rate the identified risks, as well as check the status of implementation of the plan.

A recent report by the WRC outlines the results of a survey that was conducted among urban South Africans to gauge how they perceive their water quality and related service delivery. Included in the survey's recommendations is a suggestion that municipalities' Water Safety Plans should take the drivers of **risk perceptions** into consideration when emergency plans are developed.

The provision and supply of water of adequate quality and quantity for economic and public health purposes remain continuous challenges. Water is a finite resource and, specifically in the context of South Africa, is becoming incrementally scarce. Managing water use and the waste released to the water environment is thus of paramount importance to ensure the sustainability of the resource and the activities relying on it.

"Implementation of water safety plans is now the focus, rather than the development of plans. Water services institutions are now demonstrating how they are implementing and allocating resources for their water safety plans."

– Unathi Jack, Emanti Management

Water safety planning tools and guidelines from the WRC
- Wastewater risk abatement plan (W2RAP) template (**Report No. TT 624/14**)
- Guidelines on using the web-enabled and supportive spreadsheet-based wastewater Risk Abatement Planning (W2RAP) tools (**Report No. TT 622/14**)
- Guidelines on using the refined and translated web-enabled Water Safety Plan Tool (2013 version) (**Report No. TT 581/13**)

Back to top

02

Solving the sanitation challenge

By improving how we deal with human waste, we can save lives, improve child health, and ensure greater dignity, privacy, and personal safety, particularly for women and girls. Better sanitation also contributes to economic development, delivering social and economic benefits through increased productivity, reduced healthcare costs, and prevention of illness, disability, and early death.

Solving the sanitation challenge in South Africa requires innovations that are deployable on a large scale. Innovation is especially needed in densely populated areas, where people are only capturing and storing their waste, with no sustainable way to handle it once their on-site storage—such as a septic tank or latrine pit—fills up.

Ground breaking improvements in toilet design, pit emptying, and sludge treatment, as well as new ways to reuse waste, can help local government and their partners meet the enormous challenge of providing quality public sanitation services.

This chapter reminds the municipal managers and local government decision makers of South Africa to:

- Steer away from unsustainable linear design approaches to sanitation delivery, such as full waterborne or on-site systems
- Proactively and effectively roll out proven technological sanitation innovations that allow for appropriate and sustainable solutions
- Follow an integrated approach to sanitation services that considers finance, people, institutions and technologies
- Plan and budget well for the medium to long term maintenance of sanitation, even for more affordable solutions such as on-site sanitation

The provision of sanitation is a key development intervention – without it, ill-health dominates a life without dignity. Despite its importance, achieving real gains in sanitation coverage in South Africa has been slow. Many households are still at risk of service failure and/or are experiencing service delivery breakdowns. Add to this the far-too-large percentage of informal settlements that have no services at all, or the majority of households in informal settlements making use of interim services, and we have a serious sanitation provision challenge.

The CSIR sanitation demonstration centre, to which the WRC contributed funding, allows municipal officials and councillors view a range of on-site and off-site sanitation options.

The full range of technical options for providing adequate basic sanitation is still not widely known nor are the characteristics of the different options well understood. In particular, there is little appreciation of the long-term financial, environmental and institutional implications of operating and maintaining the various sanitation systems. As a result, in many cases communities and local governments are choosing technical options that, in the long-term, are unaffordable and/or unsustainable, most particularly, the implementation of water-intensive sanitation technologies in water-scarce regions of the country.

The Water Research Commission (WRC) aims to provide technological sanitation innovations that allow for appropriate and sustainable solutions to the country's sanitation challenge. The sustainability of sanitation services relates to finance, people, institutions and technologies. The current linear design approaches to sanitation delivery used across the world, either in the form of full waterborne or current on-site systems, are simply not sustainable.

"Research has shown the failure of sanitation infrastructure investment due to poor consultation; understanding of needs of those to be serviced; ineffective operation and maintenance; and lack of technological alternatives. Through innovation, we can shift the paradigm in which we serve our towns and cities towards more responsible use of our water, energy and nutrients while achieving the main aim of sanitation: protecting public health and the environment."

– Dr Sudhir Pillay, WRC Research Manager: Sanitation Research Fund for Africa

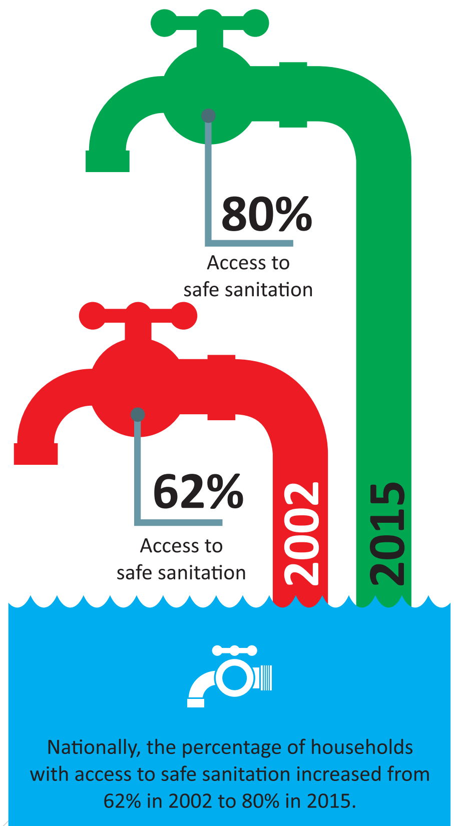
The WRC has been driving an approach in which South African communities and water users are not passive recipients of scientific outcomes, but participate in and guide research and development activities. This is in line with growing calls worldwide for science and research to deliver an actual impact in society.

In this chapter we share some of the exciting new sanitation technologies that have emerged and are on the cusp of bringing about a sea change in the sanitation challenge.

New sanitation technologies

The WRC focuses on the provision of integrated solutions to invariably complex, inter-disciplinary problems, developing technologies and systems that optimise the full wastewater and sanitation services chain in the municipal (domestic) sector. This includes the reticulation, treatment and management of the residues. The challenge is to implement fitting solutions for a particular application that will remain functional throughout the intended lifespan of the installed infrastructure. This includes the responsible management of the wastewater sludge and faecal sludge that is generated. The need for innovative technologies and solutions is recognised as we prepare for the future – achieving more stringent effluent discharge standards, developing acceptable non-waterborne sewerage solutions, reliable treatment of ever-increasing high-strength domestic wastewater, and informing future policy.

The challenge of providing safe and acceptable sanitation to all households and schools in South Africa continues to be a priority of Government. It is believed that new pour flush and low flush sanitation technologies, developed and practically demonstrated in WRC projects could assist in addressing this challenge.



While ventilated improved pit (VIP) latrines have been recommended as the minimum level of sanitation service and technology by the Government, this is often found unacceptable by communities who aspire to waterborne sewerage as the symbol of equality. Recent studies by the WRC have highlighted the challenges associated with emptying of VIPs, and the safe disposal of sludge. Many pits ultimately have to be manually emptied – a job that is not only messy and unpleasant, but also dangerous as sludge typically contains a range of infectious human pathogens.

There is the possibility of improving VIPs by looking at upsizing them. Most state built VIPs are rather small (typically about 1.1 m long by 0.8 m wide). Experts believe it's time to look at upsizing to 1 m by 1.2 m or even 1.2 m by 1.2 m, so that the structure can also be used as a wash room.

However, the ideal is to look at alternatives. A number of WRC funded projects investigating more affordable and more sustainable alternatives have delivered some innovative and effective products.

Innovative new microflush toilet

One of the exciting recent innovations is the WRC developed Arumloo – a microflush toilet capable of flushing on **less than a litre of water**. Cast in ceramic, the vortex shape and altered P-Trap design is efficient, hygienic and elegant.

The so-called Arumloo uses biomimicry in its design. The form and function of the toilet is inspired by the optimum vortex shape of the indigenous Arum lily. The clean form of the toilet removes the need for a rim, making it easier to clean and more hygienic. Water is discharged from a single point at the back of the pan and then flows in a vortex spiral around the bowl. The two-stage flush enables the user to select an appropriate mode of flushing.

Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies. The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul.

The sloped entry and long radius bend enables waste to be flushed with minimum effort. The inverted egg profile of the P-Trap reduces the water seal volume to 0.6 litres without compromising conveyance capacity. A patent has been registered.

Jonny Harris of Isidima Design and Development, the engineering consultancy responsible for designing the Arumloo says the toilet will be provided at an affordable price, but will incorporate good quality components to ensure that the toilets work well, do not break and do not leak. The associated reduction in water consumption when using the Arumloo means that the toilet will pay for itself in less than 2 years due to the saving in water cost.

"When a municipality is specifying toilets for a new project, it is important that they consider the whole life cycle cost of a particular toilet, in other words, will it be prone to blocking and need frequent maintenance, will the cistern break or leak, how much water will it use? We believe that the Arumloo will prove to be a reliable solution to these questions."

– Jonny Harris, Isidima Design and Development

Where water is particularly scarce the low flush volume of the Arumloo presents the option to flush on greywater, thereby helping to manage greywater discharge and minimise the extra water demand that might otherwise be required for a flush toilet programme. The low flush volume also means that the toilet can be connected to a variety of downstream options and can be a convenient alternative to VIP toilets. The toilet can discharge to an offset leach pit, a biodigestor, or to a simple decentralised wastewater treatment system.

The Arumloo will be manufactured from plastic and ceramic to cater for a broad range of users (private houses, schools, shared toilets).

Not only does this project have the potential to reduce water use in already water scarce areas, but it provides an easily implementable solution for communities without access to sanitation services.

The Arumloo prototype.

To watch a short video on how the Arumloo works, click here.

Community collaboration to help O&M staff?

Harris says one the biggest challenges facing municipalities at this time is the maintenance of sanitation programmes. He believes effective collaboration between the community and the municipal operations and maintenance (O&M) staff is key to reducing the maintenance burden (and cost) to the municipality and improve the level of service provision. He adds that community plumbers could play a key role here with the right support structure.

In the case of informal settlements, the provision of effective sanitation is often hindered by the complexity of service provision within that environment. However, says Harris, “We believe that this could still be done better through the provision of well serviced communal ablution facilities – with a permanent caretaker”. The cost of providing a caretaker and toilet paper is likely to be less than the cost of repairs and clearing blockages from an unsupervised facility. The communal facility could also incorporate showers and other value-added items such as cell phone charging, which could help cover the cost of maintenance.

Where a community only has communal toilets, it is critical to also provide convenient disposal points for organic waste, greywater and night soil which will otherwise be tipped onto the street or result in toilet blockage.

Back to top

On-site flush systems as an alternative

An on-site sanitation option may address the aspirations of many South Africans for a flush toilet while overcoming the logistical challenges involved with standard sewerage systems, and working responsibly within the limits of South Africa's water resources. An on-site flush system using a low volume of water produces sludge with higher moisture content and lower solid waste content than VIP sludge typically contains, enabling it to be removed with standard vacuum technologies. A sanitation system which meets these criteria could interface with a range of beneficial sludge disposal options that do not involve treatment at a standard wastewater treatment works.

Pour-flush and low-flush sanitation systems bridge the gap between on-site dry sanitation and full waterborne sanitation sustainably. Using a small amount of water or greywater (1.0- 2.5 ℓ) to flush, a pour system can terminate in a simple soak away or leach pit. It takes away the need for digging deep pits, and provides greater convenience to users in terms of smells and fly control.

From a gender and child sensitive perspective, this technology means that the latrines can be built closer to the house or building, making it safer and more accessible during the day or night.

Recognising the need for an on-site sanitation option which may address the aspirations for many South Africans for a flush toilet while overcoming the logistical challenges involved with standard sewerage systems, the WRC developed the pour flush sanitation system. The technology also works responsibly within the limits of South Africa's water resources.

Pour-flush sanitation technology consists of the toilet block attached to two leach pits. When one leach pit becomes full, then the pit is switched. The full pit is allowed to dry out normally over a period of two years and then emptied, ready to be used again once the operational pit reaches its capacity.

"Our mantra is 'We build toilets, not latrines'. The challenge in providing services to all households without basic sanitation is not just about finding the right technology to properly suit the logistical requirements. It is also a social challenge related to user preferences. Through innovative approaches we actively pursue ways to meet both needs."

– Dr Sudhir Pillay, WRC Research Manager

Rollout of pour-flush/low-flush sanitation

Pour flush sanitation has been rolled out in a number of municipalities with great success.

Back to top

Stakeholders take a closer look at how the pour-flush toilet works.

Pour-flush toilets just after installation

In previous projects the WRC has developed pour-flush toilet designs that are appropriate for the South African context. Pour-flush toilets are similar to waterborne toilets but use much less water (about a litre of water). Furthermore, they do not need the installation of a sewered network and associated infrastructure which can cost billions of Rand.

The pour-flush pedestals and their derivatives developed through the WRC aimed at bridging the gap between full waterborne systems – where you need up to nine litres to flush into an sewered network – and ventilated improved pit (VIP) latrines – dry toilets which save on water but have do not have same user acceptability. The WRC Pour Flush design and its derivatives can use up to three litres for flushing saving on water but can also be implemented at a competitive price range compared to VIP latrines.

"The pour flush toilet is effective for a number of reasons. It is safer and more sustainable than the VIP. It is very popular and does not require more than 6 or 7 litres per user per day (on average) and this does not have to be potable water. With a single leach pit, it is no more expensive than the VIP, but adding a second leach pit is a good idea for long term sustainability."

– Dave Still of Partners in Development, consulting engineers and project managers

Pour-flush toilets were initially piloted on a small-scale in houses in KwaZulu-Natal and the Western Cape, as well as in a number of rural schools. The technology was well received, and feedback from community members using pour-flush sanitation was extremely positive. It is reported that the toilets are working well without blockage, with some communities even expressing a willingness to contribute to the maintenance of their facilities.

Following on the success of the initial trials, funding was received from the Department of Science and Technology to demonstrate the potential of pour flush sanitation on a larger scale. The demonstration took place in two provinces, namely Amathole district municipality in the Eastern Cape, and Amajuba district municipality in KwaZulu-Natal.

This project demonstrated the potential and effectiveness of harnessing local skills and resources in implementing sanitation projects, providing many opportunities to work with partners in the local community, and so maximised job creation.

Back to top

User acceptance

Following construction a field team visited all the sites to evaluate performance and acceptance by users. Several households responded that they were not using the toilet, typically as they were 'waiting for the old toilet to fill up' or 'didn't have a tap'. It is important to note that it is fairly normal for some families not to make use of government sponsored sanitation services that they have not specifically asked for. In the future, it may be advisable to request the beneficiaries to make some contribution, such as the digging of the pits, to confirm that they definitely would like to be included.

More than 90% of households interviewed felt safer with the pour-flush toilet, and were especially happy about the fact that it was safer than pit toilets for small children. In fact, the popular name given to these toilets were 'the safe toilet'. In addition, an overwhelming percentage of users also noted that the toilets were safe, easy-to-clean and 'nice-looking'. In addition, over70% observed that the pour flush toilets 'smell nice'.

"Although an effective and sustainable option, I would not propose that the pour-flush be installed anywhere that people have already have full flush sanitation, as they will perceive it as a downgrade. The pour-flush can be upgraded to a low-flush toilet, but I would let users make that change at their own expense, and I would then insist that they have water meters. More water is used by leaking cisterns than is used for normal flushing, whether a normal flush or a low-flush toilet is used."

– Dave Still, Partners in Development, consulting engineers and project managers

Pour-flush sanitation is thus considered a viable option for municipalities to close the sanitation gap and is a suitable way to bring innovative sanitation solutions to rural communities. It is encouraging to note that Partners in Development, consulting engineers and project managers are now doing demonstration projects in six municipalities in South Africa – Mkhondo and Chief Albert Luthuli in Mpumalanga, Amathole, Joe Gqabi and Chris Hani in the Eastern Cape and !Kheis in the Northern Cape.

Other promising projects include the development of an even more water efficient ***P-Trap*** and the roll-out of demonstrations of Rocla's new Thuthukisa Community Cast precasting system.

Successful applications

The WRC developed pour-flush system was modified and tested to a low-flush system with a cistern. In consultation with eThekwini Water and Sanitation, two schools were then selected to participate in the trial. Sizimesele Primary School is located in rural Molweni in the Hillcrest area and Thandaza High School is located between Hammarsdale and Mpumalanga. Three toilets were placed in each school: one in the boys' block and one in the girls' block.

The provision of new toilet blocks at schools also created an opportunity to educate teachers and learners about the transmission of disease, how it can be prevented through deworming and a change in personal habits, and, ideally, influence and motivate users to make a shift to new behaviours at the same time that they make a shift to a new sanitation system.

Another WRC-funded pilot study was successfully undertaken in the Western Cape to investigate the sustainability of pour-flush toilets in high-density urban and peri-urban settlements. Pour-flush toilets were installed in three communities within the City of Cape Town, Stellenbosch and Theewaterskloof Municipalities. A total of 14 toilets were installed, and are working well.

Feedback from community members has been extremely positive, with all sites being receptive to the technology. Observations to date confirm that the pour flush design is working well without blockage. The success of the technology is further evidenced by the fact that some of the communities have expressed a willingness to contribute to the maintenance of their facilities. In townships such as Klein Begin, the communal pour flush toilets are working and being kept clean despite failure of previous flush toilets due to lack of household servicing. Furthermore, Stellenbosch Municipality is already considering incorporating pour-flush sanitation into their standard specifications for informal settlements.

Pour-flush and low-flush technology is ready for piloting on a larger scale in both residential and institutional contexts.

The particular advantages of these systems make it an appropriate option to be considered for the following contexts:

- Rural or urban schools
- Community or public ablution blocks
- Other institutional contexts
- Homes where householders are seeking an upgrade to an onsite flush system
- Communities where existing sanitation systems have failed or been rejected

The only requirement for the effective functioning of the systems is access to small quantities of water. It is also essential that wherever low-flush systems are installed, pedestals and other parts are made available to local hardware shops and plumbers to ensure that systems can be repaired over time.

To watch a video on the acceptance of pour flush technology, click here.

Off-grid systems that produce valuable by-products

The WRC is also in the process of rolling out next-generation toilets and demonstration technologies developed as part of the Sanitation Research Fund for Africa (SRFA).

Launched in 2014 by the WRC and the Bill and Melinda Gates Foundation, the fund was established to stimulate competency and capacity in the area of sanitation in the African region, in order to support the development and scaling up of sanitation solutions. The fund is being led and executed by the WRC. The initiative aims to stimulate local capacity to provide local solutions to challenges and encourages partnering with local government.

The demonstration technologies developed as part of the SRFA and currently being rolled out include totally off-grid systems that treat human waste at the source into potentially valuable by-products such as fertiliser and biochar. These systems move away from transport-and-treat and drop-and-store sanitation models currently in existence and open opportunities for operations and maintenance to be linked to servicing and collection of value-add by-products.

Back to top

Towards sustainable free basic sanitation for informal settlements

Manual pit emptying can be quite challenging.

A woman washes clothes at a communal toilet block in eThekwini.

Provision and maintenance of sanitation services in urban informal settlements still constitutes a very significant challenge for South African local authorities. One reason is that such settlements are difficult to service because of geo-physical, economic, legal and socio-political challenges.

Sanitation provision in many such settlements consequently tends to take the form of toilets in concrete cubicles along the edge of a settlement, clustered throughout a settlement between residents' houses, sometimes alongside a standpipe, or in ablution blocks offering other facilities alongside toilets. In such cases, fewer toilets are provided than there are domestic dwellings in the settlement – meaning that, other than the occasional case where a household has commandeered a toilet by locking it, households either have to share toilets, or they have to rely on public toilets that are accessible to all, including other settlement residents, visitors and passers-by.

Such circumstances have often led to filthy and dysfunctional toilets, which, according to users, is not their responsibility to clean or maintain.

A WRC-funded study undertaken by the University of Cape Town looked at the South Africa's current urban sanitation crisis, identified constraints and proposed ways to overcome them. The authors conclude that people using and/or providing toilets in informal settlements had diverse expectations of what constitutes a free basic sanitation service, and of what should comprise the associated responsibilities. Each party also experienced fear due to imagined and real health and safety risks, which affected their access to toilets in informal settlements.

Key findings:

- 'Public' janitorial services are generally more effective than 'communal' cleaning and maintenance systems
- In addition, despite being under-resourced, municipalities seemed better equipped than residents to manage cleaning services
- Municipal authorities and contracted workers can be held legally accountable for delegated

Back to top

operational tasks, whereas resident users cannot be legally bound to fulfil operation and maintenance responsibilities
- There is a disjuncture between national government's top-down policies that dictate municipal practice, and the on-the-ground reality in informal settlements
- Sanitation policy at both national and local government levels needs to be rethought to meet ordinary users' and municipal implementers' needs

The study also concluded that the effective implementation of free basic sanitation is impeded by a lack of guidance from national policymakers from providing informal settlement services, as well as by municipal incapacity and inflexible institutional processes. Residents' alternative sanitation practices often neglect the beneficial outcomes of measures established for provision of free basic services.

In establishing janitorial services, municipalities such as Overstrand and City of Cape Town, but also eThekwini, have set a precedent in rendering local government responsible for all operation and maintenance tasks and costs incurred when providing publicly accessible free basic sanitation facilities in informal settlements.

That these publicly funded and supported janitorial services have been created and have proven to be needed also demonstrates that, in assuming that users would maintain and clean facilities provided in their residential areas, national authorities have misjudged the extent that such users would reasonably contribute to operation and maintenance tasks. It also indicates that they have overlooked critical aspects of local government's administrative and financial needs, particularly in the former's conceptualisation of the free basic services' sanitation component.

What the relatively recent institutionalisation of janitorial services for municipal toilets in informal settlements shows is that municipal officials are having to adapt their local minimum free basic sanitation policies – which were largely informed by national government's standards – in ways that were not originally considered by policymakers.

All too often, what policymakers and designers of sanitation services imagine is appropriate – in terms of technology and resource availability – is considered socially and culturally unacceptable and inappropriate by users and those tasked with caring for such facilities.

There is a diversity of everyday sanitation experience in urban informal settlements, information about which is presently not being drawn up on by those who design sanitation facilities and their operation and maintenance procedures. It is suggested that such design processes should take cognisance of those diverse experiences and should become iterative processes that take serious account of all stakeholder concerns and are flexible enough to accommodate changing demands over even short periods of time.
All too often, what policymakers and designers of sanitation services imagine is appropriate – in terms of technology and resource availability – is considered socially and culturally unacceptable and inappropriate by users and those tasked with caring for such facilities.

Recommendations:
- Lived experiences should be used to inform informal settlement servicing
- Constructive, bottom-up informal settlement sanitation initiatives go beyond patronising residents through social engineering
- Municipalities should engage the community (users) and service providers in regular and well facilitated dialogue at all levels
- Implementation of a functional free basic sanitation service in informal settlements requires establishment of municipal janitorial services
- Local governments require national government funding for capital infrastructure, off-site O&M costs and for on-site O&M costs, building and maintaining human resource capacity for creating local site-specific plans, and for local government officials to administer their free basic services operations

The report concludes that it is misplaced to depend exclusively on technical professionals, with engineering or urban planning background, to achieve the goals of providing sustainable sanitation services in informal settlements. While such skills are undoubtedly necessary the dominance of such personnel seems to have resulted in repeated adoption of technology driven approaches. It is argued that trained social facilitators and policy analysts are needed to work hand-in-hand with technical personnel in South Africa's urban infrastructure sector.

Establishing a free basic public services standard

The there is a lack of practical guidance for providing public toilets in dense urban informal settlements. This gap suggests an implicit neglect of or lack of concern with the sanitation challenges within urban contexts. Moreover, as various municipal officials complained, focus on providing for rural dwellings resulted in its basing national standards of household sanitation provision of sparsely-populated rural contexts.

It is crucial now that national government develops and adopts a free basic public service definition for toilets shared by multiple households in urban informal settlements.

A consequent recommendation is that a bottom-up perspective – based on the experience of those who use, clean and manage free basic toilets on a day-to-day basis – should inform the conceptualisation of this new standard, and that it not be written as if in stone but rather that it is flexible enough to permit a wide range of local adaptations.

Given the kinds of digital technology now available for dissemination of such standards, and of policy, a further recommendation is that all such standards and policy be not only recorded digitally for ease of access, but also that the institutions that produce such standards be required frequently to update them in light of experience from around the country.

Sanitation-related guidelines and tools from the WRC:

- A Framework for Sanitation Governance in South African Municipalities **(Report No. TT 629/15)**
- Community-led total sanitation in South Africa **(Report No. TT 626/15)**
- Community led total sanitation in South Africa: Lessons and recommendations (**Report No. 2088/1/14)**
- Entrenchment of pit latrine and wastewater sludges – An investigation of costs, benefits, risks and rewards (**Report No. 2097/1/14**)
- Amending Free Basic sanitation policies and practices: Lessons from informal settlement janitorial programmes (**Report No.2120/1/14**)
- Towards the effective use of sanitation subsidies: A guide **(Report No. TT 592/14)**
- Developing a low flush latrine for application in public schools **(Report No. 2198/1/13)**

03

Reducing water loss in municipal water supply systems

While South Africa's non-revenue water levels compare well internationally, as a water scarce country we need to do all we can to prevent the unnecessary loss of water. Decision makers, managers and implementers of water supply in municipalities are encouraged to get a grip on the key issues in reducing water losses in municipal water supply systems in order to deal with water losses in cost effective and uncomplicated ways.

What is non-revenue water?
Non-revenue water refers to all the water that is lost through physical leakage or commercial losses (meter under-registration, billing errors, theft etc.) as well as any unbilled authorised consumption (fire-fighting, mains flushing etc.).

Saving water and water demand management (WDM) in general can be quite confusing to a municipality wishing to embark on some form of water loss reduction activities. A lot of work has taken place in South African and internationally to support water loss reduction in order to save money. While immediate savings cannot usually be expected, municipalities are encouraged to plan for a five (or preferably ten) year programme. The savings may be difficult to achieve, and possibly more difficult to sustain, but one thing is certain – if no action is taken to reduce water losses, the losses will continue to increase.

This chapter reminds the municipal managers and local government decision makers of South Africa to:

- Water loss reduction is crucial at this time as many parts of South Africa are experiencing drought conditions which can persist for several years
- Water losses in some municipalities are very high and there is great scope for reducing these losses given the political will
- Water losses can be thought of as a "resource", as they often represent the cheapest source of water for a municipality
- Moving to intermittent supply as a means of reducing water losses or reducing water use is not an appropriate measure and should only be considered as a last resort and not a measure of first choice
- Address the obvious, identify the issues and understand the network – until the basic issues have been addressed there is little benefit in introducing some of the more expensive and sophisticated measures
- Use the guidelines and reports of the WRC – the ***compendium of water conservation and water demand management interventions and measures in municipalities*** provides practical and useful advice based on best practice
- Use the WRC's low-cost software solutions that can assist you the water suppliers in understanding and managing your non-revenue water
- Address the issue of non-payment in domestic metering and billing
- Identify suitable pipe repair and replacement approaches and implement
- Ensure cooperation between the technical and financial departments
- Creative solutions such as community awareness and education ensure buy in – it is not possible to manage water without knowing what people need, how they understand their water resource, and what role they have in managing it

The Second National Water Resources Strategy (NWRS2) identified the implementation of water use efficiency, conservation and water demand management as a core strategy to ensure sufficient water to meet South Africa's needs going into the future. This, 'non-negotiable performance area', it says, must be implemented immediately in all water use sectors, specifically municipalities. "In view of water scarcity, it is essential that such water losses must be curtailed, especially in terms of the need to provide for the growing water demands of new socio-economic development," the strategy points out.

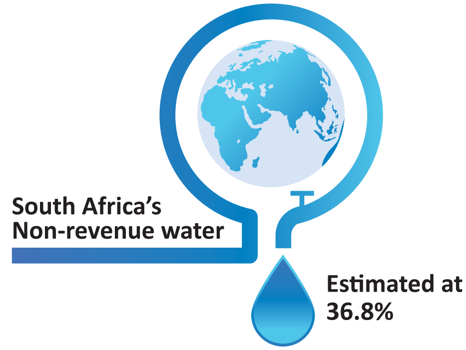
Status of non-revenue water in South Africa

In order to improve the situation, the water sector must have a clear indication of the status of non-revenue water in South African municipalities, more specifically what the actual water losses are and how they are split between physical leakage (real losses) and commercial losses (apparent losses). It is for this reason that the WRC, in collaboration with the Department of Water and Sanitation, launched an investigation into the state of non-revenue water in South Africa, which was published in 2012. The 2012 assessment involved water balance information from 132 (of a possible 237 at the time) municipalities.

"Many of the country's municipalities are realising the value of undertaking a proper and reliable water balance. Unfortunately several municipalities were found to be operating in crisis mode. More than half of municipalities were unable to provide any data on non-revenue water, and many lacked even the most basic bulk meter readings, which means they do not know how much water they are consuming let alone how much is being lost through physical leakage or commercial losses. This was of great concern to the project team."

– Ronnie McKenzie, study project leader and MD of WRP Consulting Engineers

The data gathered during the study covered municipal water supply to more than 40 million residents representing over 75% of the total volume of municipal water supply in South Africa. The results indicate that the current level of non-revenue water estimated for the country as a whole is 36.8%, with an average indicating physical leakage of 6.8. The non-revenue water figure for South Africa is similar to the estimated world average of 36.6%. It is considered high in comparison to developed countries but low in comparison to developing countries.



While South Africa compares well to the world average we do not compare well to other developed water scarce countries, such as Australia, whose non-revenue water levels are often less than 10%. "There is still much scope for improvement. As a water scarce country we cannot afford to waste so much water," adds McKenzie.

The study also indicates that South Africa still has a relatively high per capita water use (around 273 litres per person per day) which is an indication that the average citizen still does not realise the scarcity of this resource.

The overall non-revenue water for South Africa is estimated at 1 580 million m^3/annum, which is approximately one third of the total water supplied. Conservatively, this represents an annual loss of over R7 billion based on an average bulk water tariff of approximately R5/m^3.

Prof Kobus van Zyl of the University of Cape Town, who has worked on many WRC projects, stresses the importance of convincing consumers to use water more

Back to top

wisely, since some parts of South Africa are already experiencing severe water shortages. "Municipalities depend on water sales for a significant part of their income, and thus one of their most important functions is to develop a robust information management system to calculate and print accurate water bills for consumers to understand their water usage data."

Prof Van Zyl is strident in his comments about the key message he would like to convey to the municipal decision-makers and technical managers at this time.

"We need a qualified, professional, stable and apolitical technical workforce looking after our infrastructure. Our people and economy need good infrastructure to be healthy and thrive. This is true irrespective of which political party or group of councillors are the current political leaders of the municipality. Technical staff should be held accountable for the quality of service provision, not anything else (e.g. political allegiance willingness to compromise)."

– Prof Kobus van Zyl, UCT

The major challenges facing municipalities at this time, according to Prof Van Zyl are political interference (inevitably disrupting infrastructure management for short-term gain), corruption (inevitably funded through not serving the poor) and a lack of qualified and experienced technical staff serving municipalities.

In terms of the latest developments, McKenzie says DWS has just completed its 2016 annual operating analyses which are carried out at the end of each wet season (end April or May normally) in order to assess the status of the bulk water resources countrywide. These analyses are based on sophisticated computer simulation models that help predict the risk of water supply shortages over the next five to ten years, based on the analyses of over 1 000 plausible scenarios. Using these techniques, the DWS is able to assess the risk of shortages in the various water resource systems around the country. After establishing the possible risks, the DWS will take decisions on the need to implement water restrictions in the various systems which, if implemented, will quickly filter down to the individual municipalities.

In the case of the Vaal River System which is the largest water system in the country (by far), the overall storage between the various main storage reservoirs stood at around 60% at the end of April 2016 which is a significant drop from a year earlier. Although this storage is sufficient to support the demands for several years, DWS is looking at the potential risks up to five years ahead which is a sensible and responsible approach.

McKenzie adds that DWS operates the system on the basis of trying to identify drought events at an early stage into the droughts, so that limited restrictions can be implemented as early as possible in order to avoid having to implement very serious restrictions later on. Whether or not restrictions will be imposed in 2016 has yet to be decided, however, the reservoir storages are close to the point at which restrictions are normally considered.

Mckenzie says some of the major challenges in the sector at the moment include the fact that some municipalities are not spending sufficient budget on operation and maintenance (O&M) of their water supply infrastructure. If it is assumed that the water reticulation is designed for a 50-year lifespan, then 2% of the network should be replaced annually which requires 2% of the estimated capital cost of replacing the whole network.

"Some of the large metros for example have a water supply infrastructure with a replacement value in excess of R10 billion, in which case R200 million for maintenance is needed annually," he adds Replacing pipes is often the most expensive intervention that can be considered and pipes should only be replaced when they are clearly beyond repair. Other interventions such as pipe repair or pressure management will often be more appropriate as they can extend the useful life of the system at a fraction of the cost of pipe replacement. Selective pipe replacement is therefore often a more cost effective approach to reducing water losses rather than some form of "blanket pipe replacement".

"Municipalities should always repair reported leaks within 48 hours of them being reported, as this is one of the most cost effective water loss reduction actions that can be taken. In some municipalities, the response time of 48 hours is not being achieved due to re-allocation of the maintenance/repair budgets. This is a short sighted approach and the repair of reported leaks should always be a top priority in every municipality."

– Ronnie McKenzie, WRP Consulting Engineers

Finally, with the latest technology in flow and pressure monitoring, McKenzie says municipalities should try to monitor as many of their key supplies and demands as possible. It is only through the use of such monitoring, that system leaks and operational problems can be picked up quickly and rectified. The cost of such monitoring and with internet access has dropped dramatically in the past few years while the cost of water has increased significantly, making the technology very cost effective. In simplistic terms, if the Minimum Night Flow of an area is under control, then the leakage is under control and so actively monitoring the Minimum Night Flow is a simple yet effective approach to managing leakage.

In times of shortage when restrictions are introduced by a municipality, the restrictions are often not publicised properly and are rarely enforced. If restrictions are to be successful in reducing the water use, they must be implemented properly and backed up with proper enforcement. Without some form of enforcement and political backing, the water use will not decrease and it will eventually be necessary to introduce very harsh and potentially damaging water restrictions.

Responding to the challenges

It is heartening to note that the issue of non-revenue water – ignored by many municipalities in the past – is now receiving increasing attention at municipal level. All of the large metros and most of the large cities and towns are now monitoring their water use and trying to establish a proper and reliable water balance in line with international recommendations. Progress in this regard is certainly being made and both the DWS and the WRC are creating awareness and encouraging proper water auditing at the municipal level.

Non-revenue water levels per municipal category
The 2012 investigation into the state of non-revenue water in South Africa found that category A municipalities (metros) achieved non-revenue water levels of around 34,3% compared to the water losses of 72,5% (on average) achieved by B4 (small) municipalities. Non-revenue water levels of mid-sized municipalities range from 30,5% to 41,3% on average.

In many municipalities throughout South Africa there is a dedicated effort to provide safe potable water to outlying communities that have previously had no access to a formal water supply indicating a shift in focus from improving efficiency to the installation of new pipelines and supplies in line with government policy. Such measures can inadvertently lead to an increase in the levels of non-revenue water, particularly in percentage terms, when, in fact, significant improvements are often being made.

There is no single WDM intervention that will always provide the best savings at the least cost. Every water supply system is unique, and will have its own specific problems. In reality, reducing water losses is not complicated. But it does require a dedicated and methodical approach if real and sustainable savings are to be achieved.

The interventions must be selected to address the most serious problems to have a real chance of success. The key to success is to decide which interventions are the most appropriate to a specific area and how best to implement them.

The most common mistake is to believe that water loss reduction is achieved only through leak detection and repair. In such cases, large budgets are often used to search for unreported leaks using the latest hi-tech and expensive equipment. If the water losses are due to inaccurate metering or even background leakage, the leak detection activities will yield little or no results. Before starting any major water loss reduction intervention it is therefore necessary to spend some time and effort to examine the problems and to identify the root causes of the water losses. Once the real problem issues have been identified, the solutions are often obvious, and the way forward becomes clear.

Unfortunately, despite the progress being made, it seems that South Africa's non-revenue water levels remained stagnant at best during the first decade of the 2000s. "It appears that the overall level of non-revenue water throughout South Africa is not reducing, with indications that it may in fact be increasing," says Mckenzie. "Unfortunately, it is currently not clear whether the slight increase is due to more reliable data from a larger data set or due to a real increase in the non-revenue water. We require another year or two of reliable data to establish if the trend is really increasing or not."

The 2012 investigation confirmed that non-revenue water remains the product of many factors, including poor planning, limited financial resources to implement the necessary programmes, poor infrastructure asset maintenance and lack of capacity. However, several additional key problem areas were also identified.

Implementing successful water loss reduction:

- **Address the obvious** – Council officials will debate at length over a budget allocation of a few thousand Rand when a road leak may run unattended for weeks or months, and can run up a bill of hundreds of thousands of Rand. Until the basic issues have been addressed, there is little benefit in introducing some of the more expensive and sophisticated measures such as pre-paid metering.
- **Identify the issues** – Understand the basic layout of the network, repair visible leaks, implement pressure management, sectorise (cut big areas into smaller, more manageable areas that allow the water manager to identify problem areas) and log and analyse the pressures and flows in these sectors. Consider bulk management and bulk consumer meters. Address the issue of non-payment in domestic metering and billing. Identify suitable pipe repair and replacement approaches and implement. Ensure cooperation between the technical and financial departments.**Community awareness and education** – This is perhaps the most important aspect of ensuring successful water loss programmes. Too often, well designed and implemented technical interventions fail because the community they serve are not included in the planning and implementation process, and they do not "buy into" the project.

One of the greatest inhibitors to the introduction of successful water demand management in many municipalities is the proper auditing and documentation of the various interventions. If the various interventions are properly ring-fenced and audited, the results will speak for themselves and the funding needed to implement new projects will easily be approved. Such auditing will also deter many companies from undertaken non-revenue water reduction projects under the misconception that they are an easy source of income and can be completed by anyone with a spade and a shovel."

Another important aspect of non-revenue water reduction is effective billing and metering. Revenue recovery is essential in order for municipalities to provide a sustainable good quality service and as such should be decisively implemented across the country where practicable, the report points out.

Ultimately, local authorities have a mandate to generate revenue and to operate in a self-sustaining manner and this can only be achieved through proper monitoring of water-supply systems in the form of metering and creating a culture of payment for services to enable sound maintenance activities and a high standard of consumer service. Furthermore, the importance of proper planning, budgeting and maintenance of water infrastructure cannot be over-emphasised and is essential in reducing water losses and averting a potential water crisis.

Prof Van Zyl adds that there is no silver bullet to addressing water loss and poor water demand management. He says the science and art of infrastructure management is learned over time through investigations and trial-and-error and are then established through systems. The most promising new technology has to first prove itself before being implemented widely, and then should make a difference in a slow, deliberate and sustainable way.

An overlooked 'source' of water

Non-revenue water can potentially have a significant impact on water supply, and in some areas high levels of lost water have already forced the commissioning of new transfer schemes. According to experts, non-revenue water should be seen as a source of water as it actually represents a significant opportunity for municipalities to save water. The added bonus is that many of the interventions needed to reduce non-revenue water can be implemented at relatively modest cost compared to those of a new water-supply project.

Moreover, in areas that typically experience high levels of unemployment, the water demand management measures can create useful and long-term employment. In many cases, such interventions not only save water but can also create significant energy savings, particularly in systems where water is pumped at some point in the supply cycle.

WRC tools and guidelines assisting municipalities with water demand management and non-revenue water:

- Guidelines for reducing water losses in South African municipalities **(Report No. TT 595/14)**
- The state of non-revenue water in South Africa (**Report No. TT 522/12**)
- Compendium of water conservation and water demand management interventions and measures at the municipal level in South Africa (**Report No. TT 519/12**)
- Introduction to water meter management (**Report No. TT 490/11**)

04

Driving alternative energy solutions with conduit hydropower

That there are challenges in South Africa to meet the country's electricity demand is no secret. The development of alternative energy solutions is therefore an urgent requirement. Conduit hydropower is one such solution that can help address the country's critical energy shortages. It harnesses forward thinking, innovative technology that generates renewable energy, fosters the strategic management of natural resources and helps combat climate change.

Although the concept of conduit hydropower is not new, its full potential is only being recognised now because technologies have improved over the last couple of decades, allowing for the development of previously unfeasible sites. This, coupled with the recent emphasis on the renewable energy sector, as well as the high electricity price escalations make it more viable than ever before.

The largest conduit hydropower installation in South African has been officially launched at Bloemwater's Brandkop reservoir, in the Free State. The collaborative partnership between the Water Research Commission (WRC), University of Pretoria (UP), and sector partners such as the City of Tshwane, Bloemwater and eThekwini, has led to the successful development and demonstration of conduit hydropower in South Africa.

What is conduit hydropower?
'Conduit hydropower' refers to a method of using the mechanical energy of water as part of the water delivery system through man-made conduits to generate electricity. Generally, the conduits comprise existing water pipelines, such as those in bulk water supply and distribution systems.

Conduit hydropower is the extraction of available energy from existing water supply and distribution systems. The technology involves using excess energy in pressurised conduits to produce hydroelectric power. The Bloemwater installation involves the Caledon-Bloemfontein potable water supply system, which supplies the majority of the water demand in Bloemfontein. The water is supplied to the Brandkop reservoir, where the water utility's head office is located. The conduit hydropower technology involves tapping excess energy through pressure control valves before the water is discharged into the reservoir. In this manner, 96 kilowatts an hour of energy are generated – enough to power Bloemwater's head office.

The widespread roll-out of this technology could have an enormous impact on both the water and energy sectors. South Africa's 284 municipalities and several water supply utilities and mines that own and operate gravity water supply distribution systems could be considered for small, micro and pico-scale hydropower installations. Already, several potential conduit hydropower sites have been identified, investigated or constructed.

The four categories of hydropower

1. **Pico** – max 20 kWh, can supply a few domestic dwellings
2. **Micro** – 20 to 100 kWh, can supply a small community with commercial or manufacturing enterprises
3. **Mini** – 100 to 1 000 kWh, can supply 1 000 suburban households with reliable electricity
4. **Small** – 1 to 10 MW, synchronised with the municipal or national grid frequency

Hydropower systems are currently operational at Rand Water, Mossel Bay, Lepelle Water, Amatola Water, Bloemwater, eThekwini Municipality, City of Tshwane, Johannesburg Water, City of Cape Town, Eskom, and Midvaal Local Municipality, amounting to a total generation capacity of 38.6 megawatts. This has a monetary generating value of R220 million per annum.

These encouraging developments are as a result of the foresight of the WRC, which a few years ago, after it became clear that South Africa is facing critical energy shortages, enlisted Prof Fanie van Vuuren and Marco van Dijk of the University of Pretoria's Department of Civil Engineering to consider and test the feasibility of ways of harnessing potential energy in water distribution systems.

Further estimates point to an additional 59.8 megawatts being available in just the larger metropolitan areas alone (monetary generating value of R340 million per annum), and not taking into account the potential contribution from all of the mines.

"Various WRC research studies have now shown that conduit hydropower is viable and that it is technically possible to utilise existing water supply and distribution system to generate clean renewable electricity. A number of conduit hydropower plants have been constructed, showcasing the working of this technology."

– Marco van Dijk, water resource engineering specialist, UP

Van Dijk says that as of 2016 there are encouraging new developments in that municipalities and water utilities are adding conduit hydropower development costs to their budgets for the coming year to start implementing at various sites – as early as the next financial year.

This chapter reminds the municipal managers and local government decision makers of South Africa to:

- Utilise their resources (infrastructure) better by investigating the potential opportunities in untapped renewable energy
- Identify and develop the demonstrated potential of extracting the available energy from existing and newly installed water supply and distribution systems
- Follow a systematic approach assessing hydropower potential in a distribution network to ensure that all relevant factors are considered (a WRC tool is available for this purpose)
- Optimise the operation of their water infrastructure by implementing alternative energy sources such as conduit hydropower to reduce their electricity consumption and improve reliability of supply
- Monitor their water infrastructure functioning i.e. "To measure is to know"

Some municipalities are not sure of flows and pressures throughout their water supply and distribution systems and thus being able to have an alternative energy supply such as a pico conduit hydropower turbine installation, which could generate electricity at a specific site, would be very useful. As Lord Kelvin (1883) said: "When you can measure what you are speaking about, and express it in numbers, you know something about it".

Harnessing potential energy in water distribution systems

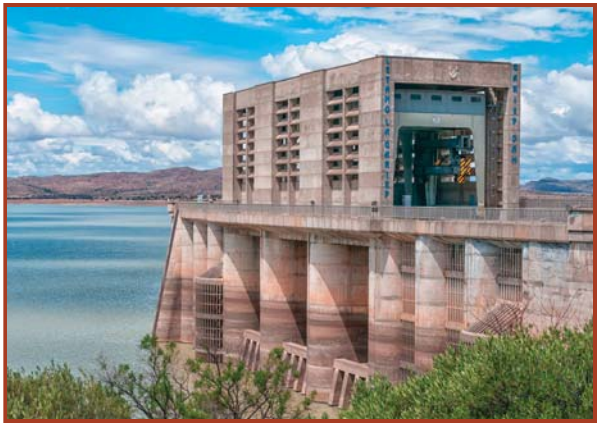
Although the conditions in South Africa do not completely lend themselves to large-scale hydroelectricity plants such as the one at Cahora Bassa, the energy and pressure of water in existing water distribution systems can be harvested to power small plants or perform specific smaller tasks, such as providing power for telemetry, security and flow measurements. Similar to energy saving, every bit of power that does not have to come from the grid will alleviate pressure on the infrastructure and resources needed to generate electricity.

As a result of its semi-arid climate South Africa has a vast network of large dams and water distribution

Back to top

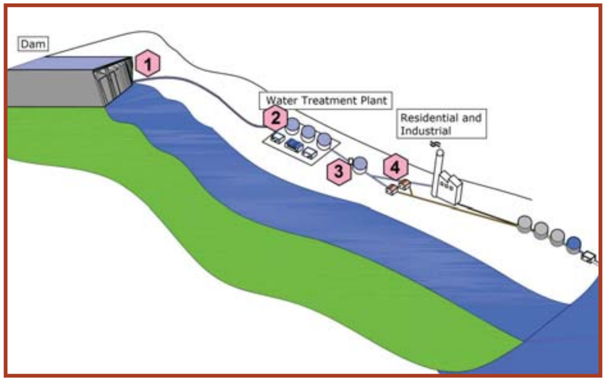
infrastructure, some of which could be further harnessed for power generation.

According to the South African National Committee on Large Dams, the total storage capacity of the major reservoirs (totalling 252 large dams) currently amounts to about 33 900 million m^3 – equal to about 70% of the mean annual runoff from the land surface of the country. In addition, some 3 500 dams with a height greater than 5 m have been registered with the Department of Water and Sanitation (DWS). Excluding pumped storage facilities, only a handful of the country's dams are equipped with hydropower generation plants, the largest being the Gariep hydropower plant situated on the Orange River, which has an operational capacity of 360 MW.



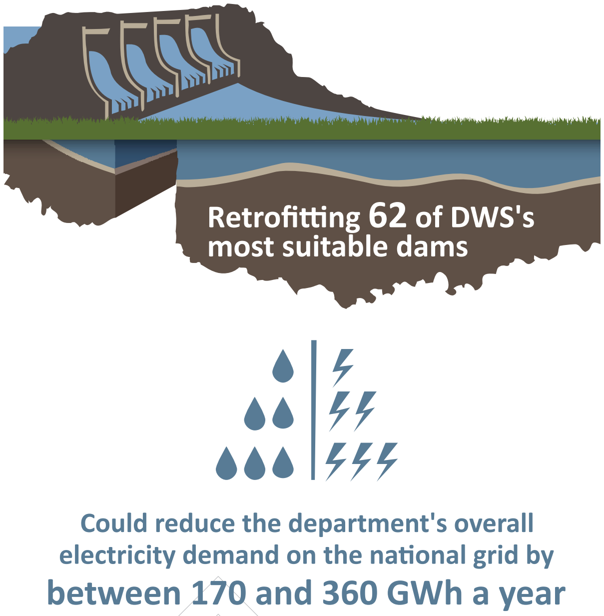
The Gariep is one of the few dams in South Africa equipped with a hydropower facility.

An earlier WRC-funded study report, authored by Prof Fanie van Vuuren and Marco van Dijk of UP, illustrated how this infrastructure can be retrofitted to provide valuable additional electricity – albeit at a small scale (known as low head hydropower). As stated in the report, unconventional hydropower development can take place in both rural and urban areas of South Africa. The report discusses the low head energy potential of eight areas: dam releases, run-of-river schemes, irrigation canals, weirs, urban areas (pipelines and stormwater systems), industrial outflows, wastewater treatment plants, and oceans and tidal lagoons.



Potential energy- generation locations in the water supply and distribution system.

The potential annual energy output from identified available capacity hidden in existing water infrastructure could produce between 35 and 115 GWh. This is potentially significant given that 100 kW is equivalent to the average energy demand of 65 households in South Africa.



Just by retrofitting 62 of DWS's most suitable dams could reduce the department's overall electricity demand on the national grid by between 170 and 360 GWh a year, the report states. By implementing low head hydropower technology at 20 suitable municipal dams municipal electricity demand could be reduced by between 35 and 50 GWh a year.

"This potential is not necessarily substantial with regard to the contribution to the Eskom national grid, but is significant with regard to the potential reduction in electricity demand on the overloaded national power generation capacity," the authors say. "In addition to helping Eskom to deliver coal-fired electricity to other needy users, implementing determined low-head hydropower will create various job opportunities in the manufacturing and operation/maintenance economic sectors."

For water supply utilities (including water user associations and municipalities) introducing enhanced in-house energy generation will alleviate, to some extent, dependency on the already stressed national grid and keep their energy costs down.

History of small hydropower in South Africa ironically, small hydropower has played a historically significant role in the implementation of electricity projects in South Africa, with the first project being a 300 kW station on Table Mountain in 1895. Early large dams, such as Hartbeespoort Dam, in North West province, and Clanwilliam Dam, in the Western Cape, were originally constructed with hydropower stations.

Unfortunately, many of these small-scale hydropower stations have fallen into disrepair. In many cases they were replaced by Eskom's (at the time) cheap and reliable electricity. In other cases, it was because of poor maintenance and general neglect. The time has now come to revive this technology. Prof Van Vuuren and Van Dijk believe South Africa's possesses the technological know-how to do so.

Case studies

In 2010, three pilot plants were identified to showcase the application: Pierre van Ryneveld in the City of Tshwane Metropolitan Municipality, the flagship Brandkop at Bloemwater, and the Newlands 2 reservoir in the eThekwini Municipality. The City of Tshwane Metropolitan Municipality, eThekwini Municipality and Bloemwater were all collaborating organisations and supplied expertise and funding.

The Pierre van Ryneveld conduit hydropower pilot plant was installed on top of a reservoir in the Country Lane Estate, using a cross-flow turbine and synchronous generator. The generated power is used for lighting, alarm systems and communication. Three extensive field tests indicated that there was sufficient pressure and flow to generate power at the picolevel. The estate uses the power generated for the above purposes. The results of this project indicated that a pico-hydropower plant may be viable for on-site utilisation. Experiencing the advantages of the project at a practical level, the homeowners' association of Country Lane Estate indicated that it would also like to utilise the power for street lighting. On 29 November 2011, the 15 kW Pierre van Ryneveld Conduit Hydropower Plant was launched, and all the site lighting was switched from the conventional municipal grid to the hydropower generated on site.

The Bloemwater project, whose launch on 31 March 2015 was mentioned at the beginning of this chapter, was the flagship pilot plant of this research study. It was constructed at the Brandkop Reservoir in Bloemfontein where Bloemwater's head office is located. A microhydropower plant was constructed at ground level this time. A 96 kW Banki cross-flow turbine, imported from Italy, was used. The turbine has sufficient capacity to supply the entire Bloemwater head office with clean renewable energy, using its own water supply infrastructure. The estimated cost of building the Bloemwater plant was R3 075 000. When Bloemwater's spending on municipal electricity accounts is considered, the project has a payback period of approximately 72 months or six years. This is a relatively short period for a return on this kind of investment. Considering that the installed technology can last for more than 50 years, it is an attractive option.

The conduit hydropower plant at Bloemwater.

The third pilot pico-level hydropower plant – Pelton turbines – was installed at the **Newlands 2 reservoir in Durban**, in the eThekwini Municipality. In the case of this particular project, two 1 kW turbines were installed, a standalone unit supplying the site with electricity, and the second feeding the hydro-generated power into the municipal grid. The estimated cost of the project amounted to R282 000, excluding the person hours of the eThekwini Municipality staff to design and construct the plant.

Following the success of the pilot plants and the launch of the Brandkop plant, several water utilities, municipalities and even Eskom are considering additional conduit hydropower development.

To watch more on the Bloem hydropower installation, click here.

Benefits of low head hydropower:

- It is a renewable energy source with high reliability
- It uses proven technology and has a long life span (50 years or more)
- It can accommodate flexible operation, has high efficiency, and very low operating and maintenance costs
- Preliminary feasibility studies indicate short payback periods, especially when retrofitting onto existing water infrastructure
- Hydropower schemes often have more than one purpose, hydropower through water storage, for example, can assist with flood control and supply water for irrigation or consumption

A number of complexities have also been identified. These include low awareness from the general public and many decision-makers about the advantages that hydropower generation has to offer; lack of skilled small contractors to construct civil and mechanical components; high cost of control system; and the regulatory and legislative aspects which appear 'fuzzy', among others.

It is important to understand the conduit hydropower development process which is different from conventional hydropower development. A decision support system (DSS) that facilitates the development process of a conduit hydropower plant has therefore been made available by the WRC.

The DSS assists in evaluation of the site, providing guidance on the data gathering procedure, describes the feasibility/ economic analysis required, and guides the developer through the turbine selection and detail design aspects. A systematic approach must be followed when assessing hydropower potential in a distribution network to ensure that all relevant factors are considered.

The procedure for determining hydropower potential is illustrated through a series of flow diagrams reflecting the different project phases, while a tool developed in Microsoft Excel (called HydroAID) facilitates calculation of all the factors that need consideration.

Water demand for electricity supply up to 2030

A long-term modelling study, based on historical water consumption data, has been used to forecast the water required to satisfy the country's demand for electricity up to the year 2030. The findings reiterate the need for municipalities to explore the benefits of alternative energy solutions such as conduit hydropower.

South Africa's energy industry, particularly the electricity sector, is currently in a state of flux as a result of social, economic and environmental pressures. The need for more energy while sustaining the society, economy and environment simultaneously, calls for unprecedented efficiency in the management of resources.

Water, being one of the basic yet constrained resources, is a vital component in energy generation. Water is used for a number of processes during power generation, such as operating flow gas desulphurisation devices, ash handling, wastewater treatment and wash water.

"For water supply utilities introducing enhanced in-house energy generation will alleviate, to some extent, dependency on the already stressed national grid and keep their energy costs down. It requires a small capital investment and has a short return on investment period. As long as people use water, renewable electricity can be generated."

– Minister of Water and Sanitation, Nomvula Mokonyane at the launch of the Brandkop reservoir in 2015

The most water is, however, used for cooling the thermos-electric power plants and this has, together with the choice of fuel technology, by far the biggest impact on the overall water supply needed as well as the ecological health of surface water bodies where it is subtracted from.

Though South Africa's electricity generation activities and large industries only account for up to 8% of total water resource use, these activities are located mostly within moderately and severely constrained water management areas. Therefore, water resource management and allocation are necessary to avoid severe water scarcity in water intensive sectors and areas.

This WRC study was thus launched to forecast water usage patterns associated with coal-based electricity generation. The study further assessed scenarios of water usage patterns based on cooling technology and power plant type. Assessed water usage patterns were determined for wet-cooled and dry-cooled power plants. The assessments were based on load type for base load and non-base load power plants.

The study proposed water saving measures within distressed water management areas.
The findings include:

- Eskom's total water requirements expected to increase from roughly 360 gigalitres now to over 370 gigalitres by 2020

Back to top

- Water use consumption of the older return-to-service (RTS) fleet of power stations is most significant, and is set to increase to unsustainable levels by 2020
- RTS fleet should be decommissioned on unit by unit basis as soon as Medupi and Kusile can make up the power shortfall and support the national grid
- Water requirements could be reduced to 320 gigalitres depending on the retirement of the RTS fleet, a reduction of approximately 40 gigalitres of water per annum, which is roughly the amount of water used by one of the larger power stations such as Kriel, Tutuka, Matla or Lethabo
- Medupi and Kusile are expected to consume four to five gigalitres thereby creating a net saving of 35 gigalitres, when the RTS fleet is decommissioned
- This saving could account for almost 15% of the forecasted deficit of 234 gigalitres by 2025

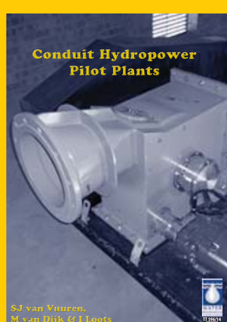
The above findings are based on the forecasted electricity output from the coal power plant fleet of 260 TWh by the year 2035. These forecasts are based on an expected installed capacity of 36 900 MW being operated at a capacity factor of 80%.

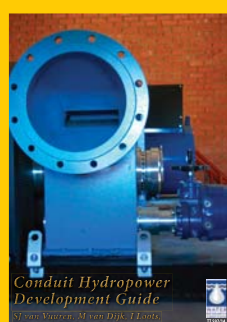
These findings reiterate the importance of exploring alternative energy solutions such as the proven and viable technology of conduit hydropower, which has been found to suit South African conditions. It is worth noting that the average percentage of water utilities' operational cost represented by the cost of energy is no less than 30%.

The results show that management of water resources in the electricity generation sector can result in informed water allocation within water management areas. Based on the completed work, the WRC has launched investigations into water usage patterns in renewable energy technologies. The results of this study will be published in 2016.

There is potential for all forms of hydropower development in South Africa, and although the country has a number of hydroelectric installations, conduit hydropower definitely has a role to play in the overall energy generation and distribution picture of South Africa.

Conduit hydropower has no carbon footprint and can provide electricity relatively inexpensively and easily. A number of requirements that hold for larger and more complex sources of energy will not necessarily have to be met when setting up such a plant.





WRC tools and guidelines for municipalities on introducing hydropower:

- Conduit hydropower pilot plants (**Report No. TT 596/14**)
- Conduit hydropower development guide (**Report No. TT 597/14**)
- Energy generation using low head technologies (**Report No. KV 323/13**)

05

Municipalities and the aquatic environment

Freshwater ecosystems provide a valuable natural resource, with economic, aesthetic, spiritual, cultural and recreational value. Yet the integrity of freshwater ecosystems in South Africa is declining at an alarming rate, largely as a consequence of a variety of challenges that are practical (managing vast areas to maintain connectivity between land and freshwater ecosystems), socio-economic (competition between stakeholders for utilisation of ecosystem services) and institutional (building appropriate governance and co-management mechanisms).

The main objective of the Water Research Commission's (WRC) water-linked ecosystems thrust is the provision of knowledge to enable good environmental governance that supports sustainable utilisation and protection of aquatic ecosystems; and to develop an understanding of the ecological processes underlying the delivery of goods and services from water-linked ecosystems.

This section reminds the municipal managers and local government decision makers of South Africa to:

- Understand the ecological processes underlying the delivery of goods and services
- Sustainably manage, protect and utilise urban and rural aquatic ecosystems
- Embrace and use the WRC's innovative tools and methods to protect local water sources
- Identify and support community research and development initiatives that advance suitable water resource (ecosystem) utilisation
- Facilitate partnerships with communities and business to advance sustainable ecosystem use and development

Sustainable development remains a core principle of all WRC projects and activities. Consistent with the WRC's vision, there is specific focus on sustainable development solutions. This is undertaken by addressing enabling principles of sustainable development, namely, protection of water resources, optimal water use, equity between generations, current equitable access, environmental integration and good governance.

In this chapter we discuss two tools that can be implemented by municipalities to play a valuable role in protecting local water sources.

Alternative technology for stormwater management

Stormwater management in the urban areas of South Africa has and continues to focus predominantly on collecting runoff and channelling it to the nearest watercourse. This means that stormwater drainage currently prioritises quantity (flow) management with little or no emphasis on the preservation of the environment. The result has been a significant impact on the environment through the resulting erosion, siltation and pollution.

An alternative approach is to consider stormwater as part of the urban water cycle, a strategy which is being known as Water Sensitive Urban Design (WSUD) and more broadly in as Water Sensitive Design (WSD); with the stormwater management component being known as Sustainable Drainage Systems (SuDS). WSD is one of the five "lighthouses"or major themes of the WRC.

SuDS attempts to manage surface water drainage systems holistically in line with the ideals of sustainable development. It aims to design for water quantity management, water quality treatment, enhanced amenity, and the maintenance of biodiversity. In so doing many of the negative environmental impacts of stormwater are mitigated and some benefits may in fact be realised.

Advice to municipal managers:

- Consider a range of options to secure water in your city, including stormwater harvesting
- Consider SuDS, which offers an affordable and viable alternative technology for sustainable stormwater management
- SuDS can also help protect or rehabilitate receiving waters in existing and developing communities
- Define your systems, make improvements, and prevent degradation of downstream water bodies
- Regularly assess performance, report results, and schedule maintenance of stormwater systems
- Remember that the large number of impaired rivers in our country emphasises the need to control both the quantity and the quality of urban stormwater runoff

A team led by Prof Neil Armitage at the University of Cape Town (UCT) first developed guidelines for implementing Sustainable Drainage Systems (SuDS) in South Africa. The report ***Alternative Technology for Stormwater Management*** was launched in 2013. The manual highlights potential opportunities for better stormwater management and is relevant to all professionals working with stormwater – and not just engineers. The associated software can be used to assist in the economic analysis of alternative approaches to stormwater management.

In 2014, the WRC launched the second report entitled ***Water Sensitive Urban Design (WSUD) for South Africa: Framework and guidelines***. The second report provides strategic guidance to urban water management decision makers (primarily city managers and other local authority officials) on the use of WSUD in a South African context. It introduces and builds the case for its adoption in a water-scarce country such as ours. It attempts to define what 'water sensitivity' might mean within the South African context – including expanding the definition of 'city' to include a broader range of settlement types – so as to motivate for adopting a context-specific vision for water sensitivity.

WSD in SA

Water Sensitive Design (WSD) South Africa's quest is to transform South African settlements into settlements that mitigate water scarcity, improve water quality, thereby protect ecosystems, through the development of water sensitive urban areas (for all) that are sustainable, resilient and adaptable to change, while simultaneously being a place where people want to live.

Following the success of these projects, it was decided that the best way to make available the latest research findings, tools and guidelines that have been developed is via the internet. This resulted in the launch of a website: http://wsud.co.za

This approach has a number of advantages: it is possible to link references to their sources; it is possible to continuously update material and correct any errors; and it is possible to collect data on new SuDS projects from the professionals involved. The research team also uses the website to showcase projects, share news, events, videos and presentations on SuDS and WSUD. Anyone interested in this field can join the WSUD Community of Practice.

During 2015 the research team held seminars around the country where they presented to municipal managers the benefits of SuDS and WSUD. A seminar series in December 2015 brought together the UCT Urban Water Management research unit, the WRC, City of Johannesburg, City of Tshwane, City of Cape Town, eThekwini Municipality, and SAICE Amathole to discuss ***SuDS and WSUD – implementation, operation and management***.

All presentations from such events are made available on the website.

Why we need water sensitive cities, settlements and developments

The availability of water of acceptable quality is considered by many to be the single greatest and most urgent development constraint facing South Africa. Rapid urbanisation means that 71% of the population will be living in our cities by 2030 – and the population is growing. South Africa therefore needs to look at 'future-proofing' these growing cities.

This means creating resilient (coping capacity), liveable (comfort capacity) and sustainable (carrying capacity) cities. Blue and green corridors are integral elements of the city's drainage infrastructure for flood conveyance. Therefore stormwater has to be managed as a resource and the water-energy-waste nexus enhanced. Multi-functional infrastructure will be hybrid between centralised and decentralised – to meet basic needs and enhance aspirational needs.

> *"Implementing a multi-disciplined approach to urban water management that unites the engineering concept of integrated urban water management, with the planning concept of urban design, creates what has been termed 'water sensitive cities' where the most efficient and effective uses of water are central considerations. WSD integrates the social and physical sciences."*
>
> *– Prof Neil Armitage, urban water management expert, UCT*

The majority of the world's population lives in so-called "developing" countries – many of them living in dire conditions in the slums to be found in most major towns and cities. A particular problem associated with these slums is poor drainage resulting in ongoing contact with contaminated water and flooding. Billions of people around the world live without improved sanitation. While not all sanitation need be water-borne, the need to cater for greywater (domestic wastewater) in addition to stormwater in high density urban areas makes it important that more serious consideration be given to providing adequate drainage.

Prof Armitage says, "Providing sustainable urban drainage in the informal settlements of South Africa depends on adequate numbers of skilled personnel who are able to plan and implement urban drainage in a timeous and holistic manner – coupled with funding needed to pay for the work."

Why water sensitive cities/settlements?

- Water is a finite and vulnerable resource
- Access to water is a basic human right
- Water is a key component in economic development
- 'Waterscapes' make cities more 'liveable' meanwhile
- Water (lots!) is required for food production
- Water is required for energy production
- Water is also essential to sustain the natural environment

South Africa needs to think about its infrastructure in a broader way; be more efficient in the way we use our water and we have to look at alternative supplies: groundwater, rainwater harvesting, stormwater, grey water and wastewater.

Viability of stormwater harvesting

Several South African cities could face dire water shortages in the next seven to ten years and are therefore considering a range of options to secure water, including tapping more groundwater from aquifers, surface water schemes and water reclamation, including – in the case of coastal cities, seawater desalination. However, options like desalination are energy-intensive and could place additional pressure on South Africa's already strained electricity grid.

Stormwater harvesting is one of the most cost-effective ways of getting water. It is competitive with groundwater and the two are often used together.

Prof Armitage says seawater desalination should be considered a last resort at this stage. "Desalination is very expensive and requires an enormous amount of energy. Energy is a problem in South Africa. If the energy comes from coal — which accounts for most electricity in South Africa — the desalination plants will enlarge our already large carbon footprint and contribute to climate change. If the energy comes from nuclear sources, there are safety concerns and problems with the disposal of waste. The energy could come from solar and/or wind, but this would require a system far larger than South Africa's current experience."

> *"It would be far cheaper to desalinate treated sewage effluent or secondary sources of water. He points out that this is already done in several cities such as Windhoek in Namibia and in Singapore, Southeast Asia, and "is perfectly safe if properly managed. Of course, it is not easy to convince the public of this."*
>
> *– Prof Neil Armitage, urban water management expert, UCT*

SuDS attempts to manage surface water drainage systems holistically in line with the ideals of sustainable development. It aims to design for water quantity management, water quality treatment, enhanced amenity, and the maintenance of biodiversity. In so doing many of the negative environmental impacts of stormwater are mitigated and some benefits may in fact be realised.

The Atlantis Water Resource Management Scheme on the dry West Coast is the only example of large-scale operational stormwater harvesting in South Africa. It's been in operation for over 30 years and is an exemplar of wastewater and stormwater reuse through managed aquifer recharge.

The recharge rate is too low to support the town, so all the stormwater from the town is added to the treated domestic effluent from the treatment works and injected into the aquifer upstream.

Planning of residential and industrial areas allowed for separation of high- and low-quality wastewater effluent and stormwater. The industrial effluent is sent to a series of treatment ponds closer to the sea and low-quality water is disposed as recharge near coast which creates a hydraulic barrier.

The Atlantis Water Resource Management Scheme started as an interim solution while a 'conventional' pipeline was developed. During this time, three decades, the town of 65 000 people survived just on groundwater, supplemented by treated and stormwater alone. Yet the uptake of stormwater harvesting (of any quality of water) has been extremely low elsewhere in South Africa.

South African case studies: findings

When UCT embarked upon the WRC-funded, initial research into SuDS in South Africa in 2012, a number of exploratory field trips were undertaken to assess what had been planned and implemented in the country with respect to SuDS. Although the case studies were limited to only three provinces (Western Cape, Gauteng, KwaZulu-Natal), these account for approximately half the population and the majority of the economic activity. They also experience different climatic conditions that roughly represent much of the country. The most promising case studies were selected for further study and reporting.

The wetlands and associated SuDS at Century City in Cape Town were studied in particular detail. The monitoring of these case studies did not include instrumentation or measurements of the quality or quantity outcomes of the systems, except in the case of Century City where monitoring had been undertaken by the landowner association. The study revealed some interesting insights.

Permeable paving is the most commonly implemented SuDS option in South Africa. This is most likely due to its promotion by the Concrete Manufacturers Association. Three case studies from across South Africa were investigated in detail. The Cape Town Grand Parade in the centre of Cape Town, a University of Witwatersrand parking area and the Pietermaritzburg Anglican Cathedral.

Permeable paving systems can manage stormwater without the need to install catchpits and stormwater pipes. Sand, silt and other fine material have a destructive effect on the drainage capacity and detention volume of a permeable paving system however and should be carefully controlled.

Green roofs are vegetated roofs which act as excellent source controls. They are relatively easy to retrofit onto many commercial buildings in high density areas where other SuDS options would be inappropriate. Two interesting retrofit projects in Cape Town (DEADP Green Roof) and eThekwini (Green Roof Pilot Project) have been undertaken in South Africa. The case studies highlighted the fact that people are generally drawn to well vegetated and pleasant environments as provided by green roofs. There is however a need for further research into the selection of plant types for the different regions of South Africa.

SuDS treatment trains increase the resilience of the system. SuDS options should not be isolated but should be connected to form a treatment train. Two new developments in South Africa, Cotswold Downs and Hawaan forest estate, have implemented SuDS treatment trains and present interesting case studies.

The Cotswold Downs Golf Estate near Hillcrest on the outskirts of eThekwini was modelled on SuDS principles from the outset. But the consultants had not initially considered source controls for private properties within the development. The developers then revised and issued a second stormwater management plan focusing specifically on the provision of these type of SuDS.

Hawaan Forest is an upmarket residential development in eThekwini. Rain falling on the estate is initially detained in source controls such as roof gardens and soakaways which ‘polish’ and attenuate it before the runoff is directed over lawn into adjoining vegetated swales. The swales link to fourteen detention ponds distributed around the lower-lying eastern side of the estate and are showcased by an ‘ornamental’ pond at the entrance.

A number of lessons were learnt through these two case studies, including: that a SuDS approach has the potential to enhance the investment potential of a development; but operation and maintenance requires expertise which may be expensive.

Large, integrated SuDS systems need to be carefully considered and monitored. Wetland systems of this magnitude require ongoing maintenance and monitoring.

First conceptualised in 1995, the last decade has seen Century City in Cape Town established as an upmarket development with the largest shopping centre in the Southern Hemisphere and containing Cape Town’s only theme park. Current land use zoning includes commercial and residential uses supported by large corridors of office park buildings. Century City offered one of the most integrated systems to be reviewed, with the longest management history, and thus provided an ideal case study.

This system collects stormwater runoff from Century City and neighbouring Summer Greens developments, and channels it into the adjoining Tygerhof detention pond. The Wingfield outfall, located at the north-eastern end of Century City’s bounds, is the stormwater outfall for the development. This case study revealed that the use of treated sewage effluent to supplement water in the wetland during dry periods needs to be carefully considered and monitored; and that a wetland system of this magnitude requires ongoing maintenance and monitoring.

Conclusions and recommendations for future research

Conventional stormwater management focuses largely on quantity (flow) management by collecting runoff and channelling it to the closest watercourse. This has resulted in the erosion of natural channels and pollution resulting in environmental degradation. SuDS offers an alternative approach through designing for water quantity management, water quality treatment, enhanced amenity, and the maintenance of biodiversity. The approach has been widely adopted overseas, however it was clear from the national workshops that there is still some degree of scepticism as to its effectiveness in South Africa.

During the course of this study several areas for further research were identified, including: inter alia; the need to determine local SuDS maintenance requirements; the development of technical decision support systems (DSSs) for South African conditions; the need to undertake long term monitoring SuDS systems in South African conditions; and the need to promote the results of this project to smaller municipalities through a series of workshops.

Benefits of stormwater harvesting

- Mitigating water scarcity
- Improving water quality and protecting ecosystems (through the development of water-sensitive urban areas for all)
- Sustainable and resilient cities that are adaptable to change and are a place where people want to live
- Proudes a climate change adaptation technology for the water sector

SuDS should be accompanied by complementary practices. Existing valuable elements of the stormwater system, such as natural channels, wetlands and riparian vegetation should be preserved by restricting the use of such areas. The risk of litter reaching the drainage system must be minimised by situating litter-producing activities in areas where it is easier to contain and control litter accumulation. In addition, pollution control measures should be applied as part of any development application.

Reducing the litter loads entering the drainage system will aid the process as well. Dealing with pollution at source can be achieved by upgrading cleansing operations by, for example, the better placement and design of litter bins, and more frequent collections of litter. Monitoring street sweeping methods to ensure that litter is not swept into catchpits and ensuring that communal collection depots are appropriately placed will assist in more efficient stormwater management. The latter may also be a way of promoting jobs in recycling. Finally, construction activity must be controlled to ensure that site management plans are in place to prevent contaminant spills and rubble from reaching the drainage system.

Ordinary South Africans helping monitor water resources

The WRC is throwing its weight behind efforts to rehabilitate degraded rivers in South Africa by funding the development of various 'how to' guidelines, technical manuals, policy briefs and bioassessment tools.

The assessment of aquatic life in rivers is a widely recognised means of determining the condition or health of rivers. Macroinvertebrates, in particular, are recognised as valuable organisms for biological assessments, due largely to their visibility to the naked eye, ease of identification, rapid life cycle often based on the seasons and their largely sedentary habits.

Through strategic partnerships, the WRC has ensured that South Africa has an exemplary history in this field, culminating in the refinement of invertebrate and other techniques and their application in a National River Health Programme. The highly successful South African Scoring System (SASS) bioassessment method forms the backbone of this programme.

Reliable indicators of water quality and river health are often difficult and expensive to derive. To address this need, the SASS river health biomonitoring method was first developed in the mid-1990s as a low technology, scientifically reliable and robust technique to monitor water quality in rivers and streams. The SASS index offers a cost-effective method for assessing the health of the macroinvertebrate community in a river. During the development of the SASS, the methodology was widely discussed, and it is now routinely being used as part of the biological monitoring of river health. It is also one of the indices which form the basis of the National River Health Programme.

The WRC subsequently developed a simplified bioassessment tool miniSASS that allows ordinary South Africans to help monitor the health of our rivers and other water sources. MiniSASS has allowed citizen science initiatives, such as ***Adopt-a-River*** to take off.

Encouraging citizen science, contributing towards river health

In 2012, the WRC in collaboration with local partners, launched the latest South African Scoring System version 5 (SASS 5) and its simplified version, miniSASS, at a special event in Pietermaritzburg, KwaZulu-Natal. The system still uses the composition of invertebrates living in rivers, and is based on the sensitivity of various animals to water quality.

"The mini-version reduces the taxonomic complexity of SASS to a few aquatic invertebrate groupings (13 instead of 90) and forms a useful educational tool for school learners and non-specialists. It also allows communities to play an active role in the monitoring of water quality of the rivers in their area."

– Bonani Madikizela, WRC Research Manager: Water-Linked Ecosystems

The revision to version five was conducted by GroundTruth, an environmental consultancy in Hilton, KwaZulu-Natal. The consultancy is run by Dr Mark Graham, who was one of the original developers of miniSASS. About 6 000 records have been taken from full environmental assessments using the SASS methodology and the data has been analysed showing a very good correlation between the SASS data and the miniSASS data. The tool itself consists of a simple net and a site information sheet to record samples found in the river and give ecological information about the site.

High scores indicate high sensitivity to pollution and low scores indicate high tolerance of pollution. A quantitative score of the system is translated into health categories ranging from ***Natural*** to ***Seriously Modified***. Support tools, such as field guides, assist identification and understanding of the bugs and worms found in the water and form part of the miniSASS tool kit.

This cheap, effective set of tools is easy to use and has the potential to make a real change at the community level. MiniSASS provides 'eyes and ears on the ground' in terms of identifying water quality problems and raising red flags. Community involvement and understanding of water quality issues would ensure that connections are made between broader catchment activities and water quality. MiniSASS is an effective way of ensuring that the next generation of consumers, river health monitors and potential polluters, as well as the next generation of leaders have a greater appreciation and understanding of aquatic ecosystems.

"MiniSASS can be used as a valuable tool to assess river health – results are reliable, repeatable and robust. MiniSASS is a wonderful conduit that municipal managers can use to create networks and build community relationships with people who are monitoring their local rivers. The tool also helps communities to build capacity and understanding around river health – this active learning and building of understanding leads to advocacy by community members for cleaner rivers."

– Kirsten Mahood, GroundTruth

The new version underwent testing at the WESSA Environmental Centre in nearby Howick by river health practitioners and environmental educators. GroundTruth and WESSA subsequently, developed a website: www.minisass.org to serve as a dedicated home for the miniSASS community river health biomonitoring tool; to promote its use; and to serve the miniSASS user community by providing a central hub for river health data, supporting materials, instruction, and news of the latest activities.

The website incorporates an interactive Google Earth map and database that allows miniSASS users to upload their results and view those submitted by others. In this way it is anticipated that a public-access, interactive map of river health across southern Africa will develop, with results continuously contributed by users as citizen science. Users can explore all results, compare and contrast river health across catchments and in relation to land use activities, while connecting with others who are sampling rivers in their community.

Why use miniSASS?

- Valuable tool to assess river health – results are reliable, repeatable and robust
- Wonderful conduit that municipal managers can use to create networks and build community relationships
- Citizen science is an important source of information about the quality of the rivers that water resource managers are meant to be managing
- Empowers people to help monitor their local rivers
- Builds water awareness among South African youth
- Has the potential to make a real change at the community level

Kirsten Mahood and Nstwaki Ditlhale of GroundTruth agree that miniSASS is being used by a wide range of community groups, providing valuable information that could improve the management of the rivers the municipality is meant to be protecting. They add that partnerships with community groups are also very valuable to facilitate the collection of reliable data that municipal managers and decision makers can use to better manage water resources.

Recent developments

In the past six months the miniSASS key and ***Ecological Categories*** have been revised. The pamphlet has also been revised to provide a clean, fresh look and miniSASS also has a new logo.

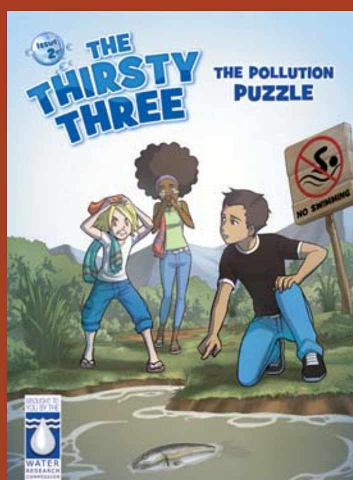
In May and June 2016 the GroundTruth team delivered presentations focused on miniSASS at the Water Institute of Southern Africa's 2016 conference in Durban and the Citizen Observatories for Water Management or COWM2016 conference in Italy.

There are new citizen science tools that have been developed and can be used in conjunction with miniSASS. These include the clarity tube for measuring water turbidity, the Velocity Head Rod for measuring water depth and stream velocity, and a simplified Stevenson's screen for E.coli count measurement, which is currently being verified on the ground.

"During their development and testing, we worked with citizens, ranging from young children to senior citizens, some with no formal education or background in the sciences. Citizens can use the tools to explore and learn about water resources and ecosystems. The tools can also be used to gather data and information, which will feed a national repository that can assist in the improved management of our water resources."

–Ntswaki Ditlhale, GroundTruth

GroundTruth routinely hosts SASS5 aquatic biomonitoring training courses, which are typically held twice a year. The four day course is designed to provide participants with the basic skills necessary to conduct SASS5 aquatic biomonitoring techniques. For those with sufficient prior experience, the course is followed by an accreditation day where a Department of Water and Sanitation auditor presides.



Following the adventures of the Thirsty Three

In 2014/15, the WRC developed the first issue of its comic book series. The graphic novel follows the adventures of the Thirsty Three, Royston, Mpho and Steyn, as they uncover the value of clean water and the role played by water science in South Africa. The book is aimed at children aged 11 to 15 years. During 2015/16, the WRC published the second instalment in the series, with river monitoring and the use of miniSASS as its central theme. This issue was very well received and is already being used as an educational tool by non-governmental organisations around the country. It is envisaged that this graphic novel and its characters can go a long way towards sharing the South African water story with a new generation of South Africans in a language that they can identify with.

Back to top

06

Striving for excellence in wastewater management

The Water Research Commission (WRC) has a dedicated thrust focused on the development of technologies and systems that optimise the full wastewater and sanitation services chain in the municipal sector. This includes the reticulation, treatment and management of the residues.

There is great concern about dysfunctional wastewater treatment works (WWTW), nationally and locally, in civil society but also in various arms of government (particularly on national level), and the WRC believes this energy can be harnessed towards solutions and improvements. Dysfunctional WWTW threaten the provision of drinking water, the safety of people living downstream and using water directly, as well as aquatic ecosystems.

The WRC has therefore recently concluded a project to evaluate and address the issue of dysfunctional WWTW through multi-stakeholder support campaigns. The aim is to better understand the position of the frontline staff at treatment works, as well as the responsible municipalities, in order to improve Green Drop scores and performance.

This section reminds the municipal managers and local government decision makers of South Africa to:

- Acknowledge and overcome institutional constraints in order to ensure adequate uptake of useful R&D outcomes for continuous improvement
- Consider improvement and innovative application of existing 'fit for purpose' technology for waterborne sewage treatment and on-site sanitation
- Optimise appropriate application of technologies to: consistently achieve strict standards, save on costs, ensure ease of operation and maintenance, and improve reliability and energy efficiency
- Identify and address the bottlenecks to achieve a better Green Drop score
- Implement ongoing capacity building and training to avoid an overreliance on consultants
- Training, capacity building, emergency interventions and inspections have to be complemented with multi-stakeholder support campaigns to improve performance and address the political questions that impact the proper functioning of WWTW
- Integrate social and local economic development into your plans to ensure the technical sustainability of wastewater treatment and sanitation services
- Facilitate an exchange between the WWTWs, their frontline staff and local government's top triangle: the municipal manager, technical manager and finance manager
- Work with financial division to ensure the WWTW budget is not reallocated to other priorities mid-year, and to ensure appropriate and adequate procurement practices

The challenge is to implement fitting solutions for a particular application that will remain functional throughout the intended lifespan of the installed infrastructure. This includes the responsible management of the wastewater sludge and faecal sludge that is generated. The need for innovative technologies and solutions is recognised as we prepare for the future – achieving more stringent effluent discharge standards, developing acceptable non-waterborne sewerage solutions, reliable treatment of ever-increasing high-strength domestic wastewater and informing future policy.

Wastewater
Wastewater is any water that has been adversely affected in quality by anthropogenic influence. Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, and from sewer inflow or infiltration.

In order to prepare for the future, it is imperative to develop technologies which can achieve future policy objectives and stricter standards. The WRC encourages the development of technologies to address the future anticipated municipal waterborne sewage and sanitation needs. It supports development of technological solutions addressing, among others: reuse, recovery, non-waterborne sewerage solutions, grey-water management, peri-urban sanitation solutions, high-strength effluent treatment, as well as industrial and domestic effluent co-treatment. It also supports research aimed at informing future policy through data interpretation, projections, risk assessments, addressing emerging pollutants and predictive models.

The wastewater risk abatement plan (W2RAP) guidelines produced by the WRC are available to assist municipal managers to plan for and apply a risk-based approach to raise and sustain wastewater performance.

Dr Zvimba says, "Continuous improvement is possible through the implementation of impact assessment, monitoring and evaluation, as well as adherence to the Green Drop system, but there have been no assessments since 2014". His other concern is the fact that there is a huge need for capacity building and training of municipal staff. On the positive side, there is ongoing capacity building and training on risk planning and implementation in 23 district municipalities in the Eastern Cape and KwaZulu-Natal.

"Municipalities need to embrace scientifically developed tools and guidelines for policy development and decision making. They need to support the implementation of the tools and guidelines on the ground for the benefit of municipalities, for example risk planning using W2RAP. They need to promote holistic continuous improvement through implementation of appropriate tools and guidelines."

– Dr John Zvimba, WRC Research Manager: Wastewater Treatment and Management

All wastewater treatment and on-site sanitation facilities generate a solid/sludge that needs to be managed responsibly. The WRC focuses on research dedicated to improve wastewater sludge and faecal sludge management practices. Research on characterisation, emerging technologies and solutions, anaerobic processes for stabilisation, minimisation, de-watering, disinfection and beneficiation is encouraged.

Improving domestic wastewater treatment through dialogue and action

At the heart of the problem of dysfunctional WWTW is a set of complex political tensions between the constitutional right of local government to provide and earn income from water services, including WWTWs, the threats that dysfunctional WWTWs pose to water users and water resources, and the urgent question of who should, can and will take responsibility for dealing with those threats.

To date, most interventions have focused on training and capacity building, emergency interventions and inspections. They have not addressed the political questions that constitute the dynamic of dysfunctional WWTW.
A recent WRC research project looked at the issue of dysfunctional WWTW and asked the research question: Can dialogue, social learning in a community of practice formed from diverse stakeholders, practical cooperation and a better understanding of the position of WWTW frontline staff as well as the responsible municipalities, lead to improvement in Green Drop scores and performance?

Dialogues were held in various regions of the country. The project created a safe space (including anonymity in dialogue minutes) in which to discuss the real obstacles to Green Drop improvements.

It was established that the main problem a disconnect between the WWTW frontline staff and local government's top triangle: municipal manager, technical manager, finance manager.

Some of the findings pointed to the issue of staff being given responsibility for Green Drop performance, then not getting budget or support. When they underperform they are held responsible for the results by top management. In some instances the researchers heard that the municipality did not take proper care of their WWTW and their staff.

This insight provided a trigger for growing solidarity and understanding between WWTW frontline staff and civil society counterparts who until then had taken a generally accusatory attitude. It was also important to recognise the dynamic inside local government. A municipal manager, who joined the dialogues later, made a frank contribution in which he explained that municipal managers are overworked ("our in-trays are overflowing"), and that the politicians they answer to have far more interest in interventions that are visible to their constituents, such as health clinics, roads and street lights, than in WWTW.

Interventions by national departments

The working group undertook a number of interviews with national government departments to explore what help they could offer.

The group found that:

- **Treasury** is reluctant to intervene. Since its focus is on money flows, the quality of the effluent and other technical parameters are not visible to these officials. However, they have taken a keen interest in Green Drop developments, from a 'value for money' perspective.
- The **Department of Co-operative Governance and Traditional Authorities** (COGTA) has undertaken a *Back to Basics* programme, which holds the promise to motivate better performance of wastewater treatment works. However, it was noticeable in interviews with Municipal Infrastructure Support Agency, a supporting agency within COGTA that interventions in municipalities can only happen when welcomed by the municipalities.
- The **Department of Water and Sanitation** (DWS) arguably has the most responsibility and opportunity to intervene. In theory, the Green Drop scheme does not replace day-to-day compliance monitoring, and could itself trigger pre-directives, and court action (against poorest non-performing municipalities). In practice, this is limited by the number of officials on the ground, and the fact that Green Drop competes with other tasks on their agenda. DWS officials pointed out that a number of directives have been issued against municipalities, and have produced results. In addition, DWS has embarked on a Municipal

Services Strategic Assessment programme, in which municipalities self-report in a number of risk areas, including wastewater treatment.

The overriding picture that emerged from interviews is that all the national departments are bound by the constitutional autonomy of local government, which is, firstly, an equal sphere of government and, secondly, has the right (or is designed) to earn income from providing water and electricity services, which it defends jealously.

The dialogues proved, again, that the majority of frontline staff at WWTW are keen to do their work properly, but need better support from local government to do so, in terms of routine procurement, maintenance and expansion of works, and staff provision. In particular, they need local government officials to be responsive to their needs before and during Green Drop inspections. The new emphasis of South African Local Government Association (SALGA) in supporting the Green Drop programme as part of SALGA's contribution to the implementation of the National Water Resource Strategy (NWRS2) could make a major contribution here.

SewPump tool to mitigate against pump station problems

Pumps are essential components in most sewer systems and are often considered by operators and managers to be the most problematic. A WRC project set out to address a number of pertinent issues with regards to sewage pumps, pump stations, and related elements of sewer systems.

As one of the proposed solutions, the research team developed a practical software tool that aids operators with sewage pump problem identification so as to help understand and identify problems at sewer pump stations. The SewPump, as it is known, was also designed to be used as a training and communication tool to mitigate against pump station problems.

The decision support tool facilitates communication between pump station operators and technical management, and provides for basic training regarding sewage pumping and related problems that can be used by individuals for self-study and by managers to facilitate training.

South African sewer systems and storm drainage systems are designed as separate systems. The sewer is traditionally waterborne. Waterborne sewers or conventional sewers use water as the mode of transport for excrement and other waste.

This research project focused exclusively on separate waterborne sewers and specifically on decentralised sewerage pump and related infrastructure in the piped sewer system.

The issue at hand extends beyond hydraulics and design criteria to enable stakeholders to decision support and communication. The aim was to link decisions to problems occurring at sewage pump stations during normal operating life, after commissioning.

One of the key issues addressed by this research and the subsequent software tool revolves around improved knowledge transfer and communication between different levels of technical staff involved with sewerage pumps.

SewPump was aimed at providing information regarding sewer pump problems. The tool was developed to act as a visual aid for staff involved with the operation and management of sewage pump stations, thus providing useful information in a structured and convenient way. The project team kept the tool uncomplicated with limited inputs and maximum output.

The SewPump aids municipalities and their engineering consultants to better understand the working of a sewerage pump station and the related problems. The expectation of a maintenance-free sewerage pump station should be replaced by empowerment.

SewPump tool applications and benefits

- Assists designers, sewage service providers and operators with understanding the various components and for problem identification pertaining to sewage pump stations
- Helps identify the most appropriate pump for the water demand under specific pressure head requirements
- Facilitates communication between pump station operators and technical management
- Helps municipalities streamline the operation and maintenance of pump stations
- Can transform to a training tool that can be used by individuals for self-study and by managers to facilitate training
- Population growth and environmental concerns impose increasing demand for pumping sewage and the SewPump can assist in meeting the many challenges and hazards to overcome (this important field is often neglected by municipalities)

Prof Heinz Jacobs of the Institute for Water and Environmental Engineering at Stellenbosch University – was the driving force behind the development of the SewPump decision support tool – says there is no doubt that the tool is effective and is used extensively. However, he says the software needs to be updated. He is currently working on other projects that are linked to the SewPump, but take a wider look at full treatment plants and as well planning, design, operation and maintenance of the whole sewer system.

The new developments will be communicated to municipal managers in the near future.

Problematic areas with shortage in financial backing exist and where municipalities are trying to supply more people with sanitary services, shortcuts have to be made to reach the goal of basic sanitation for all. This is unfortunate and the lack of efficient infrastructure is the result. With more available capital decent pump stations can be constructed with a longer lifetime and better operating conditions with less maintenance.

It is the responsibility of engineers to design efficient technologies and come up with more innovative ideas to handle solids at pump stations.

Tools like the SewPump can play a critical role in this regard.

Addressing pump station problems and underlying causes

If the underlying causes are not identified and addressed; the problems will keep occurring. This study could be considered as one addressing problems (direct) versus the underlying causes (indirect).

Sewer pump station problems were ultimately categorised into four classes. Each direct problem identified in the first phase of the project could ultimately be placed into one (or more) of these four problem classes, based on a degree of membership to each class. In presenting the framework here, aspects regarding roles and responsibilities were not included, so as to maintain the focus.

These arrived at were coined the 4 'O's of sewage pump station problems, namely overflows, odours, operation and (maintenance), other.

A workshop titled 'WRC – Practical application of research: A tool for sewer pump problems' was held during the 2012 Biennial Conference of the Water Institute of Southern Africa (WISA). A total of 28 delegates participated actively in the workshop.

The approach was to gain an in-depth understanding of the participants' views regarding sewer pump problems and the software tool. The delegates discussed various aspects of sewer pump problems, pump stations, and the intended tools developed as part of this study. The feedback from the workshop was incorporated into the final development of SewPump.

Two aspects need to be understood when referring to sewage pumping, namely the pump station (infrastructure and equipment) and the sewage stream to be pumped. This research project included a review of both these aspects.

It was concluded that both were well documented, based on former research. However, previous publications regarding solids in sewers and their behaviour were limited, particularly with regards to baskets that were found to be very common in local sewage pump installations. Limited laboratory tests were conducted to investigate the interaction between solids in sewage and screening baskets.

The outcomes of this project will aid a municipality and their engineering consultants to better understand the working of a sewerage pump station and the related problems. The expectation of a maintenance-free sewerage pump station should be replaced by empowerment.

Wastewater related guidelines and tools from the WRC:

- Process design manual for small wastewater works (**Report No. TT 389/09**)
- A simple guide to the chemistry, selection and use of chemicals for water and wastewater treatment (**Report No. TT 405/09**)
- Understanding sewage pump stations – Development of a SEWPUMP tool (**Report No. TT 627/15**)
- Guide for management and waste stabilisation pond systems in South Africa (**Report No. TT 471/10**)

WATER
RESEARCH
COMMISSION

www.wrc.org.za