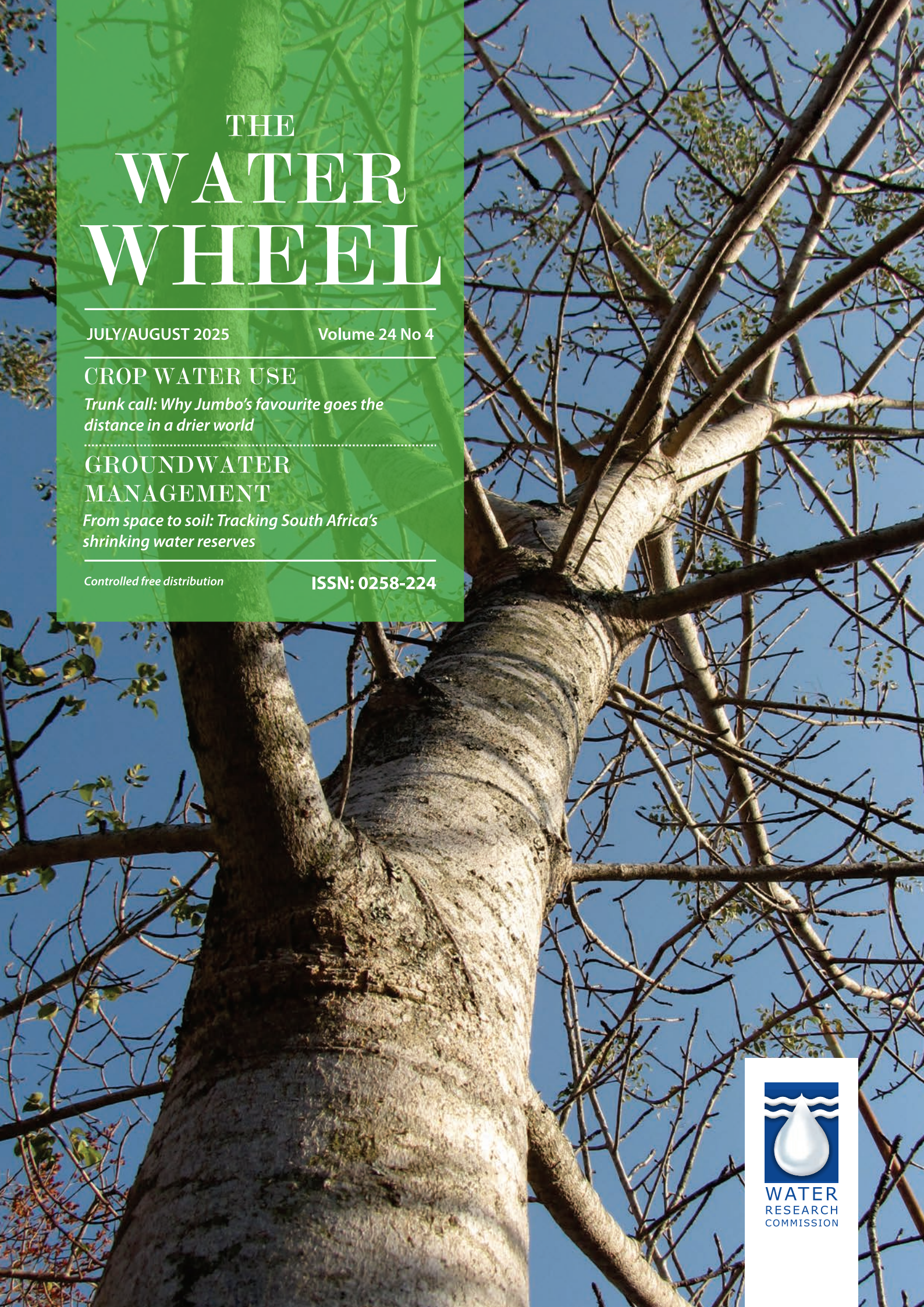


THE WATER WHEEL

JULY/AUGUST 2025 Volume 24 No 4

CROP WATER USE

Trunk call: Why Jumbo's favourite goes the distance in a drier world

GROUNDWATER MANAGEMENT

From space to soil: Tracking South Africa's shrinking water reserves

Controlled free distribution

ISSN: 0258-224

WATER RESEARCH COMMISSION

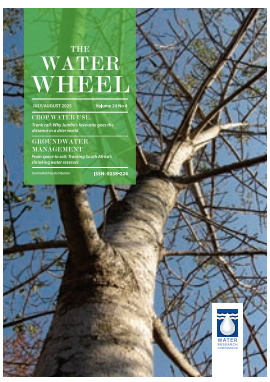
THE WATER WHEEL is a two-monthly magazine on water and water research published by the South African Water Research Commission (WRC), a statutory organisation established in 1971 by Act of Parliament. Subscription is free. Material in this publication does not necessarily reflect the considered opinions of the members of the WRC, and may be copied with acknowledgement of source.

Editorial Committee:
Prof Sylvester Mpandeli (Chair), Ms Manjusha Sunil, Mr Bonani Madikizela, Dr Mamohloding Tlhagale and Dr Sudhir Pillay.

Editorial offices:
Water Research Commission, Private Bag X03, Gezina, 0031, Republic of South Africa.
Tel (012) 761 9300.
WRC Internet address:
http://www.wrc.org.za
Follow us on X:
@WaterWheelmag
Editor: Lani van Vuuren,
E-mail: laniv@wrc.org.za;
Layout: Anja van der Merwe,
E-mail: anjavdm@wrc.org.za

Contents

In one of the first studies of its kind, researchers studied how variations in the environment affected water use, tree growth and fruit yield of marula trees. *Story on page 10.*



NEWS

Deputy Minister lauds upskilling of young engineers

Deputy Minister of Water and Sanitation, Sello Seitlholo, with Water Research Commission Board Chair, Dr Rethabile Bonang Melamu.

Water and Sanitation Deputy Minister, Sello Seitlholo, commended the skills training granted to young engineers in the water sector as it will improve service delivery of water and sanitation services at municipal level.

He was speaking at the five-year celebration of the Young Engineers Changemakers Programme (YECP) organised by the Water Research Commission in partnership with the Department of Science, Technology and Innovation (DSTI).

The YECP was launched five years ago to empower a new generation of municipal engineers in an effort to contribute to sustainable service delivery. It also provides opportunities for young South African engineers to partake in testing potential innovative water and sanitation solutions in real world sites and to gain the necessary skills required to drive municipalities of the future which are sustainable, liveable and builds socio-technical infrastructure and services. To date, 50 young engineers have been trained through 21 participating municipalities and water utilities.

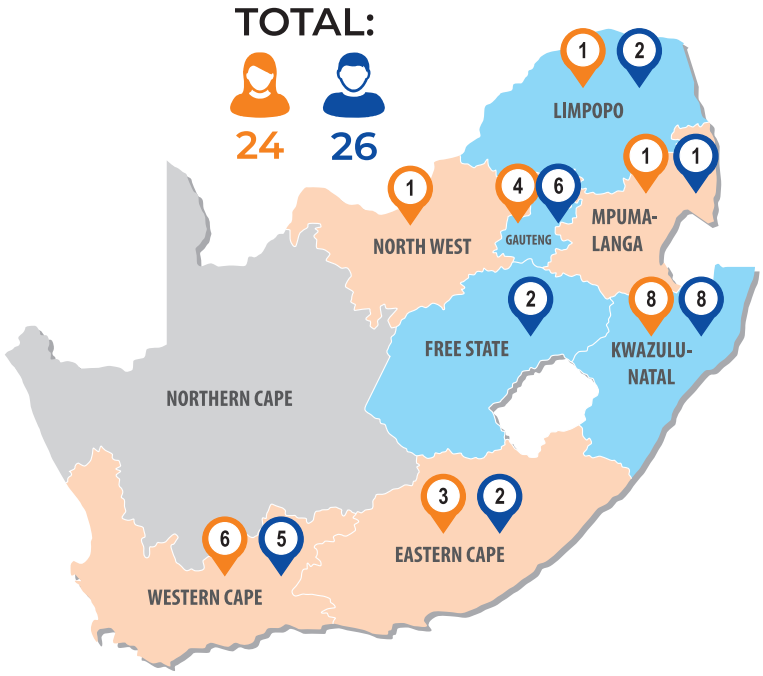
The Deputy Minister congratulated the young engineers and further reminded them that their core purpose is to make a positive contribution in arresting the decline of engineering skills in the municipalities. "We meet here to celebrate both the milestone of this important programme as well as to take stock of its potential and future in helping us to address the challenges which threaten to cripple our democracy. We cannot fix South Africa without fixing municipalities. For us to fix municipalities, requisite skills and capacity should be taken into consideration and should be prioritised. It is for this reason that we should acknowledge the joint efforts by the WRC and DSTI to empower the engineers."

Seitlholo lamented that the country was in the midst of failing infrastructure, and that a great cause of this was due to the lack of capacity and skills in municipalities, particularly engineering skills.

According to the deputy minister, the YEPC is a positive initiative that will help turn things around because municipalities are in dire need of capacity and skills. He said the Department of Water and Sanitation and other sector roleplayers will continue to provide targeted support to local government through various support and intervention programmes aimed at improving water services. "We must continue to make every effort to fund, support and incentivise such programmes to ensure that we harness the skills we need to improve the state of our municipalities."

According to WRC CEO, Dr Jennifer Molwantwa, the organisation will continue to enter into partnerships to ensure that water and sanitation issues in the country are addressed. "There is now a cohort of 50 young men and women engineers who have been trained. This achievement cannot go unnoticed although 50 is not enough. We will continue with the programme to ensure that even more engineers are trained."

To access the booklet, ***Young Engineers Changemakers Programme – A review***, https://bit.ly/4liwF1r



The distribution of the engineers under the Young Engineers Changemakers Programme.

BACK TO TOP

Partnership harnesses student power to boost SA's water quality

JSE listed company, ADvTECH, in collaboration with the IIE MSA Centre for Water and the Environment (CWE), has launched the Water Quality Monitoring Initiative, a national, student-led citizen science project aimed at protecting South Africa's freshwater ecosystems.

The innovation arms university students with professional water testing tools to track and improve local water quality. A number of water courses will be tested for select chemical contamination and the presence of excessive bacterial and viral agents, while also testing for the presence of microorganisms to discern the health of the ecosystem. Following a student awareness drive earlier this year, the campaign culminated in a successful Water Monitoring Day on 20 May, which also saw the launch of a three-month long competition. Running from July to September, student teams will now be vying for a R10 000 award based on their data and analysis.

Linda Downsborough, Head of Environmental Science at IIE MSA, says the campaign is a concrete example of how student and citizen science can help address South Africa's environmental challenges. "By equipping students with cutting-edge tools and skills, we're not just testing water; we're empowering a generation to champion South Africa's water quality."

According to Downsborough, higher education institutions – both public and private – play a critical role in advancing environmental and water sustainability, serving as hubs where knowledge is generated, shared, and applied to tackle pressing global challenges. "We are tasked with shaping the next generation of leaders and citizens, equipping them with the tools to drive meaningful change. In addition to adapting eco-friendly policies and practices to minimise our environmental impact and uphold social responsibility, higher education institutions can play a significant role by embedding sustainability into academic programmes, teaching methods, and assessments to foster skills, values and mindsets that address complex sustainability issues."

New professional designation announced

The Environmental Assessment Practitioners Association of South Africa (EAPASA) has announced progress in the professionalisation of environmental governance in South Africa with the formal recognition of environmental control practitioners (ECPs).

This milestone reinforces EAPASA's role as a statutory environmental professional body, recognised by the South African Qualifications Authority (SAQA) under the National Qualifications Framework Act (Act No. 67 of 2008), responsible for regulating relevant activities within the environmental sector. With SAQA's approval, EAPASA is now authorised to professionally register ECPs.

This new designation encompasses a broad category of environmental professionals who provide essential post-decision impact assessment follow-up services, ensuring compliance, monitoring, governance and communication on environmental performance throughout the lifecycle of development projects.

The development is a pivotal step towards the establishment of EAPASA as a fully fledged environmental council, thereby enhancing the credibility and regulation of the environmental profession in South Africa.

BACK TO TOP

GLOBAL

Changing climate making Earth too hot for amphibians

For about 2% of the world's amphibian species, it is already getting too hot to survive in their natural habitats, according to a new study published in ***Nature***.

As reported by Liz Kimbrough of Mongabay, if the planet keeps warming unchecked, this number is expected to jump to 7.5% by the end of the century.

"We found that currently, about 100 species are likely experiencing overheating events right now, where environmental temperatures exceed their physiological heat limits," reports study co-author Alex Gunderson, an ecologist at Tulane University in the US.

The research, lead by scientists from the University of New South Wales, in Australia, gives the most complete picture yet of how climate change affects the ability of amphibians such as frogs and salamanders to regulate their body temperature. The scientists used actual heat tolerance data for 524 species and then statistical methods to generate estimates for more than 5 000 species, representing approximately 60% of all known amphibian species worldwide.

The research team found certain 'hotspots' where many amphibians are overheating, including the southeastern United States, Northern Australia, and the Amazon Rainforest.

The researchers also found something unexpected. They predicted that species living closer to the equator, in tropical regions, should generally be more vulnerable to climate warming than those in temperate regions. Yet this was true only in the Southern Hemisphere. In the Northern Hemisphere, researchers found the opposite pattern. There, amphibians living at higher latitudes, or further from the equator, showed greater vulnerability to heat stress than their tropical counterparts.

• To access the original article, visit: https://bit.ly/3HYsMjm

Portable sensor enables community lead detection in tap water

Lead contamination in municipal water sources is a consistent threat to public health. To empower people to detect lead contamination in their own homes, a team of researchers developed an accessible, handheld water-testing system called the E-Tongue.

This device, described in ***ACS Omega***, was tested through a citizen science project across four Massachusetts towns. "I was driven by the reality that families could be unknowingly exposed to lead," said Pradeep Kurup, principal investigator. "With the E-Tongue we are putting knowledge and power directly into people's hands so they can protect their health and advocate for safer water in their communities."

Traditional water tests are costly and time-consuming, requiring specialised scientific equipment and long processing times. The E-Tongue works by applying a voltage to a water sample, causing any lead ions present to stick to the sensor's gold electrode. Then, the voltage is reversed, causing the lead to come off the sensor and produce an electrical current. The strength of this current indicates how much lead is in the water sample.

If lead is detected, a smartphone app linked to the device alerts the user with a colour-coded reading and a concentration value that indicates the severity of contamination. A green screen indicates that the lead concentration is below the US Environmental Protection Agency's regulatory limits. A red screen indicates that the lead concentration exceeds the regulatory limits.

The researchers hope this tool will soon be a practical option for detecting and mitigating heavy metal contaminants in municipal water sources, thereby empowering communities to keep themselves safe.

To access the original article, visit: https://bit.ly/44flb7m

BACK TO TOP

Rivers are exhaling ancient carbon – and climate math just changed

A new study has revealed, for the first time, that ancient carbon, stored in landscapes for thousands of years or more, can be released back into the atmosphere as CO_2 from the surfaces of rivers.

The findings, led by scientists at the University of Bristol and published in ***Nature***, indicate that plants and shallow soil layers likely remove around one gigatonne more CO_2 each year from the atmosphere to counteract this, emphasising their pivotal role and greater part in combating climate change. Lead author, Dr Josh Dean, Associate Professor in Biogeochemistry said: "The results took us by surprise because it turns out that old carbon stores are leaking out much more into the atmosphere than previous estimates suggested."

He added: "The implications are potentially huge for our understanding of global carbon emissions. Plants and trees take up CO_2 from the atmosphere and can then lock this carbon away in soils for thousands of years. Our findings show that some of this old carbon, as well as ancient carbon from rocks, is leaking sideways into rivers and making its way back to the atmosphere. We don't yet know how humans are affecting this flow of ancient carbon, but we do know plants and trees must be taking up more carbon from the atmosphere today for this unrecognised release of old carbon."

Rivers transport and release methane and CO_2 as part of the global carbon cycle. Until now, scientists believed the majority of this was a quick turnover derived from the recycling of recent plant growth – organic material broken down and carried into the river system in the past 70 years or so. This new study indicates the opposite, with more than half, some 60%, of emissions being attributed to long-term carbon stores accumulated over hundreds to thousands of years ago, or even longer.

The international research team, led by scientists at the University of Bristol, University of Oxford and the UK Centre for Ecology and Hydrology, studied more than 700 river reaches from 26 different countries across the world.

They took detailed radiocarbon measurements of carbon dioxide and methane from the rivers. By comparing the levels of carbon-14 in the river samples with a standard reference for modern atmospheric CO_2, the team was able to date the river carbon. Co-author Prof Bob Hilton, Professor of Sedimentary Geography at the University of Oxford, explained: "We discovered that around half of the emissions are young, while the other half are much older, released from deep soil layers and rock weathering that were formed thousands and even millions of years ago."

To access the original article, visit: https://bit.ly/4lqO3ka

BACK TO TOP

NEW WRC REPORTS

District Development Model (DDM) and its implications for water services legislation, planning and regulation

The District Development Model (DDM) offers a strategic framework for intergovernmental coordination and integrated planning, with the potential to transform water service delivery in South Africa. This booklet provides an analytical overview of the DDM's implications for water services, identifying both opportunities and challenges. Among others, the study found that while the DDM aligns with South Africa's constitutional principles of cooperative governance, gaps in regulatory alignment and explicit legislative references impede its institutionalisation. With an abundance of existing plans such as Integrated Development Plans (IDPs), Water Services Development Plans (WSDPs), and other frameworks and instruments, the DDM's introduction of One Plans adds another layer of planning that risks duplicating efforts and increasing administrative burdens. The water sector faces unique challenges that complicate the DDM's implementation, including inadequate revenue, poor asset management, lack of technical capacity, no model for faecal sludge management, and the need to revisit WSA allocations. Planning on the basis of municipal boundaries further exacerbates these issues, as water resources often span across provincial borders. Despite these challenges, the DDM presents opportunities for improving regional collaboration, enhancing accountability of district WSAs to local municipalities, and streamlining processes such as the Municipal Infrastructure Grant (MIG) approval.

WRC report no. SP 185/25
Link: https://bit.ly/4noqkmy

Implementation of effect-based methods for water quality assessment

Surface waters can contain a wide range of contaminants of concern (CECs), referred to as micropollutants. These include industrial compounds and agricultural compounds, such as pesticides, pharmaceuticals and personal/home care products, plasticizers, microplastics, and engineered nanoparticles, among others. Mixtures of compounds are present in the aquatic ecosystem that can negatively affect human and environmental health, particularly the endocrine system, including effects on reproduction, cancer, neurodevelopmental disorders, and obesity. This project aimed to test the feasibility of bioassays by applying them to different water sources and processes through case studies. This provided data on the most appropriate assays to apply to water quality monitoring, assisted the project team in making a decision-making tool for the water stakeholders as well as to affect policy in a positive direction by incorporating the bioassays in the relevant guidelines.

WRC report no. 3210/1/25
Link: https://bit.ly/44wPXKb

Infrastructure performance, water governance and climate change impacts on water resource management for smallholder farmers in the Western Cape, South Africa

Water security is a persistent challenge for South Africa's agricultural sector, with smallholder farmers facing disproportionate impacts due to limited access to resources and systemic inequities in water governance and infrastructure. Climate change, manifesting through extreme weather events such as droughts, has intensified these challenges by reducing water availability and increasing competition for resources. Ageing, inadequate water infrastructure, and governance inefficiencies have further hindered smallholder farmers' access to reliable water supplies. This project sought to evaluate the intersection of climate change, water governance, and infrastructure performance, specifically focusing on smallholder farmers in historical towns in the Western Cape, South Africa.

WRC report no. 3194/1/24
Link: https://bit.ly/4nxc1fs

Mapping woody invasive alien plant species and their impacts in strategic water source areas

Despite water being a limited and precious resource in South Africa, we are allowing a significant amount of our water resources to be consumed by alien trees. These alien trees not only guzzle water, but also decimate biodiversity and cause severe fires, and they are spreading rapidly. This project had two main aims, namely to map woody invasive alien plants using freely available satellite imagery and field data in selected strategic water source areas in South Africa, and to estimate the water use of woody invasive alien plants relative to native vegetation using freely available satellite imagery in strategic water source areas in South Africa. The specific objectives were: (1) to map the occurrence and distribution of target invasive alien plants within the selected strategic water source areas, (2) to map the density (percentage cover) of target invasive alien plants within the selected strategic water source areas, (3) to estimate the age of the identified invasive alien plant stands within the selected strategic water source areas, (4) to estimate evapotranspiration spatially for indigenous compared to invasive alien plants for the selected strategic water source areas, and (5) quantify impacts on water and compare results to the available literature.

WRC report no. 3193/1/24
Link: https://bit.ly/468UgN6

Evaluation of the impact of gender transformation interventions in the water sector to improve access to water for women

This project assessed the impact of policies, programmes, projects or interventions linked towards providing women with more access to water. To inform the impact evaluation, four case studies were selected, with each representing a different form of intervention or initiative to provide increased access to water.

BACK TO TOP

These case studies consisted of interventions aimed at changing available water resources to communities (Water Allocation Reform Strategy), providing new and alternative sources of water (Hydro Panel), revamping available sources of water (Multiple Use Water Services), as well as enabling the collection and handling of water (Hippo Roller). Fieldwork was done in three of the four case studies, while document analysis was conducted in the fourth. The objective was to assess the impact of these interventions in terms of increasing access to water for rural women.

WRC report no. 3197/1/25
Link: https://bit.ly/3FU3MJt

To download any of these reports
click on the web link provided, email:
hendrickm@wrc.org.za or visit: www.wrc.org.za

Diary

Groundwater
15-19 September
The 52nd Congress of the International Association of Hydrogeologists will be held in Melbourne, Australia. This event, held in conjunction with the 2025 Australasian Groundwater Conference, marks a significant return of the World Groundwater Congress to Australia after 12 years. Organised by ICMS Australasia. For more information, ***visit:*** https://iah2025congress.com/

Ecological restoration
30 September to 4 October
The 11th World Conference on Ecological Restoration (SER2025) will be held in Denver, Colorado, United States. The conference is described as an exciting and inspiring biennial gathering of global experts in ecological restoration. For more information, ***visit:*** https://ser2025.org/

Wetlands
20-24 October
The annual National Wetlands Indaba will take place in Gauteng. The Indaba is intended to provide a platform for a cross-disciplinary gathering of practitioners involved with the conservation and sustainable utilisation of South Africa's wetland resources. These include scientists, decision-makers, researchers, conservationists and educators hailing from various organisations and Government departments. For more information, ***visit:*** https://nationalwetlandsindaba.org/

Municipal engineering
29-31 October
The 88th IMESA conference will take place in East London under the theme 'Sustainable Engineering Solutions'. The call for abstracts is open until 10 April 2025. The main themes for the conference include buildings, structures and housing; ecological, environmental and social; electrical and electronic; financial, legal and regulatory; transport, roads and stormwater, as well as water and sanitation. For more information, ***visit:*** https://conference.imesa.org.za/call-for-papers/

BACK TO TOP

CROP WATER USE

Trunk call: Why Jumbo's favourite goes the distance in a drier world

Efforts to model water use by marula trees are bearing fruit (as it were), with an 'unexpected finding' underscoring its value in the face of climate change. Matthew Hattingh reports.

Flore de Preneuf/Flickr

Animals can't get enough of marulas. Baboons binge on the golf ball-sized fruit of the ***Sclerocarya birrea*** tree. Giraffes gobble them down, fruit and leaves. Famously, it's a favourite of elephants, who eat the bark, branches and fruit. However, the popular story about fermented marula fruit rendering pachyderms ***poegaai*** doesn't seem to hold water.

This is not to doubt that once processed, it can have a potent kick. Thanks to the 29 different yeasts present in its skin, marula beers and liqueurs certainly do the trick. Of course, the pleasantly tangy fruit can simply be eaten and enjoyed fresh. Rich in vitamin C, marulas are a valuable source of food in many African countries. It's made into (non-alcoholic) juices, jams and jellies. Its seeds are snacked on or squeezed to extract oil.

Marulas are prized for their nutritional qualities and used in medicine — conventional and traditional — to treat everything from venereal disease to flagging sperm production.

The list goes on, but leaving aside its 101 uses, the truly marvellous thing about marulas is how little water the trees need. In frequently parched South Africa, where marulas are widespread, this is a vital consideration. Moreover, with climate change expected to reduce rainfall in places, the fruit offers an alternative to thirsty exotics, like apples and oranges, favoured by commercial growers.

However, a new Water Research Commission (WRC) report reminds us that despite its economic significance, most marulas

BACK TO TOP

are not cultivated, but grow wild, and that "very little detailed research has been done on how marula trees interact with the environment in their natural habitats". The report, ***Water use of marula (***Sclerocarya Birrea***) trees in various agro-ecological regions and postharvest utilisation of its fruit and byproducts*** (**WRC report no. 3195/1/25**) addresses this absence. Its authors, Shonisani Ramashia, Mpho Mashau, Tsietsi Kgatla, Masiza Mikasi, Mashudu Makhado and Sebinasi Dzikiti, of Venda and Stellenbosch universities, have taken a long, wide-ranging look at marulas. This included research into marula carbonated soft drinks, and processing marula peels so they can serve as a source of flour and a feed for livestock.

For our purposes though, we will limit ourselves here to the parts of the report that investigated how variations in the environment affected water use, tree growth and fruit yield. To this end, the team set out to gather data, gauging the productivity of marula trees at three study sites, each with different climates, especially rainfall, and soil types. These were at:

- The Namakgale Wastewater Treatment Works near Phalaborwa, in a hot part of the Lowveld in Limpopo, with average annual rainfall below 500 mm
- The Mafemane Secondary School in Thulamahashe, near Bushbuck Ridge, in a relatively rainy part of the Lowveld, Mpumalanga and
- A ZZ2 farm in Moeketsi, near Tzaneen, Limpopo, a medium-rainfall tropical to subtropical region.

We will return to the sites, but first, the report's headline findings: Good rains alone won't guarantee good marula harvests. The soils must be able to hold the water, and this has a strong bearing on whether trees will use water efficiently. Significantly,

Project team member Mashudu Makhado installling the heat ratio sap flow method for measuring transpiration at the Phalabowa study site.

Sheona Shackleton/CIFOR

Women from a local community opening marula to separate the kernel for the oil and the pulp.

the study suggested marulas were unlikely to use much more water under future climate change. The "unexpected finding" meant marulas could prove to be an "ideal alternative" fruit tree crop as growing conditions become harsher. More on this later, too.

As a central aim, the study sought to validate a species-specific transpiration model for marula proposed by Dr Sebinasi Dzikiti, a Stellenbosch University horticulture scientist, and colleagues in earlier research (see **WRC Report No. 2720/1/22**). Transpiration is the main source of water loss in plants. Water is drawn up from the roots, through the stems and leaves, and released into the atmosphere as vapour through tiny leaf pores, called stomata. In the case of marula trees, the stomata are on the underside of the leaf. Transpiration is a key process in plant biology. It allows plants to absorb nutrients from the soil and to perform photosynthesis, converting sunlight and carbon-dioxide into carbohydrates, a store of energy that fuels growth.

The model, based on the famous Penman-Monteith equation, is a simplification or abstraction of reality. It's used to predict water loss for a given area of vegetation from a limited set of data. Crudely put, if we gather site data on variables like temperature, humidity, air pressure, radiation, wind speed, and canopy size and plug these numbers into the equation, we should be able to calculate water use specifically for marula trees.

The team set out to do this between 2021 and 2024, gathering data at the different sites at different times and seasons so that these could be applied to the model. Then, to check whether it lived up to its promise as a predictor, the results were compared with actual sap flow data (which equates to transpiration) collected from four individual trees at each of the sites.

The team used the heat ratio method to measure sap flow. Four sets of temperature probes were stuck at different depths into the stems of each of the trees at their cardinal points. In each set, a central element delivered a pulse of heat, which was detected by the two temperature probes, equidistant upstream and downstream of the element. The probes were wired to data loggers and, at hourly intervals over two to three years, recorded flow, with the ratio of the temperature changes at the probes used to calculate sap velocity. Locating the sets at the cardinal

BACK TO TOP

Mnqobi Zuma

According to the study, marula trees are a potentially valuable indigenous crop as they are not expected to use more water in drier conditions caused by climate change.

points and different depths helped average out variations in the sap wood and therefore velocity. It also allowed the researchers to calculate flow volume in litres an hour.

These measured transpiration figures were compared with the estimates from the marula-specific model, with climate data drawn from nearby weather stations. "The results show this model can satisfactorily predict the transpiration rate of marula trees under a range of growing conditions."

To deepen the research, the team recorded the leaf area index at the sites as well as the soil water content at various depths in the rootzone. They also kept tabs on the trees through the different seasons and growth cycles and reproductive events, including bud break, leaf emergence, flowering, fruit set, fruit development, fruit drop, leaf senescence (ageing and breakdown), and dormancy (temporary halts in growth). Yields at each site were recorded.

Leaf area index is the ratio of the size of the tree canopy to the ground beneath it. A higher index is consistent with higher water demand. Proprietary measuring devices were used to calculate the index, with measurements taken on instrumented trees to monitor for a correlation between the index and water usage.

The trees varied considerably in size from site to site, with those in relatively wet Thulamahashe having the biggest canopies. Phalaborwa and ZZ2 had similar leaf area indices, although the Phalaborwa trees were more spread out. In Thulamahashe, transpiration peaked at an average of 226 litres a tree per day, followed by Phalaborwa at 160 litres, with ZZ2 at 112 litres. However, once the authors adjusted the figures to account for canopy leaf area, the ZZ2 trees emerged with the highest transpiration per unit leaf area, peaking at 2.33 litres per square-metre of leaf area per day. This was followed by trees at Phalaborwa, which transpired 1.60 litres per square-metre per day. Trees in Thulamahashe recorded the least transpiration — 1.02 litres per square-metre a day.

The figures suggested rainfall was not the only factor that determined marula water use at a given site. "Rather it is more likely the combination of the amount of rainfall, its distribution and the soil type that determines the amount of water that is available to sustain the transpiration rates," said the report.

Soil moisture reflectometer probes were used to measure volumetric soil water content.

The report reminded readers that indigenous species such as marula can withstand long drought because of their extensive root systems, and with this in mind, the team put probes at various depths. Most of the fine root system appeared to be at depths of up to 60 cm, but the presence of roots from other surrounding plants sometimes frustrated accurate assessment, the study found.

In Thulamahashe, soil texture varied from loamy sand in the shallow depths to coarse sandy loam as it got deeper, with low stone content. The field capacity of the Thulamahashe soil varied between 12% and 15% at 100kPa. This is a measure of the maximum amount of water the soil can hold two or three days after rain and is expressed as a percentage of total soil volume and assumes the soil has a certain force (expressed as pressure) that resists the water's extraction. Sandy soils have the least capacity to retain water; clay soils the most, with loamy soils in between.

BACK TO TOP

Samples collected at ZZ2 indicated predominantly sandy loam soils in the shallow layers and sandy clay in the deeper 30-60cm layers. Volumetric soil water content at 100kPa was between 13% and 15%. The soil was acidic. In Phalaborwa, samples were collected at 40-60cm because the shallower layers were rocky, making samples hard to extract. The soils were mostly sandy, with the volumetric water content at field capacity, at 100kPa, between 11% and 12% at 40-60cm. The soils were generally acidic and nutrient-poor.

Keeping tabs on crop yield proved challenging because the sites were far from the team's University of Venda base. Marulas are not plucked at harvest, but drop when mature and this can be hard to anticipate. With Thulamahashe, a four-hour drive away, the team faced frustrations in the study's first year. "By the time we arrived, nearly all the fruit had dropped, so we missed the yield," they said. The following year they wised up though, hiring a local who not only collected and weighed the fruit, but also changed the batteries of the sap flow system.

The study noted that the trees flowered and the fruit set significantly earlier in Thulamahashe than in Phalaborwa and Mooketsi, and the authors suggested higher rainfall as the reason. "Early fruit set and flowering may result in extended times for fruit development, which will increase fruit output and size," the report said. Similarly, higher temperatures and lower rainfall in Phalaborwa might explain longer leaf senescence and dormancy as trees skimped on energy and water.

Average annual transpiration of trees at Thulamahashe was 28 027 litres per tree, with an average yield of 28.9 kg/tree. At ZZ2, it was 23 690 litres with a much higher yield of 53.9 kg/tree; and at Phalaborwa, 25 336 litres, with an average yield of 23.4 kg/tree. The study defined water use efficiency as the ratio of yield produced per cubic metre of water transpired. Based on the above figures, the team arrived at ratios for the three sites of 1.03 for Thulamahashe, 2.27 for ZZ2 and 0.92 kg/m^3 for Phalaborwa.

The authors felt these values were "quite low" compared with those for exotic species, citing water use efficiencies of up to 18.0 kg/m^3 for apple trees in the Western Cape. Irrigation would likely make a big difference to yield, but this was by no means certain, as attempts to irrigate indigenous rooibos have demonstrated. More research was needed, said the report.

The findings on marulas and climate change were encouraging. The authors said warmer, drier conditions were expected to lead to a 10-12% increase in atmospheric evaporative demand in the Thulamahashe area for the period 1960 to 2099. However, the change in water use rates by marulas would probably be negligible: "Daily tree transpiration is projected to increase by less than 5%."

Why so? The authors reckon that although stomata would close more, reducing transpiration, the plant's assimilation of carbon-dioxide into carbohydrates by photosynthesis was likely to be less affected. So, the yield may well remain unchanged.
"This situation may even lead to increased water use efficiency by the marula... If confirmed, this is a very significant outcome of this study wherein marula trees can indeed be possible alternative tree crops under increasingly drier conditions."

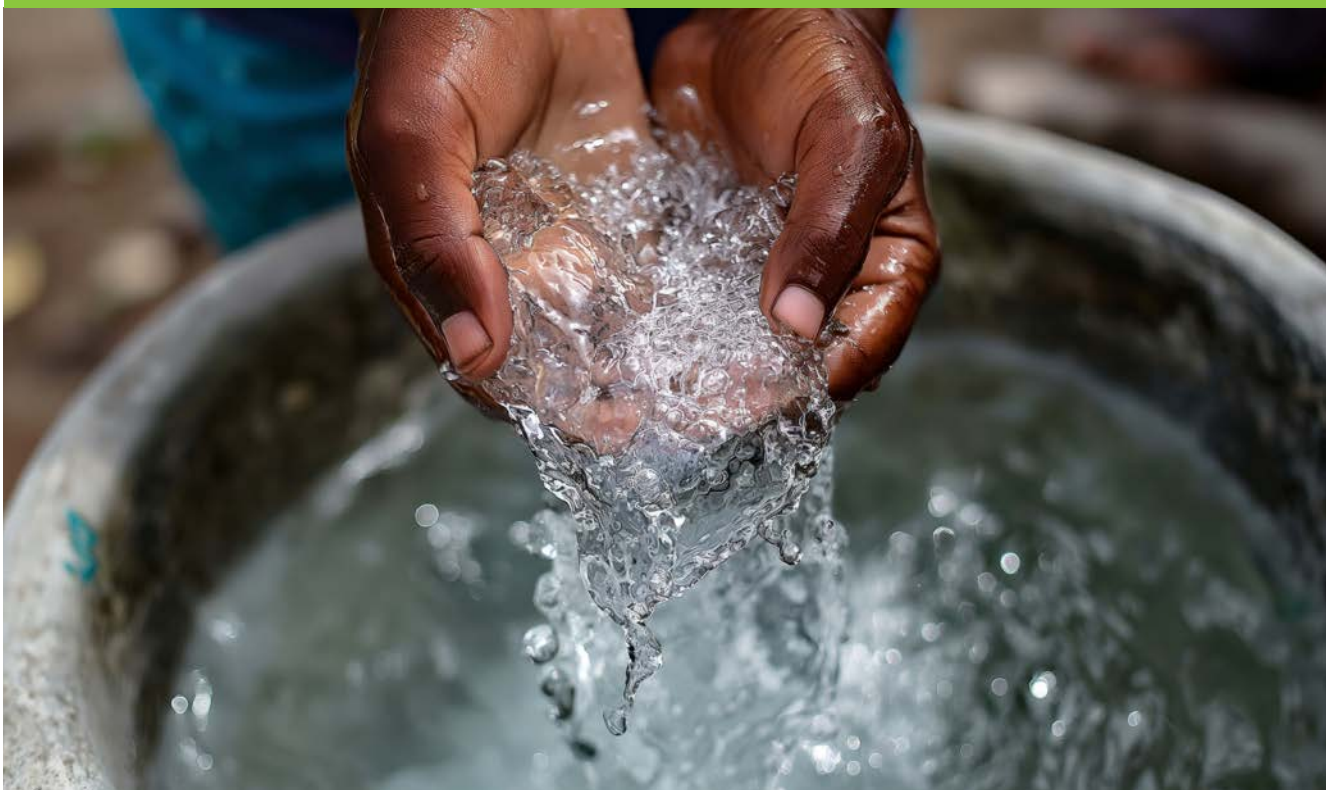
To access the research report, ***Water use of marula (Sclerocarya birrea) trees in various agro-ecological regions and post-harvest utilisation of its fruit and byproducts*** (**WRC report no. 3195/1/25**), visit: https://bit.ly/40tYQ4M

A traditional dish of corn and marula. Marula is prized for its nutritional qualities.

BASIC SERVICES

Rural communities still lagging behind in water, sanitation delivery – Stats SA

Access to safe, sufficient and reliable drinking water and sanitation is a fundamental human right, essential for health and everyday life. However, access to this right remains inequitable, both globally and in South Africa. This is according to Statistics South Africa (Stats SA) and their latest General Household Survey (2024) (GHS), released in May.



The latest survey was conducted between January and December 2024. Stats SA has been conducting the GHS annually since 2002. The surveys provide a critical assessment of the levels of development in the country as well as the extent of service delivery and the quality of services in a number of key service sectors, including water and sanitation, access to food, electricity and healthcare, among others.

According to the latest survey, while 71,8% of urban residents have access to safely managed water, only 36,7% of rural populations do – and nearly all those relying on limited, unimproved or even surface water live in rural areas. In contrast, access to basic water is higher in rural areas (44,2%) than in urban ones (27,5%), highlighting the uneven quality of supply. Basic water service refers to an improved source where collection takes no more than 30 minutes for a round trip, including any time spent queuing. If collection takes longer than 30 minutes, even from an improved source, it falls under limited access.

Goal 6 of the 2030 Agenda for Sustainable Development aims to ensure the availability and sustainable management of water and sanitation for all. It outlines specific goals, including universal access to safe drinking water (Target 6.1) and adequate

BACK TO TOP

sanitation and hygiene (Target 6.2). Tracking progress on these goals falls to the World Health Organisation/ United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Programme (JMP), which oversees global data on water, sanitation and hygiene (WASH).

Using its service ladders, the JMP enables comparisons of water and sanitation access across provinces and between rural and urban communities. "The service ladders help us understand not just who has access to services, but what kind of services they have," said Stats SA in a statement. "By using the ladders, governments and organisations can see where the biggest gaps are and focus efforts on helping people move up the steps towards safe, reliable water and sanitation."

Water services

Access to drinking water is classified using the 'water ladder', which ranks service levels based on proximity, safety and reliability of the water source. At the top of the ladder is safely managed water – a source located on the premises, available when needed and free from faecal and harmful chemical contamination.

Improved sources include piped water, boreholes, protected wells and springs, rainwater and packaged or delivered water. In contrast, unimproved water comes from sources such as unprotected springs and wells, while surface water – the lowest rung on the ladder – is drawn directly from rivers, streams, dams or ponds.

According to the latest data, more than two-thirds (67,8%) of households that fetch their water do so in under 30 minutes, while 5% spend over an hour on the task. More than a third (35,8%) of households in KwaZulu-Natal who do not have piped water in their dwellings or on site took more than 30 minutes to fetch water.

Almost four out of five households in South Africa (77,1%) had access to at least a basic level of drinking water in 2024, according to the national water ladder assessment. The Western Cape reported the highest level of access, with 99,8% of households meeting at least the basic standard, followed by Gauteng at 99,6%. Access was significantly lower in provinces such as KwaZulu-Natal, where 83.3% of households had basic water services, with Limpopo at 86,4% and the Eastern Cape at 87,8%. The latter three provinces also recorded the highest reliance on surface water, an indicator of limited or unsafe water access.

Stats SA also reports that although nationally, access to tap water inside dwellings, off-site or on-site improved by 3,3 percentage points between 2002 and 2024, it is notable that access declined in four provinces during this period. Declines were observed in Limpopo (-10,9 percentage points), Mpumalanga (-3,0 percentage points), Free State (-0,8 percentage points) and Gauteng (-0,7 percentage points).

The functionality of municipal water-supply services measures the extent to which households that received water from a municipality reported, over the 12 months before the survey, interruptions that lasted more than 2 days at a time, or more than 15 days in total during the whole period. In addition to the number of days, households were asked to specify the frequency of these water interruptions. More than half (55,2%) of households in South Africa experienced water interruptions in 2024. Weekly water interruptions (13,9%) were most common in Mpumalanga (39,4%), KwaZulu-Natal (28,5%) and Limpopo (26,0%) and least common in the Western Cape (0,8%). Only 3,2% of households experienced water interruptions only once in the past 12 months.

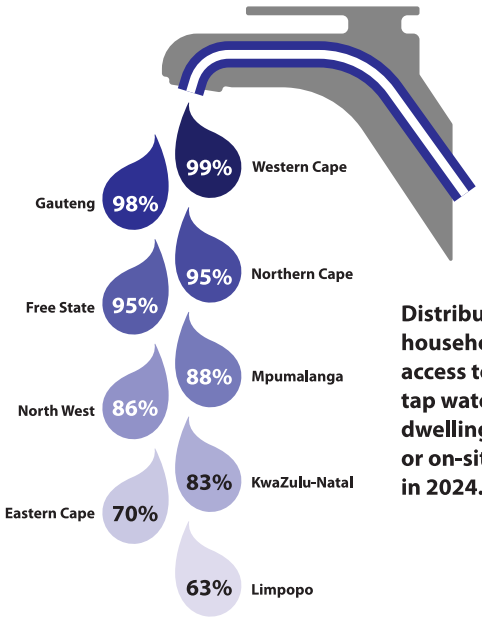
Furthermore, water interruptions that lasted at least two days were most common for households in Mpumalanga (66,2%), Northern Cape (58,0%), and Limpopo (52,0%) and least common for households in Western Cape (5,6%) and Gauteng (23,4%). Approximately one-third (33,7%) of South African households reported some dysfunctional water-supply service in 2024.

The survey also considered water quality as experienced by households. Households were asked about the taste, smell and clarity of their drinking water. Nationally, about 8 in 10 people still consider their municipal water safe to drink. Trust in water quality differed widely across the provinces, ranging from 90,8% in Limpopo, 89,4% in Gauteng and 89,6% in Western Cape to 66,8% in the Northern Cape, and 75,9% in North West.

Sanitation

Improved sanitation facilities are those designed to safely separate human waste from contact, helping to protect health and hygiene. These include flush and pour-flush toilets connected to sewer systems, septic tanks, or pit latrines; pit latrines with slabs (including ventilated ones); and composting toilets.

Under SDG 6.2, a sanitation service is considered safely managed if it meets three key conditions: the facilities must be improved, not shared with other households, and the waste must be properly treated. This can happen in one of three ways, namely the waste is treated and disposed of on site; it is stored temporarily and then emptied and treated elsewhere; or it is transported through a sewer system and treated offsite.

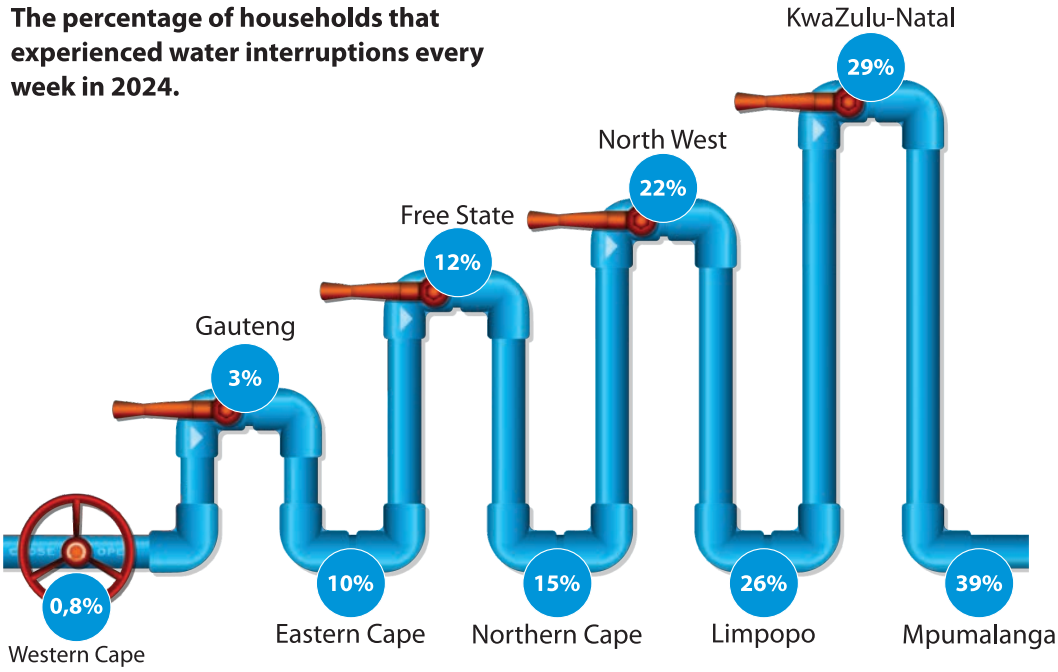


Source: Stats SA

Distribution of households with access to piped or tap water in their dwellings, off-site or on-site by province in 2024.

Source: Stats SA

The percentage of households that experienced water interruptions every week in 2024.



If the waste from improved facilities isn't safely handled, the service is classified as basic. When improved facilities are shared between households, they fall under the limited service category.

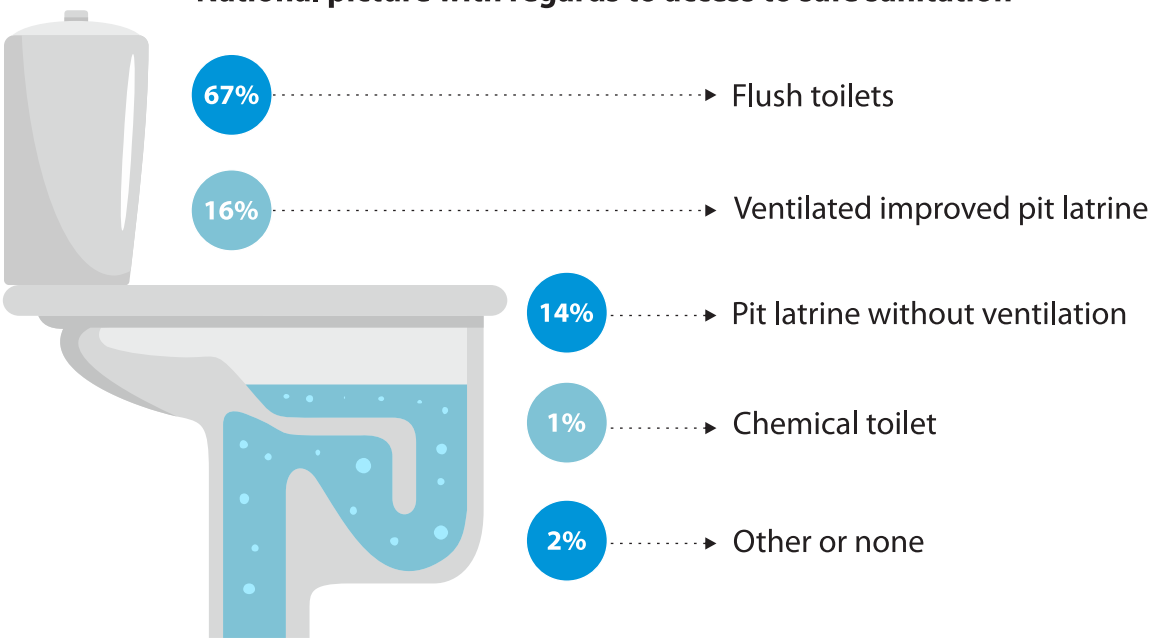
In South Africa, access to proper sanitation varied depending on where people live, the condition of the services available and their overall living environment. In 2024, just under half – 46,2% - of households reported having sanitation facilities located inside their homes.

Nationally, 76,3% of South Africans had access to safely managed sanitation services, which meet hygiene standards and ensure proper waste treatment. The highest rates were recorded in the Eastern Cape (85,3%) (reportedly due to the ventilated improved pit rollout programme), Mpumalanga (84,7%), and the Northern Cape (84,4%). In contrast, only 66,1% of the population in Gauteng had access to safely managed sanitation.

This disparity may be due to high population density, housing shortages, or limited space in cities. In many urban informal settlements, multiple households often live in cramped conditions without enough land or infrastructure to support private toilets. As a result, shared facilities become the only option. Meanwhile, rural areas, though often less developed, typically have more space per household, allowing for private or household-level sanitation, even if at a basic level.

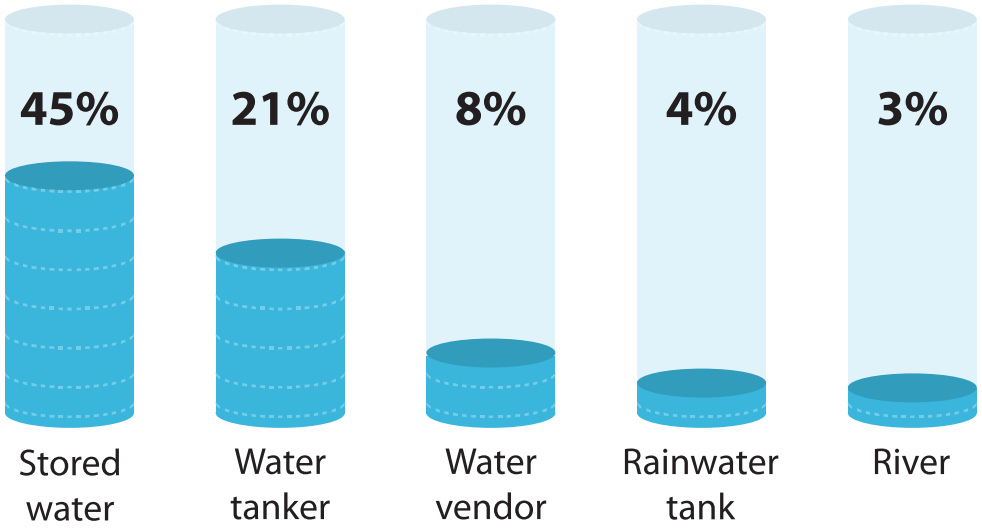
Source: Stats SA

National picture with regards to access to safe sanitation



BACK TO TOP

The five most commonly used alternative sources used by households when experiencing water interruptions



Source: Stats SA

Access to safely managed sanitation services in rural areas surpasses that of urban areas, with 79,6% compared to 74,6%. This is mainly due to the widespread use of improved facilities shared with other households, accounting for 21,4%. In rural areas, individuals relying on unimproved facilities or practicing open defecation are more commonly found.

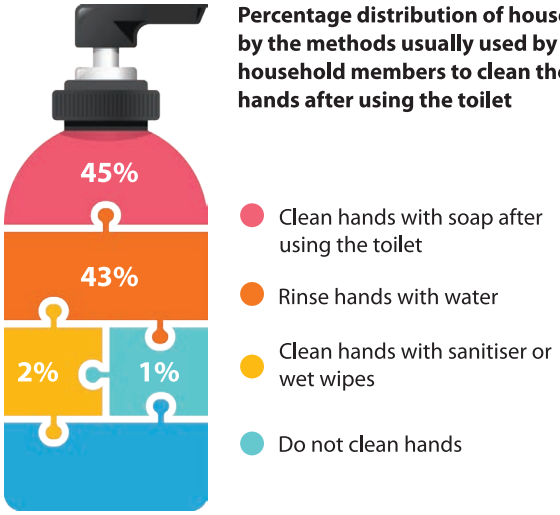
Nationally, almost two-thirds (66,7%) of households used flush toilets that were either connected to a public sewerage system or a septic or conservancy tanks, while another 16,3% used pit toilets that are connected to ventilation pipes. Households that did not have access to improved sanitation facilities largely depended on pit toilets without ventilation pipes (14,1%). The use of flush toilets was most common in the Western Cape (96,7%), Gauteng (87,8%) and Free State (78,4%). About one-third (30,7%) of households in Limpopo used some type of flush toilet, while another 31,5% used ventilated pit toilets. The largest percentage of pit toilets with ventilation pipes was observed in the Eastern Cape (42,0%), Limpopo (31,5%), and KwaZulu-Natal (27,0%).

Improved sanitation facilities are those designed to hygienically separate excreta from human contact. For sanitation facilities such as flush/pour flush toilets connected to piped sewer systems or septic tanks, excreta are treated and disposed of *in situ* or transported through a sewer with wastewater and then treated off-site. To meet the criteria for a safely managed sanitation service, the excreta from septic tanks or pit latrines (including ventilated pit latrines) and composting toilets should be stored temporarily and then emptied and treated off-site.

Nationally, only one-tenth (10,8%) of households reported that their septic or conservancy tanks, or the chambers of the pit toilets they used, have ever been emptied. Emptying was most common in the Western Cape (88,2%), Gauteng (44,2%), and the Free State (38,4%), and least common in Limpopo (1,2%) and Mpumalanga (3,4%).

Hand hygiene has decreased markedly since the outbreak of COVID-19, with only about half of households (53,7%) indicating that they regularly wash their hands with soap and water. This is despite the fact that more than two-thirds (68%) of households have access to a hand-washing facility.

Percentage distribution of households by the methods usually used by household members to clean their hands after using the toilet



Source: Stats SA

Access to water and sanitation is essential for maintaining health, dignity, and overall well-being in households. It prevents disease, supports hygiene, and improves quality of life. Ensuring reliable access to these basic services fosters safer, more resilient communities and is a critical step toward achieving global health and development goals.

To access the full survey results, visit: https://www.statssa.gov.za/publications/P0318/P03182024.pdf

BACK TO TOP

GROUNDWATER MANAGEMENT

From space to soil: Tracking South Africa's shrinking water reserves

TrigNet vs GRACE/-FO – How can ground-based GNSS stations and satellite-based gravity measurements be used to monitor droughts and groundwater depletion? Article by Sue Matthews.

A somewhat surprising effect of climate change was recently reported by local and international media, following a press release issued in April by the University of Bonn in Germany. Titled "Climate change is lifting South Africa out of the ocean", it claimed that droughts and the associated water loss caused the country to rise by 6 mm between 2012 and 2020.

The press release marked the publication of a paper by Mielke et al. in the ***Journal of Geophysical Research: Solid Earth***. This had the far less sensationalist title "GNSS observations of the land uplift in South Africa: implications for water mass loss", referring to data from the national network of continuously operating Global Navigation Satellite System base stations. Known as TrigNet, it came into operation in 1999, providing Global Positioning System (GPS) data that is used not only for surveying and mapping but also for research and monitoring of atmospheric water vapour, space weather and movements of the Earth's crust.

Recent studies by Hammond et al. (2021) and Gourley and Harig (2024) have used the data to show that the land surface in many regions of South Africa has been rising at a rate of up to 2 mm per year. These authors attribute the uplift either to dynamic topography – the interaction between the Earth's hard outer shell, or lithosphere, and the hot, slow-flowing rock of the mantle below – or to a plume of buoyant material upwelling from the deeper parts of the mantle. The mantle plume was hypothesised in 1985 by the late Dr Chris Hartnady, then of the University of Cape Town's geology department and later known to many in the water research field through his work at Umvoto, the consultancy founded by his partner, Dr Rowena Hay. He identified its likely location in the Lesotho–KwaZulu-Natal region and named it the Quathlamba hotspot after the Zulu name for the Drakensberg, uKhahlamba, meaning "barrier of spears". More than three decades later, Gilfillan et al. (2019) reported that the isotopic composition of gas samples collected from natural carbon dioxide seeps along the Ntlakwe-Bongwan fault in

BACK TO TOP

KwaZulu-Natal confirms the existence of the Quathlamba mantle plume.

The German research team proposes an alternative explanation for the observed uplift, believing that it is the elastic response of the crust to reduced surface mass load resulting from water loss during droughts. To arrive at this conclusion, they initially downloaded GPS height time series for 102 GNSS stations but excluded 14 that recorded less than three years of data. Singular spectral analysis was then used to separate long-term trends and annual and semi-annual signals from noise for the remaining 88 stations. Of these, only 57 stations were used for further data analysis, the rest being excluded because they showed unusual motions compared to neighbouring stations. The vertical motion determined from the processed GPS height time series was inverted into point mass loads to model changes in total terrestrial water storage (TWS), according to a method developed by other researchers more than a decade ago.

The resulting TWS changes were validated with those in the Global Land Water Storage (GLWS) version 2 dataset, which is produced by assimilating TWS changes derived from GRACE/-FO into the WaterGAP Hydrology Model. GRACE/-FO refers to the Gravity Recovery and Climate Experiment satellite mission, operational from April 2002 to July 2017, and its successor, GRACE Follow-on, which began providing data in June 2018. A second validation step was done with TWS data derived from the Global Land Data Assimilation System Noah (GLDAS-Noah) model, which does not include GRACE/-FO data as an input. The validation exercise revealed a correlation of 46% between GPS- and GLWS-derived TWS and 53% between GPS- and GLDAS-Noah-derived TWS, but a much stronger correlation of 84% when GPS-derived TWS was compared with the original GRACE/-FO solution used for the GLWS computations.

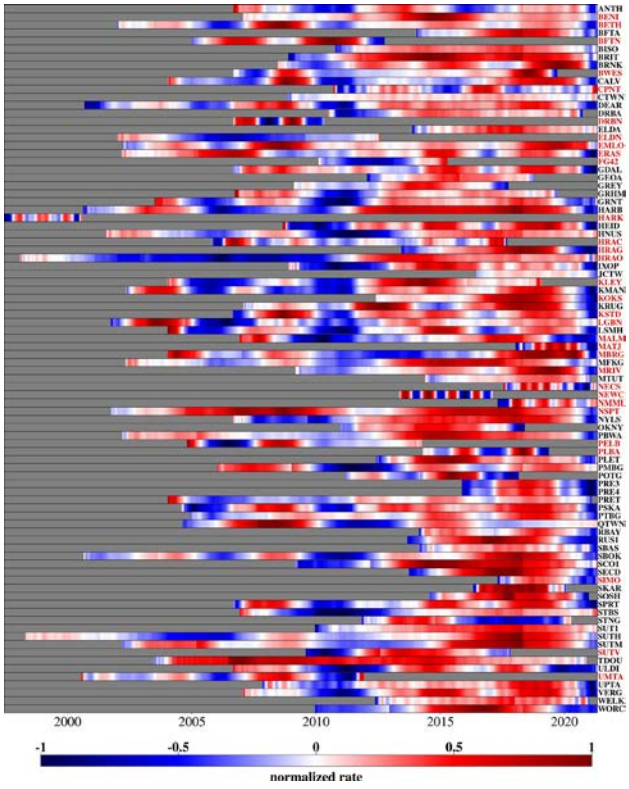
In analysing long-term trends in all three datasets, the team observed an increase in TWS during the 2011 and 2021 La Niña events and a decrease with the onset of dry periods in 2015 around the El Niño event. In total, the GPS-derived TWS exhibited a net mass loss of –71.3 mm over the entire period from September 2000 to April 2021.

Similar studies have been done elsewhere in the world, where the network of GNSS stations is denser and more evenly spread, but the research team notes that it's clear from their findings that seasonal and long-term hydrological changes can be measured even with limited GNSS coverage. "The TrigNet GNSS network in South Africa, originally set up for engineering projects, has great potential for hydrological applications such as estimating the impact of drought on water resources, especially if the network is expanded to cover more areas. For example, regions in the northwest of South Africa, such as the Northern Cape and North West, could particularly benefit from hydrogeodesy if GNSS sites are installed there," they conclude.

According to Richard Wonnacott, who was instrumental in establishing and developing TrigNet before he retired as Director of Survey Services at the Chief Directorate: National Geo-Spatial Information (CD: NGI) in 2013, the reliability of the network has been remarkably good since its inception and is now at about 95% or better, given that telecommunication links relying on copper wire have been replaced by fibre optic and other modern technologies. GNSS data is streamed to the central control station at CD: NGI at one-second intervals, 24 hours per day and 365 days per year, and processing of this data allows horizontal and vertical land movements to be estimated to a very high level of accuracy and precision.

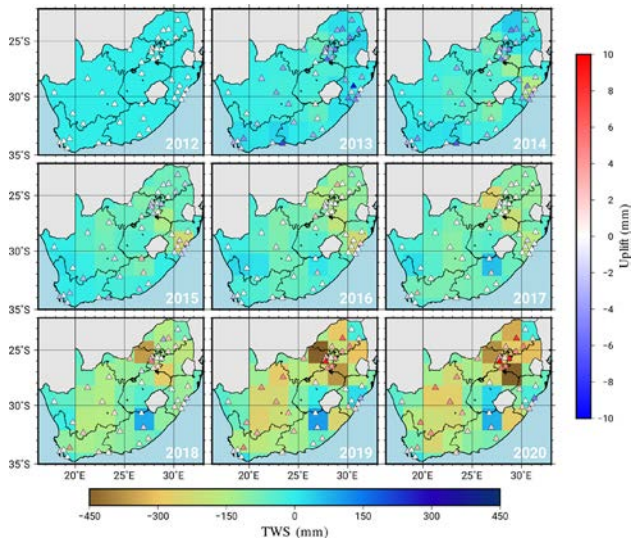
The research team points out that GNSS data can complement GRACE/-FO data, which is only accessible months after capture, has limited spatial resolution and is subject to several sources of error. The GRACE/-FO satellite mission is particularly special because it is the first and only one that allows for groundwater monitoring, but there are additional uncertainties when deriving groundwater storage changes from the TWS data. This is because TWS is the sum of all water storage in snow, ice, lakes, rivers, dams, wetlands, canopy water, soil moisture and groundwater. Extracting the groundwater data requires estimating all the other components using models, other satellite data or available field data, and then subtracting them from the TWS.

In fact, GRACE/-FO does not even measure TWS directly, but rather variations in the Earth's gravity field. And, unlike most satellite missions, its observations are not based on measurement of reflected or emitted wavelengths in the electromagnetic spectrum, which would only be useful for water in the first few centimetres below the land surface. Instead, GRACE/-FO relies on twin satellites orbiting the Earth about



Normalised daily vertical displacement rates (rate-gram) for all GNSS stations derived from the long-term trend using singular spectrum analysis (SSA), where red = rising; blue = sinking. The rise was particularly pronounced during the drought between 2015 and 2019. Station names in red, which showed unusual motion compared to neighbouring stations, were excluded when modelling terrestrial water storage. From Mielke et al., 2025. https://doi.org/10.1029/2024JB030350

BACK TO TOP



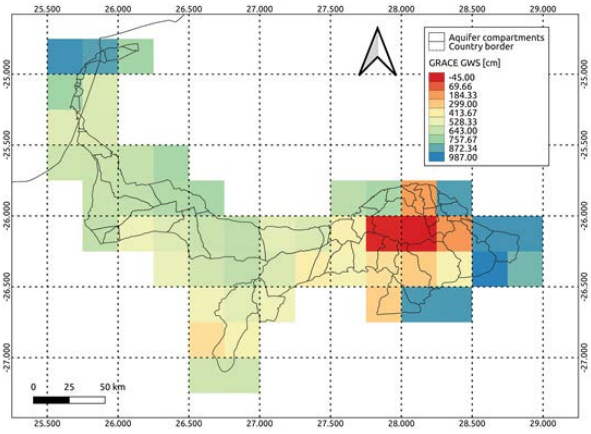
Mean annual variations in GPS-derived terrestrial water storage and land uplift at GNSS sites, both relative to the mean of 2012. The browner the region, the higher the water loss. Red triangles represent GNSS sites that had risen in height since 2012. From Mielke et al., 2025. https://doi.org/10.1029/2024JB030350

220 km apart, with the exact distance between them being measured every few seconds as each experiences a stronger or weaker gravitational pull due to surface mass changes. This and other data are used by three different processing centres in the United States and Germany – each using their own algorithms to generate different solutions – to produce monthly maps of the Earth's gravity field. With further processing, gravity field changes from month to month are used to produce monthly maps of TWS anomalies, representing a deviation from a long-term mean.

The spatial and temporal resolution of GRACE/-FO data products – 200 000 km² and monthly respectively – limits their usefulness for local application and short-term events, although various downscaling methods have been developed to improve resolution. These typically involve integrating the data products with higher-resolution datasets or using models, statistical interpolation or machine learning algorithms.

In South Africa, a number of projects using GRACE/-FO for groundwater-related research have been undertaken to date.

- Zaheed Gaffoor and colleagues conducted a study that was funded by a multi-agency coalition and published in February 2021 as the Water Research Commission report ***Big data analytics and modelling – localising transboundary data sets in southern Africa: a case study approach (WRC report no. TT 843/20)***, http://bit.ly/4nmJDMX. The main aim of the research was to investigate the use of big data analytics to integrate, match and model groundwater data to improve sustainable groundwater management at the local scale. GRACE/-FO-derived groundwater storage anomalies were one of nine hydroclimatic parameters used in a machine learning model to predict 30-day groundwater level changes at ~5 x 5 km resolution across two case study areas: the Zeerust/Lobatse/Ramotswa karstic dolomite aquifers in North-West Province and Gauteng, extending into Botswana, and the Shire Valley alluvial aquifer straddling the border between Malawi and Mozambique. The case studies were used for two papers published in 2022 in ***Hydrogeology Journal*** and ***Hydrology*** respectively, which formed part of Gaffoor's PhD thesis submitted to the University of the Western Cape.



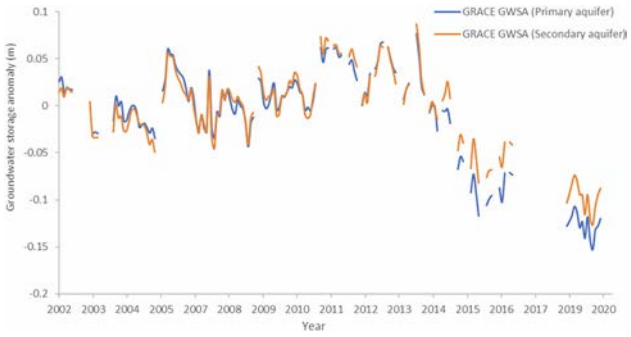
Net GRACE-derived groundwater storage anomaly 2002-2020 for the Zeerust/Lobatse/Ramotswa dolomite aquifers, compared to the baseline period 2004–2009. From Gaffoor et al., 2021. WRC Report No. TT 843/20.

- Khuliso Masindi explored the potential of GRACE/-FO data in his PhD thesis, 'Water resources modelling in the Vaal River Basin: an integrated approach', for which he was awarded his degree by the University of the Witwatersrand. In a May 2021 webinar, available on the Ground Water Division's YouTube channel, he emphasised that GRACE/-FO data is used for estimating changes in groundwater storage rather than groundwater storage itself, which would require an understanding of the aquifer properties, and there must be a significant mass movement of water for anomalies to be detectable. Although GRACE/-FO data is best applied in areas exceeding 200 000 km², the Vaal River Basin is 197 513 km², yet the results yielded no clear relationship between GRACE/-FO-derived groundwater storage change and total rainfall, annual rainfall anomaly, surface water storage or soil moisture. Nevertheless, GRACE/-FO-derived groundwater storage had shown an increase of 3.31 km³ per year over the period 2003–2014, and the drivers of this increase were probably the input of above-average rainfall events and induced recharge by the big dams in the area. Masindi noted that the GRACE/-FO-derived groundwater storage change was not validated with groundwater level data due to data scarcity, and concluded by stressing the need to continue field-based monitoring to collect this and other hydro-meteorological data.

- Manish Ramjeawon and co-authors used GRACE/-FO data to analyse groundwater storage change in the primary and secondary aquifers of the Usutu-Mhlatuze Water Management Area in northern KwaZulu-Natal. The main primary aquifer is located on the Maputaland coastal plain, where streams, lakes and wetlands are groundwater dependent to varying degrees, while the secondary aquifers occur further inland. An initial validation exercise for the period 2010 to 2016 showed good agreement between GRACE/-FO-derived groundwater storage

BACK TO TOP

anomalies and in-situ groundwater storage anomalies determined from observation borehole data, so GRACE/-FO data was used for the full study period between 2002 and 2020. The results indicated that groundwater storage increased relative to the 2004–2009 mean during the period 2002–2014 and then declined drastically during the period 2014–2020. The water level of Lake Sibayi had dropped markedly by 2020, and the areal coverage of other wetlands and waterbodies on the coastal plain had decreased significantly. The groundwater storage loss and the associated impact on surface water systems was attributed to a change in land use – particularly the rapid expansion of commercial forestry plantations – combined with groundwater abstraction and regional climatic changes, evident as increased evaporation and evapotranspiration and decreased precipitation. The research was published in the ***Journal of Hydrology: Regional Studies*** in 2022 and was the basis of Ramjeawon's PhD thesis submitted to the University of KwaZulu-Natal.

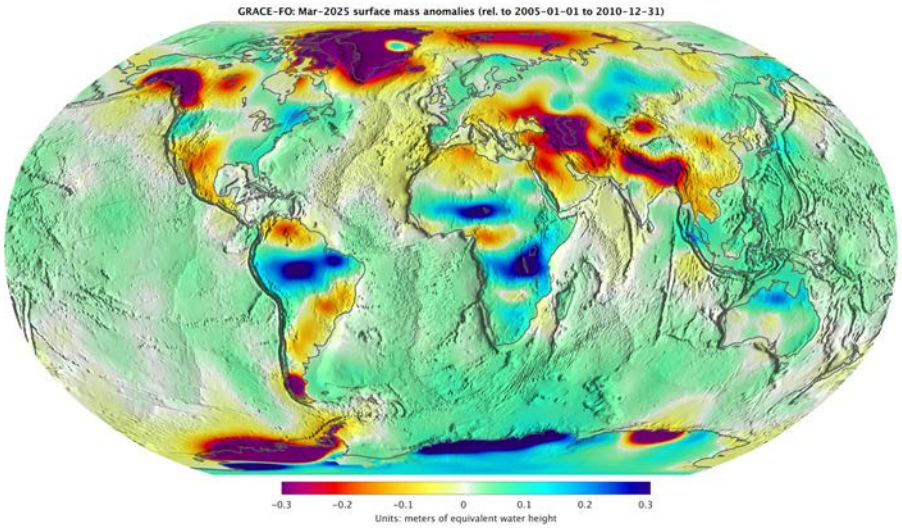


GRACE derived groundwater storage anomalies for the primary and secondary aquifers of the Usutu-Mhlatuze Water Management Area between 2002 and 2020 relative to the baseline mean (2004 –2009). From Ramjeawon et al., 2022. https://doi.org/10.1016/j.ejrh.2022.101118

- Ritshidze Nenweli evaluated GRACE/-FO data to assess groundwater storage during droughts in the Western Cape for her MSc degree, awarded by Stellenbosch University in 2023, and published the research with co-authors in the ***Journal of Hydrology: Regional Studies*** in 2024. In-situ data on groundwater storage variations in 12 of the province's aquifers were compared with that from both GRACE/-FO and GLDAS, which integrates satellite and ground-based data using advanced land surface modeling and data assimilation techniques. For GRACE/-FO data, the highest positive correlation ($r = 0.69$) was found between GRACE/-FO-derived TWS anomalies and in-situ groundwater storage variations in the Adelaide Subgroup Aquifer. This is an unconfined aquifer with an areal extent of 194 000 km² – close to GRACE/-FO's recommended resolution of 200 000 km². GRACE/-FO-derived groundwater storage anomalies combined with soil moisture changes from the GLDAS Catchment Land Surface Model (CLSM) had the greatest correlation ($r = 0.52$) with in-situ data from the Bokkeveld Aquifer. The strongest correlations were found between GLDAS-based groundwater storage anomalies and groundwater storage variations in the unconfined Table Mountain Group Upper Aquifer Unit ($r = 0.83$) and Cape Flats Aquifer ($r = 0.73$).

In addition to these studies, several papers by international research teams address the use of GRACE/-FO data to monitor groundwater in Africa's largest aquifers, including the Main Karoo Basin in South Africa.

In conclusion, the integration of ground-based GNSS stations like TrigNet and satellite-based systems such as GRACE/-FO presents a powerful approach to monitoring groundwater depletion and drought impacts in South Africa. While GRACE/-FO provides invaluable large-scale insights into terrestrial water storage, its spatial and temporal limitations highlight the complementary role that GNSS data can play in offering higher-resolution, real-time measurements. The growing body of local research using these technologies demonstrates both their current value and future potential for water resource management.



NASA-JPL

Global surface mass anomalies observed by the GRACE-FO satellites for March 2025. Over land, red indicates below-average terrestrial water amounts, while blue shows above-average water amounts. Over oceans, red indicates below-average ocean bottom pressure, while blue shows above-average bottom pressure. Ocean bottom pressure changes are related to large-scale ocean current variations, as well as overall sea level changes from ocean mass changes.

BACK TO TOP

GROUNDWATER EXPLORATION

The challenges and rewards of deep groundwater exploration

A new study funded by the Water Research Commission (WRC) offers groundbreaking insights into deep groundwater systems within the Bushveld Igneous Complex. It is one of the most detailed hydrogeological investigations conducted on deep fractured aquifers in South Africa. Petro Kotzé reports.

Amy Allwright

Drill rods to be used at the rig became progressively smaller, the deeper the drill team went down the igneous rock.

Deep groundwater remains an unexplored resource in South Africa and globally. Deep aquifer systems are expensive to explore, and those that do, like mines, are more interested in generating geological than hydrogeological data. As a result, we don't know what potential water resources lie down there – either for residential, agricultural, or industrial use, or even space for more controversial uses, such as storing carbon to offset the impacts of climate change.

A WRC-funded study aimed to shed new light on deep groundwater systems in one of South Africa's most geologically significant formations — the Bushveld Igneous Complex (BC). Conducted in collaboration with the International Continental Scientific Drilling Programme (ICDP)-funded Bushveld Complex Drilling Project (BVDP), this research is leading to significant advances in understanding groundwater flow, chemistry, and structure in deep, fractured aquifers hosted in crystalline rock.

The knowledge was hard to come by, and specifics will take time to unravel, but the results are already raising questions about what we thought we knew and how these unexplored places should be responsibly used in the future.

Drilling into the BIC

The Bushveld Igneous Complex is a large layered igneous intrusion within the Earth's crust, which has been tilted and eroded and now outcrops around what appears to be the edge of a great geological basin. The vast and ancient geological formation spans 65 000 km^2 across the provinces of Limpopo, Mpumalanga, North West, and Gauteng. Its three sections, an eastern and western lobe, and a northern extension, were formed about two billion years ago. These were created when vast quantities of molten rock from the Earth's mantle were brought to the surface through long vertical cracks in the crust. The effects of these injections of molten rock over time, combined with the crystallisation of different minerals at different temperatures, resulted in the formation of a structure rather like a layered cake consisting of distinct rock strata, including three layers, referred to as reefs, that bear the world's largest reserves of platinum Group Metals (PGMs).

BACK TO TOP

The research cohort for the first trip to the drilling site: Fanie de Lange (University of the Free State(UFS)) and Amy Allwright (Stellenbosch University); Rolene Lubbe (PhD student, UFS) and Leor Bester (Honours student, UFS); Yohey Suzuki (Japanese colleague (University of Tokyo) working on microbiological research) with Mpho Molautsi (University of Limpopo MSc student); and Jared van Rooyen (SU alumni; Eawag; Uni. Basel (Switzerland)) for the online gas analysis system (miniRuedi).

The Bushveld Igneous Complex is thus globally renowned for its mineral wealth, and the PMG reserves of platinum, palladium, osmium, iridium, rhodium, and ruthenium are the world's largest. There are also vast quantities of iron, tin, chromium, titanium and vanadium.

The broader goal of the BVDP, run by a large team of experts led by Prof Susan Webb of the University of the Witwatersrand, is to acquire two complete reference profiles through the entire six- to eight-kilometre thickness of the iconic Rustenburg Layered Series, including the ore horizons within it. This is to be achieved through donated core from the mining industry from all the limbs of the Bushveld Igneous Complex, and then a single drilled hole to complete the sequence below the resource, which is not typically drilled.

This information will answer questions about the nature of the magma sources, melting processes, chambers and emplacement that gave rise to enormous magma volumes and rich mineralisation so many millennia ago.

However, drilling that deep also created a rare opportunity that supported the WRC's hydrogeological ambitions, even though sceptics doubted its importance. Stellenbosch University lecturer, Amy Allwright, the WRC project leader and co-project leader on the BVDP, says the general feeling was that there's nothing that deep down in the solid, impermeable rock. Still, Allwright was keen to see what they would find along the planned 2 500 m borehole. The resulting WRC-supported project aimed to gather hydrogeochemical, isotopic, and structural information. This knowledge would be critical to understanding the behaviour of water in these ancient, fractured rock systems.

Though undertaking a deep drilling project of this scope would likely always entail some challenges, the extent of the logistical,

Amy Allwright

Core trays containing the first core from the borehole. The WRC-funded project managed to drill to 950 m before its time at the site came to an end; however, drilling continued as part of the larger Bushveld Complex Drilling Project.

BACK TO TOP

Amy Allwright

The project site was at the remote Impala Marula Mine in the Limpopo Province. The larger project is aiming to drill a transect through the Bushveld Igneous Complex.

technical, and financial difficulties took even seasoned scientists and drill experts by surprise.

Rolling in the deep

The borehole (BVDP-2) was drilled at the remote Impala Marula Mine in Limpopo (in the eastern limb of the Bushveld Igneous Complex), a place that felt like you were in the middle of nowhere, in a different county, Allwright recalls. Power was supplied by generators, internet access had to be negotiated, temporary offices consisted of containers, temperatures were extreme, and site operators worked extended hours.

Technically, the drilling process was complex and multi-phased. The borehole was drilled in progressively smaller diameters, with casing inserted to stabilise the hole at various depths. Water samples had to be collected quickly before the borehole casing prevented further access. "I had a small window to collect those samples," says Allwright. "Once it was cased, that was it."

Researchers also had to take cognisance of the drilling fluid, a viscous lubricant that seriously complicates water filtration and impacts the integrity of the sample.

From the outset, the borehole experienced total water loss for the first 300 m, when all drilling fluid disappeared into the rock, never returning to the surface. Despite this, progress was steady until around 950 m. Then, the problems and surprises surfaced.

"The drill rods started twisting under pressure, the borehole began to deviate, and we had to insert wedges to straighten it — not an easy fix," Allwright explains. "It totally blew our timeline. We went from 950 to just 1,200 m over several months, and eventually hit a lamprophyre dyke, which brought a whole new set of complications." Here, cementing efforts between 1 150 and 1 270 metres failed repeatedly due to persistent groundwater inflows — an unexpected and revealing hydrological behaviour in rock usually considered impermeable at depth.

The idea that there was any active water movement in these deep systems surprised many of us, Allwright says. The water chemistry, the pressure zones, the role of dykes — all of it pointed to more complexity than first thought.

Still, the complications resulted in long delays and ballooning costs. "You understand now why people don't collect water samples at these depths — from some perspectives, it's just not a reasonable investment," she explains.

Then, when the borehole was flushed with clean water, a dark, strong-smelling fluid was expelled from the hole, an unexpected anomaly that raised questions about deep hydrogeological and geochemical processes (analysis results are pending). Finally, the team managed to drill up to a depth of 950 m before the time and funds for the hydrogeological investigations ran out. Although the original aim was to reach 2 500 m by this time, the data collected still delivered valuable insights. And, as the larger BVDP project continues, Allwright says that they will collect the final water samples from the deeper section of the hole once drilling has finished.

Insights from the deep

The findings called for a revision of the existing hydrogeological model for the eastern Bushveld limb. Updates include evidence of two distinct systems — a shallow and a deeper one — based on water quality analysis. The difference in water quality supports the assumption, also made in the western limb, that shallow aquifers are generally not connected to those deeper than 300 m.

A second revision includes that a fractured aquifer between 100 and 500 m shows signs of higher hydraulic conductivity. At around 800 m, a high-density fracture zone (deep aquifer) was identified, with potential for groundwater flow. Then, the dark, strong-smelling fluid that was expelled suggests possible interaction with hydrothermal fluids, brines, or deep organic processes at depths between 1 150 and 1 270 m, where significant groundwater inflows were found.

At approximately 1 265 to 1 270 m, a lamprophyre dyke may act as either a conduit or a barrier for fluid movement, depending on the orientation and density of the fractures. The connectivity of faults and fractures controls localised recharge and groundwater flow.

This updated information reflects the complexity of the Bushveld Igneous Complex's groundwater systems, with variable hydraulic properties and flow patterns. The system incorporates deep fracture-controlled aquifers, helping assess groundwater potential at depth.

According to the final report, published in May, the findings indicate that deep groundwater systems within the Bushveld Igneous Complex could serve as a resource for industrial and mining applications, particularly in regions where surface water is scarce. Additionally, the elevated temperatures and gas anomalies suggest a potential for geothermal energy, warranting further investigation.

Another key challenge was the influence of drilling fluids during sampling, which introduced complexities in the hydrochemical and isotopic analyses. Still, the fact that valuable hydrogeological information was successfully collected demonstrates the

BACK TO TOP

potential for further deep groundwater research in the Bushveld Igneous Complex.

Allwright says they hope to get the opportunity to do precisely that. Since BVDP-2 is such a rare opportunity to study a deep groundwater system relatively unaffected by the shallow aquifer, they are hoping to keep it open. Usually, once a borehole like this is drilled, it's closed or cemented shut, especially in mining areas. The plan, explains Allwright, is to let BVDP-2 rest for about a year, allowing the drilling fluids to clear out and the system to stabilise. "It's almost like a natural lab," she says. Then, if funding allows, they will go back with more time, better tools, and fewer constraints. Then they want to collect samples that haven't been contaminated by drilling fluid.

In the meantime, work on the existing samples is ongoing. A PhD student is working on the hydrogeological characterisation of the water samples, investigating the impact and consequences of drilling fluid contamination and a third topic, studying the geochemical and structural indicators for hydrothermal fluid migration in the Bushveld Igneous Complex.

More information, more questions

There are broader implications, too. Allwright asks how we can manage, protect, or even use these systems if we do not understand them. With the pressure on for energy transitions, mining, and carbon sequestration, the deep subsurface is becoming more critical. However, we're currently moving into these areas without a clear understanding of the groundwater implications. For instance, injecting CO_2 into deep formations may not affect surface water, but it does alter groundwater chemistry and microbiology, and, she says, we don't know what that means long term.

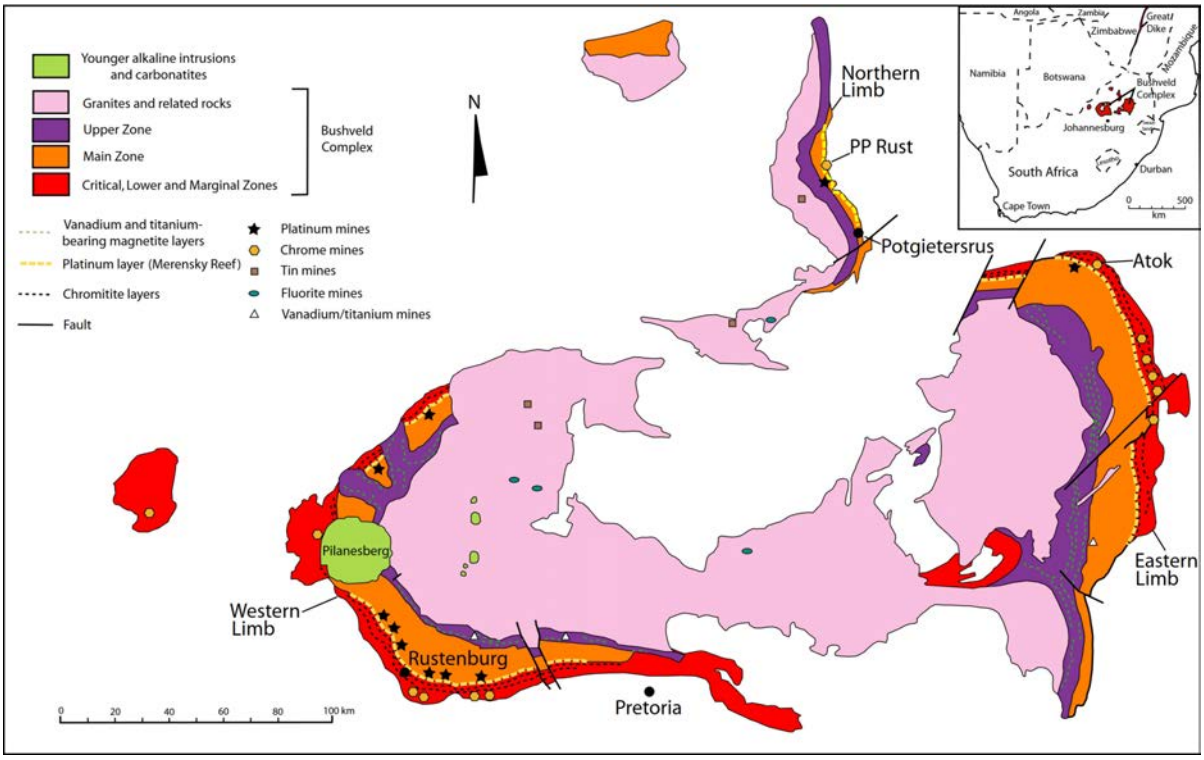
What we do know, according to this project, is that the Bushveld Igneous Complex is more complex than previously thought, with potentially important consequences for water resources management.

It also identifies key areas for further study, including geothermal energy, isotopic dating, and long-term fluid monitoring. BVDP-2 is already the deepest hydrogeological characterisation in this region. The data reveal real potential for development, but most importantly, they show that deep groundwater is not just a blank space below — it's an active, complex system that we need to understand before we start altering it.

To access the original research report, ***Research-based exploration of deep groundwater within the eastern limb of the Bushveld Igneous Complex for hydrogeological characterisation and potential future water resource identification***, visit: https://www.wrc.org.za/wp-content/uploads/mdocs/3200.pdf

References:

- Allwright, A. J., de Lange, S., Lubbe, R., Mbonambi, L., Vivier, K., & Witthuser, K. T. (2025). ***Research-based exploration of deep groundwater within the eastern limb of the Bushveld Igneous Complex for hydrogeological characterisation and potential future water resource identification*** (WRC Report No. 3200/1/25; ISBN 9780639207063). Water Research Commission.
- Department of Water and Sanitation. (n.d.). ***Bushveld Igneous Complex*** (Groundwater Dictionary). Retrieved June 20, 2025, from https://www.dws.gov.za/Groundwater/Groundwater_Dictionary/index.html?waterberg_supergroup2.htm



The Bushveld Igneous Complex is a vast and ancient geological formation that spans 65 000 km² across the provinces of Limpopo, Mpumalanga, North West, and Gauteng.

BACK TO TOP

FOOD SAFETY

Science in Action: The WRC and UP – celebrating 20 years of water quality and produce safety research

The Water Research Commission (WRC) and the University of Pretoria (UP) reflect on a partnership of over two decades to ensure that the food we eat remains safe for consumption. Liza Korsten, Loandi Richter-Mouton, Manana Dlangalala, Eunice Ubomba-Jaswa, and Samkelisiwe Hlophe-Ginindza.

World Food Safety Day is celebrated annually on 7 June to raise awareness about the importance of food safety and its impact on human health, trade, and sustainable development. This year's theme was 'Science in Action', highlighting the importance of sustainable funding, like that from the WRC. Over 54 years, the Commission has funded water research to ensure access to quality, fit-for-purpose water in South Africa. Its outputs inform policy, empower communities, promote sustainable solutions, and strengthen capacity in the water and science sectors. Over twenty years of research at UP's Department of Plant and Soil Sciences, led by Prof Liza Korsten, has focused on a multidisciplinary field of water, soil, and food safety from production to consumption. The work emphasises contaminated water's impact on food, while actively training students, from undergraduate to postdoctoral level, to develop future female leaders, in particular.

Water is essential at all stages of food production, from irrigation and processing to final consumption. It supports crop and livestock health, but can also carry harmful contaminants, such as pathogens, heavy metals, and chemicals, posing significant food safety risks. Contaminated water can lead to foodborne illnesses, health issues, and economic losses. Ensuring water quality through a holistic, science-based approach across the farm-to-fork supply chain is crucial for protecting human and animal health and fostering safe, sustainable food systems within a One Health framework.

UP researchers have recognised the need for actionable science ensuring water quality and food safety, and have, over the

BACK TO TOP

past 20 years, built up a pool of expertise to stepwise address the critical questions around the water-soil-plant-food nexus. The partnership between the WRC and the UP illustrates the progression of research initiatives, progressing from foundational studies in 2008, to applied research in 2015, and culminating in more complex and interconnected investigations in 2022.

At the farm level: Tackling contamination at the source
Small-scale farmers, who supply much of the fresh produce in informal markets, face significant hurdles in ensuring food safety. Research has shown that irrigation water is a critical point of concern. Studies have revealed diverse bacteria, including pathogens like E. coli and Salmonella, in irrigation water and leafy greens (Kgoale et al., 2023). Contaminated water can transfer bacteria to soil and fresh produce (Viviers et al., 2024), underscoring the urgent need for improved water management, routine monitoring, and treatment at the farm level.

Link to related research: https://rdcu.be/epxgW
Link to related research: https://doi.org/10.1093/jambio/lxae091

At the retail level: Addressing variability in food quality
Once produce reaches informal markets, its safety can vary widely depending on the vendor. One of the previous studies has shown higher E. coli, Listeria spp., and Salmonella spp. occurrence on spinach from street vendors versus formal retailers, highlighting the impact of poor hygiene and limited sanitation in these settings (Du Plessis et al., 2017).

Link to related research: https://doi.org/10.4315/0362-028X.JFP-16-540

At the consumer level: Confronting emerging threats
For consumers, studies on alternative water sources and antibiotic resistance raised critical concerns. Research on roof-harvested rainwater showed E. coli and Enterococcus spp. as indicators of quality risks for home gardening (Chidamba & Korsten, 2018). Meanwhile, studies in Gauteng found multidrug-resistant bacteria on vegetables, elucidating the food chain's role in spreading antimicrobial resistance (Richter et al., 2019; Richter et al., 2020). These insights emphasise clean water's role in mitigating health risks and the need for policy action.

Link to related research: https://doi.org/10.1007/s10661-018-6554-1
Link to related research: https://doi.org/10.1089/fpd.2018.2558
Link to related research: https://doi.org/10.3389/fmicb.2020.00638

Each WRC-funded project builds on prior knowledge, employing advanced methods and expanding geographical scope, with active university collaboration, notably involving Prof Stefan Schmidt at the University of KwaZulu-Natal. One of the key outcomes to date was a policy brief that is **fit-for-purpose** for local conditions by providing water quality criteria and parameters that will contribute to food safety assurance in fresh produce (vegetable and fruit) production systems in predominantly formal (commercial) food systems (Du Plessis et al., 2021. Recent efforts focus on identifying knowledge gaps to develop tailored guidelines for small-scale farmers, including water irrigation standards that enhance mitigation, market access, and food safety. Current research (2022–present) emphasises antimicrobial resistance surveillance across the river system, informing evidence-based decisions to improve farm-to-fork safety. These projects demonstrate 'science in action' – using techniques like DNA sequencing and microbial profiling to convert data into practical solutions for irrigation, hygiene, and antibiotic resistance, safeguarding South Africa's food supply.

Link to related research: https://www.wrc.org.za/wp-content/uploads/mdocs/2706%20final.pdf

Over two decades, WRC projects have also built capacity and empowered women in science, providing hands-on training in microbial analysis and molecular diagnostics, fostering leadership, gender equity, and a skilled workforce committed to sustainable development and public health, in partnership with Department of Science, Technology and Innovation (DSTI) and National Research Foundation Centre of Excellence (NRF CoE) Food Security.

2009 – 2015	2012 – 2016	2017 – 2021	2022 – 2026	2023	2024 – 2028
Project No. K5/1875/4 *An investigation into the link between water quality and microbiological safety of fruit and vegetables from the farming to the processing stages of production and marketing*	***Project No. K5/1875/4*** *Evaluation of the risks associated with the use of rainwater harvested from rooftops, for domestic use, and homestead food gardens, and groundwater for domestic use and livestock watering*	***Project No. K5/2706/4*** *Measurement of water pollution, determining the sources and changes of microbial contamination, and the impact on food safety from farming to the retail level of fresh vegetables*	***Project No. C2022/2023-00885*** *Development of a fit-for-purpose water microbiological quality guideline for smallholder farmers and informal food traders*	***Solicited WRC Project*** *An independent investigation and advisory on the role of water, sanitation and hygiene in the 2023 Cholera outbreak in Hammanskraal, South Africa*	***Project No. C2024/2025-01602*** *Building a South African human pathogenic bacteria and antimicrobial resistance surveillance network in agri-food-producing environments through a water-focused One Health Approach*

Figure 1: Timeline of research projects and collaboration between the Water Research Commission and the University of Pretoria.

BACK TO TOP

WATER RIGHTS

The right to water is out of reach for many South Africans: a case study offers solutions

South Africa's constitution says, "everyone has the right to have access to sufficient food and water." In reality, however, this right is not enjoyed by all. So writes Thembinkosi Twalo, Chief Research Specialist, Human Sciences Research Council.

Many places experience regular water shortages or cut-offs. Some people struggle to access water for drinking, household use and commercial use (mines, factories and agriculture). In other areas, tap water is of poor quality, with dangerous waterborne illnesses, such as cholera, typhoid fever and diarrhoeal diseases resulting. Water protests and dehydration are commonplace.

As a researcher who studies equitable economies, water services and education, I set out to identify the problems that have caused precarious water provision in the Chris Hani District Municipality in South Africa's Eastern Cape province. This municipality is a hub of six towns, where 849 000 people live, mostly (63,8%) in rural areas.

For years, the people of this municipality have experienced collapsing water systems and broken sewage treatment plants. Over 35% of households have no taps in their homes or have to share outdoor taps that are more than 200 metres away from the home.

My research findings were based on 10 interviews with municipal officials and water consumers. I also included information from official reports from the municipality and government departments. My research found that the municipality does not always comply with the water law that

BACK TO TOP

says everyone must be provided with a minimum amount of free, clean, drinkable water every day.

I also found that it has problems collecting payment for water because a non-payment culture is prevalent in the area. Without reliable revenue, the municipality cannot procure chlorine, maintain pumps or negotiate bulk water contracts. It ends up trapped in a vicious cycle of water scarcity and service deterioration.

I conclude from my study that residents who can afford to pay should do so, while the indigent (impoverished residents of the area) should have their water subsidised by the government. To improve the water service in Chris Hani District Municipality, the infrastructure needs an overhaul. The dams and reservoirs need to be upgraded, dilapidated pipes and equipment replaced and revenue collection improved. Finally, the municipality must ringfence the payments coming in for water and kept those to fund improvements to the service.

The major problems

My research found that the major problems in the Chris Hani District Municipality were:

- Water scarcity due to drought, water leaks and population growth
- Ageing water pipes and systems that have not been properly maintained and repaired
- Electricity cuts at water pumping stations
- Politics – although councillors are usually not subject matter experts of the departments they oversee, their political power enables them to influence the operations of the directorates. This can undermine the expertise of local government staff members who are experts, such as water engineers, plumbers and water technicians.
- Vandalism of the water system
- A water system that's not upgraded to cope with the growing population
- Residents who don't always pay for the water they use

These problems tend to feed into each other. For example, many households that can afford to pay for water refuse to do so because they are discouraged by the erratic water supplies, or don't trust that their bills are accurate, and because of the culture of non-payment for municipal services.

One participant noted that:"The municipality does not send invoices. When they do, most of the time, the bill is inflated because they do not take meter readings but just estimate the household consumption."

The research also found that the municipality's failure to comply with the Water Services Act of 1997 meant that they weren't providing the legal minimum of six kilolitres of clean drinking water per family per month. This is roughly 25 litres of water per person per day.

What needs to happen next

Some participants said they'd been without water for extended periods, along with their fellow community members. This highlights that the municipality undermined the water law's requirements for water services to be "effective enough to ensure that no consumer is without supply for more than seven full days in any given year."

Solving the water problems in Chris Hani District Municipality means finding ways to provide free, clean drinkable water and also bringing in some income to help pay for the water services. As one of the people I interviewed said: "To achieve the water provision responsibility, the municipality needs to pay for bulk water from the Department of Water and Sanitation, construction cost or capital cost, and operations and maintenance cost. These costs are not all covered by grant funding. Therefore, affording consumers should pay and the indigent should get subsidised by government."

A way forward would be for the municipality to set up a policy framework that would enable bulk water supply to be upgraded and dilapidated infrastructure to be replaced. This policy framework should also make it possible to improve revenue collection.

The lack of payment compromises delivery of water services by municipalities. Poverty is one of the key factors contributing towards the non-payment of services by residents. This underscores that job creation must be prioritised.

To discourage the non-payment culture, the municipality should be more transparent in its water bills. For example, they could provide user-friendly access to account information (bills, usage trends and payment history). This would create more trust that residents are being billed the correct amount.

Another helpful step would be ending theft and vandalism of water infrastructure. This would need the municipality to set up a close working relationship with community members and the South African Police Service.

Finally, water services need to be ringfenced. This means that payments for water are kept separately by the municipality and used only for improving the water service. Research has already found that municipalities that don't ringfence water payments end up not investing enough to keep their water systems in good shape.

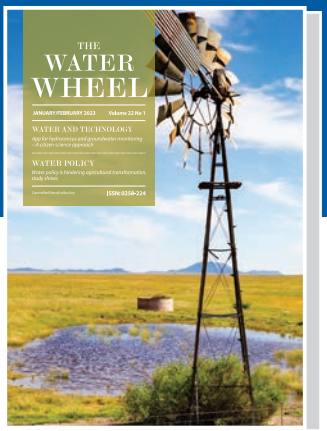
The effective provision of water services requires everyone involved to play their respective roles well – the municipality must consistently deliver and residents who are not impoverished must consistently pay.

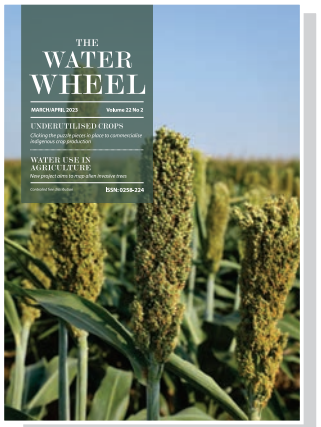
To access the original study, visit: https://apsdpr.org/index.php/apsdpr/article/view/870

BACK TO TOP

THE WATER WHEEL

SUBSCRIPTION





Contact Details

Name: _____

Company: _____

Designation: _____

Tel: _____

Fax: _____

E-mail: _____

What would your like to read more about in the Water Wheel?

_____

_____

_____

_____

WATER RESEARCH COMMISSION

The Water Wheel

Tel: +27 (0) 12 761-9300
E-mail: laniv@wrc.org.za /www.wrc.org.za
Physical address: Lynnwood Bridge Office Park, Bloukrans Building, 4 Daventry Street, Lynnwood Manor
Postal address: Private Bag X03, Gezina, 0031

BACK TO TOP

DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

www.wrc.org.za

The Water Research Commission not only endeavours to ensure that its commissioned research remains real and relevant to the country's water scene, but that the knowledge generated from this research contributes positively to uplifting South African communities, reducing inequality and growing our economy while safeguarding our natural resources. The WRC supports sustainable development through research funding, knowledge creation and dissemination.

The knowledge generated by the WRC generates new products and services for economic development, it informs policy and decision making, it provides sustainable development solutions, it contributes to transformation and redress, it empowers communities and it leads various dialogues in the water and science sectors.

The WRC Vision is to have highly informed water decision-making through science and technology at all levels, in all stakeholder groups, in innovative water solutions through research and development for South Africa, Africa and the world.

FOLLOW US ON

WATER RESEARCH COMMISSION

THE POWER OF KNOWLEDGE TO THE PEOPLE