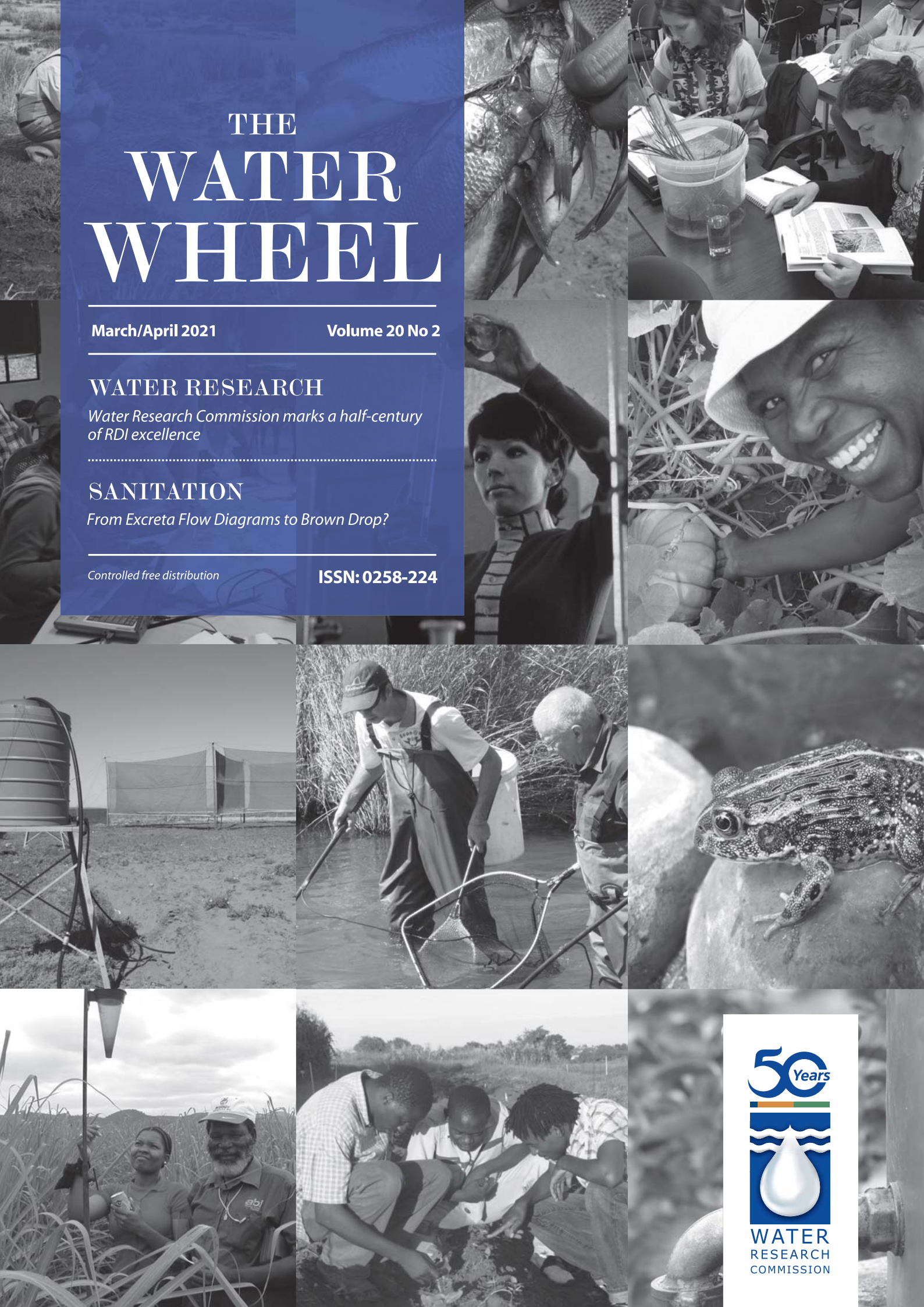

THE WATER WHEEL

March/April 2021 Volume 20 No 2

WATER RESEARCH

Water Research Commission marks a half-century of RDI excellence

SANITATION

From Excreta Flow Diagrams to Brown Drop?

Controlled free distribution

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50 Years

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.

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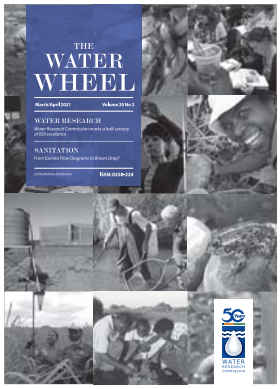

The Water Research Commission will be 50 years old in 2021. This article reflects on the history of the organisation. See story on page 12.

FLUID THOUGHTS

WRC CEO, Dhesigen Naidoo

Promise of the Year of the Ox

We have ushered in the Year of the Ox and have said goodbye to the Year of the Rat (masked).

But, as challenging as last year was, the end of the King Rat's lunar year was definitely one of the more dramatic Januaries in recent history. The first was that it saw the conclusion of the most globally consuming transitions of power in the United States ever. The storming of the US Capitol in Washington on 6 January sent shock waves around the world.

It was an event that had huge significance in many directions. To many this was the physical expression of a desire by some to return America, and the world, to a time characterised by isolationism, racial segregation (white supremacy) and a high-carbon industrial model. It is alarming how this movement found allies all over the world, despite being punctuated by the reality bites of Black Lives Matter, the MeToo movement and a groundswell of new evidence demonstrating the negative impacts of Climate Change. But, fourteen days later US President Jo Biden was inaugurated and reminded the world that for him and Vice President, Kamala Harris the core ingredients of the recipe for the America recovery was the very opposite of these objectives.

Six days later, 26 January, saw Davos Virtual – the 2021 meeting of the World Economic Forum (WEF). There was the acknowledgement that the world has been on a destructive trajectory to date, with the climate crisis being the uppermost long-term risk in the 2021 WEF Global Risk Register. South African President, Cyril Ramaphosa, in his WEF address emphasised that "..the world is at a crossroads….These challenges – from poverty to the destruction of our environment, from conflict to inequality, from illiteracy to famine – are all the results of our action, and too often, our inaction"

WEF founder, Klaus Schwab, supported by Managing Director, Saadia Zahini, introduced the theme of the much-needed ***Great Reset***. This refers to the need to right-track the global economy and how it operates in order to achieve equitable global development. The WEF showed a preference for the model of "Stakeholder Capitalism" supported by the International Business Council toolkit in the form of environmental, social and governance (ESG) metrics as the performance indicators of the new global economy.

We have already been witnessing an important shift. For example, retail investors applying ESG principles to at least a quarter of their investment portfolios went from 48% in 2017 to 75% in 2019. In 2018, sustainable investment accounted for $14.1 trillion in Europe and $12 trillion in the US with the latter projected to increase to $35 trillion by 2025. This would go a long way to achieve the banner headline goal of the meeting of the four Ps – People, Plant, Prosperity and the Principle of Governance. South Africans must be allowed a trip down nostalgia lane as we remember that the first time the first three Ps (People, Plant, Prosperity) made global headlines was at the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg.

"After a year of hardship, we can understand more than ever the significance of a (global) community with a shared vision for mankind."

Alongside WEF in January was the Climate Adaptation Summit. It was attended by 22 Heads of State, 50 ministers and leaders in all major stakeholder groups. It set itself up as a key start toward the Climate Change Cop26 (Glasgow, November 2021). The in-between steppingstones include the Global Climate Leaders Summit (USA), the Climate and Development Forum (UK), the G7 and the G20. We have to move to a low carbon development trajectory, and we have to work as hard if not harder at adaptation as we do on mitigation.

A point led by UN Secretary General, Antonio Guterres, pushing for a shift in funding prioritisation with the goal of 50% of climate funds for adaptation and resilience by 2024. The launch of the Adaptation Action Coalition by UK's Prime Minister, Boris Johnson, added impetus to host Dutch Prime Minister Mark Rutte's introduction of the Adaptation Action Agenda at the beginning of the Summit. Additionally, the launch of the 1 000 Cities Adapt Now global programme and the Coalition for Climate Resilient Investment provide invaluable pillars to build this agenda on.

President Ramaphosa in the 2021 State of the Nation Address talked to the priorities of economic recovery with inclusive growth and job creation. As an important pointer, taking heed of the important January developments, he also announced that

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the recently appointed Presidential Commission on Climate Change Coordination would have its inaugural sitting in February 2021. This may be a pivotal development in absorbing the momentum of the Great Reset.

As difficult as the Year of the (masked) Rat was, it definitely ended on a high. As President Xi emphasised in the 2021 Chinese New Year Address, the pandemic has given us much to revere, not least remembering that …"Greatness is forged in the ordinary. Heroes come from everyday people." After relating the Chinese "stories of Spring", he went on to emphasise ..."We are not alone on the Great Way and the whole world is one family. After a year of hardship, we can understand more than ever the significance of a (global) community with a shared vision for mankind.".

They say that the Ox is characterised by diligence, dependability, determination and strength. These are exactly the attributes required to build on these pillars toward a landmark year in the quest for a low carbon green sustainable and equitable future within which we see a point of inflection toward the more rapid realisation of the Sustainable Development Goals in this Year of the Ox.

Top Risks
by likelihood

1. Extreme weather
2. Climate action failure
3. Human environmental damage
4. Infectious diseases
5. Biodiversity loss
6. Digital power concentration
7. Digital inequality
8. Interstate relations fracture
9. Cybersecurity failure
10. Livelihood crises

Top Risks
by impact

1. Infectious diseases
2. Climate action failure
3. Weapons of mass destruction
4. Biodiversity loss
5. Natural resource crises
6. Human environmental damage
7. Livelihood crises
8. Extreme weather
9. Debt crises
10. IT infrastructure breakdown

Top risks for 2021 according to the World Economic Forum Global Risks Perception Survey 2020.

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NEWS

New initiative to boost use of water-smart technologies in agriculture

A multistakeholder platform which aims to boost the use of water-smart technologies by farmers in Limpopo, Free State and Mpumalanga was launched in February.

The Triple Helix (3H) initiative will provide a platform for farmers to work with local government, agri-business and research institutions towards finding joint solutions for their specific, local challenges. These solutions range from the introduction of new technologies, to the sharing of knowledge, opening networks to finance and providing skills training.

The 3H platform is the result of a collaboration between Stellenbosch University (SU) and the Maastricht School of Management (MSM) and facilitated by Agrocolleges International. "The platform will act as a multistakeholder initiative in the domain of water-smart agriculture and horticulture. It will unite local government, local academia and researchers with farmers and agri-business. The aim is to further boost adaptation of water-smart technology in these regions," said project managers Hans Nijhoff from MSM and Manuel Jackson from SU.

The establishment of this platform is based on a labour market needs assessment, conducted by researchers from SU and MSM in 2019, to gain better insights into the skills needs of the horticultural and agricultural sector when hiring graduates from technical and vocational education and training (TVET) colleges in South Africa. The project, 'Strengthening skills of TVET staff and students for optimising water usage and climate smart agriculture in South Africa' was funded by the Netherlands Universities Foundation for International Cooperation (NUFFIC), through the Dutch Ministry of Foreign Affairs.

Lack of service delivery impacting South Africa's children

There has been little improvement in children's access to water over the past 15 years, with close to six million children living in households with no access to clean drinking water on site.

This is according to the latest ***South African Child Gauge*** report, published by the University of Cape Town earlier this year in partnership with UNICEF South Africa; the DSI-NRF Centre for Excellence in Human Development, University of the Witwatersrand; the Standard Bank Tutuwa Community Foundation; and the DG Murray Trust..

According to the report, in 2018, more than three-quarters (78%) of adults lived in households with drinking water on site – compared with only 70% of children. Provincial differences are striking as the report points out. More than 90% of children in the Gauteng and Western Cape provinces have an adequate water connection. However, access to water remains poor in KwaZulu-Natal (59%), Limpopo (51%), and the Eastern Cape (39%).

The United Nations Sustainable Development Goals define safe access to water as an improved water source that is located on premises. Lack of access to adequate water is closely related to poor sanitation and hygiene.

In addition, children may be responsible for fetching and carrying water to their homes from communal taps, rivers or streams. Carrying water is a physical burden that can lead to back problems, or injury from falls. It can also reduce time spent on education and other activities and can place children at personal risk.

In terms of sanitation, the report indicates that there has been a gradual improvement in children's access to safe sanitation in the last decade. In 2002, less than half of South African children (46%) had access to adequate sanitation compared to 79% in 2018. But 4.2 million children still use unventilated pit latrines, bucket toilets or other inadequate forms of sanitation. Over 340 000 children have no sanitation at all.

For more information, Visit: http://www.ci.uct.ac.za/cg-2020-food-and-nutrition-security

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WEF Nexus winter school planned for July

The first water-energy-food (WEF) nexus Winter School or short course designed specifically for southern Africa will take place from 26-30 July in Pretoria.

This hybrid in-person/virtual event is organised by the University of KwaZulu-Natal's Centre for Transformative Agricultural and Food Systems in partnership with Global Water Partnership Southern Africa, UNESCO-IHE Delft, the Water Research Commission and WaterNet.

The WEF nexus, according to the Food and Agriculture Organisation of the United Nations, refers to the fact that water, energy and food security are interlinked and actions in any one particular area can often have effects in one or both of the other areas. The WEF nexus winter school has been developed as a capacity building initiative aimed at providing support to early researchers, post-graduate students, managers and practitioners in understanding WEF nexus thinking as a transformative approach to sustainable natural resources management and socio-economic development.

The overall objective of the WEF nexus winter school is to improve evidence-based decision-making capacities towards:

- achieving simultaneous WEF securities
- sustainable natural resources management
- socio-economic developments
- understanding WEF tradeoffs and synergies
- innovating through the WEF nexus for job and wealth creation
- linking science to informing policy and decision-making in their respective countries

"As the nexus field of research is relatively new, participants will be exposed to a rapidly developing and critically important way of thinking," said Prof Tafadzwa Mabhaudi, Co-Director of the Centre for Transformative Agricultural and Food Systems. "Participants will improve their knowledge of the WEF nexus and become acquainted with the concepts, how to facilitate discourse, and new frameworks, tools and methods for analysing the WEF nexus," he added.

According to Prof Mabhaudi, the WEF nexus winter school is set to become an annual event. "The plan is for the core content to stay the same, but there will be some variable content that will change annually to reflect the current state-of-the-art WEF nexus research and development."

The WEF nexus winter school will be held at Future Africa, University of Pretoria, Hillcrest Campus. The venue has accommodation facilities. The winter school organisers will closely monitor the COVID-19 pandemic situation and timeously communicate any changes via email.

For more information, email: waternet@waternetonline.org

SA government committed to universal access to water – Sisulu

"Water is a public good in the most practical way. However, sustainable provision of water to everyone is still a challenge facing the country. The huge disparities still remain, but our most urgent responsibility is that of providing water to everyone."

This was said by the Minister of Human Settlements, Water and Sanitation, Lindiwe Sisulu, during the State of the Nation Address debate at the National Assembly in February. Sisulu explained that the launch of the comprehensive National Water and Sanitation Master Plan in 2019 was the beginning of ensuring equal and fair provision of water to every citizen of the country. She said that various stakeholders in the water sector, including agricultural unions, provided inputs to the Master Plan and were with one voice reiterating the concept of "water for all".

"We regard our Master Plan as a transformation charter for the water and sanitation sector. This is our attempt at addressing the disparities of our past, giving direction to where we are going and ensuring that the disadvantaged are given priority. Large sections of our people in the rural areas go without water for weeks, further entrenching the divide between those who have had, those who have and those who continue to wait", said Sisulu. She further referred to the creation of the National Water Infrastructure Agency and said it will sustain and improve the performance of all strategically important water supply systems in regions where water security is at increasing risk. The Agency will work jointly with municipalities, water boards, financial and mining institutions, and agricultural community. Another important issue mentioned by the President in his State-of-the-Nation Address, is a delay in issuing water licenses. Minister Sisulu explained that there is a programme in place to improve the systems. She said there is a commitment to finalise any new and compliant water license applications between 70-90 days, as opposed to the three years' timeframe it used to take. She also reiterated her commitment to turn around the Department of Water and Sanitation.

A Disciplinary Committee is working hard to investigate and root out any maladministration, fraud and corruption and to look at audit findings and any other misconduct related matters. Sisulu said the Department is winning its legal cases one at a time, and has adopted a culture of zero tolerance for corruption. With regard to COVID-19 scourge, Minister Sisulu said the pandemic highlighted the challenges of access to water and sanitation in South Africa. However, in partnership with water boards and municipalities, a roll-out of water emergency water provision afforded the communities in the disadvantaged areas to have access to clean water.

Source: SA news

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GLOBAL

Litigation playing increasing role in addressing climate crisis – report

Climate litigation cases have spiked in recent years, making the courtroom increasingly relevant to efforts to address climate change around the world.

A UN Environment Programme (UNEP) report released earlier this year notes that climate cases have nearly doubled over the last three years and are increasingly compelling governments and corporate actors to implement their climate commitments, as well as pursue more ambitious climate change mitigation and adaptation goals.

Summaries of significant cases appear throughout this report, and it also describes five types of climate cases that suggest where global climate change litigation may be heading in the coming years.

The report, published by UNEP in cooperation with the Sabin Centre for Climate Change Law at Columbia University, shows climate litigation has become more common and more successful worldwide. In 2017, 884 cases were brought in 24 countries; as of 2020, cases had nearly doubled, with at least 1 550 climate change cases led in 38 countries (39 including the European Union courts). While climate litigation continues to be concentrated in high-income countries, the report's authors expect the trend to further grow in the global south – the report lists recent cases from Colombia, India, Pakistan, Peru, the Philippines and South Africa.

The background of plaintiffs is becoming increasingly diverse as well, with NGOs and political parties joined by children, senior citizens, migrants, and indigenous peoples. Just as they are particularly vulnerable to COVID-19, those groups of plaintiffs often stand at the forefront of climate change, enduring extreme weather, rising sea levels, and pollution.

"Citizens are increasingly turning to courts to access justice and exercise their right to a healthy environment," said Arnold Kreilhuber, Acting Director of UNEP's Law Division. "Judges and courts have an essential role to play in addressing the climate crisis".

Some of the recent trends in climate litigation identified by the report include:

- Violations of 'climate rights', i.e. cases are increasingly relying on fundamental human rights including the right to life, health, food, and water.
- Failures of governments to enforce their commitments on climate change mitigation and adaptation.
- 'Greenwashing' and non-disclosures, when corporate messaging contains false or misleading information about climate change impacts.

In the coming years, UNEP expects climate litigation to increase in national and international bodies, especially with respect to companies misreporting climate risks, governments failing to adapt to extreme weather events, and cases brought to enforce previous court decisions. A rise is also expected in cases concerning persons displaced by climate change impacts.

To access the report, visit: https://www.unep.org/resources/report/global-climate-litigation-report-2020-status-review

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New sanitation management benchmark tool for Africa

The African Development Bank, the UN Environment Programme (UNEP) and GRID-Arendal have released the inaugural ***Sanitation and Wastewater Atlas of Africa***, a tool to benchmark and propel Africa's progress towards Sustainable Development Goal targets on safe sanitation and wastewater management. The Atlas aims to help policymakers accelerate change and investment in the sector.

The result of four years of collaboration, the Atlas assesses progress and highlights opportunities where investment insanitation and wastewater management can improve health and spur economic growth. It incorporates maps, graphics and profiles of all African countries, including analyses of their water resources and provision of basic services.

The publication also explores the links between sanitation and wastewater and ecosystem health and human health, and discusses frameworks and circular economy approaches that can lead to better infrastructure and systems. "Africa cannot have a healthy society without adequate access to safe water, sanitation and hygiene," said Wambui Gichuri, the African Development Bank's Acting Vice President for Agriculture, Human and Social Development.

"In the past 10 years, the African Development Bank has invested more than US$6 billion in sanitation and hygiene improvements, but much more financing is needed from the private sector, development finance institutions, governments and other sources. The new Atlas can inform strategic investment going forward."

According to the report, more than half of the population in 34 out of 38 sub-Saharan African nations lacks access to basic handwashing facilities. It recommends investment in the necessary policies, infrastructure and human skills capacities to operationalise actions towards the achievement of goals and targets in the 2030 Agenda for Sustainable Development, including those for sustainable sanitation and wastewater management.

The COVID-19 pandemic has sharpened an already existing need to upgrade Africa's water and sanitation infrastructure. The report's authors urge African governments to incorporate sanitation and wastewater programmes into their post-COVID-19 strategic planning. "As the world seeks to recover better after COVID-19, prioritising wastewater and sanitation infrastructure in Africa is critical. Sustainable Development Goal 6, which calls for making water and sanitation available to everyone, is within reach by 2030 if we commit the needed resources. ***The Sanitation and Wastewater Atlas of Africa*** provides the tools for policymakers to focus on this important challenge," said Leticia Carvalho, Head of UNEP's Marine and Freshwater Branch.

To download the atlas, visit: https://www.unenvironment.org/resources/publication/sanitation-and-wastewater-atlas-africa

All IWA journals now open access

All the journals in International Water Association's (IWA's) stable are now open access, including its flagship journal, ***Wate***r Science & Technology. IWA publishes more than 15 journals on all aspects of water.

In partnership with Knowledge Unlatched (KU), IWA Publishing (the association's publishing arm) asked libraries and institutions currently subscribing to any of the journals to renew for 2021 on a Subscribe-to-Open (S2O) basis, thus contributing to making the journals free to readers and researchers worldwide. With this move, IWA Publishing has made one of the largest flips of a publishing portfolio to date. "We are happy that this was made possible with the support of libraries as we see open access at the core of our values and strategy," said IWA Publishing MD, Rod Cookson. "We hope that flipping our journal portfolio will shift the way our content is used by enabling everyone engaged in providing clean driking water and good sanitation around the world to read the very latest research."

Added Cookson: "It is great to see that the combined efforts of the supporters and our partners has led to a sustainable open access solution across the portfolio, setting a great example for publications and publishers of all sizes. We hope that the S2O model will be adopted more widely as an alternative to the 'Publish and Read' Big Deals which dominate the open access landscape to the detriment of smaller-scale journals."

IWA Executive Director, Kala Vairavamoorthy, commented: "We hope that by IWA fully embracing the open access movement, it will allow for information, knowledge, and best practice to be shared with the widest possible audience from around the world. Our publications will receive greater visibility and readership, leading to a potential increase in the impact of research. Greater access to, and sharing of, knowledge also provides a boost to a range of important objectives for IWA. Notably, fairer social and economic development, broader intercultural exchanges, and increased opportunities for innovation."

For more information, Visit: www.iwapublishing.com

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THE WATER WHEEL

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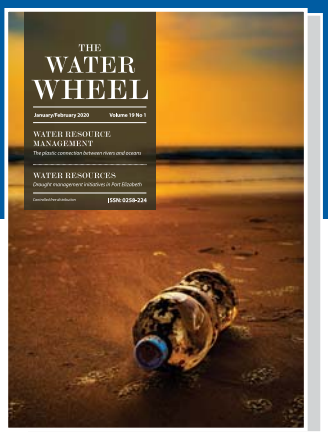

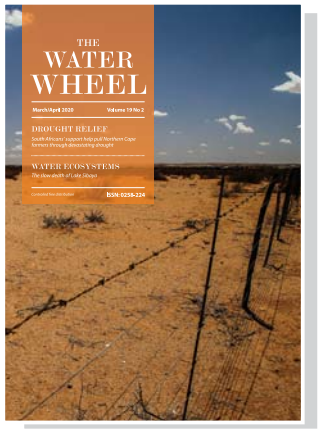

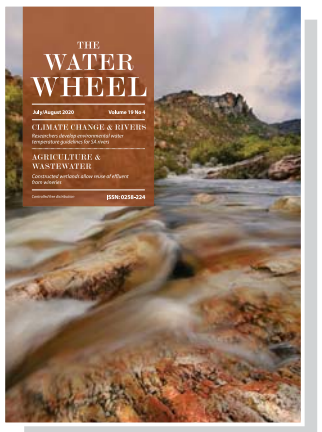

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The Water Wheel

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50 Years
WATER RESEARCH COMMISSION

WATER SECTOR MOURNS THE LOSS OF SOUTH AFRICAN DOYEN

Dr Theo van Robbroeck with Water Wheel Editor, Lani van Vuuren, at the launch of the book, In the Footsteps of Giants, which relates the history of South Africa's large dams, in 2012.

The Water Research Commission joined the rest of the South African water sector in mourning the loss of Dr Theo van Robbroeck, at the age of 89, on 17 January due to COVID-19. His death followed closely on that of his beloved wife, Irma, who passed away on 6 January of the virus.

A former award-winning water engineer and president of the International Commission on Large Dam (ICOLD), Theo will be remembered for the major role he played in the planning, development and management of the water resources of South (and Southern) Africa in a career that spanned more than 40 years.

Born in 1931 in Belgium, Theo immigrated as a young man to South Africa and studied civil engineering at the University of Stellenbosch. He joined the Department of Water Affairs in 1957, and the first dam he worked on was Ebenezer Dam near Tzaneen. In 1960 he was transferred to the construction site of Stompdrift Dam near Oudtshoorn. Setting out the most complicated shape of the domes that make up the dam wall and their intersections with the buttresses was a major problem because of the severe overhang of the arches. These complex calculations were hand-calculated with an electric calculator as no electronic computer was available at that time. Theo was the official in 1964 to arrange for DWA's first computer which was an IBM 1130.

After a short stint with Hydroconsult, Theo rejoined the department where he was placed in charge of the earth and rockfill dam division of the Design Office where he and his team were involved with the design of a large number of dams. Theo and his team became involved in a re-planning of the Tugela-Vaal Transfer Project and made a proposal in May 1970 which incorporated the Sterkfontein Dam, Woodstock Dam and various diversion canals and weirs. The proposal was accepted by the decision makers. The Tugela-Vaal Transfer Scheme transferred water from the Tugela to the urban-industrial heartland of South Africa in the current Gauteng. Additional water transfers were then required from the Tugela to the Vaal River and Theo joined up with Escom (as it was then called) to develop a combined water transfer and peak power generation project. Because of Theo's proven planning skills, he was transferred to the Planning Division where he was responsible for the Western Part of the country.

Theo had above all a charming personality which engendered a great team spirit within his sphere of activities. He always took great pains to acknowledge the contributions and support of others. This personality trait was a tremendous advantage in his important role as a water diplomat and in international circles in ICOLD. The culmination of his career was the planning and implementation of the Lesotho Highlands Water Project where he played a pivotal role. This international mega-water project benefits both Lesotho and South Africa in various ways and required a highly complex Treaty which was negotiated during very strained political times. Throughout this period, Theo was supported by his charming wife Irma, who was also a wonderful ambassador for South Africa at the various international events. Theo published extensively in addition to giving various talks and presentations. He was a regular contributor to magazines and journals, including the Water Wheel.

Theo was active in several engineering institutions in South Africa, including the South African Institution of Civil Engineering, South African Academy of Engineering, and he served as president of ICOLD between 1994 and 1997.

Theo was presented with the AD Lewis Gold Medallion in 1991 when he left the then Department of Water Affairs and Forestry on promotion to become the DG of the Department of Public Works. Theo received a number of other awards over his career, including an honorary doctorate in engineering from the University of Stellenbosch in 1994.

Dr Theo van Robbroeck has left behind a wonderful legacy for South Africa and the international water engineering fraternity of a highly dedicated and innovative person who worked for the good of humanity in providing an assured supply of water for all.

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WATER RESEARCH

Water Research Commission marks a half-century of RDI excellence

In 2021 the Water Research Commission will officially celebrate its 50th year of existence. Dhesigen Naidoo reflects on the Commission's achievements and the opportunities that lie ahead.

South Africa is a dry country and has been throughout modern history. Ingenuity, knowledge and innovation have had to be mainstays of water security from the very beginning. The indigenous inhabitants in the form of the Khoi and San were successful only because they developed smart ways to store and transport water in our largely semi-arid country where only 10% of the land area constitutes the headwaters for more than 50% of all of our scare water resources.

After the severe South African droughts of the 1960s with storage capacity in many dams dropping to less than a third, the government implemented widespread water restrictions. The most dramatic restrictions were applied to consumers dependent on the Vaal Dam which, at its lowest, was less than 27% full. A Commission of Enquiry into Water Matters was constituted in 1966 and its report was published in 1970.

The report highlighted the important role of water research in the optimum utilisation and management of the country's water resources.. "To gear modern knowledge to water resource development and utilisation there must be effective coordination of the research being undertaken by various organisations…In view of the importance and interdisciplinary requirements of water research, the Commission deems it essential that a specific committee for water research be established." As a direct result, with the promulgation of the Water Research Act (Act no. 34 of 1971), on 1 September of that year the Water Research Commission (WRC) came into being with a grand total of 7 employees.

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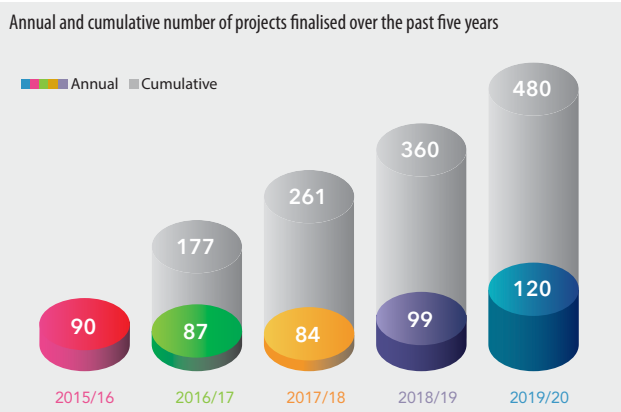
Since then, the WRC has enjoyed 50 successful years of servicing the water knowledge and innovation needs of come after South Africa with major contributions to the global environment. The Commission has over this time become a 'glue institution' for the South African water research and innovation community of practice comprising some 3 000 researchers, innovators and entrepreneurs operating from universities, public research entities, large corporates and SMMEs. It has also contributed to global institutional development being a founder member of the International Water Association (IWA) and the Global Water Research Coalition (GWRC). The WRC can claim to be a pioneer in the domain of reverse osmosis as a treatment methodology, piloted dry cooling for electricity generation as a world first, and before had international recognition for the work it funded on the environmental reserve and many others.

For many years, particularly in the last decade, the WRC has been a beacon of transformation in this still new democracy. We have important markers such as having the vast majority of project leaders being from the category of black, women and youth. The students supported on WRC projects are predominantly black and majority female. This has been achieved with the generous mentor contributions of senior researchers and innovators. This has also facilitated an important diversification of the research and innovation enterprise with a higher emphasis on impact and innovation. It represents a model that should be replicated throughout the South African National System of Innovation.

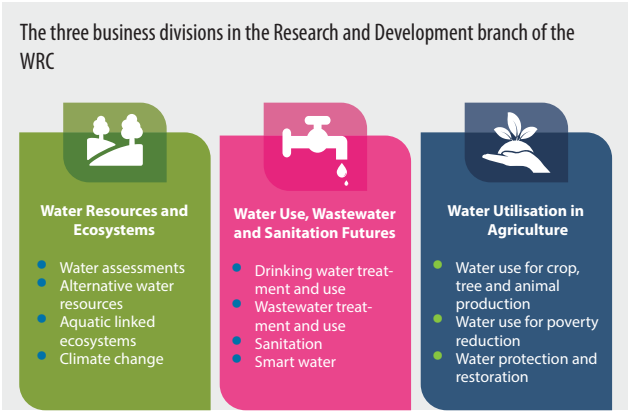
"The Commission has over this time become a 'glue institution" for the South African water research and innovation community of practice."

The Water Research Commission today

Today, the WRC's annual budget exceeds R300-million of which two thirds is applied to research and development. The water research levy remains the Commission's main source of revenue. These levies are derived as a percentage placed on bulk water consumption. In essence, the WRC provides and funds applied knowledge and water-related innovation for the improvement of the lives of the citizens who help fund the research to start with.



The annual and cumulative number of projects finalised by the WRC over the past five years.



The three main research and development areas of the WRC.

Additional leverage funding is provided by research partners. Research activities are grouped under three main thematic areas, namely water resources and ecosystems, water use, wastewater and sanitation futures, and water utilisation in agriculture.

In the last five years alone, the WRC finalised 480 research projects, indicating a significant contribution to knowledge in the water sector. The impact of this research, development and innovation can be seen across the water and sanitation sector, from the delivery of quality drinking water and safe sanitation to communities; enhanced water and effluent practices in industry and mining; decision-support for irrigation schemes and for various agricultural sectors; technologies to augment conventional water supply such as fog harvesting, artificial groundwater recharge, wastewater reclamation and desalination; to enhancing fundamental understanding of climate change and improved protection and management of natural resources.

From the start the WRC has had as one of its core objectives the development of human capital in the water sector. The result has been the establishment of a small, but productive water science and technology community of practice, which is rated as being in the top twenty globally. Many initial students on WRC projects have gone on to lead their own research, with many becoming global leaders in their field. In recent years, the WRC has adjusted its portfolio to enhance training and mentoring of new research leaders. More than 60% of research leaders on new projects are now from designated groups and most are younger than 50 years old. This is both assisting with the national transformation project as well as building the next generation of researchers.

The body of water-centred knowledge created by the WRC and its research partners has also been fundamental in the shaping of water legislation and policy in South Africa. The WRC played a critical supporting role in much of the work leading up to the national water policy of 1997 and the drafting and early implementation of the National Water Act (Act no. 36 of 1998). The Commission also helped to mobilise significant in-country capacity in the water sector to support the water policy and processes involved in promulgating the NWA.

Many years of cutting-edge WRC research had no place in the water legislation that preceded the NWA, but it was sufficiently advanced to be taken up into the new water law principles, the policy and legislation. These include studies in the areas of environmental flows, integrated catchment management, free

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The Water Research Commission has broadened its research scope to one that actively involves communities in the research projects and engages key partners to upscale and maintain interventions post-project.

basic water and small-scale irrigation, among others. The WRC was also able to fund consultancy research projects or initiate direct research projects to assist with various technical aspects and questions that arose during the drafting process.

The National Water and Sanitation Master Plan, launched by the Department of Water and Sanitation in 2019, has reaffirmed the role of research, development and innovation in developing a robust water sector that can support socio-economic opportunities for the country while managing South Africa's scarce water resources in a sustainable manner.

The WRC of tomorrow

There is significant convergence in all global analyses that from an economic, social, environmental, political and security viewpoint the increase of water scarcity on the back of decreased availability as well as deteriorating water quality is a crowning global crisis. South Africa is not immune to this. As a response, the WRC has heightened its efforts to not only grow scientific and technological knowledge in the water and sanitation domain, but to translate this repository of knowledge to tangible, accessible and affordable products and services for use on the ground. The aim is for research, development

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and innovation initiatives to not only improve the quality of life for poor communities, but to create fertile ground for industrialisation and entrepreneur development in South Africa.

A significant new focus area has been next generation, non-sewered sanitation. The WRC leads in demonstrating new sanitation solutions that require little to no water and/or beneficiates sanitation waste. This is mainly being done through the South African Sanitation Technology Enterprise Programme (SASTEP), which the WRC manages through the support of national and international partners. SASTEP supports and accelerates the application and uptake of the latest, cutting-edge toilets through evidence-based policy adjustments, demonstrations, testing and science-based improvements towards localisations and industrialisation. This includes technologies supported by the Bill and Melinda Gates Foundation's 'Reinvent the Toilet' programme. The revolutionary toilet systems have water-saving or water-recycling features, are aspirational in design, and, most importantly, eliminate pathogens and sludge production at point-of-source without the need for sewers.

The WRC is taking advantage of the technological innovations and change brought on by the Fourth Industrial Revolution. Recent and continuous projects have seen the development of remote sensing tools for the monitoring of agricultural lands and freshwater ecosystems for example, while exploring the opportunities around the water-energy-food nexus and the creation of water-sensitive cities.

The body of water-centred knowledge created by the WRC and its research partners has also been fundamental in the shaping of water legislation and policy in South Africa.

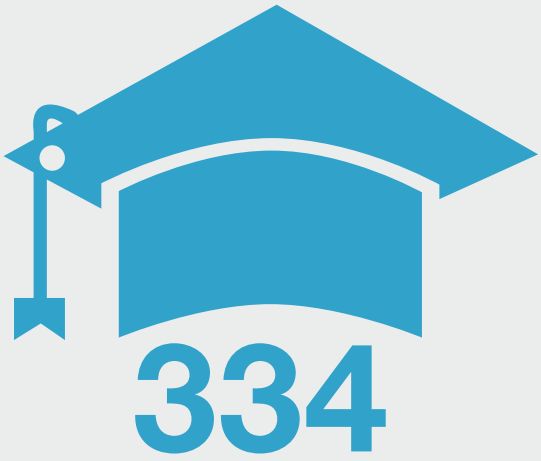
The Commission has also broadened its research scope to one that actively involves communities in the research projects and engages key partners to upscale and maintain interventions post-project. In the 2019/20 financial year alone, more than 100 research projects had a direct impact on the lives and livelihoods of communities through water-related initiatives and capacity building. Among these has been the successful implementation of so-called MUS systems in villages in Vhembe, in Limpopo province. MUS or multiple use schemes are low-cost equitable water-supply systems that provide communities with water for both domestic needs and high-value agricultural production, including rearing livestock.

The novel coronavirus (Covid-19) caused significant disruptions around the globe. While lockdown restrictions disrupted ongoing research work some WRC funding was redirected towards fighting the pandemic. This included the provision of laboratory and research work services on the monitoring of SARS-CoV-2 in wastewater and faecal sludge as means of estimating the prevalence and burden of Covid-19 infections in communities.

The WRC Covid-19 intervention is comprised of three phases, the first being the establishment of the proof of concept of presence of COVID-19 in wastewater and sanitation samples, as well as establishing sample collection and testing protocols so that monitoring results can be reliable and compared. This phase has been successfully completed. The second phase, which is currently underway, focuses on the establishment of a wider capacity of laboratories in South Africa and puts into operation more communities into surveillance. The third phase will enable the facilitation of the establishment of a national surveillance programme supported by hotspot mapping. In a related project, wastewater-based epidemiology principles have been applied to non-sewered communities in South Africa, through the sampling of rivers and surface runoff in one of the first projects of its kind in the world.

Through five decades of activities the WRC has firmly entrenched itself in the water and sanitation sector in South Africa. It remains dedicated to the creation of a water secure society for all of South Africa's citizens.

Number of PhD and Masters students in 2019/20



The WRC mandate

- To promote, coordinate, cooperate and communicate in the area of water research and development
- To establish water research needs and priorities
- To stimulate and fund water research according to priority
- To promote effective transfer of information and technology
- To enhance knowledge and capacity building within the water sector

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WATER AND THE ENVIRONMENT

Ecological infrastructure: How caring for nature helps to save money and water in the long run

A five-year research project funded by the Water Research Commission (WRC) has shown several examples of how investment in 'green' ecological infrastructure can deliver tangible benefits to the water sector and delay the need for more costly metal and concrete infrastructure projects, writes Tony Carnie.

Duncan Hay

The uMngeni Vlei is a critical wetland that feeds the uMngeni River.

Most people accept without question the need to have their cars serviced on a regular basis – or the common-sense of replacing leaking tap washers or clearing fallen leaves from roof gutters to avoid water waste or blockages.

Because in the long run, it's wise to spend a little bit of money on regular maintenance to avoid a heftier bill when things really break down due to neglect or lack of maintenance. In much the same way, the environment also needs to be maintained or repaired to ensure a reliable flow of environmental services such as clean water.

Natural scientists have long understood the importance of protecting water security by safeguarding the multitude of free environmental services that are rarely appreciated or costed using conventional economic models. This is why the term 'ecological infrastructure' was coined in the early 1980s, to promote a broader appreciation of the bedrock role of nature in creating and sustaining economic benefits for humanity.

While 'built infrastructure' is widely understood to mean massive metal or concrete structures, such as water pipelines, dams, railways or freeways, South Africa also has vast areas of green or 'ecological infrastructure' such as grasslands, wetlands or rivers that all play a fundamental role in storing or conveying water.

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Examples include large marshy areas that act much like sponges, absorbing and then releasing water gradually. Apart from trapping water in a similar way to large, concrete dam walls, these wetlands also purify and filter water to reduce the load of bacteria, nutrients, chemicals or metals that could flow into dams. And they help to anchor soil and sediments that might otherwise erode to silt up and shorten the life span of major dams.

Even so, putting a monetary price on the benefits and savings from this free ecological infrastructure remains relatively poorly researched and quantified.

This was one of the reasons motivating a five-year research project in KwaZulu-Natal funded by the WRC entitled 'Enhancing water security through restoration and maintenance of ecological infrastructure: Lessons from the uMngeni River catchment' **(WRC Report No. TT 815/20).**

The uMngeni River Basin is one of South Africa's most important water catchment areas, supporting over 6 million people and providing water to the country's third-largest regional economy and the cities of Durban and Pietermaritzburg. The catchment is dominated by large-scale farming in the upper reaches (including dairy, beef, poultry, timber and sugar cane) while the middle and lower reaches are impacted by urban development, industry and mixed rural-urban land uses.

It also includes large commercial forestry plantations that are estimated to reduce streamflow by about 64 million m^3 each year. Alien invasive vegetation in the catchment is calculated to consume between 12 and 15 million m^3 of water, over and above what would have been used by natural vegetation.

Though it has four large dams (Midmar, Albert Falls, Inanda and Nagle) the uMngeni River catchment remains a water stressed catchment, which is only just meeting the water demands of its inhabitants. Project leader, Prof Graham Jewitt, explains that while ecological infrastructure projects may not provide a complete solution to reducing water-stress in the catchment, they can help to delay the massive cash investment required for a major new dam and water transfer scheme from the uMkhomazi River.

"While ecological infrastructure projects may not provide a complete solution to reducing water-stress in the catchment, they can help to delay the massive cash investment required for a major new dam and water transfer scheme."

DUCT

Staff from the The Duzi-Mngeni Conservation Trust spray water hyacinth in the uMngeni valley.

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He says the report also demonstrates how ecological infrastructure (EI) can be used to secure more water through research that has focused on several case studies in the catchment. "This addresses a critical gap in moving from the many vague and broad conceptual ideas of how EI could form part of a catchment management strategy, to demonstrating how this can be an integral component of future water resource management plans in cities and urban areas, and ultimately, in a catchment management strategy."

Jewitt (the former director of the University of KwaZulu-Natal Centre for Water Resources Research and current head of the Department of Water Resources and Ecosystems at the IHE Delft Institute for Water Education in the Netherlands) says the four case studies have helped to reveal how tangible monetary savings can be achieved through strengthening ecological infrastructure.

One example comes from the upper-uMngeni catchment, where alien invasive plants use considerably more water than natural grasslands that have not been invaded. The researchers demonstrated that the cost per unit volume of water (m^3) by maintaining grasslands in good condition is considerably cheaper (31 cents/m^3) than for restoring degraded areas (R2.44/m^3).

This is mainly because rehabilitation of land degraded by soil erosion or invasive alien plants is more expensive and time consuming than maintaining grasslands in a natural condition. But while sound grassland maintenance is "by far the cheapest of all other water related infrastructure options" most farmers, land owners and rural communities still struggle to cover the costs of maintenance.

"This raises several questions around existing legislation. For example, should private land-owners be obligated to adhere to the Conservation of Agricultural Resources Act without financial support?"

This is especially important in strategic water source areas which produce nearly 50% of South Africa's mean annual runoff, but cover only 8% of the surface area of the country.

But how can farmers be paid or incentivised to maintain such land in a natural state? Jewitt and his fellow researchers suggest that the provincial water utility company Umgeni Water could collect revenue in the form of a water resource management charge and hold this in a trust. The trust would then assess applications from landowners and distribute funds through ecological infrastructure partnership projects implemented through the Duzi-uMngeni Conservation Trust (DUCT), a non-profit company set up in 2005 to champion the health of the uMsunduzi and uMngeni rivers.

Over the last 15 years DUCT has been involved in a wide variety of environmental stewardship and restoration projects in the catchment through the removal of aquatic weeds such as water hyacinth; clearing invasive alien plants; donga rehabilitation; installing litter booms in rivers or monitoring sewage leaks and sand-mining degradation of rivers.

The WRC study in the uMngeni has also identified other areas of significant cost-saving made possible through ecological infrastructure. For example, Umgeni Water's energy costs have almost doubled over the past five years, partly due to the increased electricity bills from pumping water from other catchments to meet the needs of the uMngeni system.

Furthermore, because of the low levels of storage at Albert Falls Dam during the recent drought, Umgeni Water was not able to fully supply parts of Durban, so additional water had to be pumped from Inanda Dam to Durban Heights treatment works – at a cost of R32 million.

"The average cost of pumping this water was 46 cents per m^3 of water pumped for the three pump stations. Therefore, it can be argued that every m^3 produced by the catchment upstream of those two dams means that water does not have to be pumped, so saves Umgeni Water at least 46 cents/m^3.

Based on the modelling exercise, every hectare of invasive wattle in the catchment uses about 200 m^3 per hectare per month more than grassland (2 400 m^3 per hectare per year). Thus, at a pumping cost of 50c per m^3, each hectare cleared and maintained – or prevented from being invaded - saves Umgeni Water R1 200/ha per year.

"The project aimed to guide catchment managers when deciding 'what to do' in the catchment to secure a more sustainable water supply, and where it should be done."

"Based on mapping of invasive alien plants undertaken by Mtshali (2017) for the Lions and uMngeni River catchments upstream of Midmar Dam, there are 125 km^2 or 12 500 ha of invasive wattle. In contrast, in 2007, mapping suggested that this area was only 30 km^2. It can therefore be argued that clearing the upper uMngeni of invasive alien plants could save Umgeni Water approximately R15 million per year in pumping costs (at 2017 rates)."

The researchers say that clearing invasive alien plants provides a relatively quick solution to providing additional streamflow without the burden of extensive legal and financial arrangements that affect built infrastructure projects.

"Investments in EI can take place relatively quickly and, in the case of clearing aliens, produce fairly quick benefits. As such, it provides an interim solution to reduce the pressure on water resources during the planning and construction of built infrastructure."

Without the uMkhomazi transfer scheme, water supplies to the residents of the uMngeni catchment are under pressure and while EI cannot provide the additional 200 million m^3 per year forecast to be needed by 2030, "our analysis shows that clearing invasive alien plants in the catchment headwaters would

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Duncan Hay

The Duzi-Mngeni Conservation Trust has been involved in a wide variety of environmental restoration projects in the uMngeni catchment for 15 years.

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Image supplied

Environmental hydrology student, Hlengiwe Ndlovu, clambers down an embankment during the WRC ecological infrastructure project.

provide at least 15.6 million m^3 of water at a 90% assurance of supply – enough to fill a significant portion of the planning and construction gap between now and the completion of the uMkhomazi transfer scheme".

A further example of EI benefits comes from saving on chemical treatment costs. In the recent study, the researchers analysed water contaminant data, chemical dosage and cost records for a five-year period (2013-2018) for the DV Harris water treatment works which draws water from Midmar Dam and the Wiggins treatment works, which draws water from Inanda Dam.

The assessment generated several interesting findings. The average cost of treating water per cubic metre was higher for DV Harris (16 cents/m^3) than for Wiggins (8 cents/m^3) partly due to the higher use of chlorine and other treatments to control E.coli contamination associated with sewage and other pollution entering Midmar Dam.

After assessing the economic and financial benefits of investing in EI from several perspectives, the researchers state: "We can conclude that there are clear water quantity and quality benefits in investing in EI in the uMngeni River catchment and that these opportunities are optimised from a perspective that views water security investments along a continuum - where built environment and ecological infrastructure investments complement each other, rather than being considered as 'one or the other'."

Jewett and his fellow researchers say the overall aim of this project was to identify where and how investment into the protection and/or restoration of EI can be made to produce long-term and sustainable water security returns.

"In short, the project aimed to guide catchment managers when deciding 'what to do' in the catchment to secure a more sustainable water supply, and where it should be done. This seemingly simple question encompasses complexity in time and space, and reveals the connections between different biophysical, social, political, economic and governance systems in the catchment."

The research teams also partnered with the uMngeni Ecological Infrastructure Partnership (UEIP), an initiative involving more than 24 groups including government departments, academic institutions, private companies and NGOs committed to investing in restoring, maintaining and managing EI for water security. This included aligning the WRC research with four restoration case studies -Mpophomeni (upper catchment), the Baynespruit in Pietermaritzburg (middle catchment), the Palmiet

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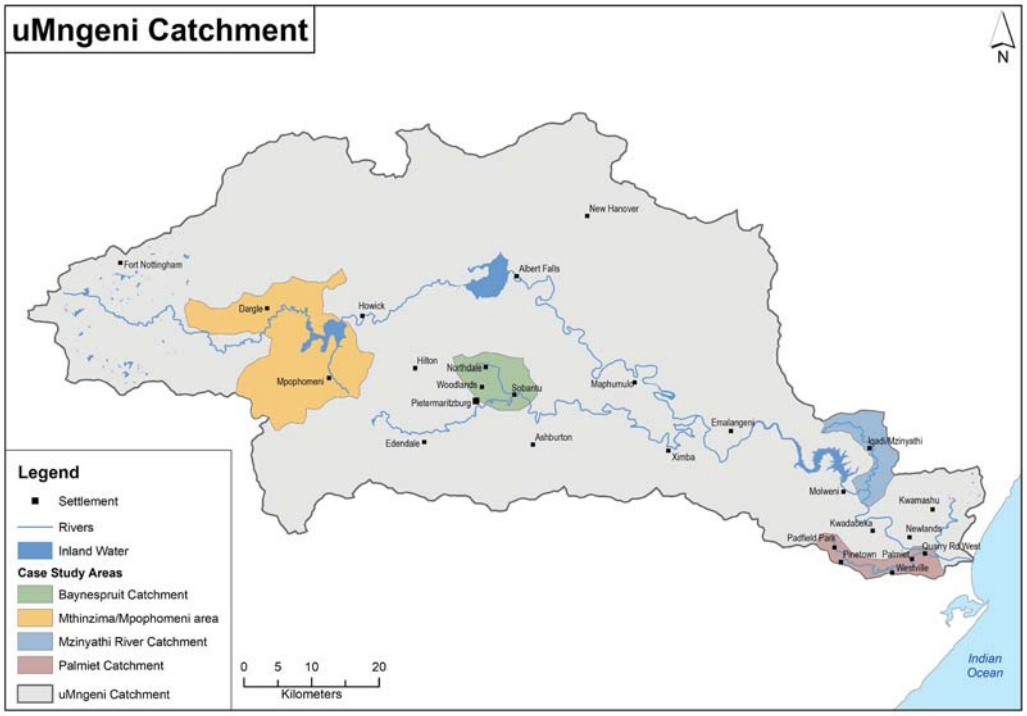

Source: Michela du Sart

Map of the study area.

River catchment and Mzinyathi in eThekwini Municipality (lower catchment).

Jewittt told ***the Water Wheel*** that installing a new artificial wetland near the Mpophomeni township was critical to reducing sewage pollution entering Midmar dam. The artificial wetland would help to further filter water below a new waste water treatment works to serve the rapidly urbanising settlement of Mpophomeni.

Jewitt says another major benefit of the study has been greater capacity development in the field of EI, with more than 30 students now exposed to this concept during the five-year project (3 Postdocs, 9 PhDs, 15 MSc, and 7 Hons students have been affiliated with the project). He hopes many of these PhD students will become leaders in water governance and EI in the future, as a result of the capacity they have built and the experience they have developed as emerging researchers engaged in action research in the uMngeni River catchment.

Though Jewitt would like to see a Catchment Management Agency established for the uMngeni, he notes that the recent establishment of a catchment management unit by Umgeni Water is a "very positive" development.

As part of the study, UKZN research colleague, Dr Cathy Sutherland, also highlighted the importance of ensuring buy-in from affected communities and the need to shift perceptions away from the concept of 'hydro-modernism".

(Hydro-modernism refers to hard engineering approaches to water which rely on built infrastructure, including dams, treatment works and pipes with a focus on technical and economic efficiency using top-down governance approaches.)

"The legacy of both colonialism and apartheid is a major challenge and barrier to improving water security. This coupled with lock-in to hydro-modernist approaches, creates a water security context that can only be shifted by working within the current system, recognizing its socio-economic, political and environmental context and relations, and using innovation through EI interventions, to slowly, patiently and wisely shift the catchment to a more sustainable, just, and socio-ecological centred set of practices and way of being," the report concludes.

To download the report, ***Enhancing water security through restoration and maintenance of ecological infrastructure: Lessons from the uMngeni River catchment*** (**WRC Report No. TT 815/20**) Visit: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20815%20final%20May%202020%20web1.pdf

Image supplied

More than 30 students were involved in the WRC ecological infrastructure project in the uMngeni catchment.

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CAPACITY BUILDING

Multi-award winning Tafadzwa pays it forward

This article forms part of a series of profiles on high achieving water researchers supported by the Water Research Commission as part of the Commission's 50-year celebrations.

Tony Carnie

Professor Tafadzwa Mabhaudhi

Prof Tafadzwanashe Mabhaudhi is gaining global recognition for his research into the critical linkages between water, food and energy. He spoke to Tony Carnie about his personal research journey and the importance of helping upcoming scientists to achieve their goals.

At the age of 37, Tafadzwa Mabhaudhi has chalked up a string of achievements. He is already a professor. He has been cited over 1 000 times by fellow scientists, written over 130 journal articles, book chapters, technical reports, policy briefing notes and popular articles. And he has received several awards for prolific academic output and helping to translate science into policy.

But, recognising the wisdom of the old African proverb that "it takes a village to raise a child", Mabhaudhi is the first to acknowledge that this success would not be possible without the support and wisdom of many 'village elders' who helped him along the path.

The experience has also encouraged him to 'pay if forward' while building and nurturing a new grouping of water and food researchers, initially nick-named "the green team".

Mabhaudi, a Research Associate Professor at the University of KwaZulu-Natal (UKZN) and Co-Director for the Centre for Transformative Agricultural and Food Systems, stumbled

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gradually into the emerging research arena known as the Water-Food-Energy (WEF) nexus, along with research into crop-water usage and undervalued traditional African food crops.

The son of a reverend, Mabaudhi grew up in Zimbabwe, and shared his father's mission to be of service to people. But it was only after he completed his Master's degree that he began to see the possibilities of how to achieve this, when he started to supervise and mentor fellow young scientists.

After graduating with a BSc Honours degree in crop science from the University of Zimbabwe, he spent nearly two years farming a 20-hectare plot on the outskirts of Harare in partnership with three friends. It was not an ideal time. Zimbabwe's economy was experiencing hyper-inflation, creating major economic challenges for the new business venture. Two of his boreholes also broke down and he watched his harvest of rhubarb and patty-pans wither in the field.

While he "burned his fingers a bit" he also learned some valuable lessons about the difficulties facing fellow farmers.

In 2008 he moved to the UKZN's Pietermaritzburg campus where he completed his Master's, PhD and post-doctoral studies, with funding from the Water Research Commission. He continued to run the farm remotely until 2009, when he decided to unplug himself completely to focus on his studies.

After finishing his Master's (which compared traditional landrace varieties of maize with hybrid maize), his supervisor Prof Alfred Modi urged him to "stick around" and do a PhD, focusing on the drought tolerance and water-use of amadumbes (taro) and Bambara groundnuts.

In his final thesis he noted that of the world's roughly 30 000 known edible plants, only about 7 000 had been cultivated or collected as food. Even more shocking was the fact that about 20 species now provided for 90% of the world's food requirements – leaving tens of thousands of edible species largely underutilised.

Many of these plants were specially adapted to range of ecological niches and also tolerant of both heat and water stress.

UKZN

Matthew Erasmus (left) and Prof Tafadzwa Mabhaudhi (right) laying out a field trial for bambara groundnuts at Ukulinga Research Farm in Pietermaritzburg.

WRC archives

Tafadzwa Mabhaudhi was honoured in 2019 with the WRC's Research Knowledge Tree award for helping to inform policy and decision-making.

Prof Modi was impressed by Mabhaudhi's work ethic, his attitude towards team work and willingness to help other researchers and said he had dreamed of building a new team of researchers who would work towards transforming subsistence agriculture.

Later, as Mabhaudhi pushed deeper out his comfort zone into his post-Doctoral studies, he received support and encouragement from several people, including Prof Sylvester Mpandeli, Dr Gerhard Backeberg and Andrew Sanewe at the WRC; Prof Mike Savage (UKZN); Prof Sue Walker (University of the Free State); Prof Yakob Beletse from the Agricultural Research Council and Dr Abraham Singels from the South African Sugarcane Research Institute.

"Prof Beletse helped me work through a lot of complex equations – and for some time he was not my favourite person! Prof Modi was also a pillar. We spent a lot of time together and he showed me how to retrace my steps, and also how to lead."

By 2013, Modi and Mabhaudhi's "team of two" began to expand.

"Prof Modi said: 'Now we are ready now to build that team we spoke about earlier'. We had 10 Master's students and three PhDs and the WRC also gave us a follow-up project and things started to go big."

"We did not have lax requirements, but our emphasis was on giving everyone a chance to help them become their best. So it

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UKZN

Tafadzwa Mbhaudhi gives farming tips to learners at the Swayimane High School near Pietermaritzburg.

was not about having everyone at (equal) high level, but rather each one operating at their high level," he says, noting that it was time-consuming to invest in every person at an individual level, taking into account their strengths and weaknesses.

However, Mabhaudhi did not see his role as a supervisor as simply directing students towards getting a degree.

"For me, it was also about paying it forward because I had been given so much support and was able to do things I did not think I could do when I began. Often, people think they can't do something because they have never had that experience, and we tend to treat unknowns as impossibilities. I take mentoring as a very key part of my work and I'm also trying to get my students to support each other, so that I am there to guide and also find resources."

In 2019, the fledgeling green team was formally rebranded as the Centre for Transformative Agricultural and Food Systems, a title chosen to reflect its work in supporting smallholder farmers, boosting undervalued traditional food crops and finding solutions to the challenges of climate change.

"It is not transformation simply from the perspective of white to black. It is more about a paradigm shift – a shift in focus and mindsets. Despite all the talk about enabling the potential of under-utilised crops, there is still very little support for such crops. You can't go and buy amadumbe seeds in a shop, even if you wanted them . . .There is potential, but still not the kind of support that is needed to produce these crops or to establish commercial markets.

"We also need to rebrand some of them, so that they are not seen as 'poor people's crops'. Before maize arrived here on a ship, we had a system going on and no one was starving. It was working, and we need to get it working again."

Mabhaudhi notes that there has been some good progress in marketing amadumbe crops produced by around 400 members of the Ezemvelo Farmers Association in Umbumbulu to outlets such as Pick 'n Pay and Woolworths. "But that is just one crop and one group of farmers. The challenge is how to replicate it at a time when the global market is waking up to the health benefits of foods which are packed with as many natural nutrients as multi-vitamin tablets."

But it was crucial to draw lessons from similar initiatives on other continents - as with quinoa, an edible South American seed rich in protein, dietary fibre, vitamin B and dietary minerals.

"Quinoa became a global sensation, but the people growing it did not benefit as they should have."

This is partly why Mabhaudhi has immersed himself in initiatives to translate science into policy: "It is not enough just to do science, if it's not informing how decisions are made. We need to ask ourselves: 'What have we done to make our information available?' ... We might think that the solutions we propose are obvious – much like wearing a mask to curb the transmission of Covid-19 yet that does not always happen.

"This can be a difficult and non-traditional role for many scientists, but the world is changing rapidly . . . You need to be sitting in the same room as the practitioners, policy-makers and decision-makers, so that you can co-design, co-learn and co-implement."

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Mabhaudhi has also begun to participate in advisory forums with government structures.

"I have gained greater insights and understanding into planning processes at a national level - including politics and people's political shelf lives . . . You can stand next to a minister, for example, to explain how fantastic some traditional food crops might be, but sometimes decision-makers are looking at things from a global or national strategic level rather than from a local perspective."

He thinks scientists should be cautious about being "too water-centric".

"It is not always helpful where you make yourself superior by declaring 'Do as we say' ... there has to be a balanced approach. Policy normally stems from good intentions, but decisions are only as good as the information people have at their disposal – and very often, hard numbers and scientific data are hard to ignore."

He also thinks South Africa can draw lessons from the Covid crisis, noting that it is unlikely that the country can go back to "the happy days".

"The future is complex. We have learned that climate change is complex because it affects everything. People lose their homes. This is often followed by disease and food price increases – so it's not just about climate models and weather."

Quite apart from emerging climate change threats, it was likely that further pandemics would emerge, making it essential to initiate new conversations with new voices to tackle new challenges. Mabhaudhi raises the example of how the peer-review system shaped his PhD thesis, which went through as many as 14 iterations following the first draft.

"Often there is a world of difference between what I wrote in version one compared to version 14 – and that is the benefit of multiple minds examining an issue."

A similar approach had emerged during the Covid crisis, with a group of experts led by Prof Salim Adbool Karim to advise the government on how to respond to the crisis. "Imagine what might have happened if they had not had some of these guys providing expert advice?" he asks, suggesting that the Ministerial Advisory Council (MAC) structure could be replicated to advise other government ministries on a range of issues such as poverty, food, water and energy.

"For me, every minister should have one. It is a very good template for creating spaces for evidence-based science to support decision-makers. But we should also be careful about making them exclusive gatekeepers. There has to be transparency and space for civil society to participate."

Noting that nearly 62% of the country's available freshwater is used for irrigation, Mabhaudhi thinks there is much scope to use scarce water more effectively – especially through recycling and reuse. But a cautious approach was needed to ensure that the savings achieved through such innovation was used for sustainable growth.

"Often, if a farmer manages to save water he just uses the saving to irrigate something else – so there have to be more incentives to guard against this situation."

WRC Executive Manager: Water Utilisation in Agriculture, Prof Sylvester Mpandeli, says Mabhaudhi's research on the Water-Energy-Food Nexus has been widely recognized globally. "Tafadzwa is a very bright young man. His work is important for several reasons, because while he is an agricultural scientist, he combines his understanding with socio-economic issues and translates that into the science-policy interface.

"He stands out ... he drives research and innovation and also engages communities, asking them whether they agree or disagree with proposals."

Recalling that the WRC funded Mabhaudh's studies from Master's to post-doctoral level, Mpandeli says he had continued to achieve success. This included being recognised among UKZN's Top Ten most published postdoctoral fellows (2016); Top 10 most published researchers under 40 years (2020), a Fellow of the Zimbabwe Young Academy of Sciences; a Y-rated researcher by the National Research Foundation and an award from the WRC for helping to inform policy and decision -making.

And just as we were concluding this interview, an email message came through on Mabhaudhi's phone that he has been awarded the 2020 UKZN Vice-Chancellor's Research Award.

Mabhaudhi, who comes across as a deep, strategic thinker, says he is grateful for these awards and the support he has received, but his biggest personal reward is seeing his students doing things they once thought were not possible. "That gives me huge satisfaction – better than any award," he says, sharing an anecdote about one of his former students who contacted him recently to report that she was now teaching in the Middle East. Thanking him for helping her to navigate life, she apologised that she was no longer involved in agriculture. However, she had now found her confidence and her true purpose.

Mabhaudhi wrote back to say that he never wanted her to grow mealies for the rest of her life and it was more important for people to be passionate in their career choices. "If you don't focus on what you really care about you will likely only be average. But you excel when you find your passion. Your work becomes more rewarding and ideas start to come to you in your sleep."

UKZN

Tafadzwa discusses irrigation problems with local farmers, the late Mr Gasa (right) and Mr Ncube (left) outside Pietermaritzburg.

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CAPACITY BUILDING

Matie student, Samantha, explores geothermal fish farming at Brandvlei prison complex

This article forms part of a series of profiles on high achieving water researchers supported by the Water Research Commission as part of the Commission's 50-year celebrations.

The Water Wheel paid a visit to Samantha Joao (30), a high-flying researcher with a passion for science, fish farming and teaching. She is among a growing number of former WRC-supported students who are now leading their own research projects. Article by Jorisna Bonthuys.

She is combining her interests in a new project in which she explores geothermal tilapia fish farming at the Brandvlei Correctional Centre. The centre is situated on the bank of the Brandvlei Dam near Worcester in the Western Cape.

Joao is the project leader of a pilot study funded by the Water Research Commission (WRC). Over the next year, researchers will explore the possibility of using geothermal spring water for tilapia (***Oreochromis niloticus***) aquaculture at the centre. This will help promote food security and skills development at the facility, which houses approximately 4 500 people, including prisoners, staff and wardens.

Stellenbosch University's (SU's) Department of Animal Sciences will collaborate with the Brandvlei Correctional Centre, the Department of Environment, Forestry and Fisheries and the Department of Water and Sanitation (DWS) on this project. Joao is working with Dr Khalid Salie on this project. He is a research associate in aquaculture at SU. Joao learned the ropes as his research assistant in 2014 in another WRC-funded project.

In that project, scientists explored technology transfer in the local aquaculture sector. At the time, Joao interviewed fish farmers in the Western Cape, KwaZulu-Natal and Limpopo to inform the findings. She gathered information on the challenges experienced by fish farmers while also exploring possible solutions. "Aquaculture is a real passion for me," Joao says. "It is a

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great opportunity to now be working on a new project, with a concept that has never been tested in South Africa before." Joao hopes this project will provide new knowledge on geothermal aquaculture that researchers can apply at other geothermal sites in the country.

Unlocking geothermal potential

A total of 52 thermal springs have been identified as suitable for aquaculture purposes in South Africa. Currently, no fish are grown using thermal spring waters in the country.

According to the Geological Society of South Africa, the Brandvlei hot spring is the hottest and strongest spring in the country. It delivers pure water at approximately 126 litres per second (10.9 million litres per day) at an average water temperature of 64°C.

In 1719, Peter Kolben described the Brandvlei hot spring in a book about the Dutch settlement in the Cape. The farm was officially registered to Petrus de Wet in 1756. The name ***Brandvlei*** (meaning burning vlei) was derived from the steam coming up from the hot spring, which gave the impression that the vlei was on fire.

The spring's water is scalding hot. In the past, locals reported that two children, an ox, a horse, an ostrich and several dogs had perished by falling into the pond at the lowermost spring.

The Brandvlei correctional facility is unique in that all its potable water is sourced directly from the natural, free-flowing hot spring. A portion of the hot spring's water is pumped through mechanical cooling towers, dropping the temperature down to 20°C. The cooled water is then chlorinated and pumped into three storage reservoirs. From the reservoirs, cold water is gravity-reticulated throughout the facility.

Samantha's Master's project focused on chickens.

Excess spring water, which the facility does not use, flows over into a second lower storage pond which DWS manages. This water is pumped into the Brandvlei Dam for domestic and agricultural use.

The advantage of using a thermal spring is that heated water will be available for warm-water (tilapia) aquaculture all year round. Joao explains: "Conventional warm-water aquaculture systems are usually limited to a six-month production period per year. It is just not feasible to artificially heat the water in these systems during the winter months."

The researchers will obtain the necessary permits and permissions, and a small energy-efficient test-system will be set up on-site. "We still need to work out how to introduce the spring water or heat into the test system, as the spring water emerges from the ground at 64°C. Tilapia requires a water temperature of 30°C for optimal husbandry and performance," Joao says.

"We are interested in any potential cost-savings that can be achieved through the use of renewable energy in comparison to a conventional system where artificial heating is used."

The water will be recirculated in the test system, which will probably consist of two portable pools and a filtration system that will be heated using an appropriately developed heat-exchange method. Excess water leaving the system will be filtered to remove organic waste and then returned to the lower storage pond for pumping into the Brandvlei dam later. Fingerlings will be introduced into the pools in the last month or two of the project.

A full growth cycle (approximately six months) will not be possible within this project's timeframe. A co-management plan will, however, ensure continued maintenance of the fish and system until harvest.

Once the test-system is up and running, a workshop will be held to provide training to students and people at the facility. Researchers will cover topics like tank maintenance and cleaning and fish grading procedures at this event.

Chicken or fish?

Since a young age, Joao has been interested in fish. As a schoolgirl, she often spent weekends on her father's small-holding in Somerset West, catching and moving tilapia between dams.

Joao completed her BSc (cum laude) in aquaculture. She then did some travel work as an aquaculture technician at a mussel hatchery in Nelson, New Zealand. She tackled and completed her MSc (cum laude) at SU's Faculty of AgriSciences. Her project investigated alternatives to antibiotics in animal feed for broiler chickens.

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Since a young age, Joao has been interested in fish.

Joao originally started her MSc project in aquaculture. But due to unforeseen circumstances and time constraints, she switched to a project with chickens. "I made the most of my situation and embraced the change. If I couldn't do research with fish, chickens were my next best choice. They are such strange but loveable animals.

"Chickens and fish are both monogastric animals, meaning they have a single stomach. Since my MSc project's focus was on monogastric nutrition, the principles that I would learn would be applicable to both fish and chickens. So I adopted that mindset."

While working on her MSc degree, she did some part-time work for Alltech, an animal nutrition company in Stellenbosch. This work entailed gizzard scoring and identifying lesions in the buccal cavity of chickens. "They later offered me a job in product sales, but I declined the opportunity because, at that stage, sales terrified me. I really wanted to get back to the fish and research side of things.

"Then an exciting opportunity opened up at the company's facility in Kentucky, USA. It was exactly what I was looking for and I grabbed the opportunity with both hands."

Joao worked as an aquaculture research scholar for Alltech in Nicholasville for a year. There she gained valuable experience in research with trout, salmon and tilapia in an indoor recirculating aquaculture system. "I followed a rather unconventional pathway in my career," Joao says. "Every opportunity has shaped me differently and I have no regrets."

She is currently a part-time junior lecturer at SU's Department of Genetics, teaching biometry to second-year and postgraduate students.

Aquaculture for the future

Joao says she is excited about this new project. "The potential use of geothermal water sources for aquaculture offers an opportunity to extend the growth periods for warm-water aquaculture," Joao explains. "The thermal spring located at the correctional centre would make a great starting site for a thermal water aquaculture pilot study."

The water is safe to use and also has constant high temperatures and fast flow rates, which would support the culture of warm water fish such as tilapia or catfish all year round. The benefit of a controlled rearing temperature can also increase growth rates by 50% to 100%, which would increase the number of harvests per year.

Global aquaculture production has made significant progress over the past three decades. "It is now the fastest-growing animal-based food-producing sector and has a crucial role to play in reducing pressure on wild fish stocks," she points out.

"In the USA, aquaculture farmers in Idaho, Utah, Oregon and California successfully grow catfish, trout, alligators, and tilapia, as well as tropical fish for pet shops using thermal waters," Joao adds. "And In China, the success of geothermal aquaculture has led to fish farms covering almost 2 million square meters."

Aquaculture can help address the gap between aquatic food demand and supply, she believes. "It can also enable countries to address some of their economic, social and environmental issues," she says.

In South Africa, marine aquaculture has become more popular in recent years. The sector is developing steadily. Freshwater aquaculture is, however, still limited by the availability of sufficient and suitable water.

A major constraint to most freshwater fish culture is the considerable variation in water temperatures between the summer and the winter months. Joao explains: "You get warm and cold-water fish species, so this often limits fish farmers to a half-yearly growth period. which, in most cases, is just enough time to complete one harvest."

Trout farmers have been more successful in selecting sites and optimising their systems to ensure sufficient cold water supplies all year round, she says. However, ensuring a constant supply of warm water that is suitable and inexpensive for optimal warm water aquaculture has proved to be more challenging.

Challenges facing tilapia production have thus limited the local supply, and demand is met through fish imports. However, the market has not been flooded by tilapia imports, Joao says. "There will always be market gaps and opportunities for locally sourced fish products, especially with fresh fish becoming a more sought-after commodity."

Exploring new possibilities

Joao is also enrolling in her PhD this year. "My research will focus on understanding the functional genetic mechanisms underpinning growth across different organ systems in dusty kob. "I have always found marine aquaculture fascinating, as I feel that there are still so many unanswered questions and opportunities to learn and create," she says. "I decided to pursue a PhD in genetics, as I have always found the 'cause and effect' concept fascinating, especially when it relates to the genetic make-up of an animal.

"I feel that cause-and-effect evaluation is a crucial step for fisheries to learn and adapt to changes, which in turn promotes viability and sustainability," she adds.

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Dusky kob (***Argyrosomus japonicus***) is a commercially valued fish species that has been severely overfished in recent decades. Due to its large size, palatability, and food value, dusky kob is targeted by recreational and commercial fisheries throughout its natural distribution range. Dusky kob aquaculture is still in its early stages of development, Joao indicates. "With the correct governmental support, it holds promise for the future."

In Southern Africa, dusky kob occurs on the east coast from Cape Point to Mozambique. It is especially abundant between Cape Agulhas and KwaZulu-Natal. In South Africa, its maximum recorded length and weight is 1.75 m and 75 kg, respectively, with a life expectancy of up to 42 years. Dusky kob only becomes sexually mature once they reach approximately one meter in total length, which takes 5 to 8 years.

Although dusky kob can be produced successfully in semi-commercial farming systems, it is not yet feasible for large-scale production locally due to high production costs and relatively low local prices still driven by wild-caught supply. Producers also face the challenge of accessing a high-value export market.

Joao will focus her efforts on the dusky kob's genome (its complete set of genetic information), transcriptome (a collection of all the gene readouts present in a cell) and gut microbiome (the collection of all the microorganisms in its gut). She wants to better understand, from a genetics perspective, why some fish grow faster than others.

"Hopefully, this will help us understand the mechanisms underlying quick growth, which will help improve genetic selection for faster-growing dusky kob in the future," she concludes.

Did you know?

- It is claimed that Chinese people have used hot springs for irrigation since the Jin Dynasty (AD 265-420).
- Over time thermal springs have been used for various agricultural activities, including aquaculture and crop drying. The heat from thermal springs is also used to heat greenhouses and produce vegetables and flowers.
- Thermal springs are by definition 'warm'. Still, there is no consensus on the exact temperature that distinguishes a spring from a thermal spring. Most researchers use normal human body temperature (37°C) as the boundary between 'warm' and 'hot' waters.
- The flow rates of hot springs range from tiny seeps to great gushes of water.
- Source: *Optimal utilisation of thermal springs in South Africa* (**WRC Report No. TT 577/13**)

More about the Nile tilapia

- The Nile tilapia (*Oreochromis niloticus*) is fast-growing and considered the most economically viable tilapia species.
- This fish species can live longer than ten years and reach weights exceeding five kilograms.
- Nile tilapia exhibits invasive potential over most of southern Africa that overlap with the natural distribution range of indigenous species such as Mozambique tilapia (Oreochromis Mozambique).
- Nile tilapia is considered an alien invasive species in South Africa. Producers must apply for national and provincial permits for tilapia aquaculture.
- Nile tilapia can be produced in different aquaculture systems, ranging from open ponds fertilised with manure to closed recirculating aquaculture systems.
- Male tilapia grow approximately twice as fast as females.
- Generally, a tilapia stops feeding when the water temperature falls below 17°C.

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SANITATION

From Excreta Flow Diagrams to Brown Drop?

Sue Matthews investigates the potential of SFDs, and what they might mean for South Africa's sanitation revolution.

Ashraf Hendricks/Groundup

It's a term that gets people's attention, and leaves little to the imagination – Shit-Flow Diagrams. Nowadays, they're typically referred to by the acronym SFDs or the more socially acceptable Excreta Flow Diagrams, but the intention is the same – to increase understanding of how faecal waste moves through a city or municipal area, from containment at the point of origin to final disposal or reuse. They're seen as an innovative tool for identifying areas of concern and engaging with stakeholders on sanitation issues, presenting information often considered taboo in an easy-to-visualise way.

An early version was used by the World Bank's Water and Sanitation Programme in an analysis of faecal sludge management carried out in 12 cities in Latin America, Africa and Asia in 2012/13. Subsequently, the tool was developed further, tested and rolled out as part of the SFD Promotion Initiative, funded by the Bill and Melinda Gates Foundation. A web portal containing background information, training materials, an SFD graphic generator, templates for SFD reports and a database of completed reports is now hosted by the Sustainable Sanitation Alliance at https://sfd.susana.org.

South Africa's first SFD was for the city of Durban and the surrounding eThekwini area, created in 2016 by Master's student and intern, Xanthe Cross, together with Prof Chris Buckley of the University of KwaZulu-Natal's Pollution Research Group. By that time, the Water Research Commission (WRC) was wrapping up its Sanitation Research Fund for Africa (SRFA) programme, established in 2012 with the aim of stimulating research and increasing capacity around 'dry' – as opposed to waterborne –

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All four of the Eastern Cape municipalities that attended the initial SFD training workshop in August 2018 opted to participate in the project.

sanitation. It comprised 12 projects from Eastern and Southern Africa on pit latrines, with half focusing on understanding the contents of pits and the biological degradation processes taking place within them. The rest sought to develop techniques for emptying the pits – a task that is typically difficult, messy and potentially dangerous – and managing the faecal sludge.

The WRC had already built up a body of knowledge of the subject through various research projects, including Project No. K5/1745, published as a three-volume report titled 'Tackling the challenges of full pit latrines' in 2012 (**WRC Report no. 1745/1/12 to 1745/3/12**), the same year it co-hosted the 2nd International Faecal Sludge Management Conference. The SFRA programme was intended to allow sharing of this knowledge beyond South Africa's borders while also learning from other countries' experience. Like the SFD Promotion Initiative, the SRFA programme was funded mainly by the Bill and Melinda Gates Foundation, although the WRC contributed towards the South African projects.

Even today, according to the findings of Statistics South Africa's 2019 General Household Survey, only 60% of households countrywide have flush toilets connected to the waterborne sewerage system. Most of the rest rely on pit latrines, more than half of these being the 'improved' type with a ventilation pipe. As government focused on the mass roll-out of these so-called 'VIP' latrines as part of its commitment to providing basic services, little planning went into maintaining and servicing the existing latrines, which tend to fill up faster than expected. And while people in rural areas historically just dug a new pit and moved their 'outhouse' over it, this is not possible in poor urban areas, due to space constraints between densely packed dwellings.

Since full pits pose a hazard to human health and the environment, latrines remained high on the WRC's agenda following the completion of the SRFA programme. So it was a natural next step to host a workshop on SFDs in September 2017, facilitated by the Centre for Science and the Environment (CSE), India – one of the implementing parties of the SFD Promotion Initiative.

The following year, the WRC initiated the research project Country-wide Shit-Flow Diagram: Establishing National Excreta Flows in South Africa (**WRC Project No. K5/2813**). The project, which came to an end in mid-2020, was awarded to Stellenbosch-based Emanti Management, but conducted in the Eastern Cape and KwaZulu-Natal. Initially, a training workshop attended by sector stakeholders was held in each of these two provinces. Four of the five municipalities that attended the KwaZulu-Natal workshop opted to participate in the project, as did all four of the municipalities that attended the Eastern Cape workshop.

More focused workshops were then held at each of these municipalities, where the area for which an SFD would be developed was agreed upon, additional data was collected – the project team having gathered some existing data prior to the workshop – and a first-order SFD graphic developed on the basis of the available information. After the workshops, the project team went on a field visit with the municipal representatives, and then continued interacting with them over the following months to close information gaps, write a draft SFD report and finalise it on the basis of feedback received.

The SFD process allows for reporting at various levels of detail, from a 'Lite' report based on the first-order SFD graphic to Initial, Intermediate and Comprehensive reports. All address service outcomes in terms of the quantity of faecal sludge produced, but differ on the data collection needed on aspects such as policy, institutional roles, investment and equality considerations.

The Emanti project team toured sanitation facilities with municipal representatives following each data-collection workshop.

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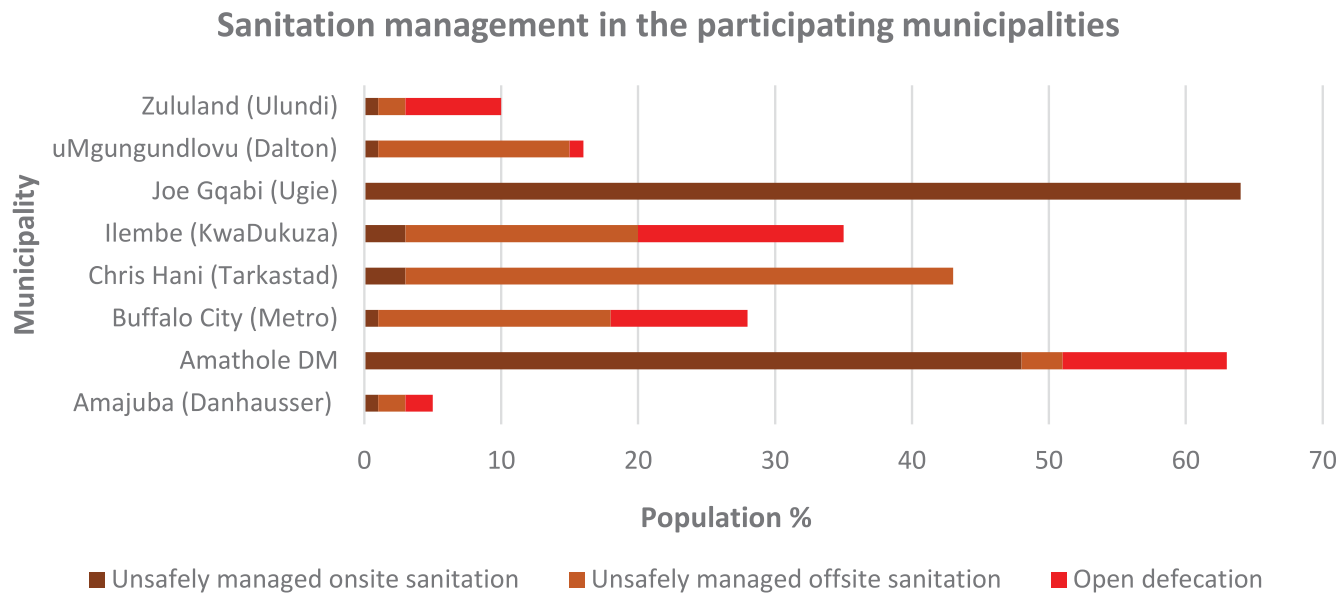
Collated results from the SFDs revealed that 36% of the population of the eight participating municipalities is dependent on onsite sanitation systems such as pit latrines and septic tanks, while 4% defecate in the open or have no sanitation facilities.



Unsafely managed onsite sanitation is primarily due to a backlog in emptying full pits, which results in people abandoning them and building new pits, or resorting to open defaecation.

Since comprehensive reports require quite extensive stakeholder engagement as well as primary data collection through direct measurements and field observations at sanitation service facilities, these were beyond the scope of the project. Adaptations were also made to the standard report format to suit South African conditions and comply with requests from the municipalities, so the completed reports fall somewhere between the Lite and Intermediate levels.

One of the adaptations was the addition of a table showing the status of treated sludge at wastewater treatment works within the municipalities, including the quantity produced per day and the percentage that was acceptable for intended use without further treatment. The SFD tool's failure to address what happens to sludge after treatment, in terms of either disposal or reuse, was seen as a shortcoming.

Municipal officials also recognised that SFD reports could help motivate for better budget allocations needed to take remedial action on existing sanitation issues, and plan ahead for future

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Participants at the SFD and FSM Toolbox training and feedback workshop in East London discuss an Excreta Flow Diagram.

ones. A Future Scenario SFD graphic was therefore included to show what would happen if strategies were not put in place for effective faecal management, and a template for a Remedial Action Plan is under development. The latter will make use of two other internationally developed tools, the FSM Toolbox and REVAMP.

The FSM (faecal sludge management) Toolbox, yet another product of the Bill and Melinda Gates Foundation, is a web platform with resources to assist the sanitation sector in undertaking assessments – including estimating the faecal sludge produced within an area – and planning interventions. Its City Service Delivery Assessment (CSDA) can be integrated with the SFD, while the planning tools include offerings for infrastructure planning, stakeholder engagement and business model selection.

The REVAMP (resource value mapping) tool, originally developed by the Stockholm Environment Initiative, allows the resources that can be recovered from faecal sludge, sewage sludge, food waste and other organic waste to be estimated and valued using an MS Excel-based model. Options for resource recovery include the production of biogas, briquettes, soil conditioner and black soldier fly prepupae, which provide a protein-rich animal feed or can be used to make biodiesel.

In their project report, the Emanti team note that REVAMP and the FSM Toolbox present an opportunity for a paradigm shift in sanitation system investments. Rather than being seen simply as a means to contain and dispose of excreta, sanitation systems can generate revenue to help cover operational costs while also providing scarce resources such as energy and agricultural inputs.

The REVAMP tool was tested with eThekwini Municipality, but a lack of data meant that the outputs were unreliable. The municipality could estimate the total solid waste generated per year, but not the percentage organic waste, and does not keep records on the faecal and sewage sludge generated. The same applies to other municipalities – indeed, during the workshops the municipalities had identified the lack of monitoring of vacuum trucks, typically called honeysuckers, as a major challenge. Nevertheless, the project team noted that the REVAMP tool could complement the SFDs and prove very useful should data collection be improved.

At the two feedback workshops held in East London and Durban in the latter half of 2019, information from the completed SFD reports was discussed, and participants were given training on the FSM Toolbox. This was very well received, based on the overwhelmingly positive comments from participants on the course evaluation questionnaires.

The end of this project is just the beginning of a much broader roll-out of SFD awareness-raising by the WRC and its partners. With the start of Phase 3 of the SFD Promotion Initiative in September 2019, the WRC partnered with CSE to scale up implementation of the SFD approach in Africa as a whole. This is seen as an important step towards bridging data gaps necessary for monitoring safely managed sanitation – and hence achieving Sustainable Development Goal 6.2 – and for improving sanitation planning. On April 2020, the WRC and CSE co-hosted a webinar on 'Mainstreaming SFD into practice in Africa', which was attended by 90 invited participants.

More recently, the WRC has articulated that its intention when introducing the SFD approach to South Africa was to catalyse the establishment of a Brown Drop programme for non-sewered sanitation systems, to complement the existing Green Drop system for wastewater systems and Blue Drop for drinking-water systems.

In their Working Paper titled 'Towards establishment of the Brown Drop – A regulatory platform in managing excreta flows in South Africa,' Sudhir Pillay and Jay Bhagwan explain that the WRC aims to achieve critical mass of SFD reporting, close the knowledge-practice for SFD reporting and facilitate the buy-in of the SFD as a regulatory mechanism. They highlight the urgent need for effective management of sanitation infrastructure, rather than reactive operations.

"The facilitation of the Brown Drop certification system will alleviate a long-term crisis and ticking time bomb with regards to regular servicing, O&M as well as giving the necessary attention to sanitation services that will ensure sustainable services, longevity of investments and protection of public health and the environment," they conclude. "The Brown Drop also offers several opportunities for creation of new jobs through infrastructure audits, and possibilities to explore circular economy approaches to sanitation."

To obtain the report, ***Country-wide Shit-Flow Diagram: Establishing national excreta flows in South Africa*** (**WRC Report No. TT 825/20**) Visit: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20825%20Main%20report_Final%20Edits_web.pdf

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GROUNDWATER

Assessing groundwater reclamation benefits of clearing invasive alien trees — insights from the Atlantis aquifer

A recently completed study in the Western Cape has yielded valuable insights into the water reclamation benefits of removing alien invasive plants. Article by Jorisna Bonthuys.

The link between water security and catchment health in water-stressed parts of South Africa has been in the spotlight in recent years, including in the greater Cape Town region.

This has particularly been the case since a recent multi-year drought (2016-2018) which almost resulted in a 'Day Zero' situation in Cape Town – the day that dams would essentially run dry.

Luckily, Cape Town survived this historic three-year drought that threatened to shut down the city's water supply at the height of the crisis. The drought highlighted the water security situation in the region, and the need to protect water source areas from land cover changes that would decrease usable runoff.

Since then, various options to improve water security, including dealing with alien plant infestations, have been explored.

"There is a real and urgent need to deal with water losses due to invasive alien trees in our catchments in a consistent and long-term manner," says hydrogeologist Richard Bugan. He works for The Nature Conservancy (TNC) in South Africa.

This global non-profit organisation is involved in catchment

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restoration efforts and green infrastructure solutions at scale. TNC established the Greater Cape Town Water Fund in 2018, a public-private partnership programme to utilise nature-based solutions to improve water security in the greater Cape Town region. This fund is one of over 40 water funds globally, and the second on the African continent.

"Invasive alien trees consume about 5% of our scarce water resources and reduce the carrying capacity of our natural rangelands."

The scale of the challenge

Many known negative impacts of invasive trees in South Africa are highlighted in the comprehensive open-access book ***Biological Invasions in South Africa*** published by Brian van Wilgen and co-authors in 2020**.** Invasive alien trees consume about 5% of our scarce water resources and reduce the carrying capacity of our natural rangelands. These trees are also a direct threat to the survival of almost half of 1 600 native species listed in South Africa's Red Data List.

Particularly damaging species include trees introduced from elsewhere in the world, including countries like America, Europe and Australia. These invasive alien species invade catchments, reduce water runoff, increase the severity of veldfires, and threaten indigenous species.

These invasive species are introduced without their natural enemies, such as insects and pathogens, giving them a competitive advantage over indigenous species that evolved over millennia.

Although South Africa has invested in programmes such as Working for Water to reduce the negative impacts of these widespread invaders on ecosystem services, much more action is needed.

Invasive alien plants are a significant problem in many ecosystems. Nationally, the impacts of invasive alien plants on surface water runoff are estimated at 1.44–2.44 billion m^3 per year. The most affected primary catchments (>5% reduction in mean annual runoff) are located in the Western and Eastern Cape, and KwaZulu-Natal.

If no remedial action is taken, reductions in surface water runoff could increase to 2.59–3.15 billion m^3 per year by 2032 – about 50% higher than current reductions. This is pointed out by Dr David le Maitre and co-authors in a chapter in ***Biological Invasions in South Africa.*** This chapter focuses on the impacts of plant invasions on terrestrial water flows in South Africa.

The scientists warn of the destructive impact of invasive plants on dam catchment inflows, among others. Riparian invasions, and those in areas where groundwater is accessible to these plants, have 1.2 to 2 times the impact of invasive plants in dryland areas.

Spotlight on the Western Cape

Invasive alien plants – including pine and black wattle – are water-thirsty and have a significant impact on water yield in the province.

With seven species in the list of 25 most invasive alien plant species in the country, the Australian acacias are also considered to be some of the main culprits. The most densely invaded areas in the province are in the Boland Strategic Water Source Area. From here, water gets distributed across the landscape via rivers, dams and pipelines into our taps.

Over two-thirds of the catchments supplying the Western Cape Water Supply System are affected by alien plant infestations, reducing the amount of water that reaches the rivers and dams that feed the region by 55 billion litres (55 Mm^3) per year. This equates to about two month's water supply for Cape Town.

If no action is taken, these water losses could double in only two decades to 100 billion litres per year.

In the Cape Floristic Region, estimates show that available water resources have been reduced by 15% due to alien invasive plants. This could rise to 37% (from 6 765 to 4 271 million m^3 per year) if invasions were allowed to grow and proliferate unchecked over the next three decades.

Studies informing the Greater Cape Town Water Fund business case launched in 2018 showed the highest return on investment could be achieved by clearing invasive alien plants in seven priority sub-catchments (54 300 ha) where 76% of the current water losses occur.

"The 55 billion litres which are lost annually, across these priority sub-catchments, could be reclaimed within only six years, through the implementation of invasive alien plant removal," Bugan explains.

When it comes to securing Cape Town's future water supply, clearing invasive alien plants from within the key water catchments will bring a better return on investment than building desalination plants as an example. It is more cost-effective to eliminate invasive alien trees in key catchments, as a nature-based solution, rather than traditional engineering strategies.

Ongoing, long-term and systematic clearing, follow up, and maintenance of cleared areas are needed to reduce the spread of these invasive plants.

Bugan and a team of experts are currently tracking the impacts and the benefits of clearing dense invasive alien tree stands in priority catchment areas on the catchment water balance and the biodiversity.

As part of these efforts, the Greater Cape Town Water Fund partnership is working in the rugged Boland mountain catchments to cut down water-thirsty invasive trees.

Zooming in on Atlantis

Bugan is the author of a study titled 'Assessing water losses as a

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The scientists conducted sap flow measurements to quantify plant water use. They inserted sap flow sensors into the xylem vessels of tree stems. The probes tracked the movement of water through the trees by using heat as a tracer.

result of invasive alien plants in the Atlantis Aquifer' in which he and a team of experts assessed water losses due to invasive alien trees in the Atlantis aquifer region.

The Atlantis aquifer is situated approximately 50 km north of Cape Town. The available water resources in the area are under increasing pressure from competing users, while climate change and the growing threat from invasive alien plants only worsen the situation.

TNC and partners has been involved in restoration efforts in the aquifer area since 2018.

Significant infestations of ***Acacia cyclops*** (rooikrans) and ***Acacia saligna*** (Port Jackson) occur in the area. These trees pose problems particularly in water-scarce areas such as Atlantis because of their ability to alter the local hydrology. They compete with and displace indigenous vegetation and reduce human access to water.

The team's research was the first of its kind to consider the actual water use of invasive alien plants in the area. At the time, Bugan worked in the CSIR's Hydrosciences Research Group, who was commissioned by TNC to do the research.

"The 55 billion litres which are lost annually, across these priority sub-catchments, could be reclaimed within only six years, through the implementation of invasive alien plant removal,"

The goal of this study was to close this important information gap by quantifying the actual volume of water that is consumed by the invasions. "We sought insights into the potential water

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savings that can be achieved by clearing the invasions and restoring the area with indigenous vegetation under different water availability scenarios," Bugan explains.

This was determined by comparing the evapotranspiration rates of invaded areas and areas covered by the indigenous vegetation (fynbos).

Unpacking the science

The transpiration rates of Acacia trees growing in the Atlantis region were measured at hourly intervals over one year, using the heat pulse velocity sap flow method. The researchers inserted sap flow sensors into the xylem vessels of the tree stems. Xylem is the part of a plant that conveys water from the roots to the leaves and stems, transporting nutrients along with it.

"The probes tracked the movement of water through the trees by using heat as a tracer of sap movement through the tree's transpiration stream," Bugan explains.

Sap is more than 99% water, and therefore, the volume flow of the sap is considered to be equal to the transpiration rate.

Two study sites were equipped, spanning a water availability gradient, from wet (shallow groundwater levels) to dry (deeper groundwater levels).

Remote-sensing and an automatic weather station provided more data. The station's sensors measured rainfall, solar radiation, temperature and humidity, wind speed and wind direction and the signals processed at hourly and daily intervals.

Implications on water savings

The scientists say removing invasive plants and restoring indigenous fynbos could result in the reclaiming of between 830 000 litres per hectare per year and 2 million litres per hectare per year in the area.

"This is a significant amount of water which can improve water security in the region," Bugan says.

The reclamation benefit of 2 million litres per hectare per year only considers the differences in evapotranspiration between the invaded site and a site covered by fynbos.

Researchers fed the study data into a hydrological model to translate this to actual groundwater recharge. The results indicated that over the simulation period the total groundwater recharge was 52 mm under the Acacia trees and 135 mm under fynbos. The difference of 83 mm, equates to 830 000 litres of water per hectare per year, represents the increase in groundwater recharge resulting from invasive alien plant removal.

The authors explained that negligible water savings can be achieved in areas where the invasions are sparsely populated and groundwater is not readily accessible.

"In places where water is not readily available to these acacias and where there are fewer trees per hectare, little or no water may be recovered by removing the invasions although these areas are important to clear to avoid spreading and protect biodiversity."

"This information may be used to prioritise implementation areas where the greatest benefit can be achieved," Bugan says. "Clearing invasive plants is also about restoring biodiversity." Good planning, long-term systematic clearing, follow up and monitoring are needed.

The results of these and other studies can now be used in water-supply system studies to estimate the impacts of invasive alien plants on water resources, Bugan says. It provides measured data of the water reclamation benefit of removing these invasive plants. Decision-makers can also use this information to prioritise areas for clearing and rehabilitation.

Long-term experiments underway

Bugan is currently gathering streamflow information from hydrological monitoring equipment set up at six remote stream sites in priority sub-catchments of the main dams in the Boland mountain catchment areas.

These are part of long-term paired catchment experiments, he says. These experiments are done to validate the science that underpins the water benefits of the Greater Cape Town Water Fund's interventions.

So far, the results have been "extremely encouraging", he says. The data observed from catchment pairs exhibit very high correlations, which is a key requirement during the baseline data collection period of the experiments.

This research will provide direct measurements of the gains in streamflow which may be achieved through the removal of invasive trees in mountain catchments.

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ESTUARIES

Environmental flows and the health and value of the Berg River Estuary

While the Berg River Estuary is considered a regional natural treasure, much needs to be done to restore the ecosystem to a healthier state. Article by Jane Turpie, Annabel Horn & Wilna Kloppers.

Zanele Jam-Jam

A bokkom producer drying fish at Bokkomlaan, Velddrif.

The Berg River Estuary, situated on the Cape West Coast of South Africa, has been rated as one of the three most important estuaries in the country. The 70 km-long estuary, located in a region known for its rugged nature and colourful fishing culture, is a national treasure featuring vast tidal mud flats and salt pans teeming with waterbirds and fringed with extensive salt marshes.

The estuary inspires artists, attracts nature lovers, sailing enthusiasts and canoeists and has captured the hearts of many anglers. It is also the lifeblood of the adjoining Weskus towns of Velddrif and Laaiplek. The estuary is a nursery area for harders that are caught out to sea and then returned to the estuary banks where they are dried and sold as "***bokkoms***". These ***bokkoms*** are the most iconic food of the area, an invaluable part of the local cultural heritage and an important source of protein for many families.

Property values are strongly influenced by proximity to the estuary, and the towns inhabitants derive significant income from the many visitors that come to enjoy the area's unique appeal. The salt marshes and reed marshes harbour a store of carbon, the preservation of which is important for climate regulation. Based on its many ecosystem services, the value of this natural asset was estimated to be over R5 billion. But its beauty and sense of place can never be fully captured in monetary terms.

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The delivery of ecosystem goods and services from the Berg River Estuary is contingent on two broad sets of policy decisions: (1) adequate quantities and quality of freshwater inflows in relation to seasonal requirements, and (2) management of activities in and around the estuary itself. The freshwater flow requirements were gazetted as Resource Quality Objectives following the Classification of the system in 2018.

The ***in situ*** management of the system is guided by the Berg River Estuary Management Plan (EMP), updated in 2019.

However, there are concerns that the Berg River Estuary still faces significant threats to its biodiversity, sense of place and value. Critically, the gazetted freshwater requirements were set on the basis of historical climate conditions and may not achieve the intended C-category (on a scale from A = near-natural to F = critically modified), especially with the expected reduction in rainfall under climate change.

Results from the recent study conducted by the Western Cape Department of Environmental Affairs and Development Planning - "***Environmental flows and the health and value of the Berg River Estuary: potential trade-offs between estuary value and regional water supply under a changing climate***" - confirmed that the health of the Berg River Estuary is already in severe jeopardy. During the 2015 to 2018 drought, no freshwater from the catchment reached the estuary at all, and monitoring data collected by the Western Cape Government showed that the upper reaches of the estuary became saltier than the sea.

There was a severe dieback of reed marshes, and the estuary's heronry at Kersefontein – one of the largest on the subcontinent – was abandoned. Count data from the Coordinated Waterbird Counts (CWAC) show that there has been an exponential decline in numbers of waterbirds on the estuary since 1994, with numbers having dropped by two thirds since then. Meanwhile, water demands on the system have been rising exponentially.

The study found that the estuary's condition is now in a D-category, with only a 53% resemblance to its natural condition, with the physical health scoring 49% and the biotic health scoring 57%. The system is thus not compliant with the gazetted RQOs. Moreover, the estuary could deteriorate to an E-category within the next 20 years as a result of the combination of increasing demands on its water and reduced rainfall under climate change.

If this were allowed to happen, it would lose a third of its value. To maintain its ecological and economic value, the system needs to be in a C-class. This means not only providing better protection of its habitats and fish, but ensuring that at least the quantity and quality of water, currently provided for by law reaches the estuary. Furthermore, after updating the hydrological understanding of the system it was determined that maintaining the estuary in a C-category would require more water than previously estimated. It was estimated that 65% of natural mean annual runoff (MAR) would be needed to achieve a C category, rather than 46% as estimated previously. This could be up to 30% less if water quality issues were also addressed.
Could that be justified in our increasingly water-stressed region? The estuary competes with the City of Cape Town as well as agriculture and local industry for a share of water from its catchment. But the extra water that needs to be freed up for the estuary can be found without sacrificing the amount of water available to these users. Water availability can be bolstered through increasingly affordable new technologies such as desalination, as well as through relatively low cost measures, such as clearing thirsty alien trees from the river catchment and implementing water demand management in urban areas.

Supplying enough water to the estuary to restore it to a C category would currently cost an estimated R0.6 with to R1.2 billion in water demand and supply measures, but this would increase the ecosystem asset value by an estimated R1.5 billion. Under climate change, the Western Cape Water Supply System's water yields would be reduced by 56%, and the cost of making up the shortfall through other means (including desalination) would cost between R1.7 and R2.3 billion.

This is less than the projected loss in value of the estuary of around R3.7 billion, if nothing is done. Given that the full value of the estuary goes beyond economic outputs and can never be fully quantified, these results suggest that as much as possible should be done to free up water for the estuary to allow it to recover to and remain in a C-category, as befitting its biodiversity importance and highly-regarded sense of place.

Acknowledgement: Anchor Research & Monitoring was appointed by the Department of Environmental Affairs and Development Planning (DEA&DP), Western Cape Government for the study of the Valuation of the Berg River Estuary, 2021. Zutari undertook the hydrological modelling. All photographs are credited to Zanele Jam-Jam, a photographer for Western Cape Government.

Zanele Jam-Jam

The estuary's vast intertidal areas and other bird habitats support waterbirds.

Zanele Jam-Jam

The Salt Pans provide important habitat for birds, and need to be restored.

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Water KIDZ

Nile – world's longest river

At more than 6 600 km long, the Nile River is considered the longest river in the world.

Spanning northeast Africa, the Nile River has long been recognised as the longest river in the world.

The word 'Nile' comes from the Greek 'neilos' which means 'valley'. Experts don't agree exactly how long the river is, but we do know that it is longer than 6 600 km.

While the Nile River is usually associated with Egypt, it does, in fact, span eleven countries. Only 22% of the Nile's course runs through Egypt.

The most distant sources of the Nile are rivers that begin in Burundi and Rwanda. Those rivers flow into Lake Victoria. From Lake Victoria the Nile flows through Uganda, South Sudan and Sudan. For about 800 km in South Sudan and Sudan the river is called the White Nile.

At the city of Khartoum, Sudan, the While Nile is joined by the Blue Nile. Further north it is joined by the Atbara River. Both the Blue Nile and the Atbara begin in the highlands of Ethiopia. The Nile continues to flow north across the deserts of Sudan and Egypt. North of Cairo, the Nile enters the region called the delta. From there the river flows into the Mediterranean Sea. Since the Nile crosses so many countries it is considered an 'international' river. There are several major cities along the Nile, including Cairo, Thebes, Khartoum, Gondokoro, Aswan and Karnak.

In Egypt, the Nile River creates a fertile green valley across the desert. It was by the banks of the river that one of the oldest civilisations in the world began. Even today, the remnants of many historical sites remain. The ancient Egyptians lived and farmed along the Nile, growing crops such as wheat and barley, as food for themselves and their animals. The ancient Egyptians used to call the Nile River the Nile Ar or Aur, which means 'black'. This name came from the black sediment along the river banks left by the annual floods.

The Nile was also an important trade and communication route. Small boats were first built from the papyrus plant which grew on the banks of the Nile River, and was used for fishing and short

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The Nile River flows through the city of Cairo, Egypt.

trips. As the Egyptians' skills developed, they began building bigger boats from wood which were able to transport cattle, stone, wood and people along the Nile. In Even today, around 40 million people (about half of Egypt's population) live in the delta region.

Historically, the Nile used to flood every year between June and September. The Egyptians called this season ***Akhet***, meaning 'the inundation'. In the 1960s the Nile government built the Aswan Dam. This dam captures all the floodwater coming down the Nile River, meaning that the Nile does not flood every year anymore.

The ancient civilisation of Egypt was made possible by die life-giving waters of the Nile River

The Nile River is home to many wonderful animals, most notably the Nile crocodile.

The period in which the floodwaters receded the ancient Egyptians called ***Peret***. As the floodwaters receded it left behind a layer of rich soil. This soil was then ploughed and seeded. Farmers also dug irrigation canals to bring water from the river to their fields. A device called a shaduf was then used to transfer the water. A shaduf was a long pole with a skin bucket on one end and a heavy weight on the other. When the weight was lifted, the bucket was lowered into the water. The farmer then raised the bucket of water by pulling down on the weight. He then swung the pole around and emptied the bucket onto the field.

Main sources: www.sahistory.org.za; www.openschool.bc.ca; www.nationalgeographic.com

The Nile River flows through 11 countries:

- Tanzania
- Uganda
- Rwanda
- Burundi
- Democratic Republic of Congo
- Kenya
- Ethiopia
- Eritrea
- South Sudan
- Sudan
- Egypt

Multimedia resources

- Nile – Know about the world's longest river https://www.youtube.com/watch?v=GPXXeypfI5A
- The importance of the river Nile in ancient Egypt https://www.youtube.com/watch?v=aEK6PT7K8OM
- History for kids – The river Nile https://www.historyforkids.net/river-nile.html
- Egypt – a civilisation https://www.becton.sheffield.sch.uk/attachments/download.asp?file=371&type=pdf

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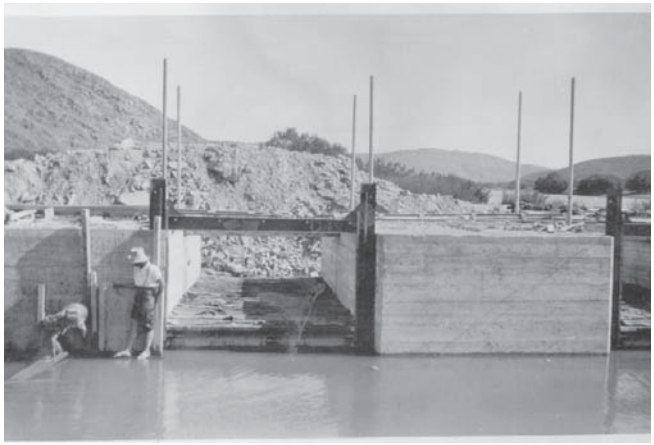
BUCHUBERG – FIRST LARGE DAM ON THE ORANGE RIVER

The Buchuberg Dam was the first large dam to be constructed on the Orange River.

The main canal of 121 km long was completed in 1934.

Lokkie van Zyl



The sluices during construction.

The sand and rock mixers on site in the early 1930s.

The recent excessive rains have once again put the attention on the great dams of the Orange River, with magnificent imagery of spilling dams filling screens everywhere. Perhaps a bit lesser known is the Buchuberg Dam. Buchuberg was the first large dam to be constructed in the Orange River. Construction started in 1929 as a direct response to the drought and depression gripping South Africa at the time. The dam construction project was launched as a work creation scheme while meeting irrigation water needs in the area. All work on the project was done by hand, with pick, shovel and wheelbarrow, with the assistance of donkeys and mules. An average of 350 men worked on the construction of the dam. By 1932, construction of the dam had advanced enough for water to flow into the canal for the first time. The dam wall was constructed to a final height of 10,7 m and is 622 m long. The dam was initially equipped with 68 sluices designed to allow sediment to pass through the structure. Although the dam had an initial storage capacity of 40 million m^3, this has been halved through the years through sedimentation. The sediment sluices have been closed permanently, and the structure is now effectively a concrete weir which supplies water into the canal on the left bank. Today, the Buchuberg canal supplies water to 7 560 hectares of irrigation in the area, most of which is used for field crops and a small portion of fodder crops.

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DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

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