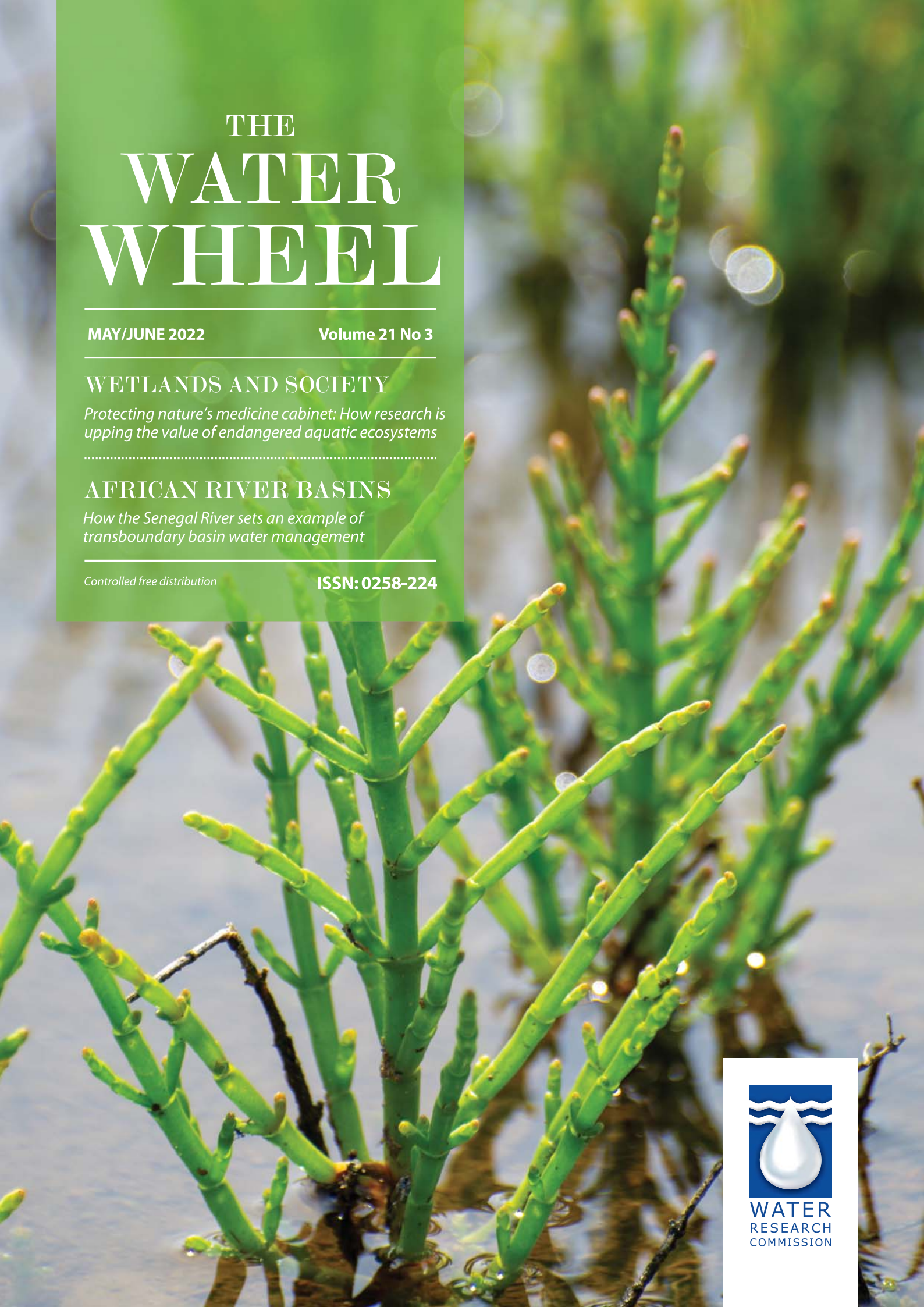

THE WATER WHEEL

MAY/JUNE 2022 Volume 21 No 3

WETLANDS AND SOCIETY

Protecting nature's medicine cabinet: How research is upping the value of endangered aquatic ecosystems

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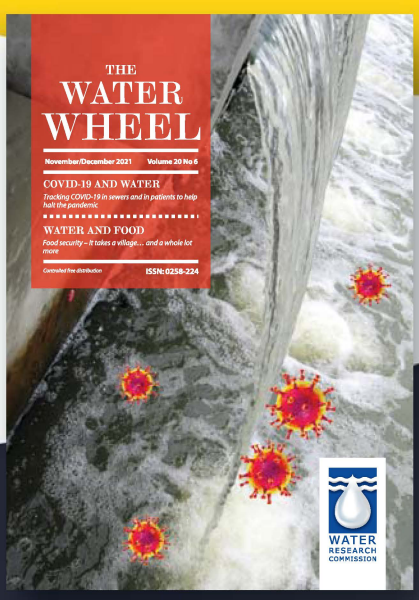

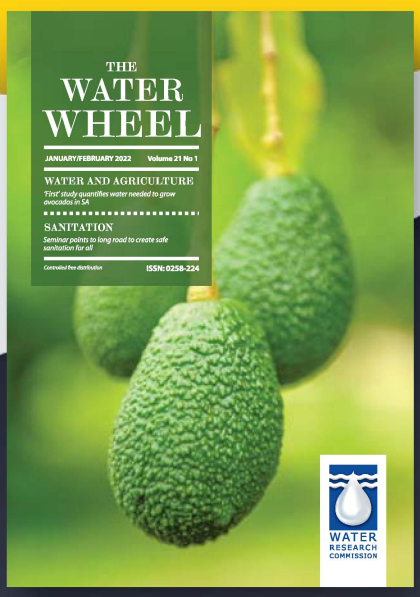

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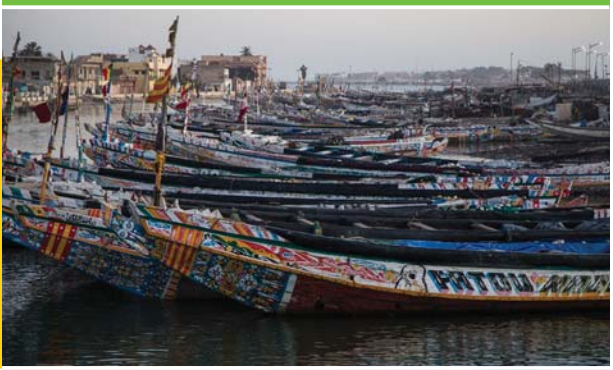

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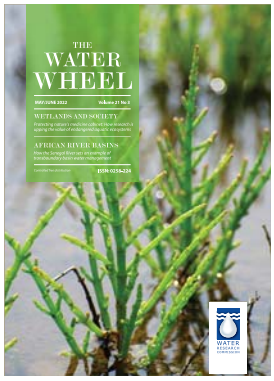

The medicinal properties of South African aquatic plants are bringing a new dimension to the conservation of the country's wetlands. Article on page 8.

NEWS

WRC welcomes new CEO

The Water Research Commission (WRC) has welcomed Dr Jennifer Molwantwa as its new CEO from 1 April 2022. She is the first black woman to serve as head of the organisation, which is the main funder of water-related research in South Africa.

Dr Molwantwa hails from Kagiso Township, Mogale City, Gauteng. She holds a PhD: Biotechnology and a Postgraduate Diploma in Enterprise Management from Rhodes University. She is a Registered Professional Natural Scientist (***Pr. Sci. Nat.***) with the South African Council for Natural Scientific Professionals (SACNASP) as well as a member of the Institute of Directors SA (IoDSA).

Her career started at Pulles Howard & de Lange (later incorporated into Golder Associates Africa) as a research assistant and water resource consultant, respectively before joining Digby Wells Environmental as a Unit Manager. She joined the Water Research Commission (WRC) in 2014 as a Research Manager responsible for water resource quality prior to being appointed Executive: Water Resource Management at the Inkomati-Usuthu Catchment Management Agency (IUCMA) where she served for five years (2016 to 2022).

She gained extensive governance experience from serving on the Governing Board of IUCMA, and the council of the University of KwaZulu Natal (UKZN) where she also represented Council on the University Senate. At present, she serves on the boards of the Water Institute of Southern Africa (WISA) and the Environmental Assessment Practitioners Association of South Africa (EAPASA). She is also a member of the Department of Fisheries Forestry and the Environment (DFFE) Sub-Committee appointed to develop the National Implementation Plan (NIP) for the management of chemicals in South Africa.

Dr Molwantwa served as a commissioner on the on the First National Planning Commission (2010-2015), an advisory body to the President, that developed the National Development Plan (NDP) and Vision 2030 for the Republic of South Africa.

Her passion is capacity building, skills development, and inclusion of Historically Disadvantaged Individuals (HDI) in the mainstream science and technology careers and economy of which water and land are integral. She believes: "the way for women to participate at all levels of the economy, science and technology, knowledge generation and business depends on the opportunities created by women before them."

Global report emphasises increasing threat of wildfires

The United Nations Environment Program (UNEP) has released a landmark report calling for a radical change in government spending on wildfires, shifting investments from reaction and response to prevention and preparedness. The report is titled, ***Spreading like wildfire: The rising threat of extraordinary landscape fires.***

Canadian researchers have also highlighted the growing challenge of wildland fires globally, concluding that the last decade saw the worst records in eight successive years for wildland fires across the globe.

Meanwhile in the Western Cape, the Department Forestry, Fisheries and the Environment, and the Expanded Public Works Programme funded Working on Fire (WoF) programme has attended to more than 70 fires already in the summer fire season (1 December to date).

The UNEP report, produced by more than 50 international researchers, including South Africans, estimates that the risk worldwide of highly devastating fires could increase by up to 57% by the end of the century, primarily because of the rate of global climate change. The report calls for governments to dramatically shift their approach to preventing, rather than only focusing on fighting, fires, which they said would be more effective.

"There isn't the right attention to fire from governments," according to fire expert at the University of Cape Town and an author of the report, Glynis Humphrey. "We have to minimise the risk of extreme wildfires by being better prepared: invest more in fire risk reduction, work with local communities, and strengthen global commitment to fight climate change."

To access the UNEP report, ***Spreading like wildfire: The rising threat of extraordinary landscape fires***, Visit: https://www.unep.org/resources/report/spreading-wildfire-rising-threat-extraordinary-landscape-fires

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Work underway to repair damaged water infrastructure

Water and Sanitation Minister, Senzo Mchunu, says work is underway to repair damaged water and sanitation infrastructure in communities affected by the recent floods in KwaZulu-Natal.

Mchunu, together with the mayors from the affected municipalities, including eThekwini Metropolitan Municipality, iLembe District Municipality and uMgungundlovu District Municipality, briefed the media on 24 April to provide updates on repairs to water and sanitation infrastructure.

Mchunu said the main damage is at the pipeline that supplies raw water to Durban Heights Water Treatment works in eThekwini. This has led to the eThekwini Metro losing about 280 megalitres of water, and that has resulted in water reduction to communities.

However, Mchunu said Umgeni Water has made improvements on the water supply side with an additional 50 megalitres per day, and made procurement of the pipelines for repairs.

The estimated cost of damage to pipelines include R63 million at iLembe District Municipality, R12 million at uMgungundlovu District Municipality and R1 billion at eThekwini Metropolitan Municipality.

The Minister assured the affected communities that the department, working in collaboration with the Executive Mayors in the affected Municipalities, is working with speed to remedy the situation.

"Most of these affected municipalities were already in deficit in terms of their ageing infrastructure. Our approach therefore is to take advantage of this situation to not only repair damaged infrastructure, but also to renew these ailing infrastructures. We are making immediate interventions by repairing damaged infrastructure, but at the same time we are embarking on a renewal programme of water and sanitation infrastructure in KwaZulu-Natal province," Mchunu said.

The Minister also raised a concern about the pollution of rivers due to sewer spillages caused by damaged sanitation infrastructure in the affected municipalities. "We need to act fast to ascertain the amount of damage to sanitation infrastructure and to determine the way forward to address the problem of contamination of our water resources by these sewage spillages."

The mayors from affected municipalities also proclaimed their commitment to improve water supply to the communities.

Source: SAnews.gov.za

Local-international research collaboration results in new early warning tool

Researchers from North-West University (NWU) and Universität Duisburg-Essen in Germany have developed an early warning tool for metal pollution in freshwater systems worldwide.

This research achievement is a collaboration between the Water Research Group, the NWU led by Prof Nico Smit and Prof Victor Wepener and the Universität Duisburg-Essen's Aquatische Ökologie (Aquatic Ecology) Group, led by Prof Bernd Sures and Dr Sonja Zimmerman.

The project is funded by the National Research Foundation and the Federal Ministry of Education and Research.

Prof Smit says the collaboration was informed by the fact that South Africa is the world's main supplier of platinum group elements, and some of the most productive platinum mining operations are located in the Bushveld Igneous Complex near Rustenburg in the North West province. "As with all intensive mining activities, there is always the potential that these activities can result in metal pollution in nearby rivers, thus a proper monitoring mechanism is needed to serve as an early warning tool."

Following a five-year collaboration, these researchers have now designed and validated a passive sampling device – an artificial mussel – that works perfectly to monitor platinum pollution in freshwater environments. Their results – which were published in the international journal, ***Environmental Sciences Europe***, showed that under laboratory conditions there is a high correlation between the uptake of platinum in artificial mussels (AMs) and the concentrations in the water.

"These laboratory tests were also validated under real field conditions in the North West province's Hex River, clearly showing the suitability of AMs for South African rivers. These AMs are inexpensive, easy to make and have the potential to become the tool of choice for water managers worldwide," says Prof Smit. "An additional benefit of the AM is that it allows the determination of bio-accessible metal fraction in water bodies in an ethical manner without using animals, which in the past has been the main standard operating procedure.

"According to the recent International Union for Conservation of Nature report almost one third of all freshwater biodiversity faces extinction, with pollution being one of the main driving factors. Taking this into account, together with human health issues related to water pollution, this new tool comes at just the right time," concludes Prof Smit.

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GLOBAL

Chlorinated water doesn't disrupt kids' gut bacteria

Using chlorine to treat drinking water in Dhaka, Bangladesh didn't disrupt the normal population of bacteria in the digestive tract of children, research finds.

The addition of the chlorine also reduced diarrhoea and antibiotic use, according to the study published in ***Nature Microbiology***.

More than 2 000 children die every day around the world simply because they lack clean drinking water, according to the US Centres for Disease Control. Engineers have devised simple, low-cost ways to purify water in low-income countries using chlorine, but a common concern is that adding chlorine to water could harm the beneficial bacteria in children's developing gut microbiomes, which play an important role in keeping health intact.

The children's microbiomes – tested from stool samples collected one year after the dispensers were installed – had a similar diversity and abundance of bacteria as children who didn't receive chlorinated water. Some slight differences were observed, including the enrichment of beneficial bugs and increases in the presence of some antibiotic resistance genes, but those changes were small and the overall make-up of their microbiomes were similar.

While chlorine inactivates microorganisms present in water during storage, transport, and delivery through the tap, this study suggests that it is not killing the good bacteria after the chlorinated water is consumed. "No doubt further studies may be helpful for understanding all the long-term health effects of drinking chlorinated water," notes Maya Nadimpalli, research assistant professor in civil and environmental engineering at Tufts University, "but this study makes it clear that the microbiome is protected after at least one year of exposure, so that the benefits of water chlorination – which can save hundreds of thousands of lives each year – continue to outweigh diminishing concerns about its safety."

To view the original study,
Visit: https://www.nature.com/articles/s41564-022-01101-3

Asia's coastal cities 'sinking faster than sea level-rise'

Manila and several other coastal Asian cities are sinking faster than the rate of sea level rise, says a study which calls for strict regulatory measure to reduce groundwater extraction, identified as a major cause for land subsidence.

Since 1993, sea level rise has been happening at a rate of around three millimetres per year, according to the Intergovernmental Panel on Climate Change.

However, the Philippine capital saw land subsiding by more than 2 centimetres per year between 2015 and 2020, almost seven times faster than the average sea level rise, increasing the likelihood of flooding. The phenomenon of land sinking faster than sea level rise is more pronounced in Asian cities than elsewhere, says the study published April in ***Geophysical Research Letters***.

The study covered 99 coastal cities all over the world, 33 of which have areas or parts that have subsided by more than a centimetre per year. Researchers Pei-Chin Wu, Matt Wei and Steven D'Hondt from the Graduate School of Oceanography at the University of Rhode Island used satellite-based Interferometric Synthetic Aperture Radar to identify 'fast-subsiding areas'.

The study said excessive groundwater extraction is most likely the reason for the sinking of some areas in these cities – potentially affecting 59 million people. Past studies have cited rapid population increase, expanding industrial and agricultural production, absence of water treatment and poor water quality of available surface water due to pollution are among the major reasons for increasing reliance on groundwater.

"In most cities, part of the land is subsiding faster than sea level is rising," the study said. "If subsidence continues at present rates, these cities will be challenged by flooding much sooner than projected by sea level rise models. The most rapid subsidence is occurring in South, South-East, and East Asia. However, rapid subsidence is also happening in North America, Europe, Africa, and Australia."

Source: SciDev.Net

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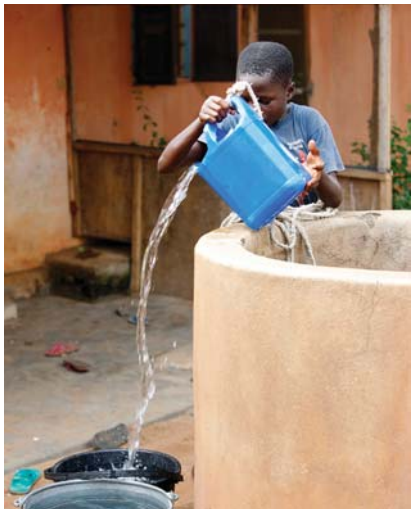
New report points to Africa's vast groundwater reserves



There is enough groundwater under the continent of Africa for most countries to survive at least five years of drought – and some, more than 50 years – according to research by WaterAid and the British Geological Survey (BGS) released earlier this year.

But gross underinvestment in services to get the water out of the ground and to those who need it most and untapped or poorly managed resources means millions of people don't have enough safe, clean water to meet their daily needs, let alone face the impacts of the climate crisis, WaterAid and BGS warn in a new report, titled ***Groundwater: The world's neglected defence against climate change***.

Groundwater – which exists almost everywhere underground, in gaps within soil, sand and rock – has the potential to save hundreds of thousands of lives and be the world's insurance policy against climate change, the organisations assert. It could help communities cope not only with slow onset impacts like drought and irregular rainfall, but also provide resilience to rapid onset impacts like floods by ensuring safe water is available for all, including in schools and hospitals, according to the report.

WaterAid and BGS produced a series of maps which chart current access to drinking water across Africa and drought resilience based on potential useable groundwater at national level. It reveals:

- Most countries in Africa have sufficient groundwater for people to not only survive but thrive – in some cases for more than 50 years.
- This includes Ethiopia and Madagascar – where only around half the population have clean water close to home – and large parts of Mali, Niger and Nigeria.
- Every African country south of the Sahara could supply 130 litres of drinking water per capita per day from groundwater without using more than 25% of the long-term average recharge , and most less than 10%. This means groundwater could provide a buffer against climate change for many years to come, even in the unlikely event that it doesn't rain.

To access the report, Visit: https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/2022-03/Groundwater%20The%20world%E2%80%99s%20neglected%20defence%20against%20climate%20change.pdf

Diary

Aquatic science
26-30 June 2022
The Southern African Society of Aquatic Scientists (SASAqS) is holding its annual conference with the theme 'Valuing our river systems: source to sea'. The conference is hosted by the University of the Free State and will be held at the Amanzi Private Game Reserve (Brandfort).
Visit: https://sasaqs.wixsite.com/sasaqs-2022

Water history
29 June – 1 July 2022
The International Water History Association is hosting a hybrid conference in Stellenbosch. This conference aims to bring together specialist water historians, sociologists, political scientists, civil engineers and scientists, as well as water sector experts in academia and professional water sector leaders and researchers to discuss the serious issue of water shortages of Anthropogenic climate change.
Visit: https://www.iwha2022.org/

Global water sector
23 August – 1 September 2022
World Water Week will be held online and in Stockholm, Sweden under the theme 'Seeing the unseen: The value of water'.
Visit: https://www.worldwaterweek.org/

Global water sector
11-15 September 2022
The International Water Association's World Water Congress and Exhibition will be held in Copenhagen, Denmark.
Visit: www.worldwatercongress.org

SA water sector
28-30 September 2022
The biennial conference of the Water Institute of Southern Africa is taking place virtually and at Sandton Convention Centre under the theme 'Navigating the course'.
Visit: https://wisa2022.co.za/

Wetlands
25-28 October 2022
The National Wetlands Indaba will be hosted by the Free State Wetland Forum (FSWF) and supported by the SA Wetland Society with the theme 'Wetlands action for people and nature'.
Visit: https://indaba.org.za/

Municipal engineering
2-4 November 2022
The 85th conference of the Institute of Municipal Engineering in Southern Africa will be held at Birchwood Hotel and Conference Centre in Gauteng.
Visit: www.wisa.og.za

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WETLANDS AND SOCIETY

Protecting nature's medicine cabinet: How research is upping the value of endangered aquatic ecosystems

The bulk of South Africans, about 70%, look to traditional medicine for their primary healthcare. An estimated 19 500 tons of medicinal plants are harvested to treat various illnesses each year. Most of these are terrestrial but the healing, and the market value of South Africa's wetland plants have now been proven scientifically too. Article by Petro Kotzé

With support from Water Research Commission (WRC) funding, three indigenous aquatic plants are close to commercialisation and will be available on the market to treat skin disorders that include acne, hyperpigmentation, and wrinkles. It's the latest step in decades-long attempts by the WRC to prove the value of wetlands, and to promote their conservation.

One of the mechanisms to protect nature is to demonstrate how it benefits people, says Bonani Madikizela, WRC Research Manager. Rather than top-down mechanisms like fences, laws, policing and punishment this approach works from the bottom up, by motivating people themselves to protect a resource of value to them. "Plants worth money, are worth protecting," he explains.

Promoting research that allows for this value to be taken all the way to the shop shelves also creates numerous other opportunities along the way, many of which are more appealing to a youth that is not interested in dirtying their hands on ground level. Still, he cautions, it has to be clear where this value comes from, in order to sustain the future of the aquatic ecosystem and the business opportunities gained from it.

It's a social-ecological systems approach, Madikizela notes. This broadly refers to an approach that includes biological, social, and economic subsystems. Funding for research in this direction had already started when he arrived at the WRC 15 years ago, he says, but it has developed in leaps and bounds since.

The research behind the research

Early work was driven by a handful of eminent ecologists, who

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increasingly understood nature as complex systems, that cannot be managed or conserved in silos, or fenced off from societies. First, the building blocks had to be laid, and initial work focused on the identification and taxonomy of wetland vegetation. "Some of the plants have been used by our local people for donkey's years, but they've never seen any kind of publicity or generated income or revenue," Madikizela says. "They have been marginalised."

An earlier WRC project focused on listing medicinal plants that occur in freshwater systems in South Africa (more than 200 were listed) and included current indigenous knowledge and the biodiversity that represents the plants utilised for medicinal purposes. An attempt was also made to identify plants that could be subjected to more detailed biotechnological research.

Aquatic plants can produce phytochemicals that protect them from environmental stresses. These phytochemicals have been used in drug development to treat human diseases for centuries, but minimal research has been undertaken to explore the potential of indigenous South African aquatic plants and their potential for the treatment of various diseases.

Then, eight years ago, Madikizela picked up a newspaper and noticed something that would propel the work forward on local shores too. Prof Namrita Lall of the University of Pretoria's Department of Medicinal Plant Sciences had just been awarded the National Order Presidential Award (Order of Mapungubwe, Bronze) for her outstanding contribution to the field of medical science. The award highlighted her work on the extraction and identification of compounds from medicinal plants used to treat tuberculosis and other bacterial infections. She was exactly the researcher that Madikizela was looking for.

From the wetland to the laboratory

Lall's collaboration with the WRC led to the identification of twenty-seven indigenous aquatic plants, selected on their traditional use, sustainability, and the quantity of available material, for further investigation. Their potential for the treatment of skin orders, including acne, hyperpigmentation, wrinkles, dental infections, tuberculosis, and cancer was investigated.

Though none of the samples displayed significant anti-cancer activity, some did show very good promise for the promotion of even skin tone and the improvement of wrinkles. Three plant extracts also showed potential for the treatment of tuberculosis and others, traditionally used for treating toothache, showed potential that could be explored further in studies for oral care.

South Africa's disappearing wetlands

A wetland is defined in the National Water Act (Act 36 of 1998) as the land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

According to the National Biodiversity Assessment 2018, estuarine and inland wetland ecosystems face many pressures and are highly threatened. Of South Africa's 135 inland wetland ecosystem types, 79% are threatened, only 6% are well protected and 61% are not protected at all. Common threats listed are freshwater flow modification; overfishing and bait collection; pollution; habitat loss; climate change; and, biological invasions. Together with indigenous forests, lakes, estuaries, mangroves, dunes, beaches, rocky shores, kelp forests, reefs, seamounts, pinnacles and islands, inland wetlands take up less than 5% of South Africa's territory, but these small ecosystem types contribute disproportionately to a large number of benefits such as water purification, nutrient cycling, carbon storage, storm protection, recreation and food. Managing, protecting and restoring these small, high-value ecosystems will secure essential benefits and deliver large return on investment.

Marize Nel

Compound isolation was done on one of the aquatic plant species. From this seven major fractions were pulled from the partition that showed the best activity (image of each fraction individually).

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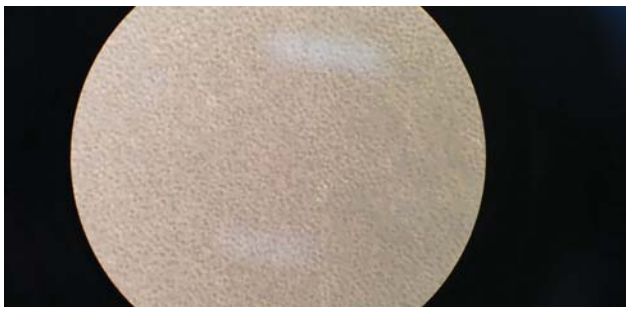
Marize Nel



Granulocytes are used to detect histamine.

Madikizela points out that such scientific endeavors are incredibly expensive, so the research team had to be very selective with the plants that they took forward. "We chose the ones that we were sure we could demonstrate to be viable and could commercialise successfully," he says. Three options were selected, all of which showed to be effective treatments.

Clinical studies confirmed that one plant was effective in promoting even skin tone after 14 to 28 days of consecutive use, twice a day. Clinical studies proved two more to be effective in reducing the appearance of wrinkles after 14 to 28 days of consecutive use, twice a day. Based on their outstanding biological activities, these plants were selected for further cultivation studies and are being grown at a farm in Limpopo Province that is involved in several community-based upliftment projects.

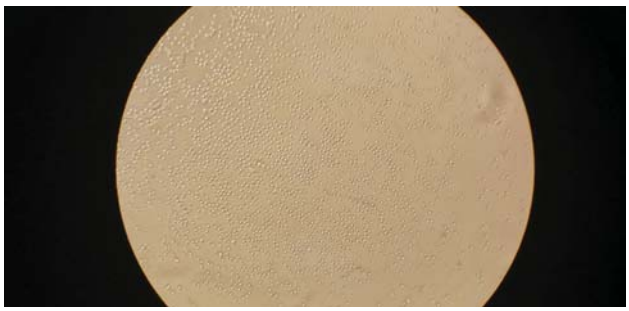
And, currently, all three plants are near commercialisation, says Lall. She also sees large potential for further studies. "There is limited information on the medicinal potential of wetland plants in comparison to terrestrial," she says. In her opinion, however, "by further investigating medicinal aquatic plants there is a potential to promote the development of South African products that are effective and have fewer side effects as well as to initiate the rehabilitation of lost wetland areas which will create job opportunities."

"Furthermore, as more information is discovered on these wetland plants it will promote the rehabilitation of wetlands since most of this land has been reclaimed for agricultural purposes or has been polluted with waste from surrounding areas."

With the groundwork now laid other researchers can continue working with the plant species already identified to have medicinal value. "That's what the research does," says Madikizela. "When you are done with one project, you already have hundreds more questions." Recommendations for future research include clinical studies for oral care for selected aquatic species and the potential for targeting antibiotic resistance associated with tuberculosis. Over and above that, three MSc and three PhD students have been funded by the WRC and are building their careers on the research topic.

Young researchers are taking the baton and running with it

One such post-graduate student is Marize Nel, who is busy completing her Master's degree in Medicinal Plant Sciences at the University of Pretoria's Department of Plant and Soil Sciences.



Peripheral blood mononuclear cells were used to detect tumour necrosis factor-alpha.

Nel says she realised the impact that herbal medicine can have when researched properly in her first year, and has dedicated her studies to the topic since. This soon developed into a focus on aquatic medicinal plants. "That interest came later in my life when I realised how under-researched these species were," she says.

"As more information is discovered on these wetland plants it will promote the rehabilitation of wetlands."

She is continuing work on the selected plants that possess hyperpigmentation properties and reduces the formation of wrinkles. These are known side effects of eczema, she says. In an attempt to reduce the severity of eczema other aspects were also analyzed such as whether they can reduce tumor necrosis factor-alpha production. This, Nel explains, is a pro-inflammatory cytokine involved in the formation of eczema and post-inflammatory hyperpigmentation. Her work also involves investigating whether one of the selected species can reduce histamine production, which causes an intolerable itching sensation that further increases wrinkle formation, she says.

She is, however, not nearly done. In the future, she would like

Preparing plant extracts

The plant materials collected from the areas surrounding the water are rinsed and frozen at minus 80°C for three days. Then, the materials are freeze-dried and ground to a fine powder. The ground plant material is weighed to allow for a 1:5 ratio of plant material to 100% ethanol. Species collected directly from the water are blended with ethanol in the same ratios after surface rinsing. Both mixtures are then placed on a shaker and left to shake for seven days. After this, the ethanolic extraction liquid is separated from the ground/blended plant material using a filter and vacuum pump. The ethanol is evaporated and the resulting extract kept in a minus 4°C freezer to be used for experiments.

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Global contribution to research

Lall has since made tremendous contributions to the field of research that explores the medicinal value of aquatic plants. She edited the book, *Aquatic Plants: Pharmaceutical and Cosmetic Applications*, that was published in 2020. The book provides a concise description of popular aquatic plants found across the globe. Chapters focus on the aquatic species native to specific continents. Written by a global team of experts the publication explains the distribution, ethnobotanical uses, genome sequencing, chemical compounds, and biological activity of these plants and addresses the cultivation and sustainable production of aquatic and wetland plants. The publication is a valuable resource for academics conducting research on aquatic plants and for professionals in the pharmaceutical and cosmetic industries who are involved with the therapeutic applications of these plants and their sustainable usage.

to investigate how one of the selected species reduces the mentioned tumor necrosis factor-alpha, as well as its effect on the condition when applied topically. Furthermore, Nel says she would like to investigate other aspects of the condition (eczema) due to its spike in occurrence over the years both in children and adults, with an eye on finding out if these plants could potentially reduce those aspects.

Nel is clear on why she has chosen this route and is sticking to it. "Aquatic plants are under-rated and their potential use is being minimised due to the continuous loss of our wetland areas." The young researcher says more research should be done on these plants in order to promote the importance of protecting the area where they come from and to emphasize how valuable South African aquatic plants are due to their medicinal properties.

Beyond her studies, she can already see how she can potentially carve out a career for her in the field. She could potentially continue at the University of Pretoria as a lecturer in the field of Medicinal Plant Sciences, she says. "Not only will this provide me the opportunity to potentially develop an effective eczema treatment but I may be able to peak more students' interest in the medicinal value of plants and show them the importance of this field."

Ensuring that the benefits ripple back to ground-level

Until the commercialisation process has been finalised, the experts are keeping on mum on details of which specific aquatic plants are being developed. Madikizela says that the process

Supplied

Medicinal aquatic plants have the potential to promote the development of South African products that are effective and have fewer side effects says Prof Namrita Lall.

Supplied

Marize Nel is one of the next generation of young scientists that will take the field of research on the medicinal value of indigenous, aquatic plants forward in South Africa.

of registering the concomitant Intellectual Property is ongoing and until then, such details will be kept under wraps. Though the process is challenging, it can help ensure that benefits are filtered back to communities on the ground level since shareholding and beneficiation will be part of a negotiation process should a developer step in, to upscale the products. The hope is that one day in the not-too-distant future, savvy shoppers can contribute to the sustainable future of wetlands, by simply swiping for the right products selected from the shop shelves.

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- Distribution, use and ecological roles of the medicinal plants confined to freshwater ecosystems in South Africa, by J Wentzel and CE van Ginkel, WRC Report No. KV 300/12

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COVID-19 AND THE ENVIRONMENT

COVID-19 sanitisers – What is the impact of the pandemic on our aquatic environment?

Some of the chemicals we rely on to slow the spread of the coronavirus may be harming the aquatic environment. Matthew Hattingh reports.

An ounce of prevention trumps a pound of cure and a little handwashing goes a long way to slowing the spread of infectious disease. It's true of the common cold and it's true of COVID-19. But what's inside all those sanitisers and disinfectants flooding the market, that we've been using so liberally in our homes, offices and public spaces?

How much is getting into the environment? What are the likely consequences for natural systems and public health? And what should be done to remedy matters? These are not really new concerns. It's been established for some time that concentrations of some chemicals used in sanitisers and disinfectants are high in the environment, but levels have likely spiked since the onset of the pandemic.

Chemical pollution of all kinds is a global phenomenon. It's responsible for an estimated 9 million deaths worldwide every year and scientists have shown how it finds its way into practically everything. How this applies to South Africa, particularly with chemicals used in sanitisers and disinfectants, was the subject of a virtual seminar hosted by the Water Research Commission (WRC) earlier this year.

Delegates heard that these products contain a 'lot of chemicals' and they are accumulating in our aquatic systems, posing a possible risk to living organisms including fish, crustaceans, plants and bacteria. Ndeke Musee, one of the guest speakers, said this was despite the work of wastewater treatment plants, some of which have "pretty low efficiencies" when it comes to removing chemicals. Moreover, the University of Pretoria associate chemical engineering professor noted heightened concerns that some sanitisers and disinfectant brands "contain ingredients that have been banned elsewhere but are still being used in South Africa".

Examples of such chemicals include fragrances like Butylphenyl Methylpropional and Alpha-isomethyl Ionone. These substances have been banned or restricted for certain uses in some countries after being linked to skin irritation and infertility among rats. Other compounds banned or restricted

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in other countries, but found in sanitisers and disinfectants in South Africa, are 4-Methylbenzylidene camphor, Ethylhexyl Methoxycinnamate and Benzophenone-3. There is some evidence that these ultraviolet filters, commonly found in sunscreens, may disrupt the production or function of the female sex hormone, oestrogen.

University of Pretoria researchers examined the sanitisers and disinfectant products most widely used in South Africa and identified 187 chemical compounds. To their surprise, said Prof Musee, they found that the data accessible nationally and internationally limited them to assessing the risk levels of a mere 21 compounds. Inadequate data prevented the team from assessing the chemicals most frequently used across brands that when found in sufficient concentrations in rivers and lakes, according to the literature, can be toxic to organisms.

Concentrations of certain chemicals in the aquatic system in South Africa and elsewhere may be approaching a "point of no return" where ecological balances are tipped irreversibly, with consequences for human wellbeing. "It will compromise the quality of water. Bacteria and other organisms are very important and they are good bioindicators of water quality. That will increase costs of treating water because it is highly polluted. Wildlife can also be affected," Prof Musee said.

In addition, the increasing use of recycled water for agriculture means a greater risk of chemicals getting into crops and accumulating in the bodies of those who eat them. However, Prof Musee noted that the team has been careful not to "become big scare-mongers" over potential threats to the food chain. This included making premature pronouncements on possible accumulation of toxins in fish or crops and the risks, if any, to the people who eat them. Rather, the team hopes to produce robust findings in the coming years on the risks posed by some of the identified compounds to the environment, including water quality.

Responding to questions from the floor, Musee said he was cautious about calls to ban or restrict certain chemicals. Reliable data must first be gathered, a process that can take years, but failure to do so risked "serious litigation". He called for a systematic evaluation of risks and a transparent approach. This would include pre-market registration of products and screening of chemical pollutants and assessing risk. "We need to be protected from COVID-19, but at the same time we need to balance the risk to the environment."

Proper modelling is necessary to learn which compounds were persistent in the environment, which accumulated in the bodies of living things and which were toxic. Also needed, he said, was an inventory of household products and their chemical constituents. This will help identify problem chemicals, but can the compounds in sanitizers and disinfectants in use since COVID-19 be quantified?

A University of Johannesburg team has been looking for answers. "Almost all of us are sanitising and using disinfectants to make sure our houses are clear of the virus," said Philiswa Nomngongo, a professor in environmental analytical chemistry at the university. She makes the very reasonable point that "when we buy more, it means we release more". It's another matter, however, to demonstrate this with scientific rigour and Nomngongo sketched some of the difficulties the team faced.

She and her colleagues have been taking samples at wastewater treatment works and from the rivers they discharge into to gauge the occurrence of sanitizer and disinfectant chemicals in the aquatic environment in Gauteng and KwaZulu-Natal (KZN). She noted that treatment works were never really intended to take these chemicals out of the wastewater. "But we want to see what levels are being removed… and how much goes to the environment," she said.

The study, which began in March 2021, collected samples during the second, third and fourth COVID-19 waves (an uptick in chemicals was observed during the third) and work was continuing. The idea was to get a "fingerprint" of the chemicals in the system at different places so comparisons could be made with current data nationally and globally.

In Gauteng the team gathered samples from rivers at 11 sites near wastewater treatment works, in Johannesburg, Tshwane and Vaal. In KZN they were able to sample at treatment works as well as up- and downstream of these in eThekwini, Pietermaritzburg, Albert Fall and Howick.

With the assistance of the University of Venda, the team used

While people require the means to protect themselves from COVID-19 it needs to be balanced with the risk to the environment.

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solid-phase extraction to concentrate and purify samples and analyse these using liquid chromatography-mass spectrometry. This is a well-established technique that uses chemical formulas and molecular weights to identify chemicals. The chemicals found were tallied up by site and classified into 10 broad types, including antibacterial, fragrance, ultraviolet filters, pharmaceuticals and preservatives.

Nomngongo noted that a single sanitiser or disinfectant product typically contains a number of chemicals. Some, such as alcohols, have a short lifespan once released, so the team's focus has been on those that persist in the environment for more than 180 days. Sampling and analysis at wastewater treatment works has historically been used to gauge the use of drugs – legal and otherwise – in particular communities at different times. Consistent with this, the study frequently found pharmaceuticals, with levels varying at the different works, as well as from river to river.

The biggest difficulty, said Nomngongo, is the dearth of studies on many chemicals in South African waters. This and the prohibitive cost of chemical standards or reference data made it hard to determine background levels. These are concentrations of different chemicals present in the waters before COVID-19 – essential data for drawing meaningful comparisons.

Nomngongo raised the likelihood that the pandemic had increased chemical levels in the environment but found it hard to say so with confidence: "We don't have prior information. Can't comment on whether concentrations are higher or lower." However, sampling continues as the team seeks to identify and quantify a limited number of chemicals, including those found in pharmaceuticals likely to have been used to treat COVID-19. These included parabens, a preservative and antibacterial that had been identified in South African waters prior to the pandemic.

Another problem was narrowing the search for chemicals. For example, the labels of some sanitisers and disinfectants list "fragrances" but give no specifics, including concentrations. And cosmetics and pharmaceuticals, which the study detected, contain fragrances too, making it hard to pin down the source of these.

The highest numbers of chemicals were identified in Gauteng, said Nomngongo, with the most (92) being recorded at a sampling site on the Rietspruit River. This was not necessarily because the site was near a wastewater treatment works. Other activities in the area, which is near the township of Sebokeng and in an industrialised part of southern Gauteng, probably contributed too.

In Gauteng the team detected high numbers of pharmaceuticals, fragrances and antimicrobials. The antimicrobials included quaternary ammonium compounds, a class of disinfectants commonly used in homes and in industry. Nomngongo noted that while these were effective in preventing disease they were also "very persistent in the environment", affecting aquatic life. A similar picture emerged in KZN, although levels of quaternary ammonium compounds were lower than in Gauteng.

She said a number of chemicals, including triclosan, are found in disinfectants, soaps and sanitizers recommended for use against COVID-19 in South Africa despite being regulated or banned in some countries including the US, Canada and in the European Union. The bans were prompted by concerns the chemicals may disrupt hormone development, make microbes resistant to antibiotics and affect environmental health.

"Can't we keep up with what the rest of the world is doing in terms of what we can use?" Nomngongo asked, calling for better labelling of chemicals. Specifics, including concentration details, were needed, combined with policies and standards, to protect the environment.

A delegate asked from the floor for details about which countries had banned triclosan. Musee confirmed that the US, Canada, and the European Union have done so, but noted this had not happened in many developing countries, including South Africa. He stressed there were no quick fixes. The court cases that led to the banning of triclosan and triclocarban in the US and elsewhere started in 1974 and were only resolved in 2016, with the ban coming into effect in 2017.

"It's not that you are going to wake up and do the banning, it takes years and years," he said.

Bonani Madikizela, of the WRC, wanted to know which government departments were responsible for regulating which chemicals in South Africa. Musee replied that he had been in touch with the departments of Agriculture; Forestry, Fisheries and the Environment; Trade, Industry and Competition; and the South African Bureau of Standards.

What did he learn? "To be honest, to be frank with you, in South Africa there is a need for a conversation about who is supposed to deal with these matters," said Musee. He said an environmental specimen bank would be a valuable aid to research and chemical management. Specimens from the environment could be collected, stored and managed and chemical analysis could be done when required or once resources allowed. This would let researchers establish baseline values, including concentrations, of different chemicals for particular places, making meaningful comparisons possible. This, in turn, would support evidence-based policy and decision making.

Calling for suggestions and dialogue on the establishment of an environmental specimen bank, he said that carefully stored and archived samples drawn regularly from plants, animals, humans, water, sediments and the broader environment could provide a picture of which chemicals were accumulating, and therefore of concern.

Africa has no specimen banks, he said, with most found in Europe, North America and the Far East. Yet more people die from chemical pollution in Africa than on any other continent. Quoting from a study he co-authored with UNISA agriculture and animal health professor Khanyisile Mbatha, on specimen banks, chemicals and Covid, Ndeke sketched the process of establishing a bank. This included feasibility assessments (including the skills and financing required) through design and development, to commissioning and beyond.

Further work was needed to establish whether there was sufficient demand in South Africa to justify an environmental specimen bank which would probably come with a price tag in the "millions of dollars".

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WATER INFRASTRUCTURE

Independent water producers – The opportunities and the challenges for SA

A recently completed Water Research Commission (WRC) project investigated the issues surrounding independent water production in South Africa. Article by Sue Matthews.

Marine salvage expert Nicholas Sloane became world-famous in 2013 for his leading role in righting and later refloating the capsized ***Costa Concordia***, which ran aground off the coast of Italy in January 2012. He was back in the news again in 2018 with his proposal to tow an iceberg from Antarctica to help relieve Cape Town's water crisis during the Western Cape drought. His plan was to get private investors to fund the project, and then sell the freshwater released from the iceberg as it melted to the City of Cape Town municipality.

This would have made Sloane and his partners independent water producers, or IWPs, according to a definition contained in a WRC Working Paper titled "The opportunity of independent water producers in South Africa". Co-authored by research consultant Kevin Foster, Bosch Capital's Rajiv Paladh and Andy Knox, and WRC Executive Manager Jay Bhagwan, the Working Paper summarises the findings of their recently completed WRC research project, in which they analysed the key areas of legislation, regulatory mechanisms, capacity requirements, institutional dynamics, and financial and social aspects of IWPs.

"An independent water producer is understood to be an entity, which is not a publicly owned water utility, but which owns and operates facilities to produce water for sale to customers," they state in the Working Paper. "Customers can include utilities, central government, municipalities and end users, like industry or farmers."

The City of Cape Town Municipality wasn't supportive of the iceberg idea, having already embarked on a range of emergency measures that were deemed more cost-effective and logistically viable. These included abstraction from groundwater aquifers and springs, three temporary desalination plants located along the coast at Strandfontein, Monwabisi and the V&A Waterfront, and a water reuse plant at the Zandvliet wastewater treatment works (WWTW). But by the end of May 2018, even before good winter rains later replenished the city's dams and allowed water restrictions to be eased somewhat in November, the municipality had announced that temporary desalination and water reuse would not be pursued further as emergency solutions, as they were not affordable and rarely provided the promised volumes of water.

Once the drought was over, the temporary desalination plants – all of which were owned and operated by private companies and were therefore IWPs – were decommissioned. The water

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reuse plant belonged to the same IWP as the Strandfontein and Monwabisi desalination plants, and since it only started yielding potable water after dam levels had recovered, it was converted into a demonstration plant without ever being integrated into the water distribution network. The municipality is now constructing a much larger water reuse facility, the Faure New Water Scheme, and investigating the feasibility of a permanent desalination plant, both of which will supplement the water supply from ground and surface sources and ensure future resilience.

In their Working Paper, Foster et al. note that desalination and water reuse from wastewater present the best opportunities for IWPs in South Africa in the short and medium term. This is partly because these relatively new technologies require skills that aren't widely available in the country, but also because implementing such projects would involve less regulatory and institutional complexity than IWP projects using ground or surface water. The National Water Act does not explicitly recognise either seawater or wastewater as a water resource, which is defined as a watercourse, surface water, estuary or aquifer. Of course, other legislation, such as the National Environmental Act (NEMA) Environmental Impact Assessment Regulations and Integrated Coastal Management Act, would still apply, and the National Water Act could potentially be amended to include desalination and water reuse. In fact, say the authors, any gaps in the water legislation should be clarified if private sector investment is going to be sought for desalination and water reuse projects, so that investors can be provided with regulatory certainty.

From an institutional perspective, both desalination and water reuse IWPs would require long-term offtake agreements with large-scale public-sector organisations responsible for water services delivery – such as Water Boards and municipal Water Services Authorities (WSA) – and would probably entail public-private partnerships (PPPs). This would have implications in terms of the Municipal Systems Act (MSA) and the Municipal Finance Management Act (MFMA). For example, section 78 of the MSA requires any municipality wanting to explore the possibility of providing a municipal service through an external mechanism to conduct a lengthy process that includes public participation, a feasibility study and a thorough cost-benefit assessment of impacts on the environment, human health and safety, as well as job creation and employment patterns.

Likewise, the MFMA stipulates under section 33 that another onerous process must be followed for long-term contracts imposing financial obligations on a municipality. This would not only require a municipality wanting to enter into a contract with an IWP to undertake public participation, but also to solicit the views and recommendations of the national and provincial treasury and the national departments responsible for local government and water. The Municipal Public–Private Partnership Regulations promulgated under the MFMA give detailed instructions for undertaking feasibility studies for PPP agreements, in addition to outlining their procurement rules and basic requirements.

All of these regulatory processes significantly increase the cost of getting IWP projects up and running, as well their timelines. In the intervening years, key roleplayers in the political landscape or within institutions may be replaced, and permissions could potentially be revoked if legislation or circumstances change. The authors point out that this threatens the business case for IWP and may act as a barrier to private sector investment.

"If the use of IWPs is to be encouraged, a means to reduce the complexity and timeframes for these processes need to be identified. Learnings from South Africa's IPP experience could add value here," say the authors, referring to independent power producers in the energy sector. But the regulatory issues are certainly not the only challenges.

"Any gaps in the water legislation should be clarified if private sector investment is going to be sought for desalination and water reuse projects, so that investors can be provided with regulatory certainty."

"Private investment decisions are based on the ability of customers to pay for the services provided by the infrastructure and there are limitations on the ability to pay throughout South Africa's water value chain," note the authors, explaining that this encompasses households, WSAs, Water Boards, the Department of Water and Sanitation (DWS) and the Water Trading Entity. "The combination of poor financial standing of these institutions, and weak governance in many of them, make investments in water infrastructure unappealing."

Overcoming this would require a coordinated programme with high levels of project management capacity and political buy-in, backed by financial guarantees, most likely from National Treasury, they add. The current situation implies that opportunities for IWPs exist primarily in financially sound and institutionally stable WSAs and Water Boards, where investors can be confident that their primary offtaker would be able to pay for the water provided.

It would also be relatively straightforward for IWPs to enter into offtake agreements with large industrial, commercial or agricultural customers. Around the country, small-scale desalination and water reuse plants have already been built and operated for private companies to ensure their own supply, while freeing up water that the WSA or Water Board could distribute to other users. However, offtake agreements between IWPs and such customers would have to be carefully considered if they were to reduce the revenue of the WSA or Water Board to the

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point of threatening their financial stability. In the case of WSAs, the authors highlight the far-reaching secondary effects.

"This would further impact on the services provided by the WSAs in the provision of water services (particularly indigent households) and other social services that are offered and cross subsidized from water and sanitation tariffs."

One solution to simplify procurement processes, offtake agreements and the requirements for credit guarantees would be to have a single offtaker for IWPs. The authors suggested that this could possibly be the National Water Resource Infrastructure Agency (NWRIA), but since the publication of the Working Paper DWS has held a two-day consultation session about the establishment of the NWRIA, which will involve a merging of the Trans Caledon Tunnel Authority (TCTA), the Water Trading Entity (WTE) and the DWS Infrastructure Branch. A statement issued by DWS at the time indicated that the NWRIA's function will be to provide raw water, and its main focus will be on the underserved and the poor to ensure a sustainable, equitable and reliable supply of water from national water resources infrastructure.

The authors note that water reuse IWPs may encounter some complicating factors that do not apply to desalination IWPs. They need a reliable source of wastewater, probably from a municipal WWTW, and the quality of its final effluent needs to be suitable for further treatment to potable standard, which may necessitate the IWP taking over the management of the WWTW to achieve this. During drought conditions, the volume of wastewater typically decreases as water usage becomes more stringent. And unlike in coastal areas, where WWTW effluent is discharged directly or via a watercourse into the sea, in inland areas it may need to be returned to a river to maintain flow rates for downstream users and ecosystem health. Both scenarios might limit the amount of final effluent available for treatment and reuse. What's more, the South African National Standard for drinking water quality, SANS 241: 2015, assumes that intake water is raw, untreated water, so it does not address emerging contaminants that may be present in elevated concentrations in wastewater effluent intended for further treatment and reuse. The authors note that regulations around this would need to be developed.

Of course, IWPs could potentially use raw water from ground and surface sources for conventional bulk production of water. Under current legislation they would need a Water Use Licence and would not own the water resource – the National Water Act designated national government the public trustee of the country's water resources – but could own the necessary infrastructure, such as treatment works and pipelines. However, the authors point out, "most of the economically feasible sites in and around the major towns and development nodes in South Africa have already been exploited. Therefore, any new development would require a higher cost than existing infrastructure and would be located further away from the economic centres that are experiencing water security challenges."

These kinds of IWPs would essentially become competitors to WSAs, Water Boards and some Water User Associations fulfilling the same function, and would probably need to link into their bulk networks. Apart from the risk of institutional friction, duplicating the role of existing institutions will likely increase the overall cost of providing water services to the end consumer.

Another option with far more positive social impact, though, would involve the contracting of an IWP by a water services committee. According to Section 51 of the Water Services Act, the Minister may establish a water services committee to provide water services in areas where the WSA is unable to.
"Secure water supply would improve economic and social outcomes for those served, and IWPs could employ local people to assist with operating and maintaining infrastructure," note the authors. "Communities are unlikely to object to private provision when public provision is dysfunctional, although this could be contingent on the revenue collection mechanism that is used."

Nevertheless, the extensive consultation process required before a water services committee can be established may act as a hinderance, with local politics potentially posing a challenge. And if the water services committee would need to operate the WSA's infrastructure to provide water to its designated area, significant investment might be needed for repairs or upgrades. This highlights another barrier: the minister may disestablish a water services committee, at which point its assets are vested with the Minister, who may transfer them to the relevant WSA or Water Board. This is clearly a considerable risk to any private party that has funded the development of infrastructure.

The authors conclude the Working Paper by posing key questions to be addressed and outlining the emerging framework for the way forward to enable the introduction of IWP in South Africa. The framework identifies the initial steps that would need to be taken and the key principles to be considered within each of these steps.

- To access the Working Paper, ***The opportunity of independent water producers in South Africa***, visit: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/Working%20Paper_IWP_Feb%202022.pdf
- To access the research report, ***Independent water production and producers in South Africa*** (**WRC report no. 3012/1/22**) visit: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/30121.pdf

Definitions according to the Water Services Act

- "Water board" means an organ of state established or regarded as having been established in terms of this Act to perform, as its primary activity, a public function;
- "water services authority" means any municipality, including a district or rural council as defined in the Local Government Transition Act, 1993 (Act No. 209 of 1993), responsible for ensuring access to water services;
- "water services provider" means any person who provides water services to consumers or to another water services institution, but does not include a water services intermediary;
- "water services intermediary" means any person who is obliged to provide water services to another in terms of a contract where the obligation to provide water services is incidental to the main object of that contract;

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AFRICAN RIVER BASINS

How the Senegal River sets an example of transboundary basin water management

When countries share river basins, conflicting needs of upstream and downstream nations can easily lead to discord, with international ramifications. It's a common concern, with so many borders that have been drawn across rivers. This is not the case in the Senegal River Basin, where member countries have been lauded for their transboundary water management. Petro Kotzé reports.

All photographs by Petro Kotzé

The Republic of Senegal, located in West Africa, shares the Senegal River Basin with Mali, Mauritania, Senegal and Guinea. The countries are collaborating over the water resources that they share, for the benefit of their people.

Africa has more share of its area (62%) within transboundary basins than any other continent. A total of 68 transboundary basins, out of 310 worldwide, are in Africa. South Africa is no stranger to the implications of these statistics. The country shares six international watercourse systems with neighbours. The four most important basins are the Limpopo, Incomati, Maputo and Orange, which are shared with Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe.

The Orange-Senqu River Basin is a case in point of the disputes that can develop between adjacent states. South Africa's largest river, the Orange originates in the Lesotho Highlands. From here the river stretches for 2 300 km to the Atlantic Ocean along a basin that includes Lesotho, South Africa, Namibia and southwestern Botswana. The last 600 km form an ambiguous border with Namibia that has led to tussles with South Africa over what constitutes 'fair' water allocation. The situation could likely escalate as pressure on water availability in the region increase on the back of worsening climate variability and escalating development demands.

Elsewhere on the continent, an exemplary example of transboundary basin management has developed in the Senegal River Basin, which is shared by Mali, Mauritania, Senegal and Guinea.

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Together with the Niger River, Lake Chad, the Volta River and the Gambia River Basin, it's one of West Africa's largest transboundary basins and is managed by the Senegal River Development Organization (the OMVS, according to the French acronym for ***Organisation pour la Mise en Valeur du fleuve Sénégal***).

Established in 1972, the OMVS has been widely lauded for its achievements. Fifty years since their establishment, in March, they were awarded the Hassan II Grand Prize for Water at the World Water Forum in the Senegalese capital Dakar. They were distinguished for achieving water and food security in the basin, and for actions towards peace, prosperity, and territorial development of its member countries. They were also nominated for the 2022 Nobel Peace prize as a facilitator of peace, stability, and development in the region.

Though each river basin has unique characteristics that call for tailor-made management approaches, the OMVS and its management of the Senegal River Basin is a valuable example of an innovative approach to how this can be done successfully.

The Senegal River Basin

The Senegal River originates in the high plateaus of the Fouta Djallon massif in Guinea, from where it transverses 1 800 km across Mali and Mauritania to empty into the Atlantic Ocean at Saint Louis in Senegal. The river is divided into an upper basin, valley, and delta. Though each has distinct environmental conditions, the majority of the basin has a sub-Saharan desert climate and is marked by long droughts. Annual rainfall varies greatly between seasons and years and decreases from about 2 000 mm per year in the upper basin to around 500 mm in the delta. Rain generally falls from June to September, followed by a cold and dry season from October to February, and a hot and dry season from March to June.

The ebb and flow of the river traditionally gave shape to the lives that depend on it. The Senegal is a key resource for livelihoods in all countries that it flows through, and the bulk of the ethnically diverse population lives close to its banks. Traditionally, they have engaged in a mix of farming, fishing, and herding activities, with rainfed agriculture practiced in the uplands and recessional floodplain farming in the lowlands. However, these activities were slave to fickle extremes. Depending on the size and duration of floods, arable land could vary between 15 000 and 150 000 hectares.

Serious floods in 1890, 1906 and 1950 were devastating, but intermittent droughts were equally crippling, especially the series of droughts experienced in the Sahel region from West Africa to Ethiopia from the late sixties to the eighties. The resulting famine killed an estimated 100 000 people, and 750 000 were left dependent on food aid. At the peak of the drought, the Senegal River almost dried up, driving a large exodus of people from the rural areas to over-burdened cities, and highlighting the vulnerability of the region's food-producing system to climate variability.

In response, the countries of the Senegal River Basin came together to collaborate on solutions. Instead of conflict over water resources, the catalyst for the birth of the OMVS was a need to join forces for the good of the basin's people.

An innovative river basin organisation backed by international law

The OMVS aims to develop food security; reduce economic vulnerability to external factors such as climate changes;

The Diama Dam has been key to unlocking the economic growth of the region as envisioned by the OMVS.

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Life along the Senegal River develops with the ebb and flow of the river. Along with rising sea levels, the water levels of the river are some of the threats faced by Saint Louis, once an important economic centre in French West Africa.

Fishing has always been one of the staples for the people of the Senegal River.

The OMVS ensures equity in access to the river's water resources among riparian countries.

accelerate the economic development of member states; preserve ecosystem balance in the sub-region and basin; and, secure and improve revenue. It was established by Mali, Mauritania, and Senegal, and joined by Guinea in 2006.

The organisation created several shared physical and institutional infrastructures, supported by what has been described as 'farsighted legislation' for the time. For one, the watershed of the Senegal River has been declared common and indivisible property of all the member states. This guarantees free navigability of the river and ensures equity in access to the river's water resources among riparian countries. This convention also implies that any intervention that could significantly affect the hydrological regime or condition of the river must be approved by all member states. The infrastructure on the river, such as reservoirs, has also been declared the common property of all member states.

In 2002, a groundbreaking Water Charter was adopted. Likely a first of its kind in Africa, it is a commitment to a shared vision for sustainable development of the river basin. It embodies all key emerging principles on equity, integrated water resources management (IWRM), and the need to protect the environment.

Broad political issues are dealt with by the highest management body, the Conference of Heads of State and Government. A Council of Ministers exercises oversight roles and is made up of one minister from each member state. A High Commissariat implements its decisions. Then, a Permanent Commission for Water acts as an advisory body. The commission consists of senior experts of member states. This is seen as part of the OMVS's unique management approaches.

Furthermore, there are established structures at national and local levels. For example, in each country, a National Coordination Committee is made up of representatives of ministries involved in or affected by water management in the basin, as well as civil society organisations.

Sharing costs and benefits

Another facet that sets the OMVS apart from other river basin organisations, is the notion of joint financing that it adheres to. This approach follows the principles of solidarity and equity to share the benefits of the basin.

It is based on a method called 'adjusted separable cost remaining benefit'. Benefits are analysed in the three categories of irrigation, energy production, and navigation, and divided among the basin countries along fixed quotas. In other words, benefits are at stake, instead of physical water allocation. An example of how this plays out is demonstrated by the funding for the Manantali Dam.

Dams have been key to the strategy for economic growth followed by the OMVS. The first to be built was the Diama Dam and embankment in 1986 a few kilometres inland from where the river empties into the Atlantic. Before the dam blocked saltwater from entering the delta, it used to seep upstream up to 200 kilometres. The reservoir stores at least 250 million cubic metres, and supplies water to the various towns and cities, including the provision of 60% of Dakar's needs as well as the domestic and pastoral needs of rural populations. It also supports expanding irrigated agriculture and several protected wetlands.

Manantali was built in 1988 on a tributary of the Senegal River in western Mali and has been generating hydropower since 2002. The two dams cost a total of about 1 billion US dollars, most of which was obtained through a loan from the World Bank at a low interest rate of about 2%. The debt was to be shared among Mali, Mauritania, and Senegal, the three member states of the OMVS at the time, on the pro rata of the benefits that would accrue to each of them. This amounted the 35.30% for Mali, 22.60% for Mauritania and 42.10% for Senegal.

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Development of the Senegal River Basin has allowed for an increased area of irrigated rice production.

More reservoirs and hydropower projects have since been constructed or are in the pipeline.

The OMVS can rely on various options to mobilise funding. These include contributions from member states, loans obtained by member states and made available to the OMVS, grants from donors, and loans obtained by the OMVS with or without guarantees from member states. Bulk water and electricity tariffs go towards the operation and maintenance of shared infrastructure but activities and administration are also funded by annual contributions from member states.

A changed basin

Today, the Senegal River Basin is a different world, shaped by the OMVS-driven development that started in the seventies. Dams have provided a year-round supply of irrigation water, preventing people from migrating to urban areas.

Salt intrusion has also been halted. The Manantali Dam has become a significant fisheries resource, while releases from Diama are maintaining critical wetlands.

These benefits have not come without costs, and the river has undergone major ecological changes. The volume and duration of annual floods have decreased substantially, leading to the areas suitable for flood-recession cropping shrinking substantially. The river is now also prone to serious invasions by ***Typha australis***, among other aquatic plants that thrive in stable freshwater bodies. Waterborne diseases that proliferated now have to be carefully managed.

In future, it seems that climate variability in the region will intensify, testing the capacity of the OMVS to continue to achieve the goals it set out for itself even further. Yet, history has shown that through collaboration, they have established an unusually sturdy foundation to build on going forward.

Petro Kotzé participated in a study tour to the Senegal River Basin, with support from the OMVS, as part of the Blue Peace Central Asia project, this March.

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DESALINATION

Has desalination entered a new era?

Dawid Bosman of the Trans-Caledon Tunnel Authority explores the latest global trends in desalination as South Africa increasingly explores this alternative water-supply option to strengthen water security.

The desalination of seawater in South Africa has traditionally been associated with situations of extreme drought, and all municipal installations I can think of have come about as emergency projects in times when conventional water resources were failing. This perception and resultant practice are being overturned, as freshwater scarcity increases, and the effects of climate change becomes more prominent. This change in paradigm is evident in the National Water and Sanitation Master Plan, where large-scale desalination features prominently, to be relied upon as a base load supply within the next eight years.

With desalination firmly in the national medium-term planning framework, it is important for water managers in South Africa to be informed of the dynamics within the global desalination industry; we need to be cognisant of developments in this sphere, as we will need to source technology and services from that market soon, to implement such projects locally.
A number of developments have come about in the global desalination industry since the later years of the previous decade, which now, in hindsight, may well have ushered in a new era for the practice. The new era is characterised by three trends as described elsewhere.

Almost simultaneously, around 2018, the six countries of the Gulf Cooperation Council (GCC, which includes United Arab Emirates, Saudi Arabia, Qatar, Oman, Kuwait and Bahrain) started replacing their vast fleet of thermal desalination plants with seawater reverse osmosis (SWRO) plants. This resulted in at least fifteen

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GWI DesalData

Figure 1: Fifteen mega-projects (>300Ml/d) installing SWRO technology in the GCC region during 2019-23.

mega-projects, all more than 300 Ml/d in capacity, entering the market between 2019 and 2023 (See Figure 1). This caused a step-change in global contracted capacity, which Global Water Intelligence regards as largely sustainable (See Figure 2), and effectively signalled the end of significant new investment in thermal desalination technologies such as multi-stage flash distillation (MSF) and multiple effect distillation (MED).

The tender request for these projects were mostly for independent water producer (IWP) contracts, whereby private developers design, finance (and hence own), build and operate the plant for a protracted period of 25 to 35 years, backed up by a firm offtake agreement. This indicates that there had been a policy shift in the GCC away from public ownership of large desalination plants.

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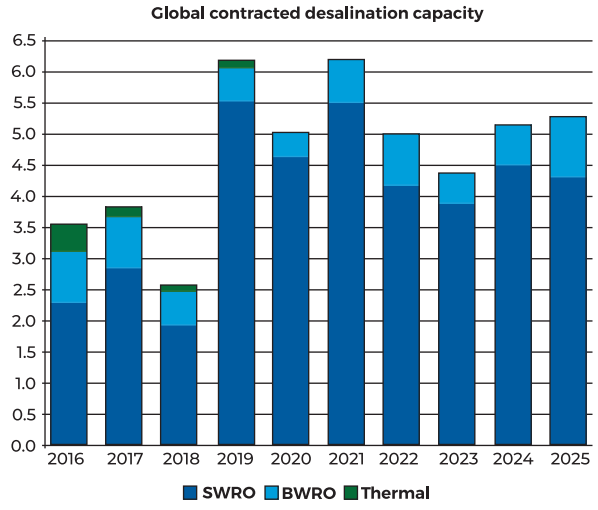

Figure 2: Global contracted desalination capacity (non-cumulative), actual and forecast, 2016–2025.

The long-standing cost benchmarks for both capital expenditure and water exit price saw a decline as these bids reached financial close; this was immediately visible due to the transparency of the IWP contracts. The benchmark capital outlay, or EPC costs, of a 600 Ml/d seawater reverse osmosis (SWRO) plant declined from $1000 per kl/d capacity in the mid-2010s to $750 – $900 per kl/d capacity in 2021. Similarly, the all-inclusive water cost declined from the $0.60 – $1.20/kl range, to the $0.40 – $1.00/kl range over the same period. In the GCC, given its market maturity, scale and risk profile, the expectation currently would be for bid prices well below $0.50/kl. It should however be noted that these cost benchmark have not yet been achieved outside of the MENA region (GCC plus Israel and North Africa).

What this comes down to is that over the past four years, there has been a significant shift towards very large SWRO plants being financed, built and operated by private developers, at lower costs than what had been seen before. All of this happened in the largest and most mature market for desalination, the Middle East.

To make sense of the trends, we need to explore what may have been the underlying, causal factors. Arguably the most prominent factor would be the transition from fossil-based energy to renewable energy, commonly referred to as the energy transition. Since the energy component comprises typically 45% of operational expenditure in desalination, any shift in energy cost will be keenly followed by the de-salters.

Ramez Naam

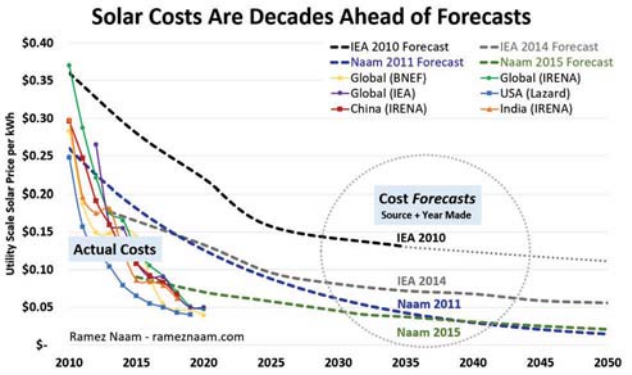

Figure 3: Solar photo-voltaic (PV) costs have breached the $0.05/kWh level some 17 years earlier than expected.

Figure 3 relates how the cost of solar PV declined much faster than even the most optimistic forecasters could anticipate. The cost threshold of $0.05/kWh, achieved some seventeen years earlier than expected, is comparable with the prices received through South Africa's REIPPP Bid Window 5 during October 2021, of R0.50/kWh for wind and R0.43/kWh for solar PV.

Wind and solar energy projects became cost-effective around 2014 globally, and thus no longer reliant upon subsidies; today, solar PV and wind are the least-cost new supply options in most markets, according to the IEA. The energy transition has now gained economic momentum, along with the imperative to reach net zero emissions by 2050.

This shift in energy costs, along with ever tighter emissions commitments, tipped the scales in favour of SWRO for the planners and policymakers in the GCC region. Herewith the view expressed by Bruce Smith, planning chief of the Emirates Water and Electricity Company (EWEC) in July 2021: "In practice, reverse osmosis becomes the lynchpin of the whole sector decarbonisation, and it comes at such a cost and efficiency advantage that the all-in cost of building and operating RO is less than a third of the all-in price of water from thermal desal. Between 2020 and 2024, EWEC will cut the carbon intensity of

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power and water production in Abu Dhabi by 50%." In essence, the combination of renewable energy and reverse osmosis now presents a very compelling case, both from an economic and climate perspective, to replace thermal desalination.

The trend towards IWP contracting seems plausible when one compares it with the other common contracting method for such projects, the design-build-operate-maintain (DBOM) contract, in terms of efficiency and risk allocation.

Some ten years ago we encountered the DBOM-based alliance contracting method, much favoured during the Australian build programme, and today still popular in Asia. This approach required the client to adjudicate and short-list DBOM proposals from a technical and financial perspective, before embarking on a 40% design phase with the two short-listed candidates. This required the client to assign resources to work with the two bidders for several months, while the designs were developed and assessed. Upon conclusion of this final evaluation phase, the losing bidder would be reimbursed in full for all expenses incurred. This resulted in a very expensive, albeit very thorough process to select the optimal technical partner for implementation of the client's plant. One implication was that the client had to maintain a high level of technical and financial involvement throughout the procurement process, and build operational capacity to take back its plant when the DBOM contract came to an end, usually after about ten years.

IWP contracts stand in contrast to the alliance contracting described above and has now become the preferred procurement method for new desalination plants in the GCC, Israel and the Caribbean. Figure 4 illustrates the growing popularity of the IWP method.

In the IWP process, the client approaches the market with a long-term concession on a well-vetted site, and bids are called from developers to fund, design, build and operate their plants on that site over a prolonged period, with assurance given of sustained off-take at an agreed price. The delivery and technology risks are transferred to the winning developer, which means that if the plant does not perform as expected, it falls to the developer to remedy the problem.

The developer retains the latitude to innovate where it deems appropriate, and to follow proprietary and best practice design codes without any constraints. IWP contracting works well in a mature desalination market such as the GCC, where very long-term off-take agreements are possible. This allows for capital to be amortised over a protracted period, resulting in a smaller capital cost component in the overall water cost.

Other factors have also contributed to the decline in cost benchmarks. The very low cost of capital in recent years helped to reduce the capital outlay, although this gain would now be under threat from rising inflation. Also, one should recognise that the latest mega-projects in the GCC are much larger than previous SWRO projects, which were mostly outside the GCC, and hence the new projects are benefitting from an element of economics of scale.

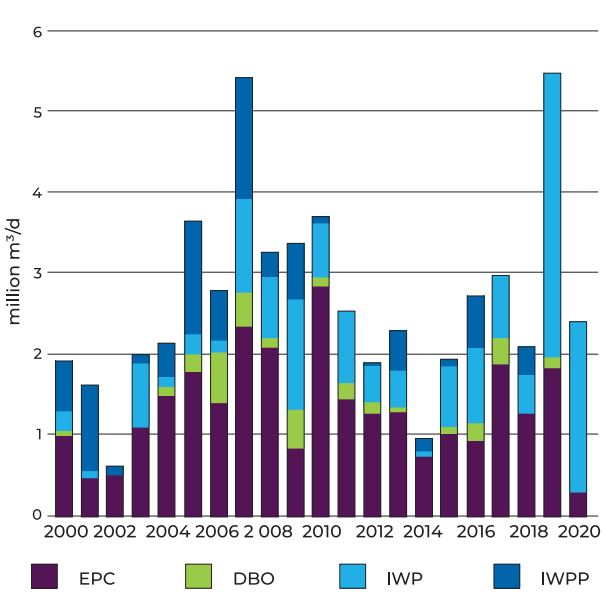
Returning to the contention that a new era has dawned for desalination, it is clear that the energy transition and the shift to IWP contracting are changing the dynamics within the industry, resulting in a lowering of costs, implementation hurdles and climate impact, to the extent that the combination of renewable energy and reverse osmosis could now be seen as one of the pivots for decarbonising the water sector.

In practical terms, the to-market strategy for the procurement of a large desalination plant would be quite different in 2022 than what it would have been even five years ago. The erstwhile onerous approach required by DBOM procurement, of "know what can be had, know what you want and find the optimal implementation partner" is now only relevant if asset ownership is required by the client. If not, as many water and power utilities in the GCC have now chosen, one can go to the market with a long-term concession on a qualified site, along with carefully considered water supply specifications, and invite a competitive price auction from desalination plant developers.

Even in a new era where the hurdles to desalination are lower, several intractable challenges to the industry remain, and will need to be focus of attention in the coming years. For seawater desalination, it is minimising the marine impact, and achieving the $0.40/m^3 price points outside of the mature market of the MENA region. For inland desalination of brackish or mine-impacted water, the challenge remains to be brine disposal.

Perhaps the most impactful challenge to resolve would be to regularly achieve the GCC cost benchmark in emerging desalination markets such as Chile, Egypt, the USA, South Africa and Australia. Common obstacles in these markets are high financing costs in the low or middle-income countries, onerous environmental compliance in wealthy countries, and failure to address demand-side risk, i.e., the flawed practice of implementing desalination as a drought mitigation measure.

GWI DesalData



Seawater desalination procurement models 2000 to 2020.

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DROUGHT RESILIENCE

Study explores the impact of multi-year drought on apple and wheat farmers in the Western Cape

Climate change is likely to impact all apple and wheat production regions in the Western Cape, albeit to varying extents. A new study explores how drought affects resilience building for crop production in the winter rainfall region of the province. Article by Jorisna Bonthuys.

For key wheat and apple production regions, the recent multi-year drought was the most severe one experienced in 30 years. This may be an early sign of the effects of climate change on agriculture in the winter rainfall area of the Western Cape. This is evident from Dr Simone Theron's PhD study. She received her doctoral degree from Stellenbosch University's Department of Horticultural Science (part of the Faculty of AgriSciences) in April. Theron's' dissertation, titled ***Improving resilience in rainfed and irrigated agriculture under the future climate in the winter rainfall region of the Western Cape: Lessons from the 2015-2018 drought***, underlines the urgent need for adaptation in agriculture. Her study sheds light on factors affecting resilience-building in crop production, adaptation approaches, and barriers to adaptation.

Theron's research focused on how producers may be impacted from a climate perspective from now until 2065. She zoomed in on two agricultural commodities, wheat, and apples, across five production regions: the Swartland, the Rûens, Ceres and Elgin-Grabouw-Vyeboom-Villiersdorp. Theron, who completed her study in 2021, worked for the Agricultural Research Council's (ARC) business unit focusing on soil, climate and water issues until recently.

The overall aim of her research was to capture the lessons learned from the drought. "The drought provides a case study

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for climate resilience and can offer lessons for adaptation under climate change," she says. "In that regard, several questions arise. How severe was the drought, and how did it manifest spatially?

"What responses were taken by farmers for both rainfed and irrigated crops? Can drought forecasting be improved in the province? What lessons can be identified for crop production in terms of drought response and adaptation?"

The apple industry was chosen to represent irrigated horticulture because it is the second-largest deciduous fruit crop grown in the province, and some key production regions share water resources with the City of Cape Town. Wheat was chosen to represent rainfed crops. It is the most profitable and widespread of the rainfed crops and covers the largest area of any crop grown in the province.

Agriculture laid bare by drought

Drought has been identified as a key vulnerability for agriculture under climate change — most notably in Southern Africa. There is evidence that inter-annual rainfall variability over southern Africa has increased since the late 1960s. Droughts have also become more intense and widespread in the region. As a result, it is considered a priority area for adaptation.

"Improving the resilience of the agriculture sector to rising shocks and stresses under climate change is vital," Theron says. "Resilience is dynamic, nuanced, socially contingent, and context-specific."

"As with all natural disasters, drought has both a natural and a social dimension," she adds. While drought is a natural and normal occurrence, it can still have damaging effects on human lives and the environment." For example, this particular drought caused devastation to agriculture in the province, resulting in approximately 30 000 agricultural job losses.

The Western Cape has been identified as a highly vulnerable region to the effects of climate change due, in part, to its reliance on winter rainfall and water storage schemes. Projections indicate that the province is likely to become hotter and drier, with more frequent drought. Such conditions may be experienced as early as 2030 to 2040.

Recent studies have shown that climate change also increases the severity of extreme events (including droughts) in the province. Researchers have found that, because of human-induced climate change, the recent multi-year drought was three times more likely to occur than it would have been otherwise.

"Without appropriate adaptation actions, climate change is likely to constrain agricultural activities in the Western Cape," Theron emphasises. "It is becoming clear that climate change will create new risk management challenges for farm-level adaptation and decision-making."

She used observed climate datasets and production data to understand the impacts of the drought on producers. Theron also investigated actual drought-related adaptations at the farm level and the factors that appear to be driving and supporting these actions. Theron analysed the physical and spatial characteristics of the drought using both agricultural and hydrological drought indices. She performed a trend analysis to investigate whether these observations form part of a long-term trend and indicate potential future conditions.

The apple regions emerged as more vulnerable to climate change than wheat. This is because apple orchards operate on considerably longer timescales than annual wheat crops, typically surpassing 25 years.

She used a questionnaire to collect data and did interviews with farmers and industry stakeholders on how the drought affected production, strategies (relating to water resources) taken to alleviate the effects of the drought, and perspectives on adaptation and resilience.

Theron also employed drought indices to determine whether they could be used to improve seasonal drought forecasts. Furthermore, she considered the differences between retrospective and prospective drought-related adaptation and how this translates to building climate resilience to drought for crop production.

Adapting to a changing climate

Drought manifests through four main stages. "It begins as a meteorological drought, brought about through below-normal rainfall over a period of one to three months. If drought conditions continue beyond a few months, it results in poor soil and subsoil moisture, affecting crop growth; this becomes the second stage, namely an agricultural drought.

"The third stage is referred to as a hydrological drought, which develops when persistent drought conditions for longer than 36 months and affect runoff, which manifests through reduced streamflow and reservoir storage. Finally, a socioeconomic drought arises when the physical water shortage affects people."

Theron says it is crucial to understand and learn from past drought events to build resilience in agricultural systems and society. This particular drought was characterised by very low rainfall amounts received, particularly in autumn and spring. Theron says the length of drought periods and their persistence is highly variable in the province, with drought return periods varying from one to four years for an agricultural drought, and up to ten years for a hydrological drought.

Both rainfed and irrigated crops will be affected by climate change; however, the risks and impacts between the two farming types will differ.

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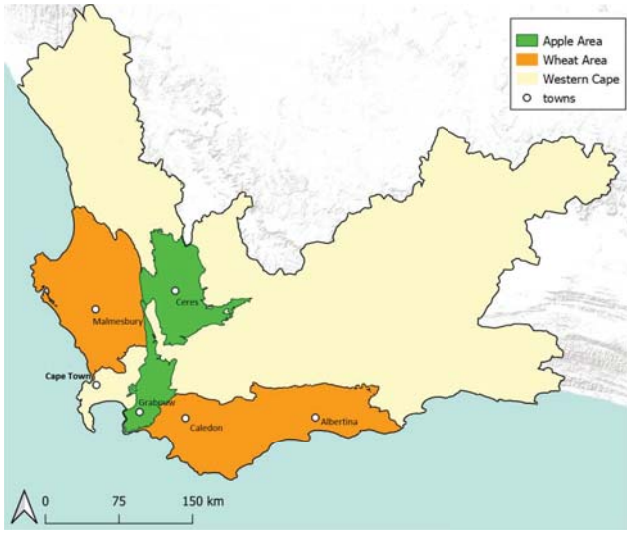

This map shows two wheat-producing areas and two apple producing areas studied. These areas are visualised according to the SmartAgri agro-climatic zones.

"The results suggest that climate change is likely to impact all crop production regions in the province, albeit to varying extents," Theron says. "Increases in minimum and maximum temperature and drought intensity were significant, with significant changes likely to occur between 2040 and 2050.

"Climate change is a 'wicked problem' or 'crisis multiplier', likely to pose the greatest threat to agriculture," Theron says. "It threatens many sectors with impacts on food security, natural resources, rural security and stability, and urban-rural migration."

Climate change will, for instance, affect rainfall and water resources and lead to higher temperatures in key apple production areas. In addition, higher temperatures will affect accumulated chill units, affecting dormancy and rest breaking of fruit trees. Increased temperatures can also lead to more sunburn damage and reduced fruit quality.

Research shows that climate change could also cause a significant decrease in the area suitable for apple production before 2050. In addition, projected decreases in rainfall and increases in drought events may heighten the risk of dams not filling adequately, which may lead to more frequent water restrictions, putting apple orchards under stress and reducing yields and fruit quality.

A reduction in winter rainfall will lead to lower storage in irrigation dams at the end of the rainy season and lower streamflow. In addition, higher summer temperatures will also lead to higher evaporation from the soils and higher transpiration from the trees. Thus, irrigation water demand to sustain existing production quantities is estimated to rise by approximately 10% by 2050.

"This means agriculture will need to produce more food for a growing population, but under more challenging conditions with likely less available resources," Theron says. "It also means there will be added pressure on infrastructure and shared resources, notably in the water sector.

"Adaptation needs to happen at all levels of the value chain, and the onus cannot be placed squarely on farmers to meet these challenges."

Competition with urban users for water resources may become a source of vulnerability for irrigated agriculture over the next few decades. "This kind of competition was highlighted in some production regions during the recent drought," Theron says. "It emphasises the interconnectivity and delicate balance of urban and agricultural water use in this region."

According to Theron's research, apple regions emerge as more vulnerable to climate change than wheat. This is because apple orchards operate on considerably longer timescales than annual wheat crops, typically surpassing 25 years. New orchards only become productive after four to five years. As a result, apple growers need to prepare for significant climate changes sooner than wheat farmers.

Mature apple orchards also use more water than young ones. As trees mature, their water requirements will increase, which will increase their vulnerability to drought and irrigation water restrictions. This suggests that the average projected age of orchards, particularly after 2040, should be considered in climate vulnerability assessments of the apple regions.

Nonetheless, to some extent, irrigated farms are less sensitive to climate change since irrigation has a mediating effect. "Importantly, irrigation reduces a farm's dependency on rainfall and reduces interannual variability of production," Theron explains. "However, this is dependent on the availability of water for irrigation."

Future-proofing agriculture

Most farmers who participated in this study are actively preparing for climate change or intend to start preparing within the next five years. The majority of participants (53%) said they are already experiencing the effects of climate change. Most farmers (72%) felt that they had learnt from the 2015-2018 drought and had changed some of their farming practices since then. Furthermore, producers who said they learned from the drought were also more likely to prepare for climate risks.

The majority of farmers employed crop management practices to respond to the drought. These practices included the use of quality seeds and planting materials, integrated pest management, nutrient cycling, and soil protection (particularly increasing the carbon content).

The adoption and expansion of conservation agriculture and the use of short-season wheat cultivars were also highly cited as drought management strategies. Adaptation options available to farmers with rainfed crops include using cover crops and mulch to retain soil moisture, switching to short-season cultivars, changing crop types, and diversifying their business both within and outside the agricultural sector.

Farmers are encouraged to adopt more efficient irrigation systems and precise irrigation scheduling to adapt to climate change and increased pressure on resources. Another option is for farmers to use other sources of water such as groundwater where the quality of water allows and rainwater harvesting. Theron says farmers using irrigation on their farms can also adapt

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by switching to more heat-tolerant crops or cultivars and using shade nets.

In response to climate change, apple farmers view on-farm water management (such as irrigation management and water recycling) as the most important strategy. On the other hand, wheat farmers' strategies are focused on crop management (including conservation agriculture). However, how these strategies will apply at the farm level and their success will vary between the two farm types and by location. For example, changing cultivars and crop types is relatively easy for an annual crop such as grain. Farmers can use seasonal forecasts to decide which varieties to plant that season.

According to Theron's results, producers' adaptation strategies did not differ too much from their drought response. "This suggests that most farmers are still focused on short term coping or recovery mechanisms rather than long-term resilience building," she says. "It may also suggest the strength of information networks in driving farmer decisions. Farmers may be more likely to adopt the practices of their peers in the fear that they may get left behind."

Theron says the results also suggest that decisions regarding climate change or drought response strategies may be attributed to other influences such as farmer information networks. "Importantly, it was found that farmers who rely a great deal on weather forecasts were more likely to feel that their farm's response to the drought was effective. This illustrates the importance of seasonal or weather forecasts in strengthening resilience."

"Guiding farmers on whether and which inputs to purchase is critical during droughts as farmers need to ensure they do not overspend," Theron says. "Considering seasonal cycles in drought forecasts can provide a considerable source of drought predictability."

She considers drought forecasting critical for providing early warning and resilience-building programmes in the region. In addition, research shows drought indices may be a valuable component of future drought early warning systems.

Most farmers cited financial barriers to adaptation. Institutional barriers were cited as the second biggest barrier to adaptation. In terms of support, farmers cited industry bodies as giving the most support to farmers, with research institutes cited as the second.

The most significant change is expected to be in drought intensity in Ceres (an apple farming area) and the Swartland (a rainfed winter wheat area). Moreover, Ceres and the Swartland are likely to experience the largest temperature increases, possibly as high as 4°C.

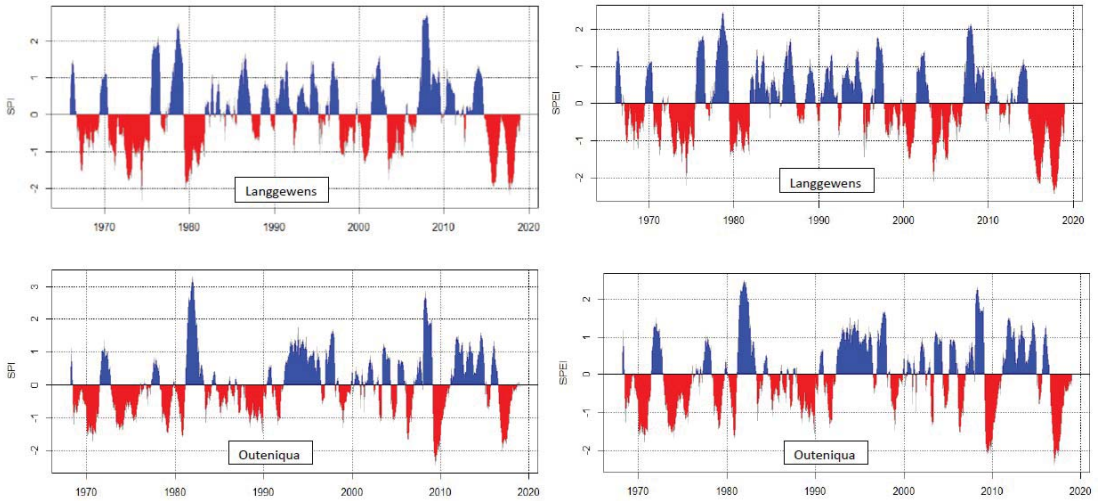
From the results, five key lessons were identified: drought is a reoccurring phenomenon in this region; forecasts are an essential tool for building resilience; drought indices can be a valuable tool for seasonal drought prediction; farmers have high autonomous adaptative capacity; and improving the various types of capitals available to farmers (including social capital).

She recommends that investments into adaptation focus on research and development, particularly with regard to cultivar development, irrigation management, tailored weather forecasting, and risk assessments.

"Although the results presented suggest a daunting outlook for agriculture in the Western Cape, the sector has already adjusted and is continuously adapting to changes in the natural resource base, including those brought on by climate variability and climate extremes.

"While some of these adjustments may be transformative or prospective such as the widescale adoption of conservation agriculture, most are more incremental, retrospective responses. Responses to the drought provide a recent example of the capacity and ability of the sector to respond to sudden and extreme climatic change."

Theron was based at the ARC's division for natural resources and engineering (ARC-NRE). Her research was supported through the ARC's Professional Development Programme.



This data reflects the drought index accumulated over 12 months for Langgewens (top) and Outeniqua (bottom) from 1965 to 2018.

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WETLANDS AND SOCIETY

Bringing science, policy and society closer together for the Maputaland Coastal Plain's wetlands management

In a project funded by the Water Research Commission (WRC), scientists are applying remote sensing technologies to quantify and determine the extent and rate of change in the wetlands of the Maputaland Coastal Plain. Article by Dr Heidi van Deventer (CSIR), Dr Karen Nortje (CSIR), Dr Laven Naidoo (GCRO), Philani Apleni (UP), Philemon Tsele (UP), Johan Bester (DFFE), Dr Piet-Louis Grundling (DFFE), Susan Janse van Rensburg (SAEON), Dr Ilse Aucamp (Equispectives Pty Ltd).

The Maputaland Coastal Plain (MCP) presents a variety of forested, grass, sedge, and open water wetland cover types that have been surveyed by botanists and earth observation (EO) specialists at local scales. The wetlands transition from freshwater to estuarine systems in this coastal corridor and landscape.

Several pressures influence the MCP wetlands negatively, ranging from water abstraction, alien invasive tree species, exotic timber plantations, and slash-and-burn of swamp forests, while uncertainties prevail on the further impact of climate change within this region. Owing to the scale of the anthropogenic and climate change impacts across the landscape, and the limitations in accessing parts of the MCP, remote sensing technologies can play a key role in quantifying and determining the extent and rate of change in wetlands and their catchments for the MCP, and potentially, the types of land covers resulting from anthropogenic impacts.

Some of the impacts on wetlands observed to date include the increasing number of peatlands that have become desiccated and burnt (Grundling et al., 2021). In addition, a continuing trend in the transformation of forested wetlands is also concerning (Van Deventer et al., 2021a&b). Climatic trends remain uncertain, because of poor representation of rainfall stations in the northern part of the MCP, though.

Changes in the landscape also occur within a social context, with different perspectives and realities influencing choices and

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behaviour. People's perception of the value of wetlands, changes in the extent of different types of wetlands, and the need to conserve these different wetland types may differ tremendously between stakeholders of the MCP. A full list of stakeholders of the MCP remains to be compiled, and a social study is required to inform possible reasons for changes in wetlands observed and quantified through remote sensing studies.

The WRC is funding a three-year project (project no. WRC C2020-2021-000427), investigating the capability of remote sensing to quantify changes in wetlands of the MCP. The project is being led by Dr Heidi van Deventer of the Earth Observation Research Group of the Council for Scientific and Industrial Research (CSIR), with funding contributions also made by the CSIR.

Aims and objectives of the study

The aim of the WRC project is to quantify the rate of change of different wetland types on the MCP using remote sensing. In addition, a subcomponent of the work is aimed to understand the social context of these changes, through enabling stakeholder engagement and communication through sharing the remote sensing output with these stakeholders.

The objectives of the project are to:

- Compile an inventory of available ***in situ*** coordinates for wetland cover types;
- Evaluate the possible wetland classes that could be used in (optical) change detection for the MCP;
- Facilitate a learning exchange between EO products and local stakeholders for knowledge co-production;
- Quantify the areal extent, rate, and types of change observed for wetlands on the MCP; and
- Draft a strategic framework for the inclusion of EO products and community engagement in the National Wetland Monitoring Programme (NWMP).

Remote sensing methods

Several remote sensing studies of palustrine wetlands in South Africa showed that these vegetated wetlands are highly separable from adjacent terrestrial vegetation, particularly in the Grassland and Indian Ocean Coastal Belt biomes (see review in Van Deventer et al., 2020 funded by the WRC). A wide range of space-borne remote sensing sensors such as the Landsat series, RapidEye, WorldView –2 and –3, and more recently the Sentinel–1 radar and –2 optical sensors proved valuable in classifying various categories of wetland trees to communities at the local to landscape scale.

A main gap, however, is the assessment of time-series data to quantify the extent and types of changes that have taken place over time. Such information is critical in the red list assessments of freshwater habitats, considering that the rate of change is one of the criteria prescribed by the International Union for Conservation of Nature (IUCN, Bland et al., 2017). In applying these criteria for forested wetlands on the MCP, land cover data was found to underrepresent the rate and types of decline of these critically endangered habitats (Van Deventer et al., 2021a&b). Improvements in the spatial representation of forestry wetlands, and other types of wetlands is therefore necessary.

The remote sensing component intends to build on the previous remote sensing studies of the MCPs wetlands, while also improving the mapping of the extent of swamp forests, a critically endangered ecosystem of the MCP (Van Deventer et al., 2021). We intend to use cloud computing, multi-seasonal data and time-series analysis to improve the detection of wetland types and quantify the types of changes in wetlands taking place in the wetland types. Philani Apeleni is an MSc student registered with the University of Pretoria (UP), that will focus on the remote sensing of the wetland types and their changes, with supervision from Heidi, Laven and Philemon.

Social component

The social component will work hand in hand with the technical EO component of this project to ensure that the research and learning gained from this project includes the input from local stakeholders as well as ensures benefits to not only science, but also society – in particular local stakeholders living in the area. The social component, under the leadership of Dr Karen Nortje from the CSIR, seeks to enhance our current understanding of the area in terms of people and their relationship with the freshwater environment.

Here the focus will be on understanding the perceptions, beliefs, and attitudes of different stakeholders in terms of the wetlands and swamp forests, and the concept of conservation. There are several different stakeholder groups in this area that have an interest in the wetlands and the conservation thereof, and the intention is to ensure that the project uncovers the diverse ways in which wetlands provide value to these stakeholders.

Outcomes and outputs

One of the important outcomes of this project is to bring society and science closer together. This will be done through participative meetings and workshops through which different perspectives of the wetlands and its value will be shared. The goal here is to create opportunity for the emergence of new perspectives of wetlands, and an appreciation for different ways

The Maputaland Coastal Plain in northern KwaZulu-Natal covers an area of more than 8 000 km², with about a quarter of this made up of wetlands.

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At Vasi Pan in the northern reaches of the region, natural dry periods combined with desiccation due to a lowering of the water table by adjacent timber plantations allowed surface fires to spread into the wetland's peat, which continued burning for months.

in which natural resources may be valued, and how this may translate as an input to collaborate ways of management and conservation of these natural resources.

The first step in the process of bringing science and society closer on this topic happened during the first week of June 2021. During this week, the team had the opportunity to present the project idea and plan to the Tembe Traditional Authority and the Mabasa Traditional Authority. During this engagement the team also requested permission to work with and engage with the local community during the project.

The project was met with enthusiasm and the team's request was approved. The team also used this opportunity to start sharing information with the community, as such two posters detailing the project aim and objectives, as well as information on key indicator tree species for swamp forests, were distributed to the Traditional Authorities at the meetings. These posters were designed by Heidi and translated by Philani (with acknowledged support from family and friends!) from English to Zulu (Van Deventer & Apleni, 2021).

Collaborators

A number of key collaborating organisations include the Department of Forestry, Fisheries and the Environment (DFFE), the Agricultural Research Council (ARC) and the South African Environmental Observation Network (SAEON). Dr Piet-Louis Grundling from DFFE has extensive years of experience on wetlands of the MCP, and has published some of the earliest reports on the MCP's peatlands. Dr Althea Grundling from the ARC has previously published remote sensing mapping of wetlands on the MCP as part of PhD work, and currently also has a WRC project on the MCP (WRC project no. C2019/2020-00098) focusing on determining peat loss.

Sue van Rensburg from SAEON will also closely collaborate with the CSIR team on the transformation of wetlands on the MCP, and how the EO can contribute to the longer-term monitoring under the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON). The EFTEON project has interests in monitoring changes in freshwater ecosystems at various scales, and to ensure that collaboration also occurs across realms (estuarine, marine, terrestrial and freshwater).

Implementers/ future work

We hope that the framework generated through this research project would inform future studies on the changes in wetlands, not only through the use of remote sensing, but methods and findings generated through the social component. Our intention is to inform on methods and approaches to consider in the National Wetland Monitoring Programme, managed by the Department of Water and Sanitation, but also have impact globally through this work. Bonani Madikizela, Research Manager at the WRC, also added that such wetlands extent change provides the most required data and information on SDG:2030, Goal No.6, indicator No.6.6.1.

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WATER RESOURCE MANAGEMENT

National Dam Siltation Management Programme

Siltation of SA dams – Working towards a sustainable solution

Earlier this year, experts gathered under the umbrella of the National Dam Siltation Management programme to garner the latest developments in the quest to improve water storage capacity of South Africa's dams. Matthew Hattingh reports.

The fine material that fills Nqweba Dam has a high silt (40%) and clay (55%) content making it tricky to work with.

When we non-specialists think of silted-up dams (indeed, when we think of them at all) we picture in our mind's eye great expanses of desiccated mud, cracked and fissured beneath a baking sun. But scratch the surface, or rather dig down a metre, and a more promising picture beckons: water. Certainly, that's what a recent pre-feasibility study found at the Eastern Cape's Nqweba Dam.

When Nqweba (Xhosa for "meeting place") was first completed in 1925, known then as the Van Ryneveld's Pass Dam, it had a full supply capacity of nearly 79 million cubic metres. Fast-forward to 2011 and its capacity had shrunk by 43%. Built for irrigation, today, it cannot meet the domestic and industrial needs of the nearby Karoo town of Graaff-Reinet.

The problem is not so much an absence of water as a surfeit of silt. Fine sand and clay – from natural erosion, exacerbated by overgrazing – carried by the Sundays River and its tributaries are choking Nqweba. A similar story can be told of many of the 320 state-owned dams managed by the Department of Water and Sanitation. Although siltation rates vary dramatically, on average South Africa's dams are losing capacity at a rate of 0.4% a year with consequences for water and food security, particularly during drought.

What's to be done?

The department has long supported surveys and studies to better understand a problem that is far from unique to South Africa: Worldwide dams are losing 0.8% of their capacity a year. And it underwrites the National Dam Silt Management (NatSilt)

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programme and its four sub-projects. One of these sub-projects focuses on dredging and was the subject of a virtual workshop, hosted by the Water Research Commission (WRC) earlier this year.

Dredging, as workshop speakers acknowledged, can be pricey. Digging or sucking up large quantities of silt often requires similarly large investments in imported plant and equipment as well as overseas expertise. Historically in South Africa it has been up to 10 times more expensive than the alternatives and brought a host of technical and environmental difficulties, not least, what to do with the silt.

Sometimes however, the alternatives are unsuitable, pose safety concerns or may increase losses to evaporation (in the case of dam wall raising). Or they may be insufficient on their own. For example, better dam and catchment area management – another of the NatSilt sub-projects – can go a long way to nipping the silt bug in the bud. But when dams are already heavily silted, mitigation measures are too little, too late.

"Digging or sucking up large quantities of silt often requires large investments in imported plant and equipment as well as overseas expertise."

Prof Gerrit Basson told the workshop that flushing was a proven way to clear dams of silt – but only if there's water to spare. Basson serves as managing director of design and consulting engineers ASP Technology, which has been contracted by the WRC to develop the dredging sub-project. This includes putting together an economically and environmentally friendly model for dredging. He is also head of hydraulic engineering at the University of Stellenbosch's civil engineering department and an international authority on dams and siltation.

Basson said that apart from a lack of water, local geography and dam design errors may rule out flushing too. He cited a number of cases, including the Free State's Welbedacht Dam. It was designed with flushing in mind, but the gates it uses to control the release of water are too high and the dam, built in 1973, is now 95% silted.

Water diversion and inter-basin pumping schemes, were among the alternatives to dredging, but these come with their own costs and complications. Back then to the Nqweba, that great silty expanse, where indeed a lack of water makes flushing infeasible.

So how do you go about dredging the 33 million cubic metres of silt trapped within the dam – the equivalent of more than 13 000 Olympic-sized swimming pools? The answer is that you don't, or at least not all of it. Instead, the aim is partial dredging – removing the optimal amount and from very specific places.

With its large surface area and high evaporation rates, Nqweba is hardly the most efficient place for storing surface water. But by dredging deeper rather than wider, it's possible to increase capacity without an increase in evaporation, said Arend van de Wetering, of contractors Dredging Africa.

What's more, targeted dredging offers a way to tap groundwater trapped beneath the dam, providing an especially useful water source during drought.

Van de Wetering told the workshop how in 2019, when the dam last ran dry, researchers dug a test pit into the seemingly dry sediment at the base of the reservoir. Less than 1 m down they hit the water table.

Bingo! "The entire sediment is seen as an aquifer," Van de Wetering explained.

How to make the most of it?

The sub-project team ran the numbers for 60 different options. These included combinations of dredging and measures such as dam wall raising, inter-river basin water transfer and a variety of energy generating and evaporation prevention measures, including solar panels and shade balls. Their calculations established the net present value cost, the rand per kilolitre cost and the firm yield of each option.

Firm yield is the maximum water a dam can be expected to provide if its worst drought-year was repeated. Net present value is a formula used to rank investment options. It's based on the principle that money spent or earned later in a project is worth less than money spent or earned at the start. It explains one of the advantages of dredging: costs can be spread out over a number of years, "resulting in a lower present unit cost compared to the capital investment". Van de Wetering stressed it was important not to look at dredging in terms of cost per cubic metre of silt removed, but relative to the water it yields. Bear in mind that some of the alternatives increase capacity but result in losses to evaporation.

'Dredging Option 6' emerged as the best bet, with the lowest price – R207 a kilolitre. It entails dredging a channel about 20 m wide and 8 m deep, following the original water course. This would be linked to a more deeply dredged area immediately inside the dam wall. This 'sump' would increase capacity while making it possible to collect groundwater seeping from the sediment bed.

The team recommends that in addition to pursuing Option 6, which entails dredging between 1 and 2 million cubic metres, further detailed investigations were needed on:

- The quantity and quality of water the aquifer could produce; and
- Implementing a scheme to transfer water between the Great Fish and Sundays rivers in 2048 at a cost of R264 a kilolitre.

Dr Jeanine Vonkeman, who is leading the ASP team on the dredging sub-project, said many case studies internationally demonstrated that reservoir dredging worked well and she felt it has become more feasible in South Africa. But Vonkeman made it clear that every dam is different so the best way to deal with silt will vary. A thorough feasibility study must be done, covering a host of considerations, not least of all cost, which again, is

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"highly site specific".

Will the dredging be once-off or will continuous, "maintenance" dredging be required? What environmental laws apply for a particular dam? Which regulatory approvals are needed and what monitoring plans are in place?

"By no means are we promoting the sustainability of dam dredging. We are not here to debate that. We are just trying to figure out how we can make it more sustainable," she said. Vonkeman explained how the team had reviewed the literature on dredging and developed guidelines and decision-making tools to assist planners. Something of a checklist, these start with the preliminary stages which might examine a number of dams to see which are best suited for dredging. Surveys and studies help model sedimentation rates, hydrology and the effects of climate change for individual dams. These findings are analysed and weighed against water demand. Yield targets can then be set and the practicalities of dredging dealt with.

Vonkeman' ASP colleague, Andreas Brooks, briefed the workshop on work done classifying and prioritising dams for possible dredging. He said the team looked at 127 medium- to large-sized dams and sought to classify these by calculating their remaining lifespan. The researchers also considered how much water was finding its way into each dam, relative to its capacity. This was to get a sense of whether there might be sufficient water to allow alternatives such as flushing.

Other considerations included whether a dam provides potable water, and Brooks shared a shortlist of dams with potential for dredging, including Nqweba, Calitzdorp and Hazelmere. Vonkeman said the team has developed guidelines that cover different dredging methods and how silt might be used or disposed of and the health risks this entails.

Dredging can stir up silt affecting aquatic habitats and water quality. It's a big topic in its own right and Antonia Belcher, an aquatic ecologist and consultant to the dredging sub-project, sketched some of the issues at play. In a video recorded for the webinar, she touched on the ecological impact of dredging and disposal silt, how to keep harm to the environment to a minimum and the legislation relevant to dredging.

Let's assume the most environmentally sound dredging technology available is put into service and mitigation measures are in place, the question remains: what to do with the silt? Water quality and waste engineer Hanief Ally made the point that "dredged sediment is contradictory in nature".
"It may be a resource in some locations and an unwanted nuisance in others," he said.

Typically it's dumped, but Vonekman notes that internationally the trend is to seek ways to put the silt to better use. What that might be, depends on the properties of the silt, including whether it is contaminated ("typically rare in South Africa"). Regardless of whether the silt is destined for beneficiation or disposal, assessment, testing and monitoring are required, delegates heard. And getting that right can be demanding. A workshop breakaway session discussed the lack of local sediment quality guidelines and noted that the international guidelines used instead, "were not amenable to South African conditions".

Ally and Vonkeman said silt can have a range of uses and mentioned a few. It can be mixed with coarser material and used for agriculture. If it has a high sand content, it might work as a construction material. Local circumstances dictate too. The silt might be required for restoring local habitats or for flood defences.

Or it could provide raw materials for income-generating projects, notably making building blocks.

"Perhaps we could create jobs and housing through skills training. And if we do brick manufacturing we can definitely make a difference through social upliftment of local communities," said Vonkeman.

Such projects might help recover some of the cost of the dredging and create jobs. "But, there's a big but. Our reservoirs are often located in remote areas, so for the benefit not just to be social but also economic, we have to compensate for transportation costs, particularly for distances greater than 50 km for where we would like to use our dredged material."

Happily, Nqweba is on Graaff-Reinet's doorstep, so this is not an issue. The fine material that fills the dam has a high silt (40%) and clay (55%) content making it tricky to work with. But the plan is, with the help of Dutch experts, patented techniques, cement and additives, to stabilise the material and make compressed-earth blocks.

So, there's useful building materials and much-needed water beneath Nqweba's cracked and fissured floor. Hope springs eternal, you might say, or as Van de Wetering put it in summary: "This is the one project that ticks all the boxes. It is the most favourable situation that you can ever have to dredge a dam in South Africa. And if it will not work at Nqweba Dam it may possibly not work anywhere else. So, it's very important that this case study be executed and that we make a success of it."

Hazelmere Dam, in KwaZulu-Natal, has been shortlisted as a possible dam for dredging.

NEW GENERATION SANITATION

Partnership approach brings latest sanitation technology to rural Limpopo community

A partnership between one of the world's largest food and beverage companies, South Africa's leading water research funder, a non-profit organisation and a local community, has resulted in the delivery of a much-needed sanitation solution to one of the most remote areas in the country.

The project, a result of a partnership between the PepsiCo Foundation (PepsiCo's philanthropic arm), the Water Research Commission (WRC), and Tsogang Water and Sanitation, has provided 120 households with off-grid, low flush toilets in Makhuduthamaga Local Municipality, located in the Sekhukhune District Municipality, in Limpopo Province. Provision of this infrastructure is one of the Foundation's four access to water initiatives across the country – ranging from affordable washing units in homes, handwashing stations in high density areas to the rehabilitation of natural springs.

Commenting on the project, Devendri Adari, the PepsiCo Foundation Lead for Sub-Saharan Africa says, "Recognising that access to water is a human right, PepsiCo's safe water access work, through multiple partnerships focuses on various programmes in support of UN Sustainable Development Goal #6: Ensure the availability and sustainable management of clean water and sanitation for all." She adds, "As the adage goes, water is life and sanitation is dignity and as a company we are heartened to see the positive impact our water initiatives have had on the communities we serve. We look forward to supporting similar efforts as we work towards our global goal of providing safe water access to 100 million people by 2030."

It is well established that a hygienic toilet can provide numerous health, environmental and economic benefits. While the South African government has made significant strides in improving households' access to safe sanitation in recent years, pockets

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of unserved areas remain. Service delivery is particularly challenging in remote rural areas, where there is a general lack of technical capacity for implementation, operation and maintenance.

In addition, the current model of service delivery tends to be a top-down approach, where communities have little say or involvement in the water and sanitation service chain. According to WRC Research Manager, Dr Sudhir Pillay, community involvement is key to ensure the long-term sustainability of water and sanitation infrastructure investments. "Involving community members in sanitation projects leads to greater technology buy-in and much-needed skills development and job creation, which ultimately ensures the longevity of the solution selected."

South African households generally aspire to have access to better sanitation options (the flush toilet being the 'gold standard'), however, given the remote location of some areas, coupled with a lack of the necessary water infrastructure, this is a daunting task. To overcome this challenge, the WRC has been investing in the development of alternative sanitation options such as the low-flush toilet that could be used in rural settings.

The toilet system was designed to have a look and feel similar to a full flush toilet but enables greater flushing efficiencies and robustness. Requiring only two litres per flush, the toilet also features a handwashing station. Unlike conventional flush toilets, the pour flush toilet can be flushed with rainwater or any greywater, such is sourced from the kitchen, for instance. Waste is flushed into a septic tank located adjacent to the toilet structure. Each unit has been equipped with two septic tanks as well as a rotatable PVC pipe, which can be swung from one septic tank to another if one becomes full. An estimated 16 000 low-flush toilets have already been installed in South Africa, most notably in the Eastern Cape and KwaZulu-Natal, where the technology was first tested.

The latest partnership has seen low-flush toilets being introduced to the Limpopo Province. The selected site is around Ga-Moela village, near Schoonoord. The WRC is well versed with this area, having been involved in projects that have seen the successful development of community-driven multiple water use infrastructure in the village.

The latest project provided sanitation to 700 people. Prior to the rollout of the project households were using locally built latrines, with some households having no access to any form of sanitation.

"Through the demonstration project, local people have been trained in the construction of the units, ensuring that the economic benefits of the project reach the community and boosts local skills development," notes Dr Pillay. In this way, small repairs can be performed by community members themselves much quicker and cheaper than if an external service provider had to be contracted.

It is expected that the Ga-Moela project will kick-start similar community-driven initiatives in Limpopo Province and the rest of South Africa. "What we have shown with projects like these is that community involvement and participation around the service value chain fosters partnerships and trust between communities and water service authorities," explains WRC Executive Manager, Mr Jay Bhagwan. "It allows communities to be better informed about their choices of sanitation solutions while, for the municipality, it ensures long-term sustainability in infrastructure investment."

To watch a video on the project click here:
https://www.youtube.com/watch?v=G53qG6mcnwQ

Community members were trained in the installation and maintenance of the toilet structures.

Ga-Moela resident, Regina Moratsebe, is one of the toilet recipients. Community members are no longer fearful that small children will fall into pit latrines or be bitten by snakes when relieving themselves outside.

The toilets have also been equipped with handwashing stations.

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SHONGWENI – DECADES' OLD DAM WALL THAT WITHSTOOD THE WORST OF KZN FLOODS

Images by Chris Bloom/Flickr

Shongweni Dam was originally constructed between 1923 and 1927.

The decades' old Shongweni Dam located outside Durban, in KwaZulu-Natal, made headlines when two of its fuse gates gave way during the floods that hit the province earlier this year.

The dam – arguably one of the first large dams to be constructed in South Africa – was built between 1923 and 1927 by the then Durban Town Council. In 1994, the dam, which is now owned by Umgeni Water, was equipped with ten fuse gates. These fuse gates are a patented non-mechanical spillway comprising independent, free-standing blocks made in steel or concrete set on a spillway weir and designed to tip off during extreme flood events when the reservoir level reaches predetermined levels.

Thus, the fuse gates are made to fail in sequence to avoid catastrophic failure of the entire dam. During the recent floods, Gate 1 on the far left and Gate 2 on the far right tipped, as per their design. "Had this not occurred, the dam was going to be subjected to more pressure, which would threaten the stability of the concrete wall, noted Wally Ranokopa, a Director in the Dam Safety Regulation Unit within the Department of Water and Sanitation.

A close up of the fuse gates, which were added to the wall in 1994.

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DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

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

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

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