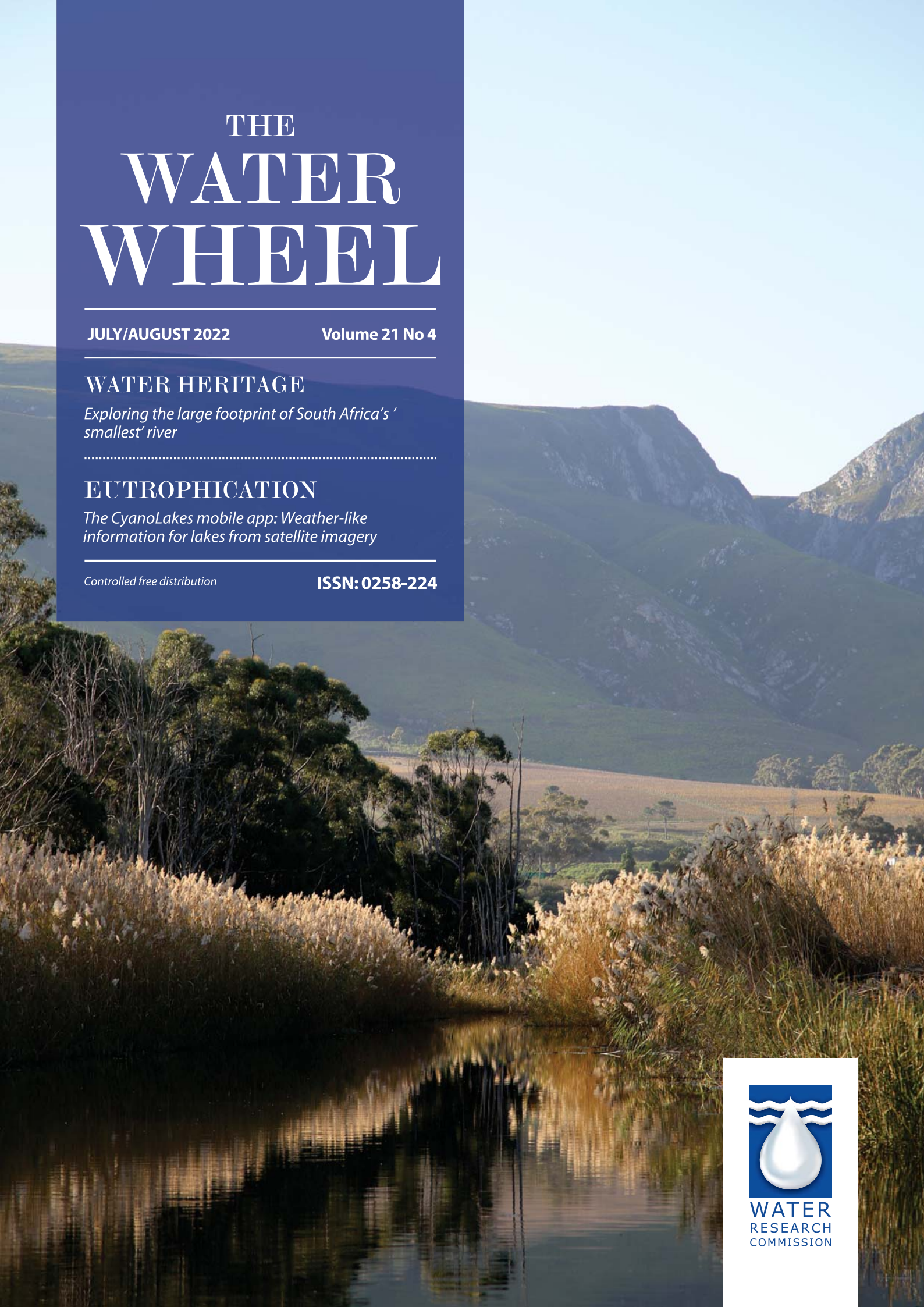

THE WATER WHEEL

JULY/AUGUST 2022 Volume 21 No 4

WATER HERITAGE

Exploring the large footprint of South Africa's 'smallest' river

EUTROPHICATION

The CyanoLakes mobile app: Weather-like information for lakes from satellite imagery

Controlled free distribution

ISSN: 0258-224

WATER RESEARCH COMMISSION

THE WATER WHEEL

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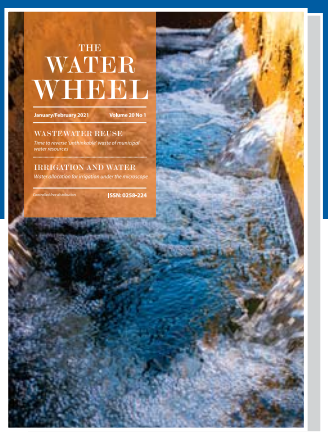

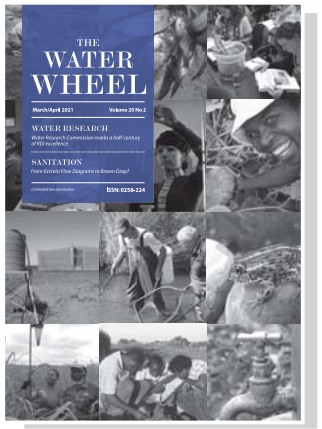

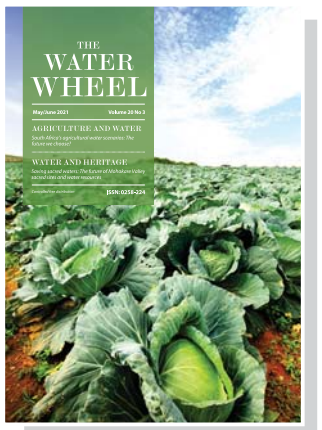

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The Water Wheel

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WATER RESEARCH COMMISSION

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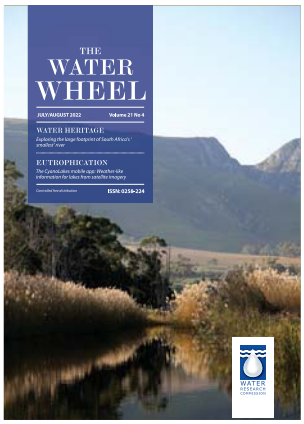

In a semi-arid country such as South Africa, even the smallest river has a socio-economic role to play. Read about the Klein River on p10. Cover photo by Petro Kotzé.

NEWS

Memorandum signed to reduce sewage pollution in Crocodile River

A Memorandum of Understanding has been signed between the Dutch Water Authorities, Inkomati-Usuthu Catchment Management Agency, Mpumalanga Provincial Department of Cooperative Governance and Traditional Affairs, City of Mbombela Local Municipality, Emakhazeni Local Municipality, Nkomazi Local Municipality, South African Local Government Association (SALGA), Municipal Infrastructure Support Agency (MISA), and Mpumalanga Treasury to improve the performance of the wastewater treatment plants to combat the pollution of the Crocodile River, which flows into the Kruger National Park.

The Deputy Minister of Water and Sanitation (DWS), David Mahlobo, who attended the event, said in his address that he did not come just to oversee the signing of the MOU but expects the parties to compile an action plan and implement it. "We do not have a national water crisis at present. People in South Africa will not run out of water; the problem is that water will not be usable because of pollution. Too much water in South Africa is polluted and polluters must pay."

The MoU sets out how the regional, local and provincial parties will co-operate with one another for the successful implementation of the Combating of Pollution in the Crocodile River within the Inkomati-Usuthu Water Management Area (referred to as the Crocodile River Project).

Cape Town residents urged to report missing manhole covers as winter rains set in

The City of Cape Town has called on residents to report stolen and broken sewer drain manhole covers so that they can be replaced in the shortest timeframe possible to help reduce sewer overflows on rainy days.

The City's Water and Sanitation team has spent about R2,6 million on replacing more than 4 900 sewer drain manhole covers that were stolen or broken in various areas across the city between July 2021 to May 2022. This figure has increased compared to the 3 382 manhole covers reported missing or stolen in the 2020/21 financial year.

"Manhole covers are an important part of our sewer infrastructure, which should only be opened by staff when they inspect the network or have to unblock the pipeline. These must not be stolen or removed," said Mayoral Committee Member for Water and Sanitation Councillor Zahid Badroodien.

Typically, there is a trend that sees an increase in sewer overflows in winter because of the combined impact of various factors, such as rainwater and foreign objects entering the sewer network. Open manholes is one way that illegally dumped waste and rainwater can enter the sewer network. Generally, waste items that are flushed, poured down sinks and drains, and which cause blockages and overflows, are already affecting the sewer system.

"During heavy rain, overflows increase because illegal dumping of rubbish, old unwanted items, stones/rocks, sand, building rubble, etc, also wash into the sewer network system via open manholes. Coupled with this, more rainwater enters via these open manholes and from illegal stormwater-to-sewer cross-connections on properties, where rainwater is channelled from roofs, gutters, and paved or hard yard surface areas into sewer drains. All these factors contribute to blockages or reduces the capacity of the pipes to convey wastewater, and damage infrastructure like pump stations, resulting in overflows and flooding," noted Badroodien.

The Cape Town water and sanitation team is doing extensive proactive work in various areas across the city to help reduce sewer overflows. This includes cleaning main sewer pipelines in most flood-prone areas using jetting machines to clear blockages, inspecting illegal stormwater to sewer connections at properties and ongoing public awareness education through the Bin it, Don't Block it campaign.

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Low recovery rate of irregularly paid monies a concern for portfolio committee

Responding to a report it received on the status of disciplinary cases in the Department of Water and Sanitation, the Portfolio Committee on Water and Sanitation raised a concern on the low pace of the recovery of irregularly paid funds.

In a statement published in May, the committee expressed the view that accelerating the rate of recovery of those funds would ensure that they are directed to service delivery and to ensure that people receive water as promised.

"While the committee welcomes the information that about R300 million has been recovered by the department and an additional R622 million has been saved by the department since 2014 as a result of civil, legal and criminal actions resulting from cases of corruption and financial misconduct, it is of the view that much more can be recovered if investigations and prosecutions are concluded expeditiously."

In line with this, the committee welcomed the commitment by the Minister of Water and Sanitation, Senzo Mchunu, to fight corruption within the department. The committee further called on the department to enhance collaboration and interaction with law enforcement agencies to ensure that investigations are fast tracked.

Meiringspoort river survey raises alarm over invasive fish

The Groot River that runs through Meiringspoort is part of the greater Gouritz system, which is the largest river system within the Cape Fold Ecoregion. The Groot River is home to four of the eight indigenous freshwater fish species that occur in the Gouritz system and is recognised as an important fish sanctuary. The indigenous fish species are the small-scale redfin P. asper, the slender redfin P. tenuis, the chubbyhead barb Enteromius anoplus and the Cape kurper Sandelia capensis, writes CapeNature ecologist, Martine Jordaan.

A freshwater fish survey was conducted in the poort following a report of the presence of alien and invasive sharptooth catfish in the river. CapeNature faunal ecologists sampled seven sites in three days and detected healthy populations comprising several size classes for all three indigenous minnow species.

The trip also yielded the first State of Biodiversity Report record for the indigenous moggel Labeo umbratus in the Groot River. On a less positive note, the presence of invasive sharptooth catfish was confirmed at half of the sites surveyed. Based on the presence of a mainly subadult population, it is evident that the catfish are breeding in the Groot River.

The results of this study will serve to inform not only long-term monitoring but also provide a basis for future conservation interventions to ensure the survival of the indigenous fish fauna of this very special river.

WATER DIARY

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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GLOBAL

Intensifying climate change impacts leaving donors short of funding

Funding needed for UN humanitarian appeals linked to extreme weather has increased eight-fold over the past two decades, with donor countries falling desperately short of meeting the demand, according to a new analysis.

Reports by the Intergovernmental Panel on Climate Change (IPCC) have made clear that climate change impacts are already widespread and intensifying, and that developing countries are paying the highest price. But since 2017, about half (54%) of all UN appeals for climate disaster requirements such as droughts and floods have gone unmet, according to the ***Footing the bill*** report released by the charity Oxfam. For every US$2 a country responding to extreme weather asked for, they received only around $1 — a shortfall of up to $33 billion, the report says.

Oxfam and other campaigners urged governments at UN climate talks in Bonn, Germany, to pledge funding for loss and damage in addition to existing climate finance and aid commitments. The talks, which took place in June, are seen as a precursor to the COP27 climate summit in Egypt in November.

According to Oxfam's report, estimated loss and damage costs could increase to between $290 billion and $580 billion a year by 2030, rising to the trillions by 2050. Much of this will be shouldered by developing countries, which are most vulnerable to the effects of climate change. Annual extreme weather-related funding appeals amounted to at least $1.6 billion for 2000-2002 and increased by 819% to reach $15.5 billion in 2019-2021, the report says.

The cost of extreme weather-related events in 2021 alone is estimated at $329 billion globally, the third-highest year on record behind 2017 and 2005, the report says. This is nearly double the total aid given by rich nations to developing countries that year.

Ethiopia, Kenya, Somalia and South Sudan are currently facing extreme hunger, fuelled by climate change, and yet are responsible for only 0.1% of global emissions, the authors note. The entire continent of Africa accounts for less than 4% of emissions.

To access the Oxfam report,
Visit: https://bit.ly/3ohCJeJ

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Women's water burden rose as COVID lockdowns hit

Demand for household water increased by as much as a third during pandemic lockdowns, forcing girls and women to spend more time searching for water for families without access to running water, analysis shows.

COVID-19-related restrictions highlighted inequalities in access to safe water, sanitation and hygiene (WASH) in the Pacific Island countries, which have some of the world's lowest rates of access to drinking water and sanitation services.

"Women's water burdens have always been heavy and anecdotal evidence indicates that they remain that way in Pacific Island countries," says Vivian Castro-Wooldridge, senior urban development specialist at the Asian Development Bank's Pacific department. "Additional burdens have come from women looking after children and other family members spending more time at home due to lockdowns, meaning more water is used and therefore must be collected and managed," Castro-Wooldridge said.

Researchers asked people in 14 countries in Africa and South Asia about their biggest concerns regarding water, hygiene and sanitation during lockdown periods. More than half of respondents said no communal WASH facilities were available, accessible or secure. The survey was conducted by WaterAid, with the University of Leeds and the African Women's Development and Communications Network (FEMNET).

Respondents expressed concerns over water and sanitation infrastructure not only in public spaces, but also in healthcare and quarantine facilities, pointing out the lack of clean water and handwashing stations. Just 5% of people said hygiene services at quarantine facilities were adequate. One in seven people said facilities were not gender segregated, while 17% said there was a lack of menstrual hygiene management infrastructure.

COVID-19 has shown that gender must be integrated into future emergency water and sanitation policies and programmes, said Desideria Benini, a researcher who worked on the WaterAid survey.

Benini said that incorporating gender into pandemic and emergency responses would "not only save more lives regardless of social differences, but also address the root causes of people's vulnerability, ensuring equitable, universal and sustainable access to WASH".

Source: SciDev.Net

Gel grabs drinking water right out of dry air

More than a third of the world's population lives in drylands, areas that experience significant water shortages. The new gel film could offer a solution to help people in these areas access clean drinking water.

The materials that facilitate this reaction cost a mere US$2 per kilogram, and a single kilogram can produce more than 6 litres of water per day in areas with less than 15% relative humidity and 13 litres in areas with up to 30% relative humidity. The research builds on previous breakthroughs from the team, including the ability to pull water out of the atmosphere and the application of that technology to create self-watering soil. However, the researchers designed these technologies for relatively high-humidity environments.

"This new work is about practical solutions that people can use to get water in the hottest, driest places on Earth," says Guihua Yu, professor of materials science and mechanical engineering in the Cockrell School of Engineering's Walker Department of Mechanical Engineering at the University of Texas at Austin. "This could allow millions of people without consistent access to drinking water to have simple, water generating devices at home that they can easily operate."

The researchers used renewable cellulose and a common kitchen ingredient, konjac gum, as a main hydrophilic (attracted to water) skeleton. The open-pore structure of gum speeds the moisture-capturing process. Another designed component, thermo-responsive cellulose with hydrophobic (resistant to water) interaction when heated, helps release the collected water immediately so that overall energy input to produce water is minimised.

Other attempts at pulling water from desert air are typically energy-intensive and don't produce much. And although six liters doesn't sound like much, the researchers say creating thicker films or absorbent beds or arrays with optimisation could drastically increase the amount of water they yield. The reaction itself is a simple one, the researchers say, which reduces the challenges of scaling it up and achieving mass usage.

"This is not something you need an advanced degree to use," says lead study author Youhong "Nancy" Guo, a former doctoral student in Yu's lab, now a postdoctoral researcher at the Massachusetts Institute of Technology. "It's straightforward enough that anyone can make it at home if they have the materials."

The film is flexible and can be moulded into a variety of shapes and sizes, depending on the need of the user. Making the film requires only the gel precursor, which includes all the relevant ingredients poured into a mould.

The US Department of Defence's Defence Advanced Research Projects Agency (DARPA) funded the work. Drinking water for soldiers in arid climates is a big part of the project. However, the researchers also envision this as something that people could someday buy at a hardware store and use in their homes.

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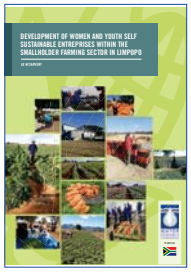
NEW WRC REPORTS

Contributions of an ethically-grounded and value-based approach to water governance – the case of two contrasting catchments

The nature and characteristics of water, being a resource that affect all aspects of human endeavour, biological and ecosystem health, implies that the consequences of systemic governance failures would likely have ethical and value implications, and thus the need to consider the contributions of ethics and value-based approach to water governance in South Africa. This is critical because values underpin the way people interact with and lay claim to water, and it has been argued that much of the conflict around water are indeed value conflict. Therefore, an ethical approach to water governance is fundamental because it helps to clarify value claims, the implication of interaction of values in specific contexts, as well as enabling a deeper reflection and analysis of the implications of policy and governance decisions on water allocation, ecosystem protection and ways in which water is being governed. Using the Lower Sundays River catchment and the lower section of the Upper Vaal River catchment as case studies, this project develops an ethical and value-based approach to water governance in South Africa. The intention is to bring ethics and value-based analysis to the domain of water governance, and to shed light on its contribution to realising the foundational values of equity, sustainability and efficiency enshrined in the National Water Act.

WRC Report no. 2934/1/22

Web link: https://bit.ly/3z1vD3T



Development of women and youth self-sustainable enterprises within the smallholder farming sector in Limpopo

A study was carried out with the aim to develop a Sustainable Model for Agricultural Enterprises Led by women and youth. The specific objectives were to: characterise agricultural enterprises led by women and youth (socio-economic, critical success and failure factors, water sources and use, commodities of choice) in Limpopo; investigate a potential model for multi stakeholder interaction (especially the need for water for ecological and social good) for agricultural enterprises led by women & youth in Limpopo; investigate the potential commodity production and value chain by agricultural enterprises; investigate the potential commodity production & value chain by women and youth agricultural enterprises within the scenarios of different water management systems (rain-fed, irrigation and ecological use groundwater); develop a model to sustain economic development by enhancing the long-term sustainability of women & youth agricultural enterprise (creation projects, propose new institutions, water management interventions, strategies, and to propose new institutions).

WRC Report no. TT 877/22

Web link: https://bit.ly/3P9tGbl

Technical and financial feasibility of alternative renewable energy sources and technologies in irrigated agriculture

Although a number of large commercial irrigated production enterprises has implemented solar and hydro schemes at farm level, there are still conceptions that alternative energy is expensive, vulnerable and not as reliable or sustainable as grid electricity, raising questions regarding the feasibility thereof at relatively small scale and in different parts of the country. There are still many questions regarding the feasibility of renewable energy in the irrigation sector, despite the success of currently implemented schemes. The need for a scoping research study regarding the technical and financial feasibility of alternative renewable energy sources and technologies in irrigated agriculture was therefore found necessary. The general objective of this research was to determine an overview of the technical and financial feasibility of alternative renewable energy sources and technologies in irrigated agriculture.

WRC report no. 2969/1/22

Web link: https://bit.ly/3PqlP7I

Risk-based and site-specific industrial use water quality guidelines

The current series of South African Water Quality Guidelines (SAWQGs) (DWAF, 1996) has been an extremely important contribution to water resource management in South Africa. It reflects the scientific thinking at the time it was produced. In 2008 a process was started to review and update the guidelines. The objective of this project was to develop a risk-based philosophy and site-specific methodology for assessing water quality requirements and fitness for use of water for industrial use. The specific aspects addressed include firstly the development of the basis of the risk approach and quantification methodology for the risk assessment; and secondly the development of the informatics for a technology demonstrator decision support system that addresses the main decision contexts for industrial water use.

WRC report no. TT 874/1/22 (Volume 1: Decision support system) and TT 874/2/22 (Volume 2: Technical support)

Web link: Volume 1:https://bit.ly/3aFZ2qZ and Volume 2: https://bit.ly/3ATHrqa

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CISMOL – Monitoring groundwater in the Hout catchment

During the last decade, an exciting trend has been recorded worldwide, with thousands of lay people from, in, and across different countries becoming engaged in citizen science (CS) projects, through various modes and channels of collecting, commenting, transcribing and analysing data. However, CS has been predominantly pursued within the realms of the natural sciences. Groundwater is an increasingly important source of water supply to agriculture, households, and industry. Groundwater is generally well protected against pollution, can be exploited anywhere depending on the local conditions, and has a year-round availability. With population growth and increasing climate variability, groundwater also plays an increasingly important role in South Africa (RSA) to enhance water and food security. Monitoring groundwater in the Hout becomes critical as it contributes to the body of knowledge on changes over time in groundwater levels, climate variabilities measured for instance by amount of rainfall or river flows.

WRC report no. 3017/1/22

Web link: https://bit.ly/3RqbUCp

Revision of the pricing strategy for water use charges: implementation of the Waste Discharge Charge System (WRCWD)

South Africa continues to face water scarcity and climate change pressures within a constrained national fiscal and economic context. The reduction in water quality increases the cost of water, threatens human health, limits food production, reduces ecosystem functions, and hinders economic growth. In response to the country's poor water quality in strategic catchments, the Waste Discharge Charge System has been developed as a key instrument in supporting water quality management of the country, with the Waste Mitigation Charge (WMC) being a critical financial resource to support catchment water quality management. This Strategy has been in development for over a decade, and implementation is critical to realising success and improvement in the quality of our water resources. The purpose of this report is to relook at the assumptions and principles used in the development of the Waste Discharge Charge System and test the Mitigation Formula for its robustness in catchments and application.

WRC report no. 3016/1/22

Web link: https://bit.ly/3yynKBL

Contributions of an ethically-grounded and value-based approach to water governance – the case of two contrasting catchments

In South Africa, there is a gradual move towards the governance of water resources in the context of social-ecological systems (SES), which recognises the coupling, interrelationship, and complex interactions between societal and ecological components of the SES. In this regard, there has been a growing body of knowledge that supports the governance and management of water resources in the context of SES. However, there is little parallel research efforts aimed at developing an ethics and value-based approach for distilling ethical criteria and principles for navigating the array of complex issues such a systemic and holistic view of water governance raises. An ethical approach to water governance is fundamental because it helps to clarify value claims, the implication of interaction of values in specific contexts, as well as enabling a deeper reflection and analysis of the implications of policy and governance decisions on water allocation, ecosystem protection and ways in which water is being governed. Using the Lower Sundays River catchment and the lower section of the Upper Vaal River catchment as case studies, this project develops an ethical and value-based approach to water governance in South Africa. The intention is to bring ethics and value-based analysis to the domain of water governance, and to shed light on its contribution to realising the foundational values of equity, sustainability and efficiency enshrined in the National Water Act.

WRC report no. 2934/1/22

Web link: https://bit.ly/3z1vD3T

Integrating nano iron production into the acid mine drainage neutralisation treatment process

This study set out to explore, through a preliminary investigation of the feasibility of generating nano iron from acid mine drainage (AMD), and the effects of this on the downstream neutralisation process parameters and outputs, particularly gypsum which constitutes one of the major wastes from the eMalahleni Mine Water Reclamation Plant, which treats wastewater from the coal mining industry for reuse. Recovery of by-products from AMD, and/or the wastes generated from the treatment of AMD, can both reduce costs of waste disposal and offset costs of the treatment process, whilst also being consistent with the principles of sustainable development and related concepts such as resource efficiency, the circular economy and industrial ecology.

WRC report no. TT 884/22

Web link: https://bit.ly/3APRaxS

To download any of these reports click on the web link provided, Visit: www.wrc.org.za or Email: orders@wrc.org.za

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WATER HERITAGE

Exploring the large footprint of South Africa's 'smallest' river

In semi-arid South Africa even the smallest river has a role to play in sustaining the country. Petro Kotzé explores the Klein River.

All photographs by Petro Kotzé

Rivers are the lifeblood of South Africa. Most of the country's water requirements are met from the roughly 160 000 km of river length that crisscrosses the country. This network densifies and increases in volume from the arid west to the wetter east of South Africa. The country's longest river, the Orange, shoulders intensive economic development along its course from Lesotho to Alexander Bay on the West Coast, but even our smallest river has supported generations of communities settled on its banks.

The title of South Africa's smallest river is debatable, but one that is claimed to be exactly that is the Klein River ('Klein' literally meaning 'small'), which runs from the northern slopes of the Kleinriver Mountain Range in the Overberg to the Klein River Lagoon or ***Kleinriversvlei*** between Stanford and Hermanus.

The river's claim to fame is the shortest distance between its origin and mouth in the world – a mere five kilometers as the crow flies, although the river itself is about 80 km long. The source of the title is today somewhat obscure, but largely rumoured to be from the Guinness World Book of Records.

While the river might, or might not be, South Africa's shortest from source to sea, it still offers a glimpse into the vast support that even 'small' rivers provide across economic sectors, to varied ecological systems, the quality of life of those that settle near them over generations and, the price that the river itself pays for this service.

The river's source

Bea Whittaker, a stalwart of civil societies in and around Stanford, sends word that the river starts as the Hartbees on the north-eastern slope of the Maanskynkop, at around

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964 m the highest mountain in the Kleinriviersberg Mountain Range and visible from along the Hemel-and-Aarde road from Caledon to Hermanus. From there, she says, you can trace the river's flow along the mountain towards Tesselaarsdal, with a number of streams flowing into it. Along with the Hartbees, the main tributaries of the Klein include the Steenbok and the Karringsmelk.

The waters that eventually converge into what we call the Klein River flow towards it from the surrounding mountainous catchment. A considerable amount arrives from the 120 km^2 catchment of the Hartbees, and around 30% is generated from the southern flanks of the Klein River Mountains between Wagenboomsdrift (Akkedisbergkloof) and Aasvoëlkop (located in the Vogelgat catchment) – a catchment area of approximately 100 km^2. The so-called 'small' river's total catchment area is just over 98 000 ha, but the highest point where this water starts to be known as the Klein River can be traced on Google Maps and can be reached with a leisurely drive along well-maintained tarred and dirt roads.

According to the Department of Statistics South Africa, with a total length of 163 533 km, South Africa's rivers would encircle the earth four times if placed end to end. The statistic was calculated from the river network data layer maintained by the Department of Water and Sanitation (DWS). Main rivers make up 47% of this total length while tributaries (smaller rivers) constitute the remaining 53%. The majority of South Africa's rivers are upper or lower foothill rivers, with a moderate gradient and little to no floodplain. Lowland rivers with distinct floodplains make up only 9% of total river length, making them relatively rare, especially compared to many northern hemisphere countries.

The way to the start is a scenic mixture of vineyards and rolling hills striped with undulating croplands, but the birthplace of the Klein is surprisingly unspectacular; a marshy area dense with port jacksons and black wattle. Today, management plans declare that almost the whole river, including its tributaries, is heavily infested with alien wattle species such as ***Acasia saligna*** (orange wattle), ***Acasia longifolia*** (Sydney golden wattle) and ***Acasia mearnsii*** (black wattle) and very little of the natural riparian vegetation remains.

Though the river disappears from view as one travels from this point along the Oudekraal road that crosses the Hartbees just before it joins the Klein, heading towards the scenic R326, signs that water is near are clear. The road cuts through extensive dryland agricultural fields, interspersed with irrigated farming operations visible by the centre pivots on the horizon, while sheep and cattle roam the quiet landscape. Agricultural activities comprise the bulk of the land-use of the Overberg region, with Stanford and Hermanus mostly making up urban development. About 44% of the total catchment area is transformed, and many of the natural vegetation represent habitats that are now considered endangered or critically endangered. These include the endangered Greyton Shale Fynbos and the critically endangered Elim Ferricrete Fynbos.

The river and its main tributaries continue through agricultural land and by the time the Oudekraal crosses it again it is as a

The bridge that runs over the Hartbees, just before it joins the Klein River.

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The official source of the Klein River, just after the Hartbees.

bridge over a well-defined river, though not running on this day. Now you can follow it as you drive on the R326 past the Stonehouse Cheese Shop, where the air smells heavy of cattle, and the Boschrivier and Raka wineries, both of which are on the opposite of the road from the Klein River as it runs close to the foot of the mountains.

This kloof is known as Akkedisberg Pass, which runs between the Kleinrivier Mountains on the North and the Perdeberg on the South, following the river through the kloof. Lady Anne Barnard, the popular wife of secretary to the Cape Government, Andrew Barnard, travelled through here in a hired, horse-drawn wagon in May 1798, when the pass was referred to as the Clyne Riviere Kloof: "***Wherever we turned as we left this place the bontebok bounded away before us, and set Johnnie's heart abeating. No village – no trees – and but one human being appeared as we travelled on. We passed the Clyne Riviere Kloof – not steep but stony and dangerous from the frequent slopings of the road – some very marshy passes – to the right a range of hills and a cascade – to the left a long row of mountains, which on turning the angle we found was succeeded by another. We passed the Hartebeest River – a good farm belonging to one Tesler – the Steenbras River – and arrived about six at Mr Wolfram's (who rents the Government baths, where people go for a variety of complaints} and slept there***."

Just after a section where the river is pushed aside with mounds of dirt to allow for the construction of a new bridge, is a small section where Hannah Baleta from the Klein River Cheese Factory farm (now closed to the public) located further along the road says you can still see some of the original riverine vegetation, though a number or large poplars and so are also in the mix. It's a densely vegetated stretch where footsteps are silenced by the soft layer of rotting leaves and the insistent croak of frogs are a clear sign of the ample amphibia around, but hidden from view. Above, the wind rustles through the autumn leaves that host verbose birdlife in the canopy.

According to management reports the instream habitat integrity of the Klein River varies between moderately modified and largely modified, deteriorating as it flows downstream. The riparian habitat integrity has been modified extensively and critically.

At the Klein River Cheese Farm, Baleta says they live close to the river. They abstract water for their farming activities, but also enjoy the view every day from when they wake. Their houses are located a short stone's throw from the river, which swells over the lawn when in flood. Her mom had indigenous trees planted next to it for her birthday and when the river rises, her husband and his friends like to canoe down it from around the Raka winery located upstream.

A couple of kilometres down the road quaint Stanford lies bordered against the Klein. Various businesses here benefit from the waterway. Boat operators offer trips up and down the river, or you can power yourself up and down in a rented kayak. The Stanford Walking Trail winds along the banks of the Klein River and through town, boasting to offer visitors glimpses of the many birds in the area, including Blue Crane, Fish Eagle or a majestic Cape Eagle Owl perched silently in a tree. The area is well known to birding enthusiasts.

From the Stanford Bridge over the R43 the river meanders for 6 km before it reaches the lagoon. Lady Ann had another noteworthy experience along this section of the Klein, when she and her party travelled too close to the edge of a sloping bank, down which ran a little stream, identified to possibly be Maanskynspruit (by author Jose Burman) as they followed the northern edge of the Klein River lagoon over the sloping mountainside.

"***For about half an hour matters went pretty well, though the shades of night fell fast about us; at last "Hey" cried Mr. Barnard – the wagon rocked - "sit close" - I felt its wheel sinking on the side I was on, and in a moment down we came like a mountain.***

Most of the land-use activities in the Overberg are agricultural, with dryland and some irrigated fields decorating the landscape along the flow of the Klein River.

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Move along Klein River – bridge construction along the course of the river.

The wagon was overturned – my head lower than my heels; and everything in the world I felt was above me. Mr. Barnard rushed out to see where we were – Cousin Jane, Johnnie and I were laid low." The party didn't suffer any injuries, though the contents of an entire ginger cask that lost its lid poured down the neck of Lady Barnard.

At the sea

Between Stanford and Hermanus, the Klein River flows into the impressively beautiful Klein River Estuary. The Klein is a temporary open /closed estuary, the breaching of which has been contentious, though the practice reportedly dates back to at least the 1860s.

It is unusual because, in general, estuaries in the Overstrand are not particularly productive as they are fed by rivers with low nutrient content, but the Klein River Estuary, as well as the nearby Bot/Kleinmond Estuary, are exceptions. Because of their size and the long residence time of the water that flows into them these systems support many fish such as ***Liza richardsonii*** (harder) while serving as nursery areas for ***Lithognathus lithognathus*** (white steenbras) and others. According to assessments, the value of the nursery function is approximately R81.3 million per annum, with the Bot/Kleinmond and Klein estuaries providing 40 to 50% of the estuarine nursery habitat from Cape Point to the Breede River mouth.

These two estuaries also support most of the waterbird fauna in the municipality, with migratory waders, rails and flamingos stopping by. In fact, the Klein River Estuary has been rated as the fifth most important temperate estuary along the country's coastline in terms of conservation importance.

The flow of the estuary, also known as the Hermanus Lagoon or Kleinriviersvlei, has reduced over the years, due to a combination of abstraction for irrigation and thirsty alien vegetation in the catchment. Concurrently, nutrient loads from wastewater treatment works, septic tanks and agricultural runoff, sedimentation and illegal fishing have increased.

River ahead! A river of any size can still make an impact on the unaware. This road sign in Stanford warns that the Klein River lies ahead.

Regardless, the estuary is of immense value to the area. Taking into account ecosystem functions, natural resource values and contribution to the local economy, its value in monetary terms has been calculated to be R540 million. Closer to the mouth sailing boats dot the water while people harvest for bait in the shallows, alongside playing dogs let loose by their sauntering owners.

Alina Polianskaya, PR Executive for the Guinness World Records Limited, sends word that there is no mention of the Klein River ever being awarded a Guinness World Records title in their database or in the book archives. In fact, there is currently no record holder for the shortest river in the world. However, though the Klein is perhaps not an official record holder as the smallest river, it is worth more than its weight in gold.

The Klein River Estuary has been rated as the fifth most important temperate estuary along South Africa's coastline due to its conservation importance.

Sunset at the end of the Klein River, perhaps not an official record-holder, but still worth much more than its weight in gold.

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The Klein River estuary's value goes far beyond the monetary to include vast additions to the quality of people's lives, and the natural beauty of the area.

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The Klein River's is a temporary open / closed estuary located between Stanford and Hermanus.

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ESTUARINE SYSTEMS

Too little/too much freshwater conundrum for Lake St Lucia estuary treasure

The Lake St Lucia wetland system, the largest estuary in South Africa, has been at the centre of much controversy over recent decades. A panel of experts has now re-iterated the need to protect this critical estuary and to ensure that it is no longer managed in isolation from the neighbouring region, writes Tony Carnie.

Tony Carnie

A skiboat heads out to sea from the mouth of Lake St Lucia.

Back in 2009, at the height of a prolonged drought, estuarine scientist Prof Alan Whitfield cautioned that: "Lake St Lucia is like a patient in intensive care. Critical decisions have to be taken now. The only long-term solution is finding a sustainable way of re-linking the life-artery of the Mfolozi River with the estuary."

More than a decade later – following some of the most severe flooding in recent memory along the KwaZulu-Natal coastline – so much, and so little, seems to have changed. Whereas the lake all but dried up into a sandy desert landscape during the winter of 2016, St Lucia seemingly has too much freshwater now following the recent severe downpours of rain.

There was so much water flowing through adjacent feeder rivers in mid-April that the recently reunited mouths of Lake St Lucia and the Mfolozi River broke open a natural pathway to the sea after another prolonged closure of the estuary mouth.

Such seasonal extremes (where there is either "too little" or "too much" freshwater) are common in many river estuaries around the world. These natural variations also shape the dynamic character of the meeting zones between fresh water from the land and salt water from the ocean. In the case of Lake St Lucia, however, the surrounding region has been modified so extensively over the last seven decades that the long series of human interventions have sparked intense public and scientific debate on how best to manage the recovery and long-term health of this national treasure.

Prof Whitfield, a senior scientist who has been studying the estuaries of KwaZulu-Natal and the Eastern and Western Cape for nearly four decades, stresses the critical, national importance of the St Lucia system relative to all other estuaries in South Africa. "When full of water, the St Lucia system covers an area of approximately 35 000 ha compared with a total South

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African estuarine area of approximately 70 000 ha, constituting approximately 50% of the nursery habitat for estuary-associated fish species in the country. Within Kwazulu-Natal, St Lucia accounts for about 80% of the estuarine area in the province," says Whitfield, Emeritus Chief Scientist at the South African Institute for Aquatic Biodiversity (SAIAB).

Because several marine species also use this estuary as a nursery area to rear the next generations of fish, he believes it is vital to ensure a connection between the sea and this lake. Yet, for several decades, managers have had to contend with the far-reaching consequences of a decision taken in the early 1950s to artificially separate the joint mouths of the St Lucia and the Mfolozi River, the lake's largest freshwater source. That decision was taken partly to reduce the volume of riverine silt entering the St Lucia mouth and partly to avoid the back-flooding of sugarcane farms in the Mfolozi floodplain.

When this artery was severed, the volume of water entering the lake was reduced dramatically. Because there was less water to push open a channel to the sea, the mouth of the lake began to close off more frequently. This led to a series of management interventions to retain the connection to the sea via regular artificial breaching and dredging of marine and riverine silt accumulations.

While these interventions to maintain the linkage to the sea were partly successful, it became increasingly clear that St Lucia was running out of water. So, in 2010, Whitfield was appointed project leader of a Water Research Commission workshop on generating the information needed to consider relinking the Mfolozi River to the St Lucia estuarine system.

One of the main conclusions of the workshop report (**WRC Report No. KV 255/10**) was that: "There is now little doubt that St Lucia will be unable to survive as a World Heritage Site unless it obtains Mfolozi River water (especially during droughts)."

Estuarine expert Prof Anthony Forbes, one of more than a dozen specialists who contributed to the report, summarised the matter thus: "What has happened at St Lucia can only be described as a national estuarine catastrophe with already visible ripple effects in terms of the collapse of the offshore shallow-water prawn fishery and the reduction in recruitment to populations of estuary-associated marine migrant fish.

"These effects will certainly be felt for several years at least, beyond the point of any restoration or recovery of the St Lucia system. Resident species have lost huge areas of habitat while critical normal estuarine function in terms of the provision of nursery grounds for migrant fish and invertebrates and feeding grounds for piscivorous birds in the largest estuarine habitat in the country has been lost."

Following that workshop, with financial support from the Global Environment Facility (GEF), a decision was taken to restore the natural link between the Mfolozi and that natural processes should be re-established as far as possible. Crucially, the iSimangaliso Wetland Park Authority also agreed to a recommendation from a subsequent workshop process that the mouth should no longer be breached artificially.

Hopes were high that, despite the risks of further sediment entering the estuary mouth, the relinking of the Mfolozi and lake mouths would gradually help to heal the water-starved lake. But towards the end of 2020, strong criticism emerged from a variety of stakeholders who were concerned that the lake mouth had remained closed for nearly six years despite relinkage to the Mfolozi.

Tony Carnie

A farm worker trims sugar cane stalks during loading operations in the Riverview area on the Mfolozi River floodplain.

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Tony Carnie

One of several sugar cane fields inundated by water during the recent KwaZulu-Natal floods.

Commercial and subsistence farmers in the Mfolozi and Msunduze river floodplains were angered by back-flooding of their fields in the wet season. Tour operators were concerned about the increasing build-up of silt and reeds near Honeymoon Bend and with the Narrows section of the lake. Saltwater anglers and some scientists were worried about the fact that marine species had been unable to re-enter the lake for a prolonged period.

So, following a stakeholder workshop at St Lucia, the mouth was breached artificially in January 2021. This decision sparked immediate controversy and was condemned by a group of seven scientists who wrote an open letter to Forestry, Fisheries and Environment Minister, Barbara Creecy.

The scientists (Ms Nicolette Forbes, Prof Anthony Forbes, Prof Derek Stretch, Dr Barry Clark, Dr Jane Turpie, Prof Gerrit Basson and Mr Eddie Bosman) characterised this decision as a deviation from scientific, evidence-based decision making by the park authority. Not only did this contravene the GEF project team recommendation against further artificial breaching, it appeared that iSimangaliso had also ignored its own management strategy and the "disastrous impacts" of prior engineering interventions.

In response, Creecy appointed a five-member panel of experts that included WRC Aquatic Ecosystems Research Manager Bonani Madikizela. The panel was chaired by marine biologist Dr Nasreen Peer and also included social scientist Mrs Busi Ngcobo, economics researcher Dr Lindile Ndabeni and environmental fluid mechanics researcher Prof Derek Stretch. It was asked to advise on the significance and impact of the artificial opening of the estuary mouth and the "exceptional circumstances" that led to the decision to breach. It was also asked to develop guidelines for the immediate and ongoing management of the system.

In its report published in April, the panel concluded that the decision to breach the mouth artificially had directly contravene the GEF recommendations. However, said the panel, the breach did not appear to contravene the park's maintenance management plan, nor did it appear to have had a significant impact on the lake's ecology.

Nevertheless, the circumstances necessitating a breach were largely undefined and the park authority needed to revise the management plan to define explicitly, what was meant by "emergency/ecological reasons" to justify future artificial breaching.

The panel also set out possible "exceptional circumstances" that might justify future breaching. These could include a prolonged and "unprecedented closed-mouth state"; an exceptional build of the sand berm between the lake and the sea; excessive accumulation of sediments; a prolonged freshwater state; build-up of alien or submerged vegetation; a decline in faunal diversity or a decrease in the nursery function of the estuary.

Another significant finding was that the exceptional circumstances definition did not take sufficient account of social and economic circumstances – including the back-flooding of commercial and subsistence farms or the decrease in tourism and recreational angling during closed-mouth states or an increase in conflict between conservation and neighbouring communities.

There was also a need to improve communication between the park and local communities and to improve catchment management beyond the park boundaries and within the Mfolozi floodplain.

There should also be a "thorough and updated investigation" of water use licences and catchment management to ensure that

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the lake system received a fair and adequate share of fresh water in a region under pressure due to farming, commercial forestry and groundwater abstraction.

To reduce the extent of sediment deposition into the area close to Honeymoon Bend, a technical task team suggested blocking off an existing "short circuit" link canal from the Mfolozi – though the full implications of this required further investigation and modelling.

Commenting on the findings and recommendations of the panel, Whitfield said there was no doubt that the original decision to relink the Mfolozi to the lake was the correct one. "The St Lucia system certainly benefited from the management decision to relink the Mfolozi River to the St Lucia Estuary. Effectively that decision saved Lake St Lucia from drying out completely during future droughts."

Unfortunately, he said, the relinkage also came at the cost of high inputs of suspended silt due to the loss of the sediment filtering capacity of the Mfolozi Swamp which was destroyed to provide land for sugar farming almost a century ago.

The volume of water provided by the Mfolozi River during the decade prior to the artificial St Lucia Estuary breach in January 2021 was sufficient to fill up the lake system but not enough to naturally breach the berm. "This prolonged loss of marine connectivity had major implications for the continued survival of estuary-associated marine fish and invertebrate species that used the lake and estuary as a primary nursery area.

"Indeed, it got so bad that some species (notably mullet) either disappeared or were close to disappearing from the system altogether. That was why I supported the assisted breach (after having supported the natural breach policy at its inception) and was very pleased to note that the estuary berm was breached naturally in April 2022.

"Both mouth opening events were/are good for marine connectivity but the lack of accumulated silt and mud removal by the outflowing flood waters is cause for major concern. This is because there has been a compaction of these fine sediments over the long, closed phase and they are now almost impossible to remove during normal summer flooding by the Mfolozi River."

While a repeat flooding episode on the scale of Cyclone Demoina might help to scour out The Narrows section, there was no guarantee of this in the near future. "Whilst I supported the GEF management plan in the first few years of its implementation, I became increasingly disillusioned as the period of mouth closure grew longer and longer – without any marine connectivity."

Whitfield is worried that there were still no clear guidelines from the panel to the iSimangaliso Wetland Park Authority as to how the St Lucia mouth should be managed going forward – other than to say that, if there are exceptional circumstances, then it can be artificially breached. "This is not a helpful recommendation from a long-term estuary management perspective. Basically, a new plan for the management of the St Lucia system needs to be developed and implemented and the panel did not make this recommendation."

Dr Ricky Taylor, the former park ecologist who spent decades researching this lake system, is also worried that St Lucia is on the verge of "flipping" irreversibly from an estuary into a shallow freshwater lake – possibly within a decade, if the high silt levels entering the lake are not managed urgently. "Although I am critical of the GEF management strategy, whenever I was asked my opinion I always responded that we should give it a chance to see if it works or not," said Taylor.

"My attitude changed radically in September 2020 when I saw the sediment accumulations and associated vegetation responses, learnt about the flooding of the Umfolozi floodplain by backing up of water and found out that almost no monitoring or assessment to this intervention was being done. There were (in my opinion) irreversible changes occurring and nobody was tracking the effectiveness, or otherwise, of the GEF management strategy."

He notes that St Lucia is already on a long-term trajectory to becoming a shallow freshwater lake rather than a functioning estuary, so he believes it is crucial to slow this down by appropriate management intervention - including dredging and artificial breaching based on sound scientific advice.

While it was necessary to "salvage the essentials of the GEF strategy" to relink the Mfolozi to Lake St Lucia, the recent increase in muddy sediment loads had to be reversed.

"We cannot implement a management strategy that relies on 'natural processes' There has been too much damage to the natural processes in the catchment and Mfolozi flats. We do need human interventions. These must be guided by competent people - who understand the area, have historical background, have experience and have the latest scientific knowledge," Taylor concluded.

Tony Carnie

At the height of a drought phase in early 2016 there was so little water in St Lucia that the lake bed was littered with dead fish.

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The waters of the Mfolozi River flow chocolate brown in a canalised section of the river upstream of the lake.

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RENEWABLE ENERGY

Keeping the sprinklers on – Farmers turning to wind, solar to water thirsty crops

As bouts of loadshedding leave South Africans in the dark for hours at a time, the country's irrigation farmers are increasingly turning to renewable energy. But there are still hindrances in the way of rolling out renewable energy technologies at a large scale in the agriculture sector. Article by Matthew Hattingh.

Kakamas table grapes farmer Dr Tokka van den Hever reckons it's been R19.2-million well spent. That's the initial sum he sunk into capturing energy from the sun, with the electricity generated used to pump Orange River water into his vineyards and to keep the harvest cool before it leaves for markets in the Northern Hemisphere.

In the Northern Cape winter, when Van den Hever's farms need little power, he feeds his surplus into the national grid. This earns credits, which are used in summer when he draws on the Eskom grid. Such have been the savings that, with tax breaks, Van den Hever reckons his sun-fuelled system should pay for itself in six years.

Elsewhere in the country, from a lucerne, potatoes and pecan grower in Limpopo with 768 solar panels, to a dairyman in Cookhouse, in the Eastern Cape, who powers his pumps with electricity from his own hydro plants, farmers are looking to renewable energy sources, particularly to water their crops. And it's a growing trend, according to a new report published by the Water Research Commission, entitled ***Technical and financial feasibility of alternative renewable energy sources and technologies in irrigated agriculture*** (**WRC Report No. 2969/1/22**).

Its authors, Sarlet Barnard, Bennie Grové, Isobel van der Stoep, and Richard Moyo, of Isowat Consulting and the University of Fort Hare, explain the shift to renewables. They consider the pros and cons of the different technologies; look at how to properly plan an alternative energy system; and discuss how more

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farmers can be encouraged to follow suit. Here we are talking about energy sources that are not depleted when used – such as solar or wind. They represent alternatives to Eskom's coal-fired power stations, which not only generate 77% of South Africa's electricity, but also receive considerable criticism for adding to the world's greenhouse gases, which have been linked to climate change.

More than a quarter of the country's farming depends on irrigation. It helps ensure the security of our food supply, it guarantees an income for farmers and many others and it stimulates rural development. But getting water out of boreholes and dams and onto crops takes energy, especially electricity and diesel. A combination of carrots and sticks is prompting farmers to seek alternatives. Among the biggest sticks is the rising prices Eskom is demanding for its increasingly precarious service. From 2008 the power utility's tariffs have outstripped inflation, even as load-shedding leaves farmers high and dry at the very times they need electricity most – when crops need watering.

The juiciest carrots include the potential savings alternative energy offer. The technology to tap the sun's energy or harness the wind has for a long time been expensive, but in recent years growing demand, particularly for photovoltaic systems, has spurred mass production, driving down prices.

The alternative energy sources considered in the report are all, it concluded, technically up to the task. But depending on site conditions and other factors, some make more sense than others. And it's for photovoltaic energy that the authors generate the greatest enthusiasm, describing it as "the future" for South African agriculture and calling for a follow-up study.

They chart how prices for photovoltaic panels have tumbled by 80% between 2012 and 2015, with further falls predicted. In sunny South Africa, where solar radiation is plentiful and more direct (than in countries at higher latitudes or in cloudier regions), the case for photovoltaic-powered pumps seems self-evident. As the report notes: "When the sun is shining it feeds irrigation systems ensuring that they work hardest in the hot summer months when they are needed most."

Batteries can be used to store any energy not immediately needed. And inverters and other devices are often added to the system to turn the direct current from panels into alternating current and to regulate its frequency. The system can be arranged to feed any surplus electricity into the grid too. The green icing on the solar irrigation cake is that photovoltaic systems can be sited near pumps, doing away with lengthy and expensive power lines.

Yet, despite these and other advantages, photovoltaic energy, the report notes, waters a mere 2 000 hectares of the 1.2 million hectares of land under irrigation in the country. It's a drop in the ocean.

Why is this so? Cost remains a big reason. Panels, despite a fall in prices thanks to Chinese mass production (underpinned, as others with an eye for irony have observed, by cheap, coal-fired electricity) still come with a hefty price tag. But that's only part of the story.

If a photovoltaic system is to run off-grid – without top-ups from Eskom – or if it must supply energy come rain or shine and at night, batteries are needed. These remain pricey and that's before you wire in a controller and other power electronics to prevent overcharging or discharging of batteries. It all adds up, leading the authors to observe that "investment in battery banks to meet a full off-grid capacity required to run a farm is usually not financially feasible".

So, even if a farmer powers his pumps from a photovoltaic system, chances are he will still be buying electricity to meet his other needs. And, as the report explains, a grid connection saddles the farmer with fixed costs that must be borne irrespective of how little Eskom (or municipal) electricity he draws.

Although photovoltaic energy works with a variety of irrigation techniques, including drip, micro sprinklers and rain guns, it does impose some additional costs and complications. Farmers must make hay, as it were, while the sun shines. And to do this, the authors recommend photovoltaic systems be designed with two-and-a-half times the capacity of conventional systems. "Large water tanks can be used to store the extra water pumped during sunny days from where the water can gravitate to the small water tank when needed. Storage for two or five days should be sufficient," the report said, advising that the size of the water storage should be optimised with cost in mind.

The authors stress that irrigation sites differ widely and farmers must understand their needs in detail. This includes getting to grips with soil types, groundwater depth, elevation of storage dams, times of the day when water is required and more.

Next, the irrigation system's energy needs can be determined and thereafter the costs of tapping different energy sources can be calculated and compared. When renewable energy supplements Eskom power, or vice versa, farmers must make the most of seasonal and time-of-use charges that apply at peak, standard, and off-peak periods under the utility's Ruraflex tariff.

As ever, the devil lies in the detail, and the authors work to bring order to a deluge of data. Their report provides a summary of the literature, as well as formulas, maps and other tools to aid planning and arrive at an optimum irrigation and energy setup. A

Some of the 768 solar panels at Becker Farm, which generate energy for a direct pump irrigation system.

Becker Farm in Limpopo has a 250kWp DC system and 200kVA AC.

renewable energy system makes economic sense only if its initial cost, together with installation, operating and disposal cost over its lifespan (typically 25 years) is less than grid power based on current tariffs.

With no end to Eskom tariff hikes in sight, the future looks rosy for alternative energy. Nevertheless, as the report notes, "electricity rates for the agricultural sector are still competitive" – or at least for now.

What about feeding surplus renewable energy to the grid? Farmers who do so earn credits that can be set off against the power they buy from Eskom at other times. It improves the feasibility of some projects, but it does come with its own difficulties and costs. But before any of this can happen, farmers must register and get approvals from the National Energy Regulator of SA, Eskom or the local municipality. This can involve a lengthy and frustrating paper chase.

Other hassles include getting finance (this can be especially hard for smallholders); panel theft; and a general lack of specialist solar power irrigation systems suppliers, servicemen and advisers. Here the report comes to the rescue by including a directory, listing service providers, plus case studies and the contact details of farmers who have made a success of alternative energy installations.

But perhaps don't bet the farm on it just yet. The authors note, quoting other researchers, that, "Solar power is not yet a viable option for large irrigation companies who service between 90% to 95% of the commercial irrigation farms."

So much for the sun, what of wind, water, biomass and other renewables? Biomass is about using fuel from plant-based materials like wood and bagasse (think sugarcane waste) to generate electricity. The report concluded this was more viable in the wetter, eastern parts of the country, but noted this energy source was not being used for irrigation and was considered the most expensive of the renewables. Wind, like sunshine, is plentiful in South Africa, but local conditions can vary widely and this must be considered.

The flamboyant Queen frontman Freddy Mercury once sang, "Any way the wind blows doesn't really matter to/ Me, to me." But down on the farm, consistency is king. Obstacles may get in the way of the wind causing turbulence so you want your turbines reasonably high off the ground and robustly mounted. This comes at a price and is part of the reason for the high capital costs of small-scale wind turbines.

The report quotes prices ranging from R36 500 for a 1kW turbine, to nearly R100 000 for a 3.5kW turbine. It suggested a particular brand of supposedly European-made turbines, with considerably lower price tags might be "worth looking into". But sadly, online customer reviews of the brand's products and pre- and after-sales service are scathing.

Leaving aside prices and the merits of individual suppliers, the real problem with wind is that it's fickle. Sometimes there may be no wind at all, or too little to generate electricity. At other

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A storage dam on Becker Farm Limpopo supplies centre pivot irrigation to potatoes, onions, lucerne and pecan nuts.

Becker Farms is tied to Eskom and is considering feeing back into the system. A R120 000-R150 000 monthly electricity bill and unreliable Eskom power prompted the farm to install a photovoltaic powered irrigation system.

times a gale may strike and then turbines typically cut out to save themselves from destruction. To get around this problem the authors suggest hybrid wind-diesel generator power or combining wind and solar energy.

Water power is certainly in the mix. Small, local-level projects to turn the movement of water into electrical energy for irrigation are technically feasible, the report found. It cited a Department of Water and Sanitation study that noted a network of more than 6,500km of canals in 47 schemes in South Africa. "A multitude of structures such as syphons, control gates, weirs, chutes and drops exist in these canals. All of these hold large unexploited hydro-kinetic potential," the report said.

But the authors also explain why exploiting this potential can be hard to do. Ours is a water scarce country, which is also part of the reason the National Water Act requires authorisation of all hydropower plants, regardless of size. Also discouraging small and micro hydro facilities are: the long waits for approval from various government entities; complex water use regulations; and a lack of locally-developed components and maintenance.

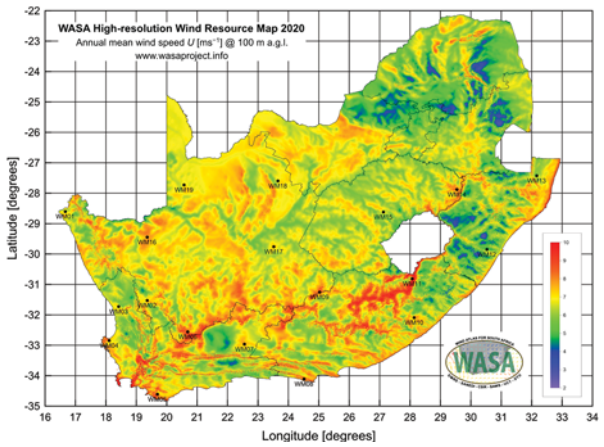
Beyond such financial, technical and planning difficulties – and this applies to all alternative energy sources – there's a sense that farmers are slow to adapt, or perhaps conservative. "Many associations indicated that they will also take time and significant effort to change the conventional agricultural mindset of farmers and their behavioural tendencies to embrace sustainable agriculture," said the report.

It's hard to dispute that South Africa's largely coal-dependent grid leaves a heavy carbon emissions footprint and that reducing this would be good for the environment, but appeals to altruism seldom trump economic concerns. Nor are the tax deductions currently available to farmers who install alternative energy sufficient motivation.

What can be done to encourage a switch to alternative energy? The report identified the banking of surplus electricity; finding other uses for the energy produced; getting farmers to organise themselves to share costs; the trade in carbon credits; and subsidies. "There is a need for the government to play a more active role," said the authors.

More carrots are needed before we can expect a greener harvest.

To download the report, ***Technical and financial feasibility of alternative renewable energy sources and technologies in irrigated agriculture*** (**WRC Report No. 2969/1/22**). https://bit.ly/3PqIP7I



The South African Wind Atlas Guide is a useful tool for those considering wind power. The areas shaded in red and dark orange have the highest average wind speeds. The Eastern Cape is considered particularly well placed to harvest this energy source.

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OPINION

What did cause the April KZN floods?

What caused the floods that devastated coastal KwaZulu-Natal in April and did climate change play a part? Prof Roland Schulze dissects a disaster and looks to the future. Additional reporting by Matthew Hattingh.

SDG

It was the not-so-little girl who caused the trouble. The April KwaZulu-Natal floods that claimed 448 lives – with 88 people still missing at the time of writing – owes its origins to a complex phenomenon on the other side of the planet.

Every now and then, winds cool a vast swathe of surface sea east of South America. The Pacific catches a cold, as it were, and the world's weather sneezes. It's known as La Niña (Spanish for "the girl") and we are at present in her grip, meaning generally heavier rains and more frequent floods.

And so it happened around the second weekend of April. A cut-off low pressure system began brewing south-east of Durban. These occur when the atmosphere's usual west-east passage is disrupted, trapping a pool of low pressure in a huge eddy. Where pressure is lower air is freer to rise and the moisture it carries condenses and falls: It rains.

By Monday, 11 April, the cut-off low, code-named "Issa", had grown in intensity and from midnight through to midnight on Tuesday unleashed more than 300 mm of rain in places along the coast. That's the equivalent of 30% of the region's average yearly rainfall. Remember too, that days earlier, 50-150mm drenched the region. The ground was already sodden.

Such was the deluge that the Shongweni dam, 12 km west of

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central Durban, popped two fuse gates, sending a torrent down the Umlazi River. The gates are safety mechanisms designed to save the dam wall from bursting. Just before the river passes beneath the N2 it enters a canal for the final few kilometres of its journey to the sea. Swamped, the canal spilled its waters onto the highway and flooded the coastal plain, including parts of south Durban's industrial heartland.

Similar scenes unfolded elsewhere in the eThekwini municipality. Low-lying parts of Amanzimtoti looked like a lake. To the north, holiday flats terraced into the forested dunes above Umdloti, crumbled spectacularly. In Durban's western suburbs, streams normally too insignificant to have names grew mighty overnight, tearing apart homes.

Across eThekwini, 8 584 homes were destroyed, with a further 13 536 listed as "partially destroyed". Raging waters washed away bridges, collapsed roads and let loose landslides. Some 100 electrical substations were flooded, plunging large areas of the metropolis into darkness. The floods damaged pipelines, cutting water supplies to some areas and the water treatment works in Tongaat, a 40 minute drive north of central Durban, sustained R30-million in damage, part of an estimated R25 billion in infrastructure damage across eThekwini.

Provincial Premier, Sihle Zikalala, at a briefing a month later called the floods "the worst in history". Given the devastation and death toll, Zikalala's assessment is understandable, but is it accurate? Let's first consider a few rainfall figures for 11-12 April, taking in Durban and the coastal region as well a few towns or cities in the hinterland by way of comparison:

- Margate: 311 mm
- Mt Edgecombe and Pennington: 307 mm
- Virginia Airport: 304 mm
- King Shaka Airport: 225 mm
- Port Edward: 188 mm
- Pietermaritzburg: 99 mm
- Mtunzini: 66 mm
- Greytown and Mooi River: 44 mm

Prof Jeff Smithers, of the Centre for Water Resources Research at the University of KwaZulu-Natal, estimated the one-day rainfalls recorded in coastal areas from Margate to Virginia Airport were in the order of a 1 in 50 year to a 1:100 year event. Expressed differently, there was between a 2% and 1% probability of such rainfall, or more, in any given year. A little inland, at a somewhat higher altitude, for example in Pinetown, the estimates were of these being between 1:100 and 1:200 year rainfalls. But remember, we are in a La Niña phase, when flooding is more likely. None of this is new, as detailed by BS Young's 1960 scientific paper on Floods in Natal in the Royal Meteorological Society's journal ***Weather***, as well as P Badenhorst and co-workers' Survey of the September 1987 Natal Floods, published in 1989 by the Foundation for Research and Development.

In addition, newspaper articles tell us of significant floods in the Umgeni River system, along the coast of KwaZulu-Natal and inland to the Drakensberg.
These include:

- 1856: 686 mm of rainfall was recorded in Durban from 13 to 15 April (***Natal Mercury*** of 18 and 25 April 1856), with the uMgeni breaking its banks, straightening its course and inundating the city, the Isipingo Flats becoming a lake and the sugar industry hard hit.
- 1905: From 31 May, the edge of a tropical cyclone, it is believed, brought rains and hail, spreading as far inland as

GCIS

President Cyril Ramaphosa visited the flood-stricken areas of KwaZulu-Natal on 13 April. A total of 459 people lost their lives while thousands were left homeless.

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GCIS

It cost billions of Rand to repair the provincial and national road infrastructure damaged by the floods.

Dundee, but with Durban receiving 381 mm in 15 hours, Pinetown 398 mm in 15 hours and with 200 drowned in the Umhlatuzana and Umbilo rivers.

- 1917: 432 mm fell from 23-26 July, apparently with little damage, but in October, 320 mm was recorded in Durban in one day.
- 1984: In the Domoina tropical cyclone floods, the Richards Bay-Sodwana area, for example, measured 950 mm and an area of 107 000 km^2 received in excess of 370 mm, with over 80 000 people stranded. These are probably the heaviest rains experienced over much of KwaZulu-Natal since official measurements began around the 1850s.
- 1987: A cut-off low moved moist air over the southern parts of the country, commencing with general rains over the former Transkei and KwaZulu-Natal, with parts of the province receiving over 900 mm, mainly on 28 and 29 September. There were 506 known fatalities. Badenhorst estimated this to be an event with a recurrence interval of 120-150 years.

The late Zoltan Kovacs, from what is now the Department of Water and Sanitation, did a major comparative scientific assessment of the 1984 and the 1987 floods, which was published in 1988 in ***The Civil Engineer***. He concluded that heavy rain fell over considerable areas, with Domoina covering larger areas for rainfalls up to 700 mm, but with the 1987 floods covering larger areas where more than 800 mm fell.

So, if we agree the '87 floods were in fact the province's worst in recorded history, how does this compare with flooding elsewhere in the world? A popular worst-floods list puts the 1931 floods in China at the top, with a death-toll of 2.25 million. The next worst, also in China, in 1887, also caused estimated casualties in the millions. More floods in China, at different dates in the twentieth and nineteenth centuries followed and then there were floods in the Netherlands and England in the fourteenth and ninth centuries. Filling out a grisly top 10, were floods in the Holy Roman Empire. The 1987 floods came in at only 102nd place on the list, with 506 deaths.

What about climate change? Did it play a part in the April floods? Climate change is a phenomenon where the release of carbon-dioxide and other 'greenhouse gases', whether by man-made or natural processes, causes a warming of the earth's atmosphere. Evidence suggests this will increasingly have a bearing on where, when, how often and how hard rain falls. But climatic systems can be extraordinarily complicated. Researchers are using complex computer modelling and other techniques to develop a clearer picture of what's happening, but theirs remain very much a work in progress.

When it comes to drawing direct cause-and-effect links, scientists generally err on the side of circumspection. Governmental spokespeople, however, can be rather less reticent. And in the wake of the disaster, some were unequivocal on the subject of climate change. They tended to forget about the history of flooding in KwaZulu-Natal.

Inevitably, many politicians visited flood-affected areas, including the President, the ministers of Police and of Co-operative Governance, the premier and mayors. They issued many statements, some no doubt out of conviction or from ignorance of the province's flooding history, but still others, possibly for reasons of political expediency or point-scoring, jumped onto the climate change bandwagon to hide the shortcomings of their own governance.

President Cyril Ramaphosa, when inspecting the damage, said: "This disaster is part of climate change. It is telling us that climate change is serious; it is here." Desigen Naidoo, of the Institute of Security Studies, commented that the April floods were "arguably one of the most visible and deadly signs of climate change in the country to date".

However, the SA Weather Service could not with any "quantifiable precision" attribute the floods to climate change. Nor is there consensus in the scientific literature on trends in the currently observed data regarding the impacts of climate change on floods. We need to remember that climate change, real as it is, has become a buzzword and often serves as a convenient scapegoat or distraction from governmental inefficiencies.

La Niña helped give rise to Issa, which in turn was the primary source of the flooding. With the soils already saturated, there was a certain inevitability to it.

But what do we mean by the "inefficiencies" referred to above? Instead of constructing and then neglecting stormwater infrastructure we need to focus more on maintenance. Municipalities must tackle the litter, rubble and alien invasive riverine vegetation that block drainage systems and make flooding worse. An interesting research project would be to calculate the cost of proper stormwater system maintenance vs the additional cost of flood damage and loss of life because the system failed to function efficiently during, say, a 1 in 2-year, or a 1:10 or a 1:20-year flood, let alone a 1:50 or a 1:100-year flood.

But even with the best will in the world, preventing flooding can be hard to do. There are physical, economic and possibly even social limits in the construction of stormwater infrastructure. And even well designed and maintained infrastructure may prove inadequate in an extreme event.

The floods did considerable damage to the informal sector. EThekwini's growing shacklands are home to 1.2 million people, mostly poor and frequently recent migrants to the city. Their

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homes seldom have solid foundations and are often built on steep slopes or in floodplains.

The municipality must continue to bring these areas into its planning. And it must enforce bylaws on where people may build. But the problem goes beyond maintenance and the better handling of informal settlements. Drains in some business districts were blocked with litter too.

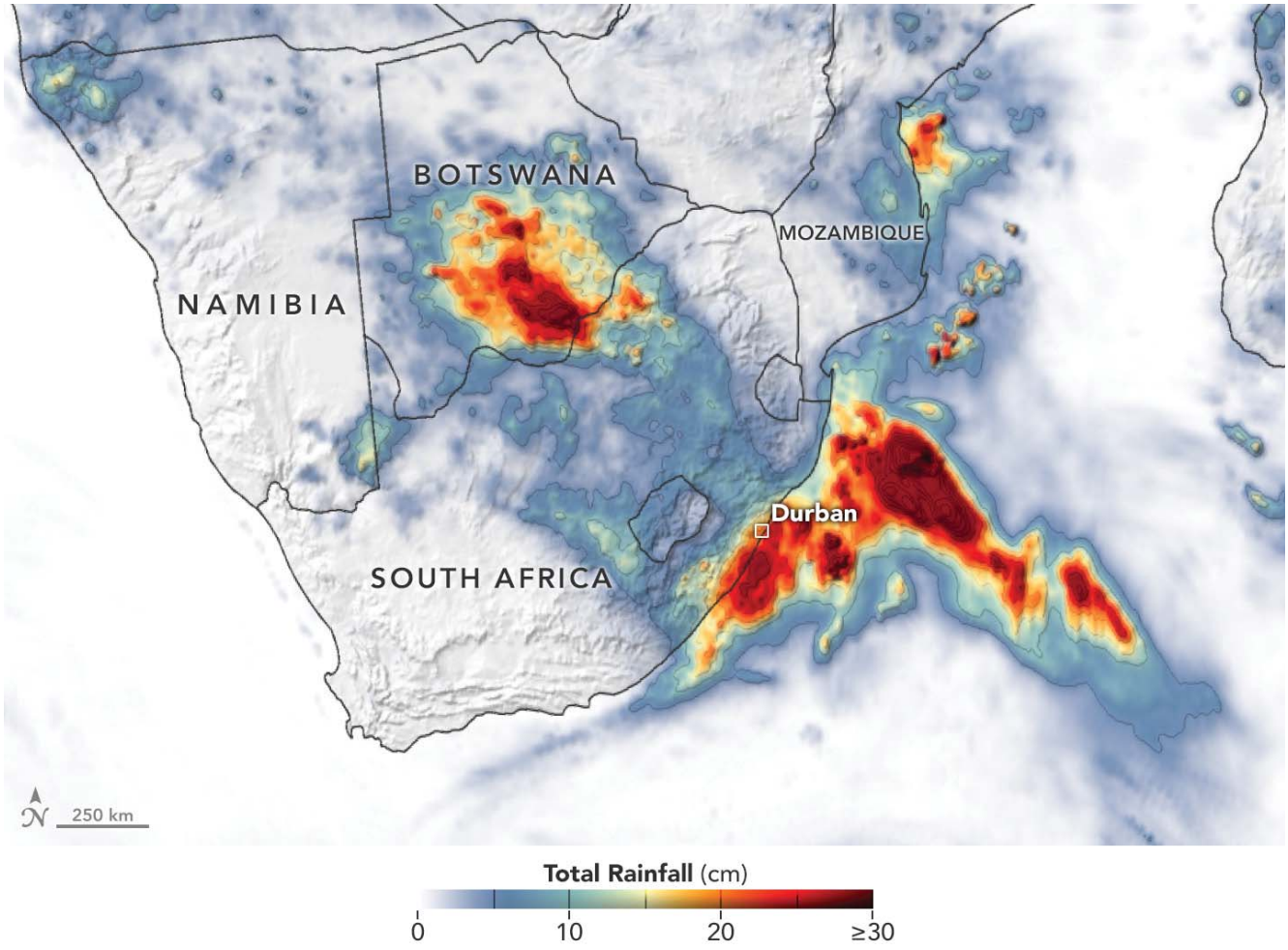
When it comes to flooding, we need to appreciate that land use change is often as important, if not sometimes more important than climate change. Hard roofs and roads do nothing to slow run-off when it rains and this can be a much more significant factor in flooding than climate change, as a recent study in Pretoria found. In rural areas, over-grazing often strips the ground of its surface protection, leading to direct run-off and erosion.

What should we do? Too often, climate change research focuses on annual changes and areas on a large scale. We need more research on local issues and the individual floods they experience, including flood-prone streams; steep slopes susceptible to mudslides; local soil-types that become saturated easily; and building materials used. In the longer term we must reduce greenhouse gas emissions and close the gap between climate change policy and how it's put into practice.

In the middle term we must redesign drainage infrastructure guided by computer modelling of floods and risk assessments. Building codes and standards must be updated and aspects of town planning revised. More immediately, we must take high alerts from the SA Weather Service seriously and develop smart early warning systems. These, with efficient and well-capacitated rapid response systems, will help save lives and property, and hasten recovery.

Infrastructure must be maintained, building codes enforced, and respect encouraged for the 100-year floodline. Flood lines are shifting and the frequency of rainfalls is in flux, but change will vary from place to place. For example, for Pietermaritzburg our research shows that in next 30 years rains of 100 mm per day are projected to increase by more than 8%, rains of 150 mm/day by more than 37% and falls of 200 mm/day by over 50%, while for those same thresholds of rainfall around Durban the models show little change.

- Roland E Schulze is a Professor Emeritus of Hydrology at the Centre for Water Resources Research School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg Campus.



Joshua Stevens/NASA Earth Observatory

A satellite-based estimate of rainfall over a seven-day period ending on April 13, 2022, that swept over the eastern area of Southern Africa. The darkest reds reflect the highest rainfall amounts, with some places in Botswana and South Africa receiving as much as 3 000 mm or more.

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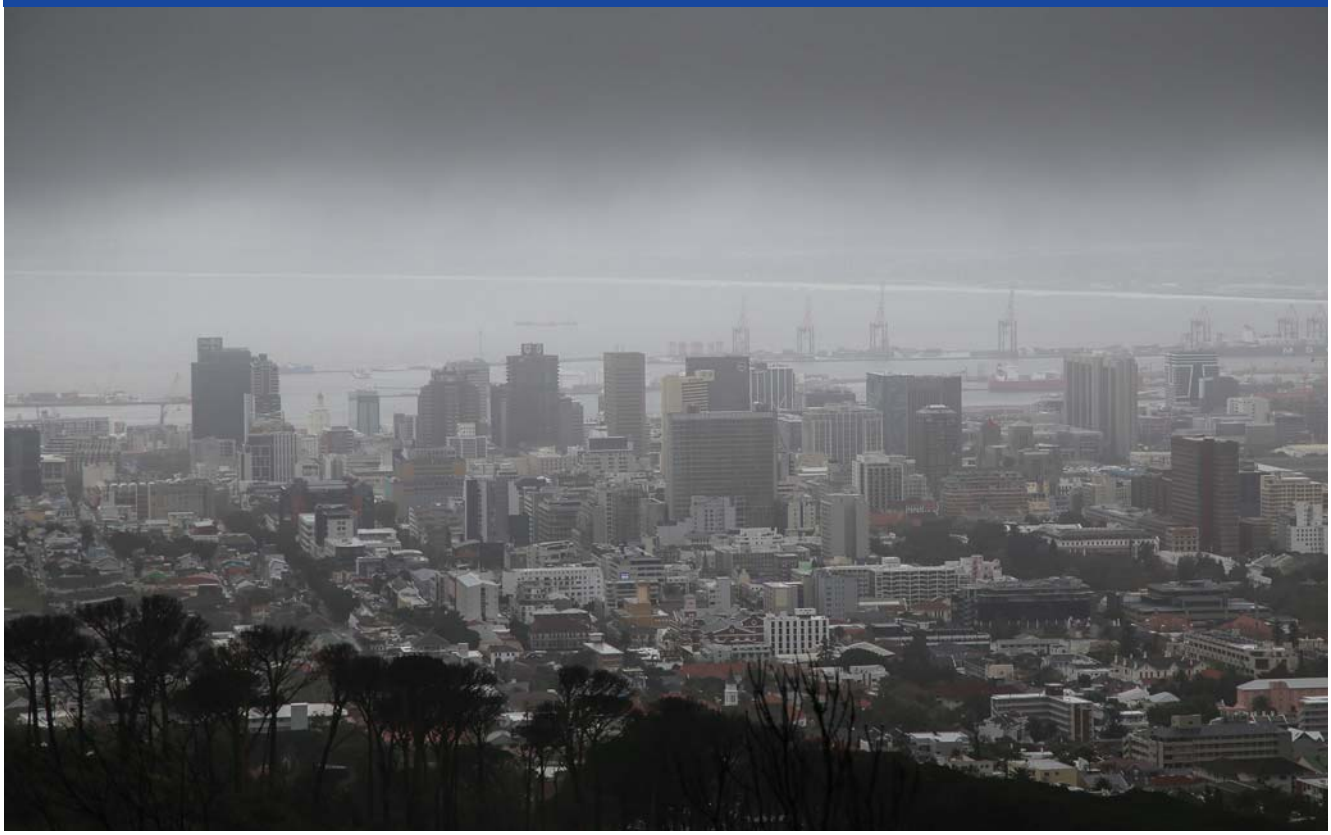
WEATHER FORECASTING

Improving extreme weather forecasts for South Africans

Petro Kotzé reports on the South African Weather Services's Impact-Based Severe Weather Warning System and what this means for disaster management in South Africa.

Petro Kotzé



Cold snaps and gale force winds might become more common to South Africans in future.

In mid-April, severe weather and flooding devastated parts of KwaZulu-Natal. Extreme rainfall and widespread flooding resulted in billions of Rand of damage across all economic sectors. The eThekwini Municipality announced an estimated R3.8 billion in damage caused by the floods to city infrastructure, excluding human settlements. Thousands were misplaced and had to seek shelter, food and health facilities as many parts of eThekwini were wrapped in darkness as power stations folded. At the time writing, 459 fatalities have been confirmed with dozens of people still missing.

Though the severity came as a surprise, the weather did not arrive unannounced. At least four days before the worst of the weather hit, a weather forecaster at the South African Weather Service (SAWS) head office in Johannesburg raised the alarm to provincial disaster risk management teams, who conducted their operation with hourly backups from the SAWS as the cut-off low system swept over South Africa's south-west coast.

Their collaboration was one of the results of the new severe weather warning service introduced across South Africa by the SAWS in 2020. It is known as the Impact-Based Severe Weather Warning System and entails a change from the previous threshold-based warnings to impact-based warnings. Impact-based forecasting combines hazard, exposure and vulnerability data to identify risk and support decision-making. In essence, it's

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Lauren Dauphin/NASA Earth Observatory

Tropical cyclone Eloise, which hit the east coast of Southern Africa in January 2021. Leading up to, and during, the heavy rainfall caused by Tropical Storm Eloise, regular updates received from SAWS assisted disaster management in preparing in advance.

a change from communicating what the weather will be to what the weather will do. The ultimate objective is to encourage early action to reduce damage and death from natural hazards.

The change was in line with World Meteorological Organization (WMO) guidelines that have seen many National Meteorological and Hydrological Services agencies across the globe begin to explore impact-based forecasting and warnings as a means to communicate risks and impacts to the public and sector end-users. In South Africa, the project is carried out in collaboration with National Disaster Management Centre, a key element of its success. It also links the country to the first four of the Seven Global Targets of the Sendai Framework for Disaster Risk Reduction (2015 – 2030), to which South Africa is a signatory. The targets in question are to substantially reduce global disaster mortality and the number of affected people globally; reduce direct disaster economic loss; and substantially reduce disaster damage to critical infrastructure and disruption of basic services.

What is impact-based extreme weather forecasting?

Impact-based forecasting is a way of strengthening weather awareness amongst the public, says Hannelee Doubell, SAWS Communications Manager. In impact forecasting, hazard forecasts are translated into the impact they can potentially have on the ground. The decision on which impacts need to be communicated, and which ones not, are made in collaboration with emergency managers that are familiar with the situation as it is happening.

SAWS forecaster Elizabeth Viljoen, who started working on the development of the system at the SAWS in 2016, explains that the process still starts with a weather forecast based on a numerical weather prediction model. The forecaster, with support from the team on duty and in regional offices, decides if the forecast could result in anything that could cause an impact, such as disruptive rainfall, severe thunderstorms, damaging winds, disruptive snowfalls, reduced visibility, damaging waves and storm surges. If the answer is no, no warning is issued but if it is yes, a process kicks in that is vastly different from the previous SAWS approach.

Rainfall impact table

Impact-Based Forecasting: RAINFALL Impact Table

Minimal	Minor	Significant	Severe
Business as usual	Localised Business as usual	Localised Short term strain on emergency personnel	Widespread Prolonged strain on emergency personnel
• Some **pooling** of water on roads or in formal/informal settlements • Day to day activities not disturbed • Wet roads and reduced visibility • Minimal traffic congestion • Isolated mudslides and rockfalls	• **Localised flooding** of susceptible formal/informal settlements or roads, low-lying areas and bridges • Major roads affected but can be used, increased travel times • Difficult driving conditions on dirt roads • Minor motor vehicle accidents due to slippery roads and/ reduced visibility • Closure of roads crossing low water bridges • Localised and short term disruption to essential services (water, electricity, hospitals, schools etc) • Localised mudslides, rockfalls and soil erosion • Localised disruption due to sinkholes/potholes/blocked drainage systems • Isolated cases of breakages of farm dam walls • Localised damage to mud-based/make-shift houses/structures • Localised disruption of access to drinking water and damage to crops	• **Flooding** of roads and settlements *(formal and informal)* • Danger to life (fast flowing streams / deep water) • Displacement of affected communities • Some communities temporarily not accessible/cut-off • Damage to property, infrastructure, loss of livelihood and livestock • Major disruption of traffic flow due to major roads being flooded or closed • Possible damage to roads and bridges • Disruption to essential services (water, electricity, comms, schools, etc) • Mudslides rockfalls and soil erosion • Disruption due to sinkholes/potholes/ blocked drainage systems • Isolated incidents of communicable diseases • Isolated cases of breakages of informal/farm dam walls • Damage to mud-based/make-shift houses/structures • Disruption of access to drinking water and damage to crops	• **Widespread flooding** of roads and settlements • Danger to life (fast flowing streams / deep water) • Large communities not accessible/cut-off for a prolonged period • Widespread displacement of affected communities • Widespread damage to property, buildings and loss of livelihoods and livestock • Widespread transport routes and travel services severely affected • Major roads and bridges damaged or washed away • Widespread, prolonged disruption to essential services (water, electricity, comms, schools, etc) • Widespread mudslides, rockfalls and soil erosion • Long term disruption due to sinkholes/potholes/ blocked drainage systems • Widespread incidents of communicable diseases • Breakage of dam walls • Widespread damage to mud-based/make-shift houses/structures • Widespread disruption of access to drinking water and damage to crops

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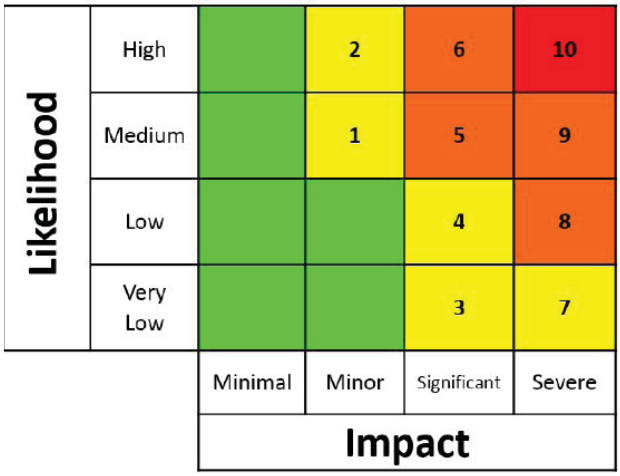
The forecast impact level is first determined based on impact tables that were generated in collaboration with stakeholders, including disaster managers from each district across the country, in months of workshops as part of the years of preparation before the 2020 launch. "It's not something we did overnight," she says. "It has been a long process."

SAWS level of impact



Based on Impact Tables (above is an example for rainfall), the most appropriate impact level is identified for the region. Meteorological systems will aid the forecaster to determine the expected likelihood that these impacts could occur. From this, the appropriate warning risk level is established (below).

For yellow warnings, disaster management at the district or provincial level might be consulted, but not necessarily. This is a key difference from the previous system. "Our relationship with disaster management has changed," Viljoen says. "We are literally on first-name basis with them. We can phone them any time, and they are waiting for our calls." In return, it has made our work in disaster management easier by providing ready access to professionally-developed, relevant information which can guide effective decision-making," according to the Mopani Disaster Management Center (in written replies).

Previously, disaster management was never consulted, Viljoen says. "We just issued warnings." Once a yellow warning is issued, disaster management also has the power to negotiate a downgrade or upgrade of the warning depending on the situation in real-time. The disaster manager might phone and explain that the situation on the ground is such that the danger is not that serious, and request the warning to be lifted. "We can talk to each other," Viljoen says.

Any orange and red warnings are discussed with district disaster managers prior to their issuance, in order for the impacts to be verified and evaluated before they are published in media reports and on social media. Just this morning, she says, disaster managers in the Western Cape sent her photos of the informal settlements in the province in flood. "Our rain gauges can't tell us that," she says, "but now we know that if there is even more rain expected, we might need to adjust the warning levels." In this case, the impact of 50 mm of rain in the Western Cape will be very different than 50 mm of rain in the Northern Cape, and the new system allows for that to be reflected, she explains.

Doubell adds that that is the strength of the system, that they now talk about the impacts that are expected. "We try to make people aware of what kind of daily activities they should be careful of when certain weather is coming."

The Orange Level 9 warning for KwaZulu-Natal and parts of the Eastern Cape issued by the SAWS on 12 April, for example, warned that "disruptive rainfall leading to widespread flooding of settlements, schools, roads, bridges, sinkholes, mudslides, soil erosion and major disruption of traffic is expected over the extreme south-eastern parts of KwaZulu-Natal."

Weather forecasters have had ample opportunity to test the efficiency of the system. Numerous extreme weather events have plagued South Africa since the 2020 launch. In November of that year, a tornado tore through Mbolompo (northwest of Mthatha) as multicell thunderstorms ripped roofs off homes, uprooted trees and caused heavy downpours and flooding. In January 2021 Severe Tropical Storm Eloise devastated parts of the South-East Coast of Africa. In January 2022, record-breaking temperatures were recorded during a heat wave in the Western and Northern Cape. In February 2022, Tropical Cyclone Batsirai bore down on the African east coast and a month later, Tropical Storm Gobe swept over the Mozambique Channel. June of this year saw a series of cold fronts make landfall over the western parts of the country that resulted in strong winds, high waves, light snow, a significant drop in temperatures and the heavy rainfall that caused the flooding that was brought to Viljoen's attention that morning.

However, the new system has proved its worth. In reply to how the impact-based system has impacted their work, the Mopani Disaster Management Centre replied: "Leading up to, and during, the heavy rainfall caused by Tropical Storm Eloise, regular updates received from SAWS assisted us in preparing in advance and establishing a JOC for joint decision-making. Using the already established Mopani RIMS (Road Incident Management System) network, weather warnings and updates could also easily be disseminated to first responders on the ground. This gave services the opportunity to prepare in advance ahead of the arrival of Eloise, ensuring that equipment was ready and sufficient staff were available."

Furthermore, "a great example of how the weather warnings were used to good effect was in the case of the Sanral-appointed RRMs (Routine Road Maintenance) teams. The RRMs worked to protect Sanral road infrastructure by ensuring that potential problem areas were addressed and storm water drains were all clean, especially along the Escarpment areas where the heaviest rainfall was expected. There is no doubt in our mind that this pre-planning prevented damage to key road infrastructure which keeps the local economy running."

Surveys that Viljoen conducted as part of her PhD research have provided more input on the impact of the system. Asked if people took any action because of the weather warnings, many responded yes. These ranged from taking their animals to higher ground when floods were expected to stocking up on groceries ahead of potential bad weather. Other people selected to work from home, or chose safer roads for travelling. A farmer reported organising alternative transport for workers that had to cross a

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low-water bridge flagged to be potentially affected by flooding. "We won't know for sure, but that could potentially have saved lives," Viljoen says.

Disaster managers, again, reported they kept equipment like chainsaws on standby due to the warnings. This could help them to quickly remove fallen trees blocking roads, for example, allowing emergency vehicles access to affected areas. "Those are the types of feedback we receive, and we feel that's exceptionally positive," Viljoen says. Still, she says, they are always trying to improve. Most of these efforts are geared towards better communicating the weather warnings and extending their reach.

On the ground during Cyclone Eloise

"We keep a careful watch on weather activity in the south-west Indian Ocean basin during the tropical cyclone season. Contact was established with SAWS a week before the onset of Eloise, which gave (disaster management) extra time to plan and prepare. As soon as SAWS confirmed that Eloise was going to track inland towards South Africa, those plans could be put into action and a Joint Operational Centre (JOC) was formally established. The JOC saw representation at management level from a variety of services and related departments or interested parties, including Disaster Management at local and district level, Mopani Fire & Rescue Services, Emergency Medical Services, South African Police Service, Traffic, the Kruger National Park, Department of Public Works, and Department of Water and Sanitation, Routine Road Maintenance (RRMs), among others. For the first time in our history, a virtual JOC had to be established due to the COVID-19 pandemic. Once established, the Mopani JOC joined the National JOC, which had been established by the National Disaster Management Centre, for presentations by national structures, including a crucial presentation from SAWS. Following this, a virtual meeting of Mopani JOC members was held to deliberate finer-detail planning specific to the Mopani District, with direct input from SAWS. Engagement was sought directly with managers before the establishment of the Mopani JOC to ensure full participation. The Mopani JOC and Mopani Roads Incidents Management System (RIMS) groups were then used jointly for the dissemination of further impact-based weather warnings and receipt of information related to incidents or flood damage. All flood-related incidents reported were captured in GIS. There was thus a continuous, uninterrupted flow of information up and down through various structures which facilitated a meaningful response, including the action taken by the RRMs to protect road infrastructure."

Source: Mopani Disaster Management Centre

Learning and improving

The SAWS remains a scientific organisation, Doubell says, and scientific organisations often struggle to communicate in simple language or to the media. "We're not really there for entertainment," Doubell says but she adds that they are also aware that they must lose a bit of their 'gravitas'. "It's a matter of obtaining a balance," she says. After all, she adds, "a large part of the system's success or failure is the public's capacity to receive and read it." The organisation is continuously trying different ways to do that better.

Some of the improvements SAWS has made since the launch of the new system are to use more graphics and less text in its warnings. Another potential improvement on the cards is voice messages translated into some of the country's eleven languages and sent directly to people's phones. The organisation is also conducting community outreaches and welcoming any traditional or technology-based communication channels. "We've heard that in certain villages in the Eastern Cape they use pots and pans to get the villager's attention, we can think we can even use that," Viljoen enthuses.

Timely warnings of extreme events will become even more important in future.

Cold snaps, rough seas and gale-force winds, bitterly cold weather, snowfall, flash flooding and thunderstorms are some of the many extreme weather terms that South African have already become familiar with and, it will likely increase. Following the April floods, the SAWS announced that as weather scientists, they cannot attribute individual weather events occurring on short timescales to longer-term events occurring over years or decades. However, they can state with confidence that globally, as a direct result of global warming and associated climate change, all forms of severe and extreme weather such as heatwaves, heavy rain, and coastal storm surge events are becoming more frequent and more extreme than in the recent past. "In other words, heavy rain events such as the current incident [in reference to the April KwaZulu-Natal floods] can rightfully be expected to recur in the future and with increasing frequency."

With more extreme weather in the pipeline, one has to remain on your toes, Doubell says. "You have to make sure that the information gets out there." We are entering uncharted territory when it comes to the anticipated impacts of climate change, the Mopani Disaster Management Centre representative adds but, "we do, however, believe that we are on the right track with the impact-based weather warning system and that this will grow and develop to keep pace with changes as they occur."

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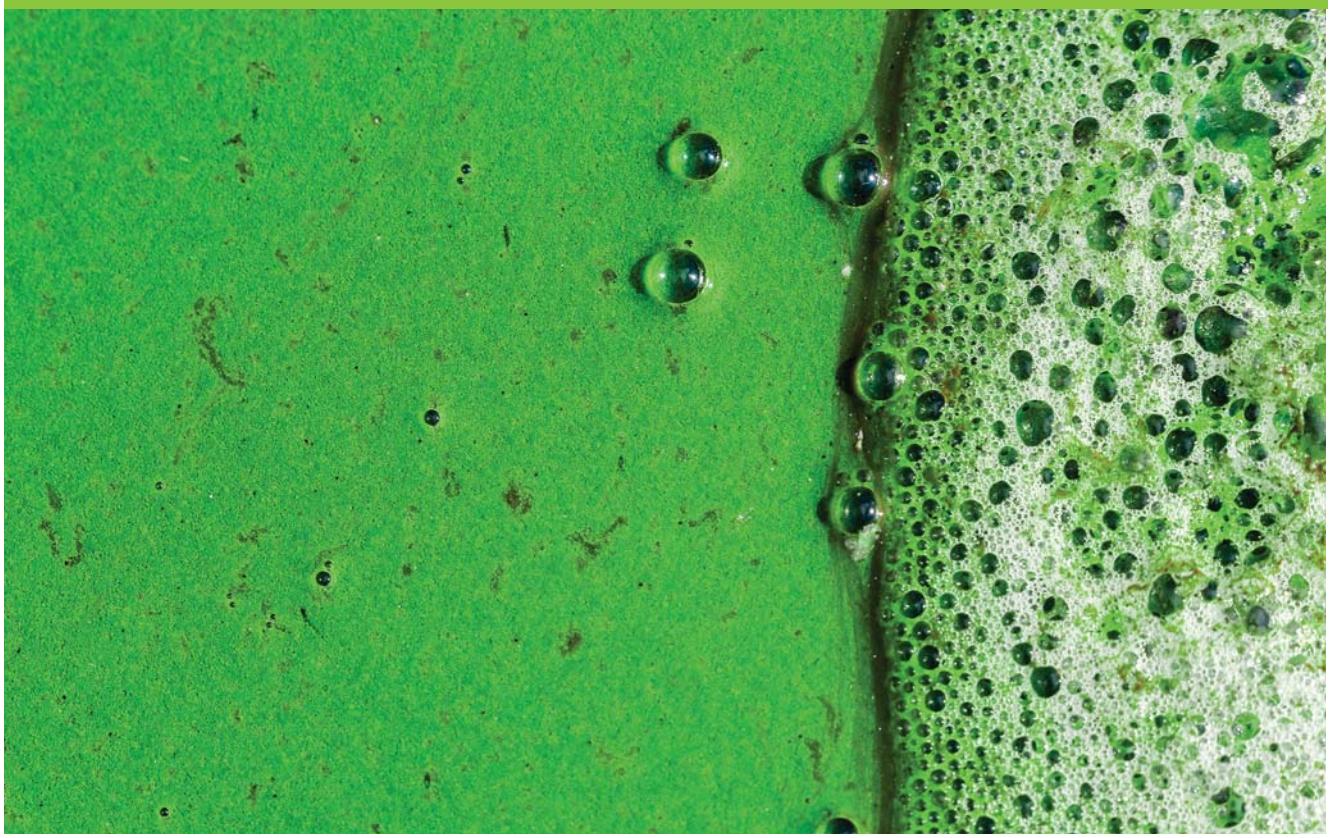
EUTROPHICATION

The CyanoLakes mobile app: Weather-like information for lakes from satellite imagery

Remote sensing scientist and founder and CEO of CyanoLakes, Dr Mark Matthews, reports on a new tool available for the monitoring of eutrophication in lakes and dams.



Cyanobacteria blooms and associated eutrophication in the world's lakes represent an increasing threat to safe water supply, recreational water users and ecosystems, and are worsening with climate warming. Cyanobacteria produce harmful toxins (cyanotoxins) associated with chronic diseases such as liver cancer, and acute poisonings of animals and rarely humans. Cyanobacteria are often the primary cause of nuisance taste and odor problems in drinking water. There is an immediate need for up-to-date information to protect public health and enable water companies, lake user associations and water professionals to respond to problem blooms in a timely manner with necessary interventions.

The CyanoLakes mobile app ('Your Weather App for Lakes') provides up-to-date weather-like information on cyanobacteria and algal blooms in the world's lakes from satellite imagery. The technology was funded by the South African Water Research Commission (**WRC Project No. 2019-2020-00198**), which has been funding research and development projects on satellite detection of water quality since 2015. The most recent project funded the development of the CyanoLakes mobile app (the app) to complement the CyanoLakes web app, a commercial product that is aimed at the public utility sector. The app, designed to make user-friendly information available to professional and novice users around the world, was released

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in November 2020 on both the App (iOS) and Google Play (Android) Stores.

Description

The app presents potentially complex information related to water quality in an intuitive easy-to-understand format similar to the way in which information is presented in weather apps (see Table 1 for an explanation as to what information it provides). The app features a dynamic graphic background corresponding to the most recent satellite measurements of chlorophyll-a and cyanobacteria presence giving the user an immediate sense of the likely water colour and clarity.

A user must add lakes to their app by selecting an existing lake from a map, or by dropping a pin to add a new lake.

The app currently handles lakes larger than 600 m^2. The user is able to add or remove lakes as needed, with a limit of four lakes that can be added at any one time for free users. By upgrading to a premium monthly or annual subscription, the limit on the number of lakes falls away, and the user is then able to access high-resolution satellite imagery (from Sentinel-2 satellites) and set notifications for updates and alerts for various bloom risk-level thresholds.

Table 1. Summary of information provided by the app

Parameter	Explanation
Chlorophyll-a concentration	The green pigment found in all plants and a robust proxy for algae and cyanobacteria abundance
Cyanobacteria cell count	The estimated cyanobacteria cell count derived from chlorophyll-a (2000 cells per 1 ug/L chlorophyll-a)
Potential ***microcystin*** concentration	The potential concentration of ***microcystin*** toxin (the most commonly occurring cyanotoxin) converted from chlorophyll-a (0.4 ug/L ***microcystin*** per 1 ug/L chlorophyll-a)
Cyanobacteria risk level	The risk level to human health from cyanobacteria based on World Health Organization guidelines
Pollution level	The trophic state or level of nutrient enrichment based on chlorophyll-a which is a robust proxy for pollution from human sources
Recreational advisory	An advisory for both full and partial-contact recreational water use
Area coverage for cyanobacteria, scum and vegetation	The overall area in percent of the lake affected by cyanobacteria presence, cyanobacteria scum or floating aquatic vegetation

The app uses the World Health Organization guideline (2003) values to derive health risk levels for recreational users determined by the concentration of chlorophyll-a from cyanobacteria (see Table 2 for how these risk levels are defined and Table 3 what them mean for recreational users). The cyanobacteria cell count and potential ***microcystin*** toxin concentrations are determined using conversion factors from the WHO guidelines, although these are not directly estimated from satellite. Similarly, the pollution levels are also derived from chlorophyll-a concentration using accepted OECD guidelines for lakes.

The recreational advisory is determined with reference to both the cyanobacteria risk level and pollution level to provide an advisory for both full-contact water use (e.g., swimming) and partial-contact water use (e.g., fishing). It is important to always follow advisories issued by your local authority, as guideline values differ between countries, states and territories. The information should also be used in conjunction with additional water quality information before determining safety for any use. More details regarding the thresholds used by the app and the information it provides can be found in the app's Frequently Asked Questions (FAQs) page.

Table 2. Cyanobacteria health risk levels presented by the app

Risk Level	Low	Medium	High	Very High
Chlorophyll-a (ug/L)	< 10	10 – 50	50 – 100	> 100
Cyanobacteria count (cells/L)	< 20 000	20 000 – 100 000	100 000 – 200 000	> 200 000
Potential ***microcystin*** toxin (ug/L)	< 4	4 – 20	20 – 40	> 40
Partial-contact recreation*	YES	YES	NO	NO
Full-contact recreation*	YES	NO	NO	NO
* US EPA guidelines recommend value of < 8 ug/L microcystin for recreational use				

Table 3. Explanation of cyanobacteria health risk levels

Low	No cyanobacteria have been detected from satellite. There is a **low risk** of adverse health effects from cyanobacteria. But since cyanobacteria can exist below the detection limit of the satellite, cyanobacteria may still be present. Recreational activities may be safe, provided that additional water quality information is first consulted and that any advisories issued by local authorities are followed. Routine sampling should be performed to determine if cyanobacteria are present.
Medium	Cyanobacteria have been detected from satellite at medium concentration. There is a **small risk** of adverse health effects, however high-risk individuals should avoid recreational activities. The water should be observed carefully for any areas of high concentrations that may form as a result of wind. Recreational activities may be safe for uncompromised persons, although full contact recreational activities such as swimming should be avoided. Additional water quality information should first be consulted, and any advisories issued by local authorities must be followed. Sampling frequency should be increased to monitor for the development of any accumulations.
High	Cyanobacteria have been detected from satellite at high concentrations. There is a chance you may experience adverse health effects from cyanobacteria. It is recommended that **all recreational activities be suspended**. Satellite imagery may be used to determine whether recreational activities can be continued in **medium or low** risk areas. Depending on the prevailing wind, dangerously high concentrations of cyanobacteria could form within minutes to hours. Frequent sampling should be implemented to monitor the situation.
Very High	Cyanobacteria have been detected from satellite at very high concentrations. There is an increased probability you may experience adverse health effects from cyanobacteria. It is recommended that a**ll recreational activities be suspended**. Satellite imagery may be used to determine whether recreational activities can be continued in **medium or low** risk areas. Cyanobacteria scums are likely to be present which may contain high concentrations of cyanotoxins that could cause acute poisonings of animals. Frequent sampling should be implemented to monitor the situation.

The app's information is derived from multiple satellite sensors, including the Sentinel-3 Ocean and Land Color Instrument and Sentinel-2 Multi-Spectral Imager of the European Space Agency Copernicus Mission. The information is updated daily, however, seasonal changes in cloud, ice or snow cover may reduce the number of updates. Information is typically available within three hours after the satellite image is acquired on the same day. The app is similar to the US Environmental Protection Agency's CyAN App (available on Android and web) but differs in the design, functionality and information it provides, its daily update frequency (as opposed to weekly updates), the availability of high spatial resolution imagery for subscribers, and in being available for lakes worldwide and not only in the United States.

Use and availability

The app, which already has 1 000+ downloads across iOS on Android, is being used by both recreational water users (sailors, fisherman, boaters), lake user associations and water utility companies to improve their knowledge of prevailing conditions in lakes. It is helping recreational water users to steer clear of potentially dangerous blooms and pollution problems, whilst also helping utilities improve decision making for water treatment and ecological management. The app can be downloaded free from the Apple App Store and Google Play Stores.

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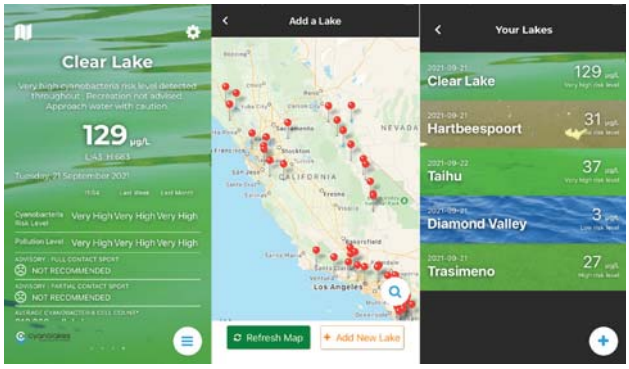

Screenshots from the app showing (from left) the home page, add a lakes page and the list view.

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CAPACITY BUILDING

South Africa completes comprehensive tracer study on the country's PhD graduates

A survey of doctoral graduates from South African universities for the period 2000–2018 has yielded important demographic data, as well as useful insights on PhD financing and subsequent employment. Article by Sue Matthews.

For those of us with a biological or environmental science background, some of the findings of South Africa's first comprehensive National Tracer Study of Doctoral Graduates may come as a surprise. We've seen how students in these fields typically progress straight from undergraduate to postgraduate degrees, perhaps taking a gap year for overseas travel (pre-pandemic) before they embark on an MSc, but also often upgrading the MSc to a PhD to have earned the title 'Doctor' by their late twenties. Their studies have generally been funded by the National Research Foundation (NRF) bursary scheme, sometimes with top-up from supervisors' research grants, generous parents, or piecemeal work on- or off-campus.

By contrast, the Tracer Study found that the average age of doctoral graduates from a range of disciplines over the past two decades was around 40, the majority (61%) studied part-time, and were funded through either self-financing (33%) – including bank loans and financial support from family members – or assistance from their university (30%). Only 22% relied on bursaries and scholarships from national funding agencies.

The Tracer Study was funded by the Department of Science and Innovation (DSI), managed by the Water Research Commission (WRC), and executed by a project team from Stellenbosch University's DSI-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy, under the leadership of Prof Johann Mouton.

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"The number of PhD students graduating from South Africa's public university system has more than doubled from around 1 400 PhDs in 2010 to about 3 400 PhDs in 2019, but what has not been certainly established are the career pathways, mobility and impact of the cohorts of these PhD graduates, both South African and foreign," says Bheki Hadebe, DSI Director: Research Development. "The study was therefore commissioned by the DSI to explore the above question with a view to inform policymakers, funders and the public about the benefits of continued investments in doctoral education."

But how did the WRC come to manage this cross-disciplinary study? John Dini, Research Manager: Water Governance, explains: "The idea for a national tracer study of all PhDs from South African universities was born in another project funded by the WRC, focusing on water PhDs. This project examined the paths taken by students graduating with water-related PhDs between 2013 and 2017 (**WRC Report no. 2851/1/20**). The DSI was part of the reference group for this project, and after its completion was curious as to whether the water sector results were indicative of PhDs across all sectors and disciplines. As a result, DSI decided to fund such a study and asked the WRC to manage it on their behalf."

The earlier water-focused study identified 112 doctoral graduates in the water and sanitation field and received questionnaire responses back from 48 of them. For the more recent, broader study, over 15 000 doctoral graduates were emailed the link to a Survey Monkey questionnaire, and almost 6 500 responses were received. In addition, the project team conducted 113 in-depth interviews with respondents drawn mainly from the water sector.

The vast majority of the doctoral graduates indicated satisfaction with their decision to do a PhD, but extracts of questionnaire and interview responses contained in the report reveal a range of perspectives and experiences. Some were positive, with respondents highlighting the advantages of their PhD.

"It's opened up new doors. I would not have had the job opportunities that I've had, and the learning experiences that I've had, if I hadn't done it. It's definitely been a gateway for me," said a senior research fellow at a university.

"It also gives you a level of confidence in how you approach issues," according to a science council manager. "And believe it or not, it helps gain a little bit of respect and cooperation because your team members, whether they're older or younger than you, are comfortable that you know what you're talking about."

But some were clearly disappointed that all their hard work had limited their options somewhat.

"It's not easy to get employment because you find that other companies, like private companies that deal with water, rarely hire people who have reached the level of PhD. They rather hire people who have attained their diplomas or degrees and then they train them for the job," said one senior lecturer.

"I embarked on a PhD late in life as a 'bucket list' item, something that I did to satisfy myself and I achieved that. What I did not anticipate was that once I became 'Dr' I became immediately unemployable. Despite my broad industry experience, academia appears only interested in published articles and teaching experience, while industry appears unwilling to pay the extra dollar for a PhD," said another survey respondent.

Although only 2–3% of respondents indicated that they could not find employment within a year of completing their doctoral degree, nearly one in five could not find a position related to their field of expertise. Further analysis of the data showed that this has been more of a problem for those who received their doctoral degrees in the past five years, compared to 15 years ago, and that social science and humanities graduates were more affected than STEM graduates.

"These results are interesting and pose challenges to policy," note the project team. "Even though South African doctoral graduates are successful in finding employment, they are increasingly indicating that the employment is not what they expected or wanted."

More than 50% of the respondents had found employment in academia, but most had already been employed in the sector while doing their PhD, and typically just remained with the same employer. Many of the rest (about 20% of all respondents) had accepted a postdoctoral fellowship, and one in three became "serial postdocs", something that the project team points out is a symptom of a saturated system. Graduates in the biological and environmental sciences, and those aspiring to find a permanent position in academia, are particularly affected.

"Although our results show that such fellowships carry benefits, other results lead us to conclude that the South African science system is reaching capacity in its ability to absorb increasingly younger graduates, whose lack of full-time employment options lead them to apply, often repeatedly, for a finite number of postdoctoral fellowship positions."

About 70% of respondents indicated that a doctoral degree is a requirement of their current employment position, but this applied more to those in the higher education sector (83%) than the government sector (53%). When asked to rank the application and utilisation of five different aspects of their doctoral studies in their current employment, the general knowledge they acquired – such as critical thinking and academic writing abilities – came out tops, closely followed by research skills and expertise. Not surprisingly, their own PhD findings ranked lowest, more so for those who had completed their degree many years ago. Just over half of the respondents indicated that their jobs involve substantial managerial responsibilities.

As for concerns about "brain drain" from South Africa, the study found that South Africa has, in fact, benefitted from the inward flow of doctoral students.

"Of the 3 770 graduates in our sample who were born in South Africa, 372 or 9.2% left the country after graduation. At the same time, of the 1 812 graduates in our study who came from outside the country, 633 (or 35%) remained in the country. This translates into a net brain gain of 261 graduates or 4.6% of our sample," note the project team. "If we average this out over the past twenty years, it means that South Africa has a net gain of 1 400 doctoral

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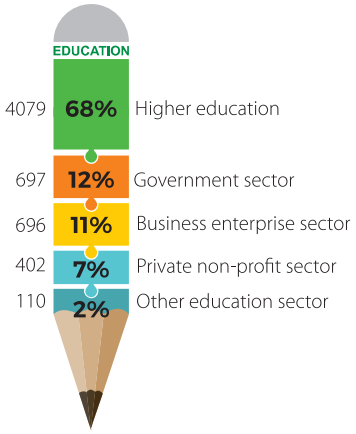
graduates from other countries who remained in the country after subtracting those South African nationals who left the country."

The project team explore the data in greater detail in the research report, providing considerable insight into gender- and race-based differences, among other things. They conclude with a number of recommendations for further research and dialogue, and also make a strong case for a policy review, pointing out that South Africa currently has (a) too few full-time doctoral students who are (b) properly funded and (c) able to commence and complete their doctoral studies at a much earlier age.

"From a policy point of view, these facts call into question some of the rules of the most recent NRF funding policy that focuses exclusively on students who study full-time (the minority in the system), who are not older than 32 at commencement of studies (again the minority of students across all disciplines) and also to ignore (for all practical purposes) the huge contribution that non-South African students (more than 30% of all doctoral students are from the rest of Africa) have made to our higher education and science system," they note. "We therefore strongly recommend that the NRF revisits and revises their current policy to take these facts into account."



Where are PhD graduates employed? Nearly two thirds of study respondents were employed in the higher education sector at the time of the survey and have remained in the sector.

South Africa has benefitted significantly from the inward flow of doctoral students to the country. While 9.2% of South African PhD graduates had left South Africa, 35% of graduates from other countries had remained.

Water sector findings

In an appendix to the research report, the project team provide a separate analysis relating to doctoral graduates in the water and water-related sector, which made up 220 of the almost 6 500 respondents. Of these 220, two-thirds were male, with females in the water sector being slightly underrepresented compared to the main sample. This finding was not unexpected as the same trend is evident for STEM disciplines as a whole.

"This, however, sends a signal to the WRC that it could play a stronger role, through its support to postgraduate students, in bringing about gender parity in disciplines that remain male-dominated," says WRC Research Manager John Dini.

The analysis also revealed that water graduates are, on average, four years younger at the time of completing their doctoral degrees when compared to the total sample, probably because they are more likely to study full time. There are higher percentages of international students, especially African students, suggesting that the water sector is providing training and skills in a strategic area of specialisation.

The findings showed water graduates are more likely to accept a postdoctoral position on completion of their doctoral studies, and many do more than one. An analysis of the type of employment held by water graduates revealed that they are more likely to be involved in technology development, innovation or entrepreneurial activities. As for the utility of skills obtained during the doctorate, water graduates considered the findings of their PhD to be less useful in their current employment compared to other graduates. Generally, however, the trends observed in the employability of graduates in the water sector are comparable to that of the overall sample.

"The study is of benefit to the WRC in a number of ways," says Dini. "It shows that the investment by WRC in building capacity, in the form of supporting postgraduate students (PhDs in this case), has delivered returns. This is reflected in the high rate of employment of PhD graduates generally, and water PhDs specifically, their low rate of migration out of the water sector and the net brain gain within the country. The findings do, however, suggest that some water PhD graduates may struggle more to find work related to their field of study than graduates in other disciplines. There are signs that the market has reached saturation for certain types of skills."

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ENVIRONMENTAL DISASTER RISK

Flood hazards in a changing world: Challenges and opportunities in the Garden Route

Article by L Smith-Adao, R Blanchard, I Kotzee, D Le Maitre, P Ntshotsho, M Audouin, G Forsyth and M Walters

In its 2022 Global Risks Report, the World Economic Forum states that environmental concerns dominate the top five long-term risks (in terms of likelihood) with three of them also being among the top five in terms of impact. Biodiversity loss and ecosystem collapse, as well as climate action and adaptation failure and extreme weather are highlighted as the top three environmental risks over the next ten years. Anthropogenic environmental disasters, natural disasters and water crises are expected to have significant impacts on economic stability and social cohesion over the next decade (World Economic Forum (WEF), 2022).

A disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk. Risk is the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between human-induced or natural hazards (i.e., a potentially damaging physical event such as floods, droughts and wildfires) and vulnerable conditions. A hazard can be specified as a potentially damaging physical event, phenomenon, or human activity. Natural hazards can be classified as geological (e.g., earthquake and landslides), hydrometeorological (e.g. floods and wildfires or veldfires) or biological (e.g. epidemic diseases and insect plagues) (Baas et al., 2008; Abbott and Patrick, 1996).

In developing countries like South Africa, natural disasters can have a profound effect on human well-being, the economy, and the natural environment. This vulnerability of developing countries to climate-related disasters is thought to be attributed to poor adaptation strategies (i.e., typically a lack of financing for climate change adaptation) (Nyahunda and Tirivangasi, 2019; Ndaki, 2014). Natural disasters can cause the destruction of property, loss of financial resources, and personal injury or illness. Economic impacts include, for example, the loss of income, reduced tax revenue, loss of infrastructure and the expense of reclamation efforts. Many local communities experience significant economic losses, such that recovery becomes difficult and protracted, if not impossible (Matlakala et al., 2021). However, some communities do find opportunity in the aftermath of a disaster to rebuild better and stronger than before. In addition, ecosystems can be destroyed or suffer severe damage by a single disaster event (e.g., unseasonal wildfires) and may take years to recover.

The information captured across these different sources assists researchers in identifying drivers of impact or change (e.g., change in climate variables or land use change) and to prepare for future events by identifying the strategies needed to reduce these impacts. Anticipating and planning adaptive strategies to deal with risk in future is therefore very important (Hulme, 2005). For example, the lessons learnt following the Knysna veldfires in 2017 include improving disaster preparedness, disaster response times, risk identification, overall hazard reduction and increasing resilience. These fires were arguably the worst wildfire disaster in South Africa's history (Forsyth et al., 2019) with 973 homes destroyed and 560 houses damaged; about 2600 people displaced and roughly 2000 jobs affected. It was reported that the towns of Bitou and Knysna had municipal infrastructure damage of R 66 million while 15 700 ha of pine plantations were destroyed (EDM, 2018). Insurance claims amounted to around R2.5 billion (Forsyth et al., 2019). We should not have to wait for a disaster to occur to have the necessary processes in place to reduce detrimental impacts.

When it comes to flood hazards in South Africa, many rivers are already under stress due to excessive water withdrawal and land development in floodplains. Climate change with its potential to alter rainfall, temperature and runoff patterns will only magnify these existing risks (Palmer et al., 2009). By identifying and prioritising actions that can be taken now to enhance the resilience of urban ecosystems in the face of disturbance we may minimise impacts accompanied by severe flooding in future. To minimise the risks posed by extreme flooding we can take proactive or reactive measures. Proactive measures are actions that, if implemented, will improve the capacity of river systems to absorb disturbances while minimising threats to the environment and human populations. Whereas reactive action involves responding to problems as they are generated by repairing damage or by mitigating ongoing impacts. Currently, we are not adequately prepared to pre-empt the impacts (i.e. respond to floods and their accompanying risks) and are forced

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to respond to the flood risks reactively. The problem with solely using this approach is that it can be very expensive and may result in species loss, infrastructure damage and loss of human lives. The ideal is to be able to anticipate change and adapt flood management to those changing circumstances, whilst having disaster relief, flood control infrastructure and evacuation plans in place.

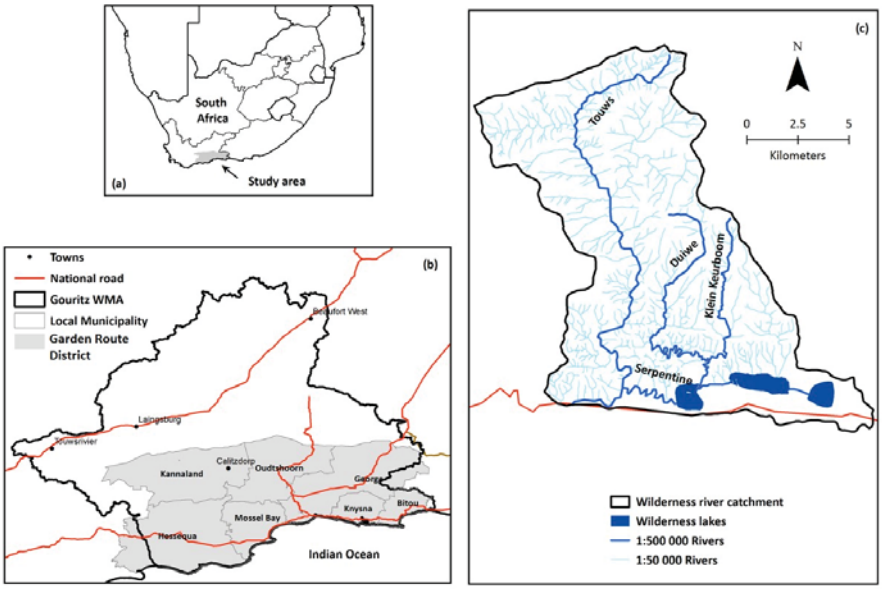
Historical records, hazard modelling, early warning systems and simulations can help to identify areas where disasters are likely to occur and the impact they might have. These hazard or risk maps facilitate planning at all levels of government and society. The Council for Scientific and Industrial Research (CSIR), in partnership with the National Disaster Management Centre, recognised the importance of finding innovative ways to reduce risk. They developed an open access online applied knowledge resource, called the Green Book (visit www.greenbook.co.za). This multi-disciplinary disaster risk profiling and adaptation tool provides a municipal overview of hazard profiles as well as available resources to minimise these hazards. Its goal is to contribute to sustainable, resilient, and liveable human settlements through climate change adaptation. However, such tools are all dependent on having relevant and up-to-date information and people who understand how to use the tools to identify and implement adaptation and mitigation measures.

Using the Garden Route, situated in the Western Cape Province of South Africa, as a case study we highlight how historic and desktop data can be used to identify flood hazards, as well as inform the development of mitigation and adaptation strategies to address such hazards. The research approach involved a combination of modelled, observed, and measured data. Datasets from a wide range of sources were integrated. The analysis in the study focuses on two scales: district level (Garden Route District Municipality) and catchment level. The former involved a flood risk assessment while the latter sought to examine historical rainfall and streamflow changes (i.e., identify extreme flood events) in the Wilderness River Catchment.

Location of the study area

The Garden Route is situated in the Garden Route District Municipality (23 321 km^2), Figure 1b. The District Municipality comprises seven local municipalities (i.e. Bitou, George, Hessequa, Kannaland, Knysna, Mossel Bay and Oudtshoorn) and is well known for its diverse natural areas in the form of nature reserves, national parks and unspoilt coastline (Eden District Municipality (EDM), 2008). Most of the area's vegetation is still unconverted, with 64% consisting of indigenous fynbos and the remainder comprising Succulent Karoo, and Albany Thicket (Mucina and Rutherford, 2006). The Wilderness catchment (178 km^2) forms part of the Garden Route coastal catchments (Middleton and Bailey 2009), Figure 1c. The area is ecologically sensitive and has a rich biodiversity which include the Wilderness Lakes system, a Ramsar site protected in the Garden Route National Park (Cowan and Marneweck 1996; Russell, 2013). This catchment can be divided into two main sub-catchments, the Touws River including the estuary (102 km^2), and the Duiwe River which feeds the lakes (± 73 km^2).

Figure 1: Location of the Garden Route study area within the southern cape region of the Western Cape Province, South Africa (modified from O'Farrell et al., 2015).



Modelling flood hazard in the Garden Route

Very high or prolonged rainfall (i.e. intense rainfall) events often leads to flood discharges (Smithers and Schulze, 2004; Goudie, 2006). Rainfall in the Garden Route occurs throughout the year, but peaks in March and October (Reyers et al., 2015). Around one in five cut-off low events over Southern Africa typically results in flooding and associated damages to the coastal areas of the district (Holloway et al., 2012), which is often exacerbated by the steep catchments in the coastal areas resulting in high runoff and flash flooding (Nel et al., 2014). Likewise, the shallow soils and limited groundwater storage of the TMG quartzitic sandstones make the river flows highly responsive to rainfall events. Early studies have shown that landscape drivers of run-off can halve the return period of a flood event, and that managing ecological landscapes (e.g., riparian buffer zones) is a key risk management and climate change adaptation mechanism (Le Maitre et al., 2011).

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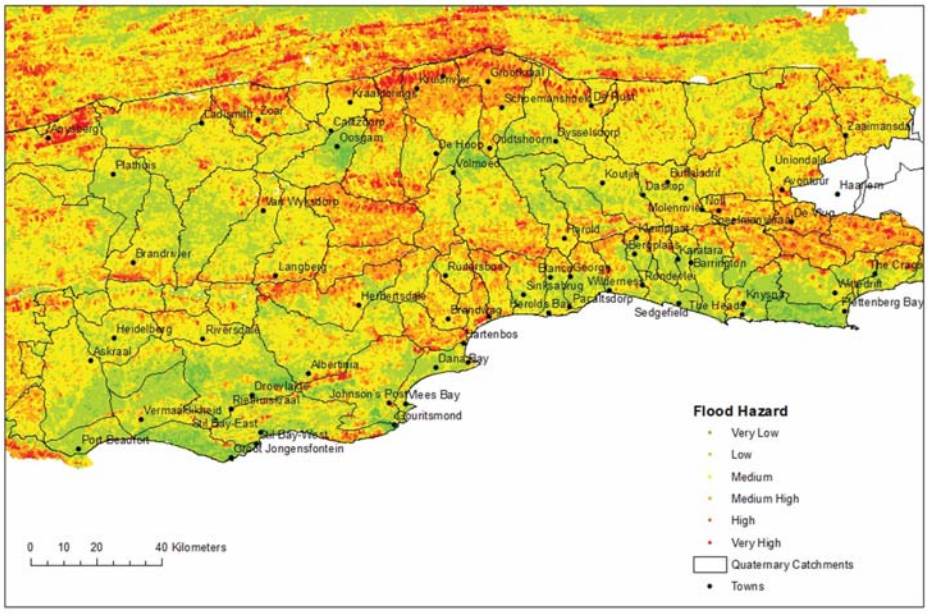
The Sensitive Catchment Integrated Modelling and Analysis Platform (SCIMAP), a decision support tool developed by the Durham and Lancaster Universities along with the British Environment Agency (http://www.scimap.org.uk/) was used to model flood hazard based on the catchment characteristics. Data inputs include a 30 m DEM, national land cover map, design rainfall for a 50-year return period and hydrological soil type data. This model was chosen as it can be applied to catchments with limited data using global, regional, and local datasets. Results of the flood hazard, as based on the SCIMAP model, is shown in Figure 2. The model shows a landscape view of the associated flood hazard which allows for understanding across a catchment and to identify areas that are most likely to generate flood water during a storm event.

According to the model output a band of very-high to medium-high flood hazard can be found along the Langeberg mountains which separate the coastal area from the Klein Karoo and the small coastal catchments of the Garden Route (e.g., Mossel Bay, George and Wilderness). Very-high to medium- high flood hazard areas are also found in the inland area of the Klein Karoo catchments of Oudtshoorn, Calitzdorp, Zoar and Ladismith and Anysberg. The Wilderness Catchment is shown in detail to illustrate the outputs of the model which is represented at a point scale (Figure 3b). In this zoomed in view very-high to high flood hazard zones are displayed along the Touws River, and which is the main river system (240.7 km in length) in the catchment (Figure 1c). High flood hazard is also shown along the tributaries of the upper part of the Duiwe river, as well as the tributaries surrounding the wilderness lakes. Prioritising and targeting these areas for mitigation actions can be an effective way to reduce damages. Understanding the nuances of flood

Figure 2: Flood hazard for (a) the Garden Route District and (b) Wilderness River catchment based on the SCIMAP model.

a



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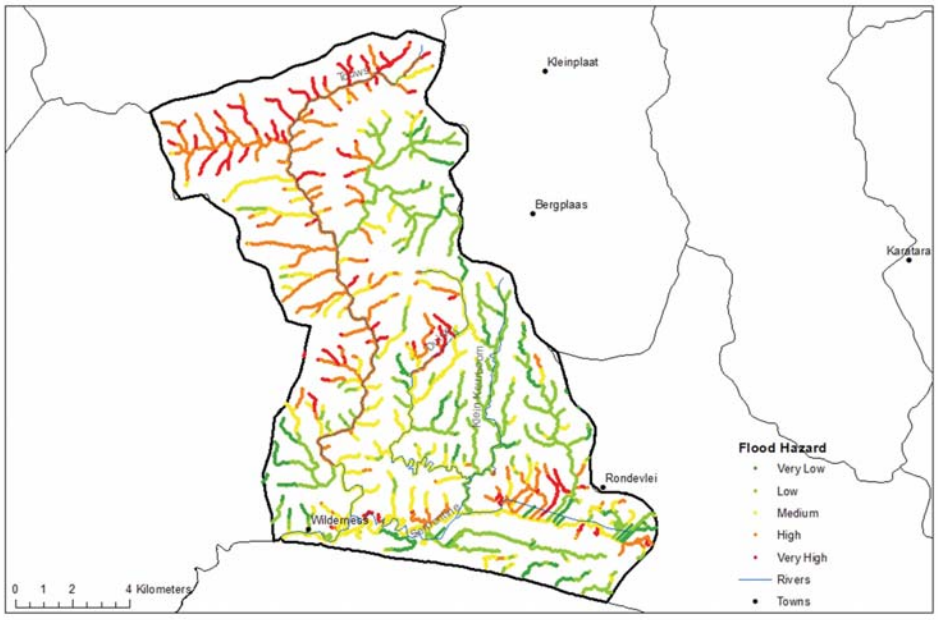

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Understanding the nuances of hazard areas in the Garden Route

Another useful measure of the flood risk is based on the record of observed floods and measured heavy (50 to < 100 mm) to extreme (≥ 100 mm) rainfall events. Spatial data on flood hazard was assessed by examining and interpreting hydrological information (i.e., rainfall intensity and duration as well as flood magnitude and frequency) obtained through historic rainfall (daily measurements from the SAWS and private landowners) and streamflow records (i.e., monthly, and yearly weir gauge measurements from the DWS). Note that < 75% of mean annual rainfall (i.e., dry years) suggests droughts while > 125% of mean annual rainfall (i.e., wet years) suggests floods (after Laing, 1992; Vogel et al., 2000). Existing data gaps were mainly dealt with by combining datasets (i.e., to obtain a complete as possible dataset) were the station data time series overlapped (e.g., Woodville (Bos) and Tura-Kina rainfall stations).

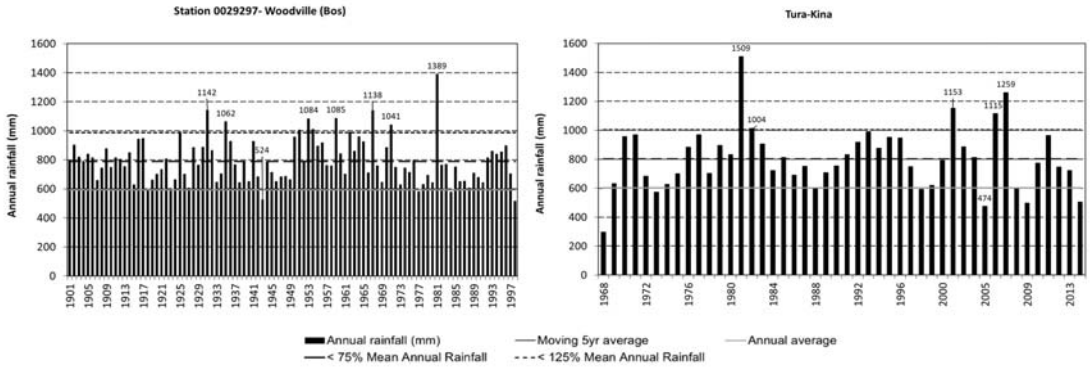
The results showed that the study area is subject to regular floods (Figure 3) related to the drivers of severe weather, land use change and alien plant invasions. In Wilderness extremely wet rainfall years are quite frequent with heavy to extreme rainfall years occurring at least once in every 10 years (e.g., 1959, 1969, 1971 and 1981), Figure 5. The peaks in rainfall often coincide with cut-off low pressure systems which are often associated with extreme weather events (Holloway et al., 2012). Beaumont (1981) reported that the removal of catchment and channel vegetation typically increased large flood events. A case study in a lakeside urban plain found that changes to plantation forestry management altered the 1:100-year flood events to a 1:80-year return period (Nel et al., 2014). Agricultural activities associated with crop cultivation and plantation forestry have transformed 18.6% of the landscape in the Garden Route District. The Klein Keurbooms River channel (27.86 km, location as per Figure 1c).

Figure 3: Flooding in the Duiwe River catchment illustrating channel morphological changes, Wilderness.

The Klein Keurbooms River channel (27.86 km, location as per Figure 1c). before the June 2011 flood (a), the channel during the June 2011 flood (b) and the channel after the June 2011 flood (c). Photographs by Mr Roger Titley (Beyond the Moon Guesthouse, Wilderness).

The remaining areas have been transformed by alien plant invasions (e.g., pine trees and black wattle) and rapid urban expansion that results in land use change seen in increased pressure for housing development and associated infrastructure. Invasive species are important variables key to modifying river flows and affecting sediment erosion and deposition thereby influencing floods of differing magnitude and frequency (Figure 3). These species may alter channel bank resistance and stability, overbank hydraulic roughness and sedimentation and channel morphology (Smith-Adao and Scheepers, 2017). Hence, substantial control and invasion management efforts are required.

Figure 4: Annual rainfall in Wilderness.



Data sources: The South African Weather Service and private landowner, Mr Karl Reitz (Tura Kina Farm).

Figure 2b indicates that the Touws River has a high flood hazard potential. This river system has no dams or major abstraction points above the gauging weir, and flows are largely natural. However, plantations in the upper catchment influence the flows in the Touws River although large areas have been cleared or burnt in recent years. The river is highly responsive to heavy rainfall with very marked peaks in the months that are particularly wet with much lower flows in most other months. We can see this in the yearly streamflow for the Touws River (Figure 5).

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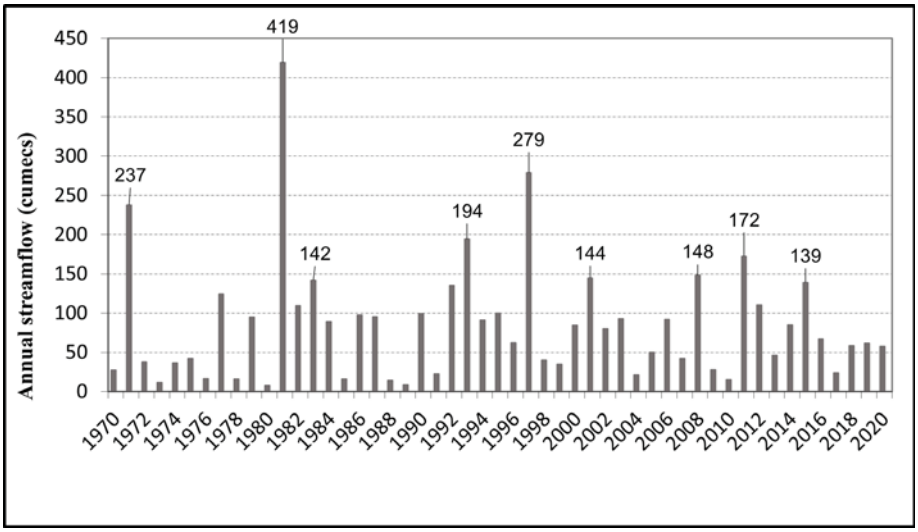
Figure 5: Yearly streamflow for the Touws River, Wilderness.



Data source: The DWS (visit https://www.dws.gov.za/Hydrology/Verified/hymain.aspx).

High magnitude flows (> 130 cubic metres per second [cumecs]) were encountered during the years 1971, 1981, 1983, 1993, 1997, 2001, 2008, 2011 and 2015 (i.e., on average twice a decade). A flood event of 419 cumecs (i.e., similar to the May 1981 flood in this area) can be expected to occur once in 100 years. When data on rainfall, streamflow and major floods in Wilderness were cross-checked, there was a general concurrence. However, not all major rainfall events resulted in flooding (i.e., catchment characteristics such as preceding rainfall and surface hardness play a role). The results from CAELUM database showed no flood records within this catchment over the time period studied. It must be noted that is mostly related to a data quality issue with regards to location accuracy (e.g. place names and accurate coordinates).

Challenges in the Garden Route

Data collection and monitoring

Good progress was made in the assessment of water resources in South Africa over the past 60 years with exponential growth in computational processing power (i.e., high performance computing) and the associated development of highly sophisticated new tools. Two of the primary sources of hydrological data are rainfall and river flow. However, the main worry in recent times has been the serious decline in hydrological monitoring. This includes for example, the low and declining number of weather stations across the country (Foden et al., 2019). This trend can also be seen in the Garden Route where the river systems have very few gauging weirs. Rainfall and steamflow data limitations hampered the identification and verification of extreme events in this study. In general, this speaks to a data gap which is either costly to overcome or indicate that the data is simply not available for the area of interest.

If we examine the number of useful rainfall and flow gauges open, there is a serious cause for concern. Pitman (2011) showed a decline in numbers from a high around 1970 to only about half of that in 2004 (i.e., since 1990 there has been a steady decline), which is roughly the same number of stations as in 1920. Rainfall is the most important and shows the biggest decline in terms of rainfall stations which have closed down. This is a major problem If this trend continues as rainfall is the primary input to any rainfall runoff model. At present there are over 2000 flow-gauging stations in South Africa. However, many are in a state of disrepair, preventing vital flow data from being collected (Job et al., 2019). This deterioration of data makes it harder for hydrologists and water resources practitioners to enter data of the necessary quality into water resource models. It is imperative that this decline be addressed, especially if we are to deal effectively with problems related to natural hazards and climate change adaptation. We also cannot monitor each catchment through in situ measurements, therefore complementary modelling supported by reliable data would be critical.

Funding for monitoring

While South Africa has some robust biodiversity and advanced monitoring programmes, many are dependent on state funding and capacity to execute. Existing monitoring programmes (e.g., National Aquatic Ecosystem Health Monitoring Programme (NAEHMP), which is focussed on rivers) need to be refocused and capacitated. These efforts should be linked with international efforts and should take advantage of new methods and innovative technologies. As critical as ensuring the continuation of the current suite of monitoring programmes, is the need to analyse and incorporate this information into focussed management and implementation plans, which can interpret, respond and adapt to the latest monitoring results as they become available. Monitoring is essential for detecting change and to address uncertainties, particularly with the increased impacts resulting from climate change and the effectiveness of measures taken to minimise the impacts.

Importantly, we need to maintain, enhance and expand time-series monitoring efforts and improve our understanding of change to enable effective adaptation measures. Given the numerous interventions in place and the complexities of implementation, gauging success, failure or impact of any particular intervention requires a broad evaluation protocol.

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The protocol should contain a suite of indicators that measure the effectiveness of the interventions against both hazard and socio-economic (e.g. cost efficiencies) objectives. In addition, restoration interventions on rivers for example, that are implemented to manage and conserve these ecosystems, are often not monitored, which makes adaptive management of the activities near impossible. This includes Environmental flows from many public dams. Cooperative governance, research and citizen science are key elements of successful hazard monitoring.

Future change: Natural hazards are increasing

According to regional climate change scenarios, climate change is unlikely to affect South Africa in a uniform manner. 'Hotspots' of concern have been identified in the south-west of the country, the west coast, and, to a lesser extent, the far north of the sub-continent (Dallas and Rivers-Moore, 2014). Warming is expected to be greatest in summer, followed by autumn, winter and then spring (Kruger and Nxumalo 2017). Regionally, the inter-annual variability of rainfall is projected to increase with more irregular events in the southwest. Seasonal rainfall is changing with regards to onset, duration, intensity, dry spell frequencies (Niang et al., 2014). The prediction for South Africa is an increase in between 2°C and 4°C by 2050, and at worse, up to 8.5°C in the interior. Intensification of droughts due to reduction in rainfall and/or increased evapotranspiration are made with medium confidence (Davis-Reddy and Vincent 2017). Shifts in rainfall, air temperature and evaporation will have a direct impact on water availability, both surface and groundwater. The main impacts include changes in runoff patterns such as mean runoff volumes, flow variability, duration and timing and changes in groundwater recharge rates (Dallas and Rivers-Moore, 2014).

In South Africa, these shifts will be exacerbated by the fact that the region has a low conversion rate of rainfall to runoff (9% on average) and groundwater recharge of 55% on average (DEA, 2013), and very high inter-annual climate variability (Stuart-Hill et al., 2012). There has been a general trend of increased frequency of extreme rainfall events (20 mm of rain falling within 24 hours) in the latter half of the 20th and early 21st centuries, but these show no clear spatial coherency (De Waal et al., 2017). Likewise, there is likely to be an increased frequency and intensity of extreme weather events, including very hot days (i.e., > 35°C) (Davis-Reddy and Vincent 2017) and heat waves (Engelbrecht et al., 2015), and other events such as rainstorms (i.e. low confidence and storm surges. Climate-induced shifts in the water cycle will also result in more frequent and intense periods of flooding and drought. Nel et al. (2014) showed that climate change in the Garden Route will increase the frequency of all natural hazard events examined, substantially so in the case of floods, droughts and storm-waves and to a lesser extent for wildfires.

Opportunities in the Garden Route

Natural hazards can be reduced by appropriate land management

Nel et al. (2014) indicated that through appropriate and pro-active land use management, it would be possible to reduce the impacts of natural hazards to a large degree. Clear-felling of timber plantations should ideally be associated with rehabilitation and re-vegetation to avoid increasing the flood hazard. Because the timber plantations (mostly Pinus sp) are similar to dense stands of invasive alien trees, the flood model also supports the clearing of invasive alien trees to reduce the hazard posed by flood events soon after a wildfire. The impacts of climate change can be substantially reduced by clearing invasive alien trees and restoring the indigenous vegetation which is also an effective tool for reducing wildfire and drought hazards. Invasive alien plants (IAPs) are a key threat to rivers and their riparian areas as they alter hydrology as well as nutrient accumulation and cycling. Riparian invasions are also less stable during floods and the debris that is washed down can block infrastructure (O'Farrell et al., 2015). The costs to clear existing invasive alien trees in the Garden Route are much smaller than the estimated losses caused by damaging wildfires to, for example, timber plantations (Nel et al., 2014). We must offer mechanisms and incentives for appropriate land management in these areas providing a stimulus for the implementation of effective integrated catchment management. More importantly, conceptualize and engage with catchments as social-ecological systems.

Similarly, the management of hydrological connectivity is a crucial component of land management activities, notably through the use of buffer zones to protect river systems but also through the flood pulse concept (Junk et al., 1989) which recognises the biophysical benefits that can accrue from maintaining connectivity between the river and its floodplain (i.e. the lateral exchange of water, nutrients and organisms between the main river channel and the connected floodplain). The uncontrolled spread of alien invasive plants in riparian buffer zones poses a significant risk to water-based ecosystem services (i.e. plants reduce overall water yield due to increased evapotranspiration). Lane et al. (2003) using the SCIMAP model investigated the role of upland shallow surface drains, along with observed changes in rainfall patterns, in relation to flood generation and linkage between river and floodplain in relation to flood risk. Localised sources of overbank flow which diffuse across the floodplain were identified. There is a clear spatial variation in inundation depth that is strongly related to extant land use. The model provided a more cost-effective flood defence design through the spatially explicit treatment of the inundation process. Therefore, tools like SCIMAP are required if we are to develop truly integrated approaches to collaborative catchment management that escape the problems of current sectoral concerns. A sectoral approach involves exploring all dimensions of a problem such as flooding in relation to possible causes like land cover and climate change (Lane et al., 2003).

Ecosystem-based adaptation

The incorporation of ecosystem-based management approaches, in tandem with other approaches (e.g., mitigation or engineering responses), into disaster risk reduction and climate change adaptation is crucial, there is a need to build an evidence-base. Disaster Risk Reduction (DRR) is a systematic approach to identifying, assessing and reducing risk. The Garden Route has a relatively well-capacitated Disaster Risk Reduction unit compared to other districts in South Africa. However,

much like in many parts of the world, efforts are still very much focussed on recovery from disaster (e.g. through providing disaster relief funding), or short-term disaster preparedness (e.g. through early warning systems, or ensuring adequate supply of fire engines). Longer term efforts to reduce risk are still lacking (Nel et al., 2014). Disaster risk education is also important. It is essential to integrate DRR into development and education programmes.

The adverse impacts of flooding can be reduced through enhancing and conserving natural ecosystem flood regulation capacity, land use adaptation, and flood resilience strategies (Barbedo et al., 2014). Intact landscapes can capture and store water from rainstorms and slowly release it in a process known as flood regulation, of which the benefits are enhanced safety to human life and human constructions (Millennium Ecosystem Assessment (MA), 2003). Natural ecosystem features and processes can, depending on rainfall intensity, moderate flood impacts or, in some cases, even prevent flooding (Brocca et al., 2008). The capacity of a landscape to store water is dependent on the underlying geological and climatic characteristics, its land use and how those uses are managed (Puigdefábregas, 2005). Strengthening capacity for meaningful active adaptive management needs to be addressed to make progress in this arena and to insure a sustainable future.

Opportunities for disaster management are also related to investments funds (water-food funds). A water fund for example invests in water security (e.g. Greater Cape Town Water Fund). Other funding opportunities include biodiversity stewardships facilitated by, for example, WWF or CapeNature. The latter is an approach to entering into agreements with private and communal landowners to protect and manage land in biodiversity priority areas.

Active citizenship

A new trend globally, as well as in South Africa, is to involve citizen scientists, to complement the state-funded monitoring programmes, however, it is critical that gaps in monitoring sites and variables at key sites are filled. Active citizenship refers to people getting involved in their communities and democracy at all levels from local to national and global. The SAWS for example, to a large extent, relies on ordinary citizens to read their rainfall gauges each morning and send the data to SAWS for processing. After the devastating Bitou and Knysna veldfires in 2017 the Garden Route Rebuild Initiative (GRRI) was established to fast track the rebuild of both these towns with a special focus on doing the rebuild in a "climate smart" way and "building back better" (EDM, 2018). Public-private partnerships between the private and public sectors such as the Garden Route Initiative (GRI) and other forums (e.g., Wilderness Lakes Catchment Management Forum (WLCMF) and Touw River Conservancy) are key. We need to form strong governance alliances between scientists, civil society, land users and decision makers (O'Farrell et al., 2015).

Conclusions

Increases in extreme weather events are expected to lead to increases in the occurrence of floods and fires threatening communities and infrastructure in the Garden Route. People will be more exposed and therefore vulnerable. Social vulnerability and exposure are key determinants of disaster risk and help explain why non-extreme physical events and chronic hazards can also lead to extreme impacts and disasters, while some extreme events do not. Interactions between vulnerability factors in a community are key to understanding risk reduction. The future of disaster risk includes building more resilient and safer cities nested in more resilient landscapes in a changing world. Improving society's capacity to protect itself from disasters includes adapting to changing climates. Reducing disaster risk has to be a critical component of those adaptation strategies. Through pro-active management of key drivers of land cover change, the people in the Garden Route will be able to reduce the impacts of natural hazards such as floods and wildfires. In considering the trade-offs of such ecosystem-based approaches with alternative forms of disaster risk reduction, the multiple co-benefits of land management and restoration need to be considered.

- For the full list of references, contact the Editor.

Acknowledgements

Our study emanates from an internal five-year CSIR project entitled, "Risk to business from biodiversity loss and ecosystem service failures: Developing an Environmental Risk and Opportunities Analysis (EROA) decision support tool" which started in 2020. The aim is to enhance strategic planning, decision-making and reporting capabilities in both the private and public sectors, related to natural hazards. The project developed a draft toolkit through a process of knowledge co-production that provides improved environmental intelligence to support businesses to help manage disaster risk. The decision support tool is based on our understanding of natural capital, the ecosystem services it provides and the links between these services and socio-economic development in South Africa.

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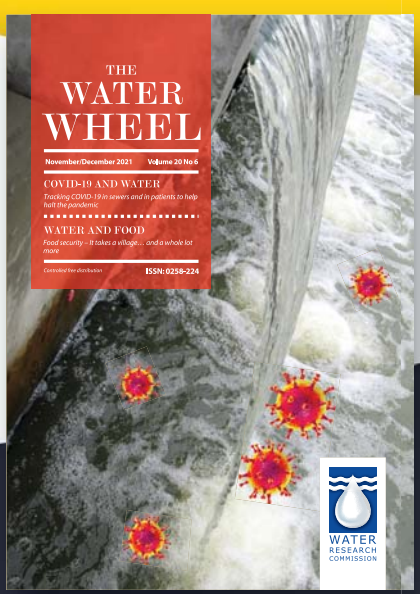

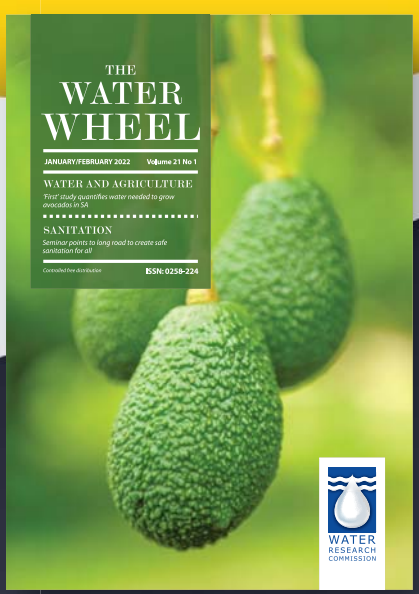

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Originally constructed by a cut-to-fill process, with embankments on three sides, the Molteno reservoir experienced several failures and leaks until being lined with concrete in the seventies.

For the complete story about the Molteno Reservoir, see the article in the November/December 2015 edition of the Water Wheel, Visit: https://bit.ly/3cc6QBg

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Molteno Reservoir during construction.

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