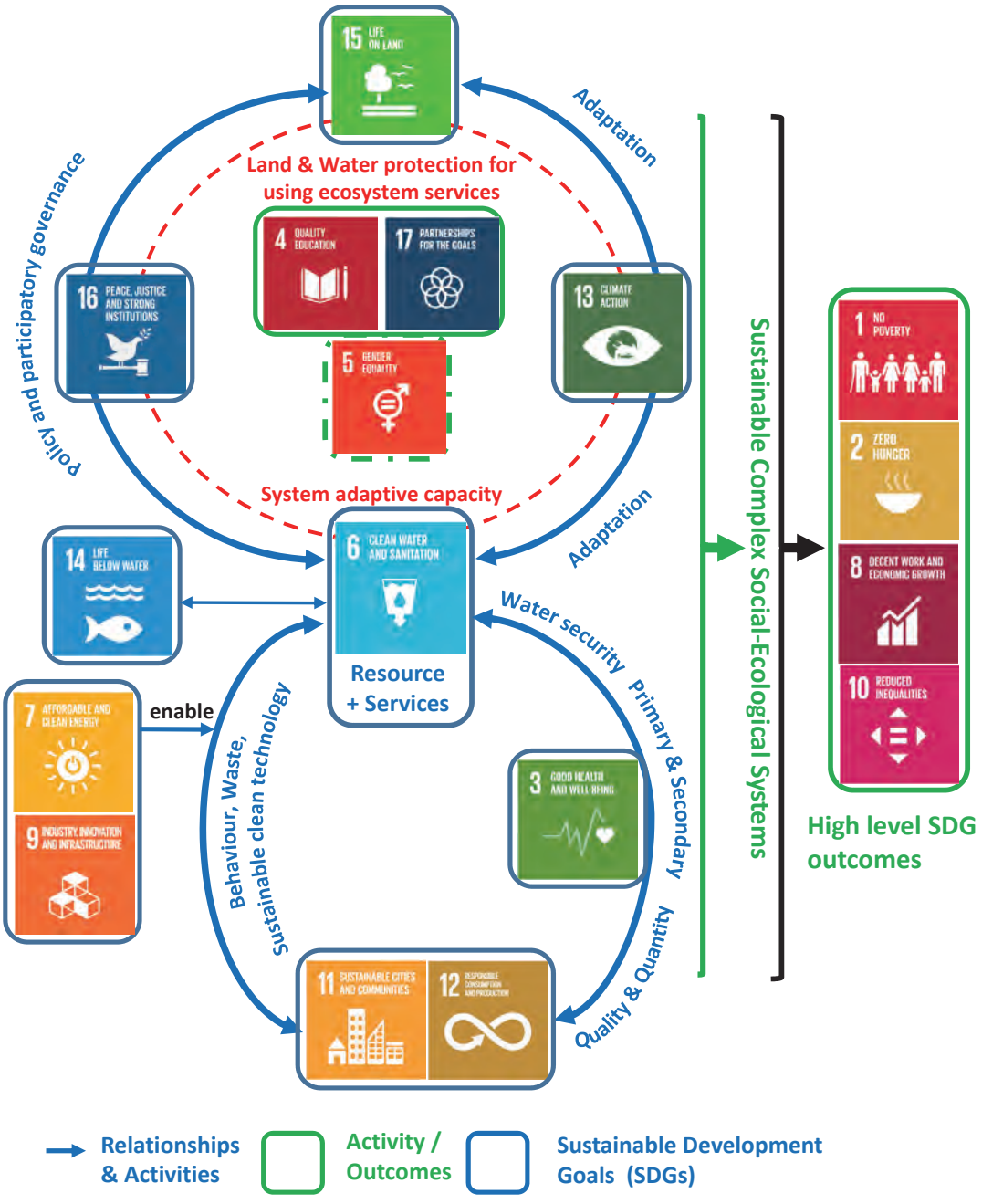
Institute for Water Research

IWR

RHODES UNIVERSITY
Where leaders learn

ANNUAL REPORT 2019



The cover diagram puts SDG 6 at the centre of IWR water related domains. The biophysical world above supports water for society below. Linked to: SDG 15 Life on Land; SDG 13 Climate Action; SDG 16 Peace, Justice and strong institutions; SDG 3 Good health and wellbeing; SDG 11 sustainable cities and communities and SDG 12 Responsible consumption and production.

The workshop will use an ARUA Water CoE SDG model where SDG 6 is the centre of transgressive action, and links it to other SDGs. This SDG6 (Water and sanitation)-centred model has been adopted by the ARUA Water Centre.

The landscape water resources cycle involves three key SGDs: i) SDG 13 - Climate Action, ii) SDG 15 - Life on Land and iii) SDG 16 – Peace, Justice and Strong Institutions. Strong ethical institutions are the basis of sound natural resource management that is responsive to climate change, and other global changes. That responsiveness depends on a capacity for ADAPTATION. So, Land (SDG 16) and Water (SDG 6) are linked to Climate Action (SDG 15) through Adaptation; and are supported by SDG 16 (Peace, Justice and Strong Institutions) through Policy and both formal & participatory Governance (Red broken-line Circle).

Together, this suite of SDGS (6,3,15,16) provides a research & research capacity development focus on Land and Water (catchment) Protection for using Ecosystem Services, supported by Human/System Adaptive Capacity. The Water CoE views people in the landscape as a complex social-ecological system (CSES). Wherever CSESs are sustainable, high level SGDs are moving towards being met (1,2,8,10: end poverty & hunger, provide decent work, & reduce global inequity) (Green Overarching Bracket) .

In the centre of the adaptively governed natural resource circle (above), are three SDGs supported by the way the Water CoE will function. SGD 4, Quality Education, is supported through the development of ARUA researchers and their post-graduate students and the communities with whom they will engage. SDG 5, Gender Equality, is supported through mainstreaming gender into all ARUA Water CoE activities and outcomes. SDG 17, Partnerships for the Goals, describes the essence of the Water CoE and the explicit collaborative, and integrated partnership aims of this ARUA/GCRF project funding. The engaged action research method always brings partners, and therefore the co-creation of knowledge, into research capacity development and research.

The blue circle below SDG 6: Effective, reliable water treatment & supply services delivery. Water service delivery is fundamentally essential to SDG 3, Good Health and Well-being, which requires research attention on Primary and Secondary Water Security in terms of both the Quantity & Quality of water. Primary scarcity is a lack of water from the hydrological cycle (exacerbated by drought & climate change), and secondary scarcity is a lack of water resulting from poor governance or other human failures. The nature of water always includes both the amount of water (linked to security of supply), and the quality of the water (which limits what water can be used for). Water security is necessary for SDG 11, sustainable cities and communities; and for SDG 12, sustainable consumption and production. Sustainable production includes attention to pollution (water quality). Research into Human Behaviour, Waste Management & Sustainable Clean Technologies will support SDGs 11 and 12.

We see SDG 7 – Affordable Clean Energy, and SDG 9 – Industry Innovation and Infrastructure as enablers of Water Service Delivery and as indicators of partnerships we need to seek with other ARUA CoEs. We see the weakest direct links with SDG 14 - life under water (mainly the marine environment). However, rivers meet the ocean through estuaries, and at least two of our nodes are in coastal cities.

This model uses the theoretical framing of sustainable Complex Social-Ecological Systems (C-SESs). Wherever a CSES (for example a catchment or a city) is sustainable, high level SGDs are supported.

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Back Row: Dr N Griffin, Ms J McLean, Prof C de Wet, Dr A Copteros, Dr N Odume, Ms B Mdudla, Ms P Ramtsabana, Dr C Nnadozie, Mr S Xoxo
Third Row: Mr M Mkatali, Mr D Forsyth, Prof T Palmer, Dr M Weaver, Mr W Liversage-Quinlan, Ms T Zondani
Second Row: Mr C Ndzabandzaba, Ms K Mokoena, Mr A Edegbene, Mr F Akamagwuna, Ms M Ralekethla, Dr G Ezenne
Front Row: Ms N Nzimande, Ms P Ntloko, Ms W Mahlaba, Dr N Libala, Prof T Palmer, Dr J Tanner, Ms N Mti, Ms A Chili, Ms T Mngadi, Mr A Fry
Inset: Prof D Hughes

STAFF AND MEMBERS OF THE INSTITUTE

STAFF

Dr Athina Copteros	Postdoctoral Fellow
Dr Gloria Ezenne	Postdoctoral Fellow
Mr David Forsyth	Principal Technical Officer
Dr Neil Griffin	Research Officer
Dr Notiswa Libala	Postdoctoral Fellow
Dr Sukhmani Mantel	Senior Research Officer
Ms Juanita McLean	Administration Manager
Ms Ntombekhaya Mgaba	Senior Technical Officer
Ms Ntombekhaya Mti	Intern
Dr Chika Nnadozie	Postdoctoral Fellow
Dr Nelson Odume	Senior Research Officer; Director: UCEWQ
Prof Tally Palmer	Professor; Director: IWR
Dr Jane Tanner	Research Officer
Prof Tony Palmer	Honorary Professor
Dr Matthew Weaver	Postdoctoral Fellow

ASSOCIATES

Prof Brian Allanson	Honorary Research Fellow
Dr Jai Clifford-Holmes	Research Associate
Prof Chris de Wet	Professor Emeritus
Mr Greg Huggins	Nomad Consulting
Prof Denis Hughes	Professor Emeritus
Dr Paul Mensah	Research Associate
Dr Nikite Muller	Research Associate
Dr Eric Igbinigie	Research Associate
Ms Delana Louw	Rivers for Africa
Mr Stephen Mallory	IWR Water Resources
Dr Victor Munnik	Research Associate
Dr Andrew Slaughter	Research Associate
Dr Jill Slinger	Visiting Professor

REGISTERED POSTGRADUATE STUDENTS

Mr Dennis Choruma	PhD (Water Resource Science)
Ms Asanda Chili	MSc (Water Resource Science)
Mr Augustine Edegbene	PhD (Water Resource Science)
Mr Adebayo Farounbi	PhD (Water Resource Science)
Mr Anthony Fry	MSc (Water Resource Science)
Mr David Gwapedza	PhD (Hydrology)
Mr Pierre Kabuya	PhD (Hydrology)
Mr Will Liversage-Quinlan	MSc (Water Resource Science)
Mr Zwido Lidzhegu PhD	(Water Resource Science)
Ms Bawanile Mahlaba	MSc (Water Resource Science)
Ms Bukanani Mdludla	MSc (Water Resource Science)
Ms Kopano Mokoena	MSc (Hydrology)
Mr Coli Ndzabandzaba	PhD (Hydrology)
Ms Pindi Ntloko	PhD (Water Resource Science)
Ms Mateboho Ralekhetla	PhD (Water Resource Science)
Ms Phatsimo Ramatsabana	MSc (Hydrology)
Mr Sinethemba Xoxo	MSc (Water Resource Science)

REGISTERED POSTGRADUATE STUDENTS
CO-SUPERVISED IN PARTNER DEPARTMENTS

Mr Frank Akamagwuna	PhD (Zoology)
Ms Nkosazane Masuku	BSc Hons (Geography)
Ms Nqobile Nzimande	MCom (Economics)
Ms Pippa Schlegel	PhD (Geography)
Ms Sibuyisele Pakati	MSc (Geography)

2019 GRADUATED STUDENTS

Ms Asanda Chili	BSc (Hons)
Mr Edwin Greyling	BSc (Hons)
Mr Christopher Hale	BSc (Hons)
Ms Notiswa Libala	PhD (Water Resource Science)
Ms Eunice Makungu	PhD (Hydrology)
Ms Qawekazi Mkabile	MSc (Water Resource Science)
Ms Bawanile Mahlaba	BSc (Hons)
Ms Kopano Mokoena	BSc (Hons)
Ms Matseleli Mosikili	BSc (Hons)
Ms Mateboho Ralekhetla	MSc (Water Resource Science)
Mr Kyle Smetherham	MSc (Hydrology)
Ms Caitlyn Smith	MSc (Hydrology)
Mr Matthew Weaver	PhD (Water Resource Science)
Ms Margaret Wolff	MEd
Ms Thantaswa Zondani	MSC (Hons)

MEMBERS OF THE BOARD

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Dr Roman Tandlich	Faculty of Pharmacy, Rhodes University
Mr Ramie Xonxa	Makana Local Municipality

INSTITUTE FOR WATER RESEARCH

DIRECTOR'S REPORT

In 2019 the IWR had a rewarding year of renewal, and 2020 herald's consolidation and growth. Individual achievements are reported in the Hydrology and UCEWQ reports. We welcome Tony Palmer as an Honorary Professor in the IWR. Tony leads research in Eco-Hydrology.

IWR: A Strategic Research Driver in Rhodes University Business Plan 2019-2024

Under the leadership of Dr Nelson Odume, and with financial results provided by the Rhodes University Finance Division, the IWR developed and presented a Business Plan to the University for the period 2019-2024. Here, we present the Executive Summary:

Reputation and performance

The Institute for Water Research (IWR) has been a leading research institute at Rhodes University for 28 years, with a sustained history of national and international reputation, research excellence and financial sustainability. The most recent evidence of this is our success in becoming the African Research Universities' Alliance (ARUA) Water Centre of Excellence (CoE), in a competitive process.

Risk and response

Cash flow challenges in 2017-2018 indicated a new risk horizon and stimulated a concerted strategy to diversify incomes streams. Two new initiatives were implemented rapidly:

1. Income from teaching. The IWR researchers developed new modules, and now teach four Honours course modules, in the Environmental Water Management Honours degree. This teaching has enabled the Geography Department to retain the degree in the University calendar, and to attract new students. Rhodes University entered an agreement with the IWR in which student fees from the EWM Honours course provides an income stream to IWR teaching researchers. The associated income from government subsidy accrues to Rhodes University.
2. Acceleration of international research grant income. After several unsuccessful collaborative, international grant applications over the period 2017-2018, experience has brought success. The IWR has been awarded a UKRI:GCRF grant of £600K over 3 years. This grant supports Capacity Development of the ARUA Water CoE, and in accordance with ARUA & UKRI-GCRF rules, Rhodes University has approved a matching $150K USD over 3 years, and will renew Professor Tally Palmer's contract for a further three years (2020-2022). (Since developing the Business Plan Dr Nelson Odume has successfully secured a €1.4M European Union grant to support intra-African research mobility, and Rhodes university will offer Dr Nelson Odume a 5-year contract dependent on income being secured.)

Financial benefit to Rhodes University

Over the period 2014-2018 the IWR has consistently accrued a net income to Rhodes University of more than R1M per year, even in the low direct income years of 2017-2018. This stability was largely sustained through subsidy income to Rhodes University. The projected budget 2020-2024 demonstrates sustained profitability to Rhodes University based on: 1) staff retention, and consequent increased post graduate student enrolment and productive publication, and 2) the likelihood of increased international grant income, particularly associated with ARUA.

Rhodes University fundraising for water

In line with the imperatives of the Institutional Development Plan and the recently launched Transformation Development Plan, the University has identified six areas of strategic need to focus its fundraising efforts in 2020. One of these is Water. The IWR is collaborating with the Directorate for Communications and Advancement in this endeavour. We have emphasised that investment in Water needs to close the gap between University water research and water infra-structure and use management. This is particularly possible in the areas of groundwater monitoring and management, water use monitoring, and rainwater harvesting. The IWR laid a foundation for this by donating ground-water monitoring in 2019.

A continental leader in water research

The IWR is host to the ARUA Water CoE. Professor Tally Palmer is the Water CoE Director. Dr Jane Tanner (IWR) and Professor Zerihun Woldu (Addis Ababa University, Ethiopia) are co-directors. The CoE comprises eight university-based nodes in seven countries: Addis Ababa University, Ethiopia; University Rwanda, Rwanda; University Cheikh Anta Diop, Senegal; Dar es Salaam University, Tanzania, Makerere University, Uganda; University Lagos, Nigeria, University Cape Town, University of KwaZulu-Natal, and Rhodes University (the CoE hub), South Africa. The CoE was formally launched by Dr Ernest Aryeetey, ARUA Secretary General, at an event hosted by Rhodes University Vice Chancellor, Dr Sizwe Mabizela. The launch was part of an Inception workshop 26-30 May 2019, where all the CoE nodes were represented and a strong, vibrant network emerged from the process. We collectively agreed on the CoE name, research focus and direction, principles of collaboration, and began the process of building a directory of CoE researchers and their expertise. Web site development will follow in early 2020.

The launch was followed by a strong co-operative effort to develop a proposal for a UKRI:GCRF Capacity Development Grant entitled Water for African SDGs, which has been awarded. The first activity will be a training course for three participants from each of the CoE nodes: a senior- / mid-career, an early career researcher and a post-graduate student. The course will be presented and facilitated by Tally Palmer and will focus on applying a Systemic Adaptive Approach to engaged, transdisciplinary research. The design of the Systemic Adaptive Approach supports research that catalyses change towards social-ecological justice (see Wolff et al. [2019] in our publications list). The Systemic Adaptive Approach is the basis of a UKRI:GCRF Research Excellence proposal submitted by the CoE in November 2019, to compete for one of six £2M grants, to be allocated in February 2020.

The CoE was well represented at the ARUA biennial conference in Nairobi. We hosted an early career research workshop on Systems Thinking, focussed on land and water and the SGDs. Drs Tanner and Kabenge and Prof Faye presented papers in the Water parallel session, and Professor Palmer spoke in the final plenary panel.

Water Centre of Excellence delegates at the Inception workshop, with ARUA Secretary General Professor Ernest Aryeetey. (Top from left: Professor Serigne Faye (U Cheikh Anta Diop), Professor Joel Norbert (U Dar es Salaam), Dr David Mfitumukiza (Makarere U), Dr Nsengimana Venuste (U Rwanda); Dr Christian Sekomo (U Rwanda); Dr Kevin Winter (UCT), Dr Deogratias Mulungu (U Dar es Salaam); Professor Alioune Kane (U Senegal); Dr Isa Kabenge (Makarere U). Front from left Professor Noble Banadda (Makerere U), Dr Jane Tanner (Rhodes U) Professor Ernest Aryeetey, Professor Tally Palmer (Rhodes U), Dr Tena Alamirew (U Addis Ababa). Delegates from the University of Lagos (Prof Ezechiel Longe and Dr James Akanmu) joined the group later.

ARUA CoE Representatives and Workshop Participants at the ARUA Conference in Nairobi, November 2019.

Dr Peter Clayton Rhodes University Deputy Vice Chancellor Research and Innovation, and Professor Tally Palmer participated in ARUA DVCs meeting and the launch of the ARUA African Identities Centre of Excellence in Kampala.

Water CoE early career researcher builds a systemic picture of the SDGs.

The Water CoE Board members are Dr Peter Clayton (Chairperson), Professor Frances Cleaver and Dr Vanessa Speight (U of Sheffield) Dr Olivier Barreteau (Institut national de recherche en sciences et technologies our l'environnement et l'agriculture); Professor Raphael Tshimanga (Kinshasa U). The first meeting of the Water CoE Board took place 28 November as a virtual meeting, with apologies from Professor Cleaver. The meeting primarily comprised a Director's report to inform the new Board members. Board documents have been submitted to Professor Aryeetey and UKRI. It was agreed we would meet six-monthly, alternately in the virtual format. The next meeting will be held at one of the nodes, times to coincide with an ARUA event.

In the last CoE event of 2019, Dr Jane Tanner represented ARUA at the French-South Africa Science and Innovation days at the CSIR in Pretoria, and spoke in a plenary panel on the role of Science to address SDG 6. We particularly thank Dr Peter Clayton for his strategic leadership within ARUA and for his active support of the CoE.

Mediating water conflict in Makana

Post-Doctoral Fellow Matthew Weaver successfully nominated Tally Palmer for the 2019 Vice Chancellors Distinguished Award for Community Engagement. The IWR engaged research team worked together with the Division of Community Engagement to facilitate an engaged research event rather than the traditional award lecture. We hosted a public meeting "Water: Clean, Reliable, Fair" at the Makhanda City Hall, attended by 150 residents including municipal leaders and officials, government departments, civil society organisation, local business leaders, who each had the chance to learn about, and share their knowledge about how water in Makana and its catchments, can become reliable, clean and fairly distributed.

From left to right: Mr Mzukisi Mpahlwa, Makhanda Mayor; Prof Tally Palmer, Dr Sizwe Mabizela, Rhodes University Vice-Chancellor; and Mr Ramie Xonxa, Makhanda Councillor at the "Water: Clean, Reliable, Fair" public meeting.

Group discussions by participants at "Water: Clean, Reliable, Fair" public meeting held in Makhanda City Hall.

IWR Strategic Adaptive Management

Since 2016 the IWR has adopted Strategic Adaptive Management as the way we work together and with others towards our vision and goals. The overall vision and mission of IWR can be summarised as: **The IWR undertakes excellent, collaborative research that catalyses change towards fair and sustainable African water catchments**. Each year we use an Adaptive Planning Process to develop an objectives hierarchy – the objectives we are working towards, some of which depend on meeting other objectives. We identify the top three objectives, and IWR members take responsibility for their part in achieving the objective. We monitor the process of progress by reporting every two weeks, we reflect on progress and adapt activities. The three primary objectives for 2019 were research income generation, the image of IWR at all scales, and research outputs. In each of these areas IWR performance in 2019 was significantly successful. Dr Nelson Odume published thirteen papers –the most productive individual publication record in the history of the IWR.

Adaptive Water Resource Management and Water Governance Research

Hydrology, Water Quality and Aquatic Ecology research group achievements are recorded in the reports that follow. Prof Tally Palmer leads Adaptive Water Resource Management and Water Governance research. Tally was awarded the Vice Chancellors Excellence award in Community Engagement for her work in developing and applying engaged, transdisciplinary, action- research methods. In April 2019 graduations were: Notiswa Libala, Matthew Weaver, Qawekazi Mkabile, Mateboho Ralekhetla, Margaret Wolff (Masters). Matthew, Notiswa and Mateboho have remained in the IWR as post-doctoral fellows and doctoral student respectively. Matthew and Margaret attended the Vice-Chancellors Student Achievement function, acknowledging their research publications. Notiswa, Matthew and Margaret are active in the large Department of Environment, Forestry and Fisheries-funded Tsitsa Project, Margaret as Project Manager, Notiswa as Co-ordinator of the Governance Research Community of Practice, and Matthew the Capacity Development co-ordinator in the in the Knowledge and Learning Community of Practice. The Governance research progressed well with the development of a Capability Pathway for participatory governance development, and the appointment and training of Community Liaison Officers. Master's student Anthony Fry has lived in the catchment and is undertaking innovative work in systemic governance mapping and Dr Athina Copteros joined the governance research group as a post-doctoral fellow. Ms Ntombekhaya Mti provided the team with excellent support as a workshop translator, field co-ordinator and research assistant.

Acknowledgements

IWR researchers and post-doctoral fellows work extremely hard to perform in multiple arenas. They generate the research income for the IWR, teach in the Departments of Geography and Environmental Science, undertake and publish research, supervise post-graduate students, and volunteer for many activities such as Faculty Open Days, the National Science Festival and community engagement, as in supporting the Makana Water Forum. Drs Nelson Odume and Jane Tanner exercise active, effective leadership within the IWR, and generously offer tremendous collegial support. Nelson has excelled in 2019 in all areas of academic achievement. Emeritus Professor Denis Hughes continues to make substantive contributions. The Departments of Geography and Environmental Science, and the Environmental Learning Research Centre, are much appreciated as key partners. The Dean of Science, Professor Tony Booth; the Deputy Vice Chancellor Research and Chairperson of the IWR and Water CoE Boards, Dr Peter Clayton; and the IWR Board members offer us sound guidance, and we continue to receive valuable strategic and financial support from the University.

Prof CG (Tally) Palmer, Director: IWR

Prof Diana Hornby (left) with Prof Tally Palmer (right), recipient of the Vice-Chancellors Distinguished Award for Community Engagement, at 2019 Graduation Ceremony.

UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY (UCEWQ)

DIRECTOR'S REPORT

Introduction

The Centre continues to make significant contributions to water research and education locally and internationally. I would like to congratulate all our 2019 graduates: Dr Notiswa Libala (PhD), Dr Matthew Weaver (PhD), Ms Qawekazi Mkabile (MSc), Mrs Mateboho Ralekhetla (MSc), Mr Frank Akamagwuna (MSc), Mrs Margaret Wolff (MEd) and the honours students. One of the highlights of the year is the funding news for the Intra-Africa Mobility grant. Through the grant, a consortium of 5 African Universities and one European University will be established. Rhodes is the lead, and the partners include: University of Kinshasa, Democratic Republic of Congo; Federal University of Technology, Minna, Nigeria; Makerere University, Uganda; National School of Hydraulic Engineering, Algeria; and TuDelft Netherlands (European, Technical partner). The European Union Commission-funded Intra-Africa mobility scheme is aimed at strengthening capacity for research and teaching, promoting internationalisation, multiculturalism, and multilingualism among African Universities. With this grant, we will be able to attract talented African students (including South Africans) to the Centre and the IWR as a whole. Another highlight of the year, is the Vice-Chancellor's Distinguished Community Engagement Award to Prof Tally Palmer. Instead of delivering the usual lecture, Prof Palmer used the opportunity to organise an engaged workshop in which Makhanda's citizens participated on how to achieve fair, reliable and clean water supply in the town for all citizens. Congratulations to Prof Palmer on the well-deserved award.

IWR PhD graduates and their supervisors. From left: Dr AR Palmer (supervisor), Dr B Gusha (PhD graduate, Environmental Science), Dr ON Odume (supervisor), Prof CG Palmer (supervisor), Dr N Libala (PhD graduate) and Dr MJT Weaver (PhD graduate).

Last year, I reported that Dr Nnadozie was joining the Centre as a postdoctoral fellow, opening the Centre to microbial water quality and impact on human health. Dr Nnadozie successfully attracted a four-year WRC-funded project on antibiotic resistant restrains of Campylobacter spp. in water sources. With the new project, she is beginning to position herself as a research leader. In 2019, we welcome two Postdocs, Dr Notiswa Libala and Dr Mathew Weaver, both of whom were supervised within the Centre. Dr Libala is the leader of a WRC-funded project on interlinkages of the sustainable development goals (SDGs). Dr Weaver's time is split between the IWR and the ELRC.

Participants at the community engagement award workshop

National, Regional and International Influence

Our staff and students remain extremely active within the water and environment sector both locally and internationally. Dr Odume co-organised and facilitated the first ever special African session at the 2019 Society for Freshwater Science (SFS) Conference in Salt Lake City, USA. The special session attracted African delegates from most regions (East, South, North, West) of Africa. Dr Nnadozie also attended and presented a paper at the 2019 SFS conference. For the future, Dr Odume will initiate discussions with the SFS committee on the possibility of establishing opportunity for student and staff exchanges between North American and African freshwater scientists. Dr Odume was invited to participate as a panellist on water governance challenges in the Eastern Cape, during a water colloquium organised by GIZ. In 2017, the Centre was invited to participate in a transformational learning workshop by the Institute of Environmental Systems Research at the University of Osnabruck, Germany. Following this invitation, in 2018 the Centre together with other partners in Germany and South Africa put together a proposal for a training workshop on transformational learning to be held in 2019. The application was successful, and the first workshop was co-hosted at Rhodes University by the Environmental Learning Research Centre (ELRC) and the IWR. Mr Edegbene attended and presented papers at the International conference on Lakes and Reservoirs, Poland, and international conference on water pollution and treatment, Italy. Prof Tally Palmer also

attended and presented a paper at the International River symposium, Australia.

On the local front, the Centre staff and students also presented papers, organised and facilitated workshops. Ms Khaya Mgaba presented an invited talk at the 2019 Water Research Commission Symposium, while Dr Weaver presented a paper at the 37th Annual Conference of the Environmental Education Association of Southern Africa. Mr Fry presented a poster at the Society for Ecological Restoration Conference. Mrs Mateboho Ralekhetla also attended the Society for Ecological Restoration Conference.

Ms Khaya Mgaba (second from left) on a panel at the 2019 WRC symposium

As with previous years, our community engagement initiatives led by Ms Khaya Mgaba continue to flourish. The Centre took learners from Kingswood college on a mini-SASS5 demonstration in the Palmiet River just outside Makhanda. Learners were exposed to the complexity of water quality challenges, and the responses of aquatic biota to water pollution. The Centre also participated in the Round Square conference hosted by Saint Andrew's College. The theme of the conference was "embracing our realities, growing our opportunities". During the conference the Centre staff, led by Ms Khaya Mgaba demonstrated to conference delegates water quality testing, freshwater invertebrate adaption and water quality assessment using min-SASS.

During the 2019 Faculty of Science Open Day, the Centre's staff and students were fully engaged, as they organised a workshop on water and water-related issues. The workshop included a water-wise quiz session, demonstration of the water supply systems in Grahamstown as well as an overview of the kind of research undertaken within the IWR as a whole. We are committed to community engagement, and we will continue to explore opportunities for showcasing the Centre's work publicly and contributing to our immediate and remote communities.

Ms Asanda Chili and Kingswood college students during the field trip to the nearby Palmiet River

Partnerships and Linkages

Unilever South Africa remains the core founding partner of the Centre and we remain grateful for their support. Last year, I reported that the 3-year MOA was replaced with a 2-year MOA (2019 – 2020) with almost 50% cut in funding. We are grateful to Unilever SA for their continued support and funding of the activities of the Centre. As part of the new MOA, the Centre and Unilever SA agreed to work closely together to address some of the identified water challenges in the Klip River catchment. To this end, the Centre put in a proposal on water governance and ethics, to investigate some of the water governance challenges in the Klip Catchment. Work on this project has begun. We are also developing a decision support system (DSS) that will allow the regulator to issue water quality licences to water users within the catchment. With the DSS, the regulator will be able to effectively interrogate how meeting licence condition improve the resource conditions.

With the intra-Africa mobility grant kicking off, and the ARUA Centre of Excellence in Water, the Centre (UCEWQ) is poised to strengthen its partnership and linkages within Africa and beyond.

In 2019, Rhodes University applied to host one of the Centres of the Africa Multiple Clusters of Excellence on African studies. The clusters are funded by the University of Bayreuth. UCEWQ, through Dr Odume, is part of the Cluster of Excellence at Rhodes, opening up further opportunities for postdoc and PhD student funding as well as opportunity for inter- and transdisciplinary research. Assured Turnkey Solutions (PTY) LTD and Scherman Environmental CC remain key strategic industry partners.

Our laboratories and cultures are in excellent condition and we continue to participate in the National Laboratory Proficiency Testing Scheme.

I would like to express my deepest appreciation and gratitude to all staff and students of the Centre who have worked tirelessly to make 2019 a success. I would also like to thank the Water Research Commission who has continued to fund the majority of the research projects undertaken by staff and students of the Centre.

Dr ON Odume, UCEWQ Director

Ethics workshop that was conducted in the Lower Sundays River

HYDROLOGY REPORT

Introduction

Hydrology within the IWR has had an eventful year in 2019 with significant media coverage around our involvement in local drought relief activities. Dr Jane Tanner and Dr Sukhmani Mantel continue to work closely together and Prof Denis Hughes still contributes enormously to the Hydrology Group. Postdoctoral fellow Dr Gloria Ezenne also made key contributions to hydrology in 2019, and we are grateful to Prof. Tony Palmer for his work with Dr Ezenne on the high-level evapotranspiration equipment. We would also like to congratulate the two MSc hydrology graduates Ms Caitlin Smith, who achieved a distinction for her work on palmiet wetlands, and Mr Kyle Smetherham whose work on groundwater was instrumental in the IWR's ability to contribute directly to the drought relief efforts.

In February 2019, Dr Gideon Groenewald of Gift of the Givers contacted us to request information on the town's groundwater supplies. The hydrology group has been collating data on local groundwater for a number of years, and was in the best position to provide technical support for the citing of boreholes for drought relief efforts. Sixteen boreholes were sunk in total and were located in key areas (schools, Rhodes University, the 1820 Settler Monument) or in locations where the boreholes could be linked into the water reticulation system. The IWR played an active role in the citing of these boreholes.

MSc graduate Ms Caitlin Smith who obtained a distinction for her work on palmiet wetlands

MSc graduate Mr Kyle Smetherham at graduation

Gift of the Givers, Dr Gideon Groenewald (left) and representatives with Dr Jane Tanner (2nd left) and Prof Denis Hughes (3rd right) at an artesian borehole on Rhodes University campus

The additional boreholes have provided us with a large amount of additional data, and these are being collated by Mr Mzwanele Makatali who is on a Sector Education and Training Authority (SETA) supported internship. Mr Makatali has continued to monitor around 30 private boreholes (including boreholes at schools), 10 boreholes supplying Rhodes University, as well as 5 boreholes currently supplying Makhanda located at the Waainek well field. There is a significant amount of data being produced, much of which is in active use. We therefore regularly share the data with the Department of Water and Sanitation, and there are a number of parties interested in the final report which Mr Makatali is producing. We have been contacted by the Council for Geoscience who have also requested our data for the planning of a large aerial geophysical survey of the region. These data will be enormously useful in improving understanding of groundwater resources in this area, which are complex. We have signed a contract with the Council for Geoscience who have agreed to freely share the data collected during this survey. The data will be used in a new MSc project starting in 2020 jointly supervised by myself and Dr Stephen Buttner of the Geology Department at Rhodes.

We are saying goodbye to our hydrology post-doctoral fellow Dr Gloria Ezenne who has been with us for two years and is returning home to continue work at the University of Nigeria. Dr Ezenne has focused primarily on increasing our capacity in the use of the high-level equipment for measuring evapotranspiration and has produced a number of publications in this regard. We will continue our work with Dr Ezenne through the ARUA network, as University of Lagos is a Water Hub partner and does collaborate with the University of Nigeria.

International collaboration

Dr Jane Tanner spent two weeks in Montpellier with the IRSTEA research group from 10 to 23 February 2019. This time was spent learning Agent Based Modelling (ABM) with IRSTEA director Dr Olivier Barreteau, as well as designing research proposals to jointly submit. Subsequently Mr David Gwapedza, a hydrology PhD student was sponsored by IRSTEA to attend a two-week course on ABM in Montpellier in October 2019. One of the outcomes of this collaboration was an invitation to Dr Tanner to speak at the recent French-South Africa Science and Innovation days held in Pretoria on 3-4 December 2019. Dr Tanner and Dr Sukhmani Mantel attended the innovation day and are actively pursuing increased collaboration with French researchers. IRSTEA director Dr Olivier Barreteau has recently been appointed as a board member on the ARUA CoE Water advisory board.

The IWR was visited by representatives from OOWV, a German public utility that supplies drinking water in Germany and from the Technical University of Braunschweig on 27 March 2019. The visit has resulted in a number of proposals being submitted with the Hydrology group as well as a publication, and resulted in PhD student Mr David Gwapedza spending 3 months (September to November 2019) on an exchange at the Technical University of Braunschweig in Germany. This visit involved setting up a detailed hydrological model for the Buffalo City Municipality.

Dr Jane Tanner, Dr Sukhmani Mantel and Prof. Tony Palmer attended a course on Google Earth Engine, a processing program for remote sensing imagery in Cape Town in April 2019. The course was taught by international Google representatives and was a valuable and challenging time.

Dr Sukhmani Mantel and Prof Denis Hughes taught a SPATSIM course at Stellenbosch University and following that received EU funding to conduct hydrological modelling for the entire Zambezi River. Once the model has been set up for the Zambezi (IWR's Global options model and WEAP) future scenarios will be run. We are hoping this work leads to further EU funding for Prof Hughes' models.

The Royal Society-DFID Africa Capacity Building Initiative CRuHM (Congo River User Hydraulic and Morphology) project continues to be a large active project lead by Prof Hughes. The project is a collaboration between the IWR, the University of Kinshasa in DRC, the University of Dar es Salaam in Tanzania, the University of Bristol, and the University of Leeds in the UK. The aim is to carry out large scale hydraulic and geomorphological science research on the main navigable channels of the Congo River to address the severe lack of basic scientific knowledge and understanding in these water engineering fields for the world's second largest river. PhD candidate Pierre Kabuya is currently based at the IWR and jointly supervised by Dr Raphael Tshimanga and Prof Denis Hughes.

Students

Honours: Five honours students supervised by Dr Jane Tanner and Dr Sukhmani Mantel in 2018 graduated in 2019. They received special commendation on the quality of their research projects from the external examiners.

Two interesting hydrology honours projects were completed in 2019. This included a project by Mr David O'Beirne on a geophysical investigation of the Fairview spring which resulted in a greater understanding of the subsurface features resulting in the emergence of water at the spring. The second project was carried out by Mr Onke Mazeke and analysed the effects of the pumping of groundwater on the aquifer at the Waainek well field. Mr Mazeke will continue on at the IWR as an MSc Hydrology student in 2020.

The honours course ran successfully for its second year and this year was joined by Masters student Sinetemba Xoxo and SETA intern Mzwanele Makatali. The students were taken on a three-day field trip in the Krom which resulted in significant data being collected.

We have received sponsorship from the Groundwater Division (GWD) of the Geological Society of South Africa to send the hydrology honours class for 2020 to a week-long field school run by the GWD. This will be groundwater focused and will include honours students from around the country (five universities).

Honours students at mountain drive viewing subsurface water seepage in the grey dam catchment (photo taken by Mr Sinethemba Xoxo)

MSc: Two hydrology MSc students completed year 1 in 2019, both aiming to complete in 2020. Two water resource science MSc students supervised by Dr Sukhmani Mantel and Dr Jane Tanner also completed year 1 of their MSc degrees. Dr Tanner is co-supervising an MSc student in Geography with Dr Bennie van der Waal. Details of these projects are found in the student reports below.

PhD: PhD students Coli Ndzabandzaba and David Gwapedza are currently writing up and plan to submit in early 2020. PhD student Pierre Kabuya plans to submit by December 2020. Dr Tanner is co-supervising a PhD student in Geography with Dr Bennie van der Waal. Details of these projects are found in the student reports below.

Conferences

Dr Jane Tanner and hydrology MSc student Ms Kopano Mokoena both presented at the Groundwater Division of the Geological Society of South Africa Biennial Conference in Port Elizabeth in October 2019. Dr Tanner presented on the work she and Prof Hughes have worked on around the Fairview spring, and Ms Mokoena presented on her groundwater drought work. Dr Gloria Ezenne attended the Waternet conference in Johannesburg in October 2019, and presented on her work with eddy covariance systems. Dr Tanner presented at the 2nd biennial ARUA conference on the fourth industrial revolution in Nairobi, Kenya in November 2019. MSc student Ms Phatsimo Ramatsabana presented a paper on her work with groundwater drought at the postgraduate conference held at Rhodes University in August 2019. Dr Tanner attended the Academic Council of the United Nations Systems annual conference in Stellenbosch in May 2019 with the relevant theme: The UN and Africa: Progress towards achieving the SDGs.

Consulting

The hydrology group continues to actively consult with both Prof Hughes and Dr Tanner contributing to international and local consultancy projects.

Other notable successes

Dr Jane Tanner has been invited to be part of the technical advisory group of the newly established Environmental Freshwater and Terrestrial Environmental Observation Network (EFTEON). After the first meeting in October 2019, this seems to be an exciting initiative which will form new instrumented research catchments in South Africa. Dr Tanner has been appointed as a senate representative for the Rhodes University Environmental Committee.

MSc student Ms Kopano Mokoena is currently part of the first cadre of the GreenMatter Water Fellows and the Makhanda Nodal Co-ordinator for the Young Water professionals (YWP) South Africa. She is also a recipient of the Investec Rhodes Top 100 Student Leadership award.

Two WRC grants were awarded in 2019 including one lead by Dr Sukhmani Mantel which is a collaboration with the CSIR titled: The role of Ecological Infrastructure in enhancing drought security. The second is a collaboration with SAEON titled: Critical catchment hydrological model inter-comparison and model use guidance development. One WRC project lead by Dr Tanner concluded successfully titled: Impacts of climate change in determining the ecological Reserve. A second 5-year WRC project lead by Dr Anthony Palmer also concluded titled: Rehabilitation of grasslands after eradication of alien invasive trees. We did not apply for any WRC grants for 2020 as we would like to concentrate our efforts on obtaining international funding.

A big thank you to all the staff and students contributing to the hydrology group, particularly Prof Hughes who continues to provide invaluable guidance and support.

Dr JL Tanner, Head of Hydrology

HYDROLOGY PROJECTS

REHABILITATION OF GRASSLANDS AFTER ERADICATION OF ALIEN INVASIVE TREES

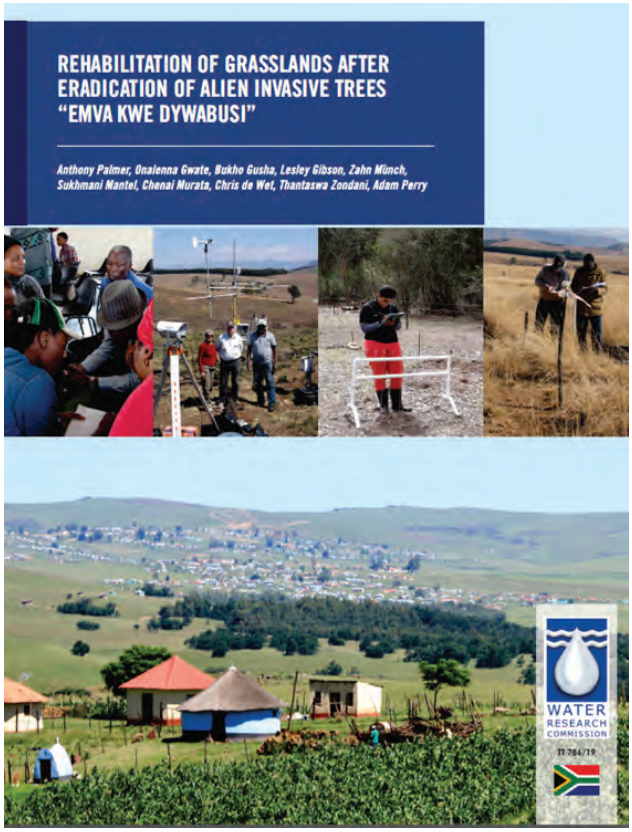
Sponsor: Water Research Commission
SK Mantel
Collaborators: AR Palmer (Agricultural Research Council), Z Munch (University of Stellenbosch), L Gibson (Cape Nature), A Perry (previously affiliated with Fort Hare's Institute of Social and Economic Research), C Murata (Previously of Umhlaba Consulting Group (Pty) Ltd, East London; Currently PhD student under an NRF grant, Rhodes University), R Scholtz (Joe Gqabi District Municipality)
April 2014 – March 2019

Clearing of the Invasive Alien Plants (IAPs) on their own is not sufficient motivation to proceed with the national Working for Water (WfW) programme, and there needs to be consideration of the sustainability of the landscape when the activities of WfW are completed. In order to ensure sustainability of landscape processes for human benefit, it is essential to build stronger links between the control of undesirable woody plants and the derived benefits to humans occupying the catchment. In order to strengthen this linkage, empirical evidence of the water use of every component of the landscape needs to be collected. The landscape units or land cover types that are encountered in the mesic regions of South Africa are diverse, comprising inter alia areas of irrigation agriculture, dryland cultivation, residential, extensive rangeland and forests. Superimposed on this are two different land tenure systems, namely freehold farms and communal or leasehold areas, with diametrically opposing approaches to landscape management. There is a need to improve our understanding of how to balance water use and carbon capture between different land cover types and land tenure systems as both these cycles are important to people and their livelihoods. Two possible approaches for assessing the relative efficiency of the landscape for secondary production are livestock water productivity (LWP) and water use productivity (WUP). In the rural landscapes of the south eastern parts of South Africa (e.g. former Transkei and Kwa-Zulu Natal), land use is dominated by a complex arrangement of dwellings, livestock grazing, dryland cultivation and forestation, all within a communal land tenure system. The capture of carbon by the landscape is the primary driver of livestock and food production in this human-dominated social-ecological system (SES) and understanding the total economic value and water use efficiency (WUE) of these processes requires an empirical assessment of the water cycle. Thus, the aims of this project were:

1. To parameterize, evaluate and modify suitable models for evapotranspiration (ET), LWP and net primary productivity (NPP) estimates for IAPs and grasslands.
2. To explore and compare ET, LWP and NPP in two catchments with contrasting land tenure systems, comprising diverse biomass and condition states for grassland and IAPs.
3. To apply the selected models for predicting ET, LWP and NPP to these catchments.
4. To examine the possibility of using a Reward for Ecosystem Services (RES) system in rural rangelands as a possible solution to degradation and water issues (quantity and quality).

The project had three focal catchments in the Eastern Cape and the project has funded three postgraduate students at Rhodes University – Onalenna Gwate (PhD, Rhodes University; graduated 2018), Perpetua Okoye (MSc, Stellenbosch University, graduated 2016) and Bukho Gusha (PhD, Rhodes University; graduated 2019) – and three Honors student, Chris Scorer (BSc, Rhodes University, graduated 2017), Liezl Vermeulen (Stellenbosch University, graduated 2018) and Thantaswa Zondani (part-time Honours, Rhodes University).

The project has completed and the final deliverable was delivered to and has been approved for publishing by the WRC.



Cover of the final report of the WRC funded project on rehabilitation of grasslands after eradication of alien invasive trees

IKS TO ENHANCE REWARDS FOR ECOSYSTEM SERVICES IN RANGELANDS INFESTED WITH INVASIVE ALIEN PLANTS

Sponsor: National Research Foundation
SK Mantel
Collaborator: AR Palmer (Agricultural Research Council)
January 2017 – December 2019

Rewards for Ecosystem Services (RES) is gaining increasing attention as a means of translating external, non-market values of ecosystem services, including water, into tangible incentives for local actors to benefit financially by providing ecosystem services. As a policy instrument, RES is described as particularly suited to addressing environmental problems in ecosystems that are mismanaged because associated benefits are externalities from the perspective of ecosystem managers. The proposed work seeks to conduct an in-depth investigation into how indigenous knowledge systems can be leveraged to develop locally appropriate and beneficial models of the Reward for Ecosystems Service practice in communities living in rangeland areas that are infested by invasive aliens. In the Eastern Cape Province the clearing of invasive alien plants is being driven by the Working for Water programme in which target areas are selected and a select number of local community members are hired to cut invasive wattle trees especially in riparian zones. The programme is heavily overloaded and under resourced and as a result it is moving at a very slow pace and it does not seem that it will be able to reach all the targeted areas in the next ten years. Effects of this can be mitigated by promoting community-based ecological management practices using simple local knowledge tools. Thus, the project will aim to identify existing forms of indigenous knowledge systems and practices used by local communities to manage rangeland resources in both communal and private lands and develop community-based Reward for Ecosystem practices using a bottom up approach.

Mr Chenai Murata, who has conducted workshops on the WRC project 'Rehabilitation of Grasslands After Eradication of Alien Invasive Trees', is registered as a PhD student under the NRF funded project and is currently in the final year of his research. The title of his research is 'A realist exploration of the role of indigenous ecological knowledge in people's understanding of and dealing in ecosystem services in Eastern Cape, South Africa'. He is being supervised by Dr Anthony Palmer and Dr Gladman Thondhlana (Department of Environmental Science, Rhodes University). The aim of the PhD project is to establish the relevant indigenous knowledge and practices that people in communal villages have historically been using in understanding and management of ecosystem services, and how such knowledges and practices have adapted and evolved over time. Mr Murata has completed all his field work and is finalizing his thesis currently. He also is the lead author on a publication listed under peer-reviewed journal papers.

INFRASTRUCTURE FUNDING INSTRUMENT GRANT FOR EVAPOTRANSPIRATION FLUX

Sponsor: National Research Foundation
SK Mantel
Collaborator: AR Palmer (Agricultural Research Council)

Dr Anthony Palmer (Agricultural Research Council) and Dr Mantel motivated for a National Research Foundation (NRF) 2014 call for National Equipment Programme grant for equipment for measuring the carbon and water fluxes using the Eddy Covariance and Scintillometer systems. The funding proposal for R1.8 million (of which R1.249 million is provided by the NRF) was approved and we received all three systems last year. Dr Palmer, Dr Mantel and Mr Gwate have installed one Eddy Covariance system on a secure thicket site outside Grahamstown. The data gathered by the equipment has been used by Mr Gwate on the WRC project K5/2400/4 for his PhD thesis and by Dr Gloria Ezenne who is a postdoc at the Institute. Currently the two Eddy Covariance systems are being used to compare carbon and water fluxes over grasslands versus bush encroachment areas in the Eastern Cape. The Large Aperture Scintillometer was used recently to measure the evapotranspiration from the Krom palmiet wetland in the Eastern Cape and the data were used to validate measurements from remote sensing platforms. The results have been submitted as a paper for publishing in *Geosciences*.

Scintillometer installed in the field by Prof Tony Palmer for measuring evapotranspiration

THE ROLE, BENEFITS AND PRIORITISATION OF ECOLOGICAL INFRASTRUCTURE (EI) IN MITIGATING THE IMPACTS OF DROUGHTS IN SOUTH AFRICA

Sponsor: Water Research Commission
SK Mantel and JL Tanner
Collaborators: D le Maitre (CSIR), A de Vos (Department of Environmental Science, Rhodes University)
April 2014 – March 2019

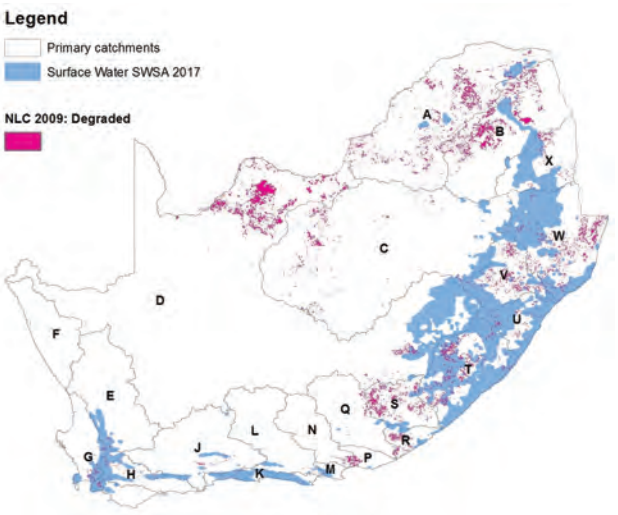
South Africa is an arid country with a mean annual rainfall of less than 500 mm, only 9% of which ends up as water in rivers and aquifers, so every drop is scarce and it is imperative that water is optimally used. Water supplies are unevenly distributed, only 8% of the land area yields about half the runoff (see Figure), and these major water sources need to be managed to protect the quality and quantity of the water they provide. Since most of the high yielding areas are still under natural vegetation, it is critical to ensure that these are maintained for optimal water production.

South Africa is currently experiencing a severe drought since 2015, and this has resulted in crop losses, imposition of water restrictions and significant impacts on water and food security. Droughts are likely to become more intense and more frequent in the future due to changing climatic regimes; at the same time, energy, land and water demands are expected to increase globally. This has implications for associated impacts on availability of grasses for livestock, and water and food security (due to crop losses and water availability). It is clear that South African society needs to respond more appropriately to droughts through timeous and transformative interventions, moving away from responses that do not yield long-term gains, to optimise the supply of water resources.

Humans have modified catchment properties, particularly the vegetation, to provide grazing for livestock, for cultivation, and plantations for food, wood, timber and fiber and to establish settlements (Foley et al., 2005). These modifications are necessary to meet human needs, but typically they have altered how the rainwater is partitioned, often reducing river flows or increasing the volume of floods, or both. Changes in water flows are also closely linked to sediment flows, and the reduced vegetation cover in heavily- or over-grazed lands or poorly designed cultivation may result in increases in soil erosion. Typically, this triggers a negative spiral with further, more rapid erosion, sedimentation of dams and less usable water. Thus, it is crucial for people to recognise the early stages of such degradation (see accompanying Figure) and alter their land-use practices to halt further damage and restore the ecosystems that protect their catchments.

Therefore, the aims of the WRC project are:

1. To explain how well-managed ecological infrastructure can help to mitigate the impacts of droughts on human livelihoods and well-being and to propose strategic responses that will maintain and enhance the value of this service that people will embrace and implement.
2. To provide an assessment of how the ecological infrastructure facilitates drought mitigation.
3. Assessment of ecological infrastructure presence, current state and prioritisation in three focal catchments.



The location of degradation areas in South Africa (2009 National Land Cover) relative to the surface water strategic water source areas (SWSA) by primary catchments

IMPACTS OF CLIMATE CHANGE INTO THE DETERMINATION OF ECOLOGICAL RESERVE

Sponsor: Water Research Commission
JL Tanner, NJ Griffin, AR Slaughter, SK Mantel, P Dubula, DA Hughes, MG Wolff
Collaborators: Dr Piotr Wolski (Environmental and Geographical Science, University of Cape Town), South African specialists on macroinvertebrates (Dr Nelson Odume), fish (Dr Bruce Paxton, Freshwater Research Centre), riparian (Dr James MacKenzie) and geomorphology (Dr Bennie van der Waal, Rhodes University)
April 2018 – March 2019

This project (a solicited WRC proposal) aimed to evaluate the impacts of climate change into the determination of ecological Reserve. Environmental water requirements (EWR), or 'ecological Reserve' flows are the only 'right' to water, in addition to the Basic Human Needs reserve under South Africa's National Water Act (NWA, Act 36 of 1998). The vulnerability of freshwater resources to the impacts of climate change has been recognised by the Intergovernmental Panel on Climate Change (IPCC Fourth Assessment). The Water Research Commission

has also placed emphasis on the need for research on climate change with potential consequences on water resources through increased temperatures and increased hydrological variability (surface and groundwater). These are anticipated to manifest as changes in seasonal rainfall patterns, potential flooding and drought, and sea levels changes in the coastal areas. Thus, the motivation behind the project was the knowledge gap of the impacts of climate change on the ecological Reserve that will be determined using the Habitat Flow Stressor Response defined in the Revised Desktop Reserve Model.
The specific aims of the project were:
1. Determine the impacts of climate change on ecological reserve
2. Assess the resulting impacts of the increased variability
3. Identify and evaluate the adaptive response options.

The project focused on the Doring River in the Western Cape (Figure 1). Doring is a naturally seasonal river that lies to the east of the Olifants River in the Western and Northern Cape. Scenarios of climate change indicate that the region may receive up to 15% less rain in the next 50 to 100 years. The Clanwilliam Yellowfish (*Labeobarbus capensis*), a vulnerable endemic, can be found in the river as one of eight endemic fish in the system, making it a fish biodiversity hotspot.

The project team utilised climate projections (rainfall and evaporation) for the area from Dr Wolski for Representative Concentration Pathway (RCP) 2.6, 4.5, 6.0 and 8.5 (with 43-100 GCMs under these RCPs). Figure 2 shows the range of uncertainty in the mean annual evaporation, which is significantly different from current day values for the Eastern quaternaries. Climate predictions in general reflected reduced future flows, but these predicted future flows overlapped at times with present day flows. In general, there was consensus that changed patterns in flow would result in a future ecological category that was one half to one category below the most recent Present Ecological State (PES). The major drivers of predicted impacts are the length of no-flow periods, and the availability of suitable habitat to enable breeding and survival during no-flow periods. Greater erosion (which will impact habitat suitability) and seasonal salinity levels will further impact riparian and instream biota. The report ends with recommendations for mitigation strategies that can be put in place and future research needs.

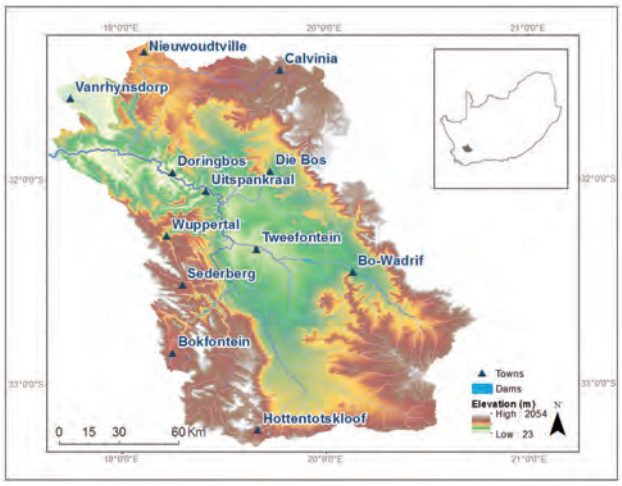


Figure 1 Map of Doring River catchment in the Western Cape that was investigated for the project

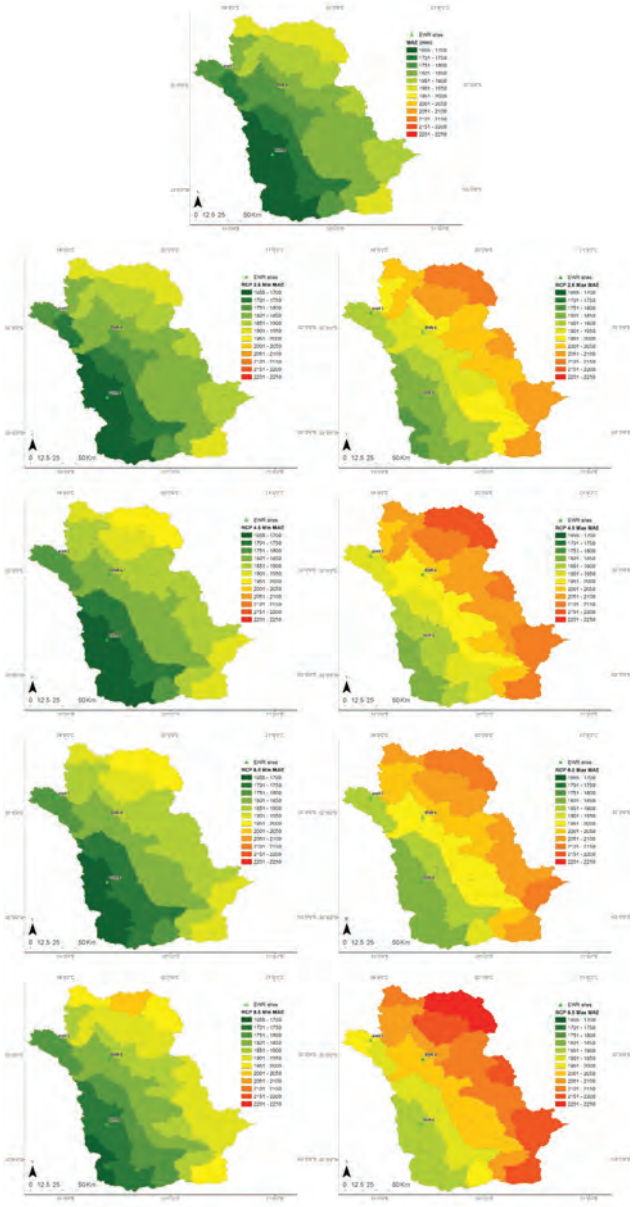


Figure 2: The range of uncertainty in the future mean annual evaporation (MAE) for the four RCPs relative to present day MAE (top figure) for the Doring River quaternaries

THE CONGO RIVER USER HYDRAULICS AND MORPHOLOGY PROJECT

Sponsor: Royal Society – Department for International Development (DFID)
DA Hughes
Collaborators: Bristol University, UK, Leeds University, UK, Kinshasa University, DRC, University of Dar es Salaam, Tanzania.
January 2016 – January 2021

The Congo River User Hydraulics and Morphology project (CRuHM) aims to carry out large scale hydraulic and geomorphological science research on the main navigable channels of the Congo River to address the severe lack of basic scientific knowledge and understanding in these water engineering fields for the world's second largest river, with follow-on economic benefits to both vital river navigation transport and hydroelectric schemes. Prof Denis Hughes leads the IWR contribution to the project and Mr Pierre Kabuya is a PhD student based at the IWR supported by the project.

The CRuHM is an initiative for research and capacity building in water resources of the Congo River Basin. It is funded under the Royal Society – Department for International Development (DFID) Africa Capacity Building Initiative, and is led by a consortium of partner institutions that include the Universities of Kinshasa in the Democratic Republic of Congo (DRC), Dar es Salaam in Tanzania, Rhodes in South Africa, and Bristol and Leeds in the UK. The overall objective of the CRuHM initiative consists of carrying out large scale hydraulics and hydrological science research on the main channels of the Congo River in order to address the severe lack of basic knowledge and understanding, in support of socio economic benefits with regard to water resources services.

The main activities of 2019 include:

- Installation of sediment sampling equipment and data collection at the Kutumuke site, Kasai River;
- Fieldwork training and data collection at Pool Malebo;
- Installation of automatic water level recording stations at N'sele River and Pool Malebo;
- Establishment of the Congo Basin Water Resources Research Centre – CRREBaC;
- Conference attendance;
- FLAIR Award: Royal Society-African Academy of Sciences.

Further details on the project are provided in Mr Pierre Kabuya's hydrology project description.

CRITICAL CATCHMENT MODEL INTER-COMPARISON AND MODEL USE GUIDANCE DEVELOPMENT

Sponsor: Water Research Commission
JL Tanner and DA Hughes
Collaborators: South African Environmental Earth Observation Network, University of the
Western Cape, University of Cape Town, Stellenbosch University and University of KwaZulu Natal.
June 2019 – March 2022

Catchment hydrological modelling has become a critical component of water resource management in South Africa. Modelling is used to predict catchment inputs to water supply reservoirs, estimate flows in ungauged catchments, and assess the likely impacts of land cover and climate changes, among other applications. There is a plethora of modelling tools available with differing approaches and structures for representing hydrological processes. Given the existing and growing reliance on modelling to inform catchment and water management decisions, there is a need for continued research and capacity building that enables the water sector to take full advantage and make wise-use of the diversity of modelling strategies and tools.

Different catchment hydrological modelling tools, such as WRSM-Pitman (Bailey and Pitman, 2015; Pitman, 1973a; Hughes, 2004), ACRU (Schulze, 1986, 1995; Schulze and Davis, 2018), or SWAT (Arnold et al., 1998; Neitsch et al., 2011), have different structural options, algorithms, and formats. These differences have implications on the input data and assumptions needed in model set-up, the model's outputs for different variables and scales of interest, the types of scenarios and changes that can be explicitly considered using the tool, the quantification of uncertainty, and the computing resources needed. The modeller must determine what type of model structure to use for a given setting and modelling question and which modelling tool to use to achieve this.

All modelling tools have different advantages and disadvantages. While there will not be a single best choice of tool for a given use-case, there will be more or less appropriate and advantageous ways of applying a selected tool. A comparison of structural options of different modelling software tools, and an exploration of the implications of these when applied, would be of use in the modelling process, particularly for newer modellers entering the water research and management sectors. Such analyses would provide the basis for giving guidance for determining suitable model structures and using modelling tools to achieve these.

This project emerged from the shared experience of several early-career researchers involved in catchment

scale hydrological modelling and faced with the task of selecting modelling approaches and tools. It was timed to take advantage of modelling work being done for the Socio-Economic Benefits of Ecological Infrastructure (SEBEI) project, focused on the uMgeni, Berg, and Breede catchments, and various initiatives in the Kromme catchment: the Algoa Water Fund, recent WRC projects (K5-2527 and K5-2548), and other ongoing academic and applied research in the area.

These ongoing projects provide a useful opportunity to explore multiple modelling tools in practice by applying them to case study catchments for which the project team has developed an understanding and a database. Additional areas will be added to diversify the application settings considered. Experiences and learning from the modelling tool application process will be supplemented by consultation with modelling experts, particularly those curating and developing the modelling tools, and a systematic structural review based on model documentation and literature regarding these tools.

The overall aim of the project is to provide informed and accessible guidance that can assist modellers selecting and applying commonly used catchment modelling tools in South Africa for typical use cases.

The objectives include:

- Review and compare the structures and structural options in a selection of commonly used catchment modelling software tools in South Africa.
- Apply a set of catchment modelling tools to a diverse set of case study catchments and scenarios of change to allow for more quantitative exploration of the implications of structural differences.
- Document user experiences with the tools through application to the case-studies, workshops, and other interactions.
- Synthesize the resulting data and information to produce guidance materials for modellers.

THE DEVELOPMENT OF AN INTEGRATED SYSTEM FOR ADAPTATION AND MITIGATION TO HYDROLOGICAL DROUGHT IN SOUTH AFRICA

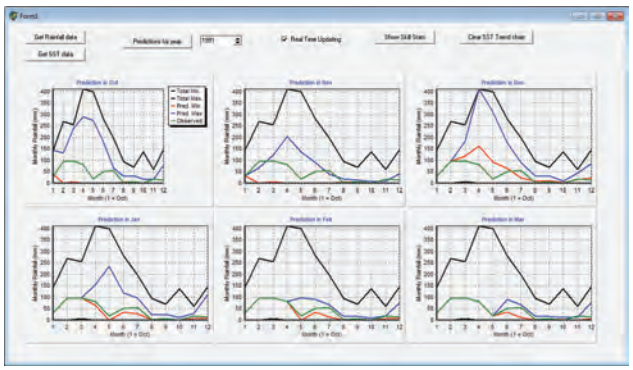
Sponsor: Water Research Commission
JL Tanner and DA Hughes
Collaborators: IWR Water Resources Pty (Ltd), University of Cape Town,
Inkomati Usuthu Catchment Management Agency
June 2017 – September 2020

The project initially focused on rainfall prediction using General Circulation Models (GCMs). The original methodology was focused on using the predicted rainfall from the GCMs to drive hydrological models and produce time series of predicted streamflow. A yield model would then use the predicted streamflow to predict dam storage changes, with the ultimate goal of producing a 3-month forecast of water resource availability. This system utilises the SPATSIM framework (designed by Prof Denis Hughes at IWR) as the platform.

However, initial results from GCMs showed very limited skill in predicting rainfall. As an alternative to using GCMs to predict rainfall, alternative statistical methods have been developed. The alternative methods will be incorporated into the Drought Prediction System as the original methodology envisaged is not possible using GCMs.

The southern Africa seasonal rainfall exhibits substantial interannual variability. Previous work on mechanisms controlling the South African rainfall showed that teleconnections are major drivers of interannual variability of seasonal rainfall in southern Africa. The teleconnections that play major roles in southern Africa seasonal rainfall include the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Antarctic Oscillation (AAO). However, while several studies have attempted to quantify the relationship between the seasonal rainfall and these teleconnections, there is a controversy on the spatial distribution of the relationship. Nevertheless, all studies indicated that the relationship between teleconnections and southern African seasonal rainfall can be explored in developing a statistical model for predicting the seasonal rainfall.

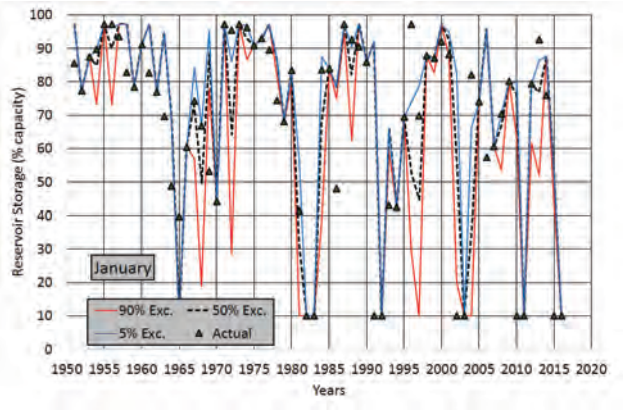
The work aims at establishing a procedure for forecasting rainfall over quaternary catchments in RSA based on locally-specific relationships between rainfall and global modes of climate variability. A model has been developed which is based on ENSO Sea Surface Temperature (SST) anomaly data. Comparing annual rainfall based on a Standardized Precipitation Index (SPI) and SST anomalies indicates that there is some potential skill but this is not throughout. Outputs from the comparison are shown in the image below which shows rainfall for summer months in a summer rainfall region during the drought in 1991. Each graph represents a month (Oct to Mar), and shows total minimum, total maximum, predicted minimum, predicted maximum (these are constrained using the previous month's actual rainfall) and observed. Nov results are acceptable, Dec results are poor, Jan results are acceptable, while Feb and Mar show good results. It is expected that as the wet season progresses, and the model is updated with actual rainfall from month to month, the results will improve.



A comparison of the simulated reservoir (dam) storage using the predicted rainfall, and actual measured storage for January months is shown in the image below.

The next stage of the project focuses on testing the system in other case study areas, including particularly winter rainfall regions.

In addition to the focus on surface water resources, the project also includes a groundwater drought component. Currently, there is no drought prediction system available which integrates the prediction of surface water and groundwater drought. Two Masters students in the IWR are focusing on the groundwater drought component of the project and further details on this component can be found in their student reports under hydrology projects.



The comparison between actual storage and predicted storage for January is generally quite good. The pattern of variation in the triangles (actual) is generally similar to the predicted ensembles and the band of uncertainty is narrow.

ENVIRONMENTAL WATER QUALITY PROJECTS

SDG INDICATORS FOR SDG6 AND CROSSOVER SDGS

Sponsor: Water Research Commission
N Libala, NJ Griffin and A Nyingwa
June 2019 - June 2020

The Millennium Development Goals (MDG) were a United Nations (UN) programme consisting of development targets. The MDG programme ended in 2015, and, while not all goals were achieved in all countries, was broadly considered successful. Since then, the MDG have been replaced by the Sustainable Development Goals (SDG), a wider programme of development and environmental goals. South Africa is committed to the SDG process and has begun work to align medium term policy to the SDGs.

While the individual SDGs have different foci, several of the targets and indicators associated with each SDG overlap. The adoption of overlapping or crosscutting goals, targets and indicators has been both praised and critiqued. An example of overlapping goals is the inclusion of integrated water resource management (IWRM) and protection of water-related ecosystems under SDG6, and conservation of freshwater ecosystems under SDG15. The interlinkages between the SDG targets have been described as binding the SDGs together into one indivisible unit through the complicated network of interactions between targets. They also reduce the possibility that SDG implementation could develop in silos where different stakeholders manage different SDGs in isolation from one another.

Sustainable development goals

The project team are engaging with key stakeholders to explore potential interactions between indicators of SDG 6

and other SDG indicators. Stakeholder interactions will be followed by the use of social network analysis to assess the level of interconnectedness of SDG 6 indicators. The ultimate aim of this process is to identify synergies and trade-offs between SDG 6 indicators and indicators or other SDGs. Synergies occur where progress towards one target may facilitate achieving another target. As an example, achieving water related ecosystem targets under SDG 6 is likely to facilitate targets related to freshwater ecosystem conservation under SDG 15. Constraints occur where achieving one target may have negative consequences for achieving another. An example might be where increasing economic growth under SDG 8 may have negative impacts on water quality under SDG 6. Identification of synergies and constraints, together with assessment of the level of interconnectedness of the indicators, will facilitate prioritization of indicators, and contribute to breaking down silos that may hinder South Africa in achieving the SDGs.

MICROPLASTICS AS EMERGING CONTAMINANTS: METHOD DEVELOPMENT, ECOTOXICITY TESTING AND BIOMONITORING IN SOUTH AFRICAN WATER RESOURCES

Sponsor: Water Research Commission
NS Mgaba, ON Odume, PK Mensah and NJ Griffin
April 2019 – March 2022

Microplastics have been described as emerging pollutants, accumulating in aquatic environments worldwide. To gain a clearer understanding of the availability of microplastics and the threat they pose to aquatic life, and ecological processes, it is important to obtain accurate measures of their abundance in surface water, sediments and benthic organisms. Previous research shows that microplastics can be harmful to aquatic organisms such as fish and invertebrates. This is because they can constitute threats as chemical and physical stressors. As chemical stressors, chemical makeup of microplastics can leach, potentially posing threat to aquatic life and the environment. As physical stressors, microplastics can cause abrasion to soft tissues, accumulate and block such tissues, potentially posing a significant risk. A third dimension, which will not be investigated in this project is that microplastics can act as vectors transporting both chemical pollutants and pathogenic microorganisms. Thus, the aim of this WRC funded project is to evaluate the potential toxicity of microplastics as chemical and physical stressors and to develop/adapt methods for such studies.

In order to achieve the project aim, it has the following specific objectives:

- Evaluate the potential toxicity of microplastics as chemical stressors (plasticizers) using novel endpoints based on selected test species: *Melanoides tuberculate Caridina Nilotica* and *Danio rerio,* as well as multiple life stages.
- Evaluate the potential toxicity of microplastics as physical stressors with a focus on size and shape using novel endpoints based on selected test species: *Melanoides tuberculate Caridina Nilotica* and *Danio rerio,* as well as multiple life stages.
- Adapt and/or develop methods for microplastics biomonitoring in freshwater systems and apply the adapted/developed methods in selected South African river systems (Swartkops and Buffalo Rivers)
- Undertake a comprehensive review of microplastics research in South African freshwater systems.

CASE STUDY FOR LINKING WATER QUALITY LICENCE CONDITIONS WITH RESOURCE QUALITY OBJECTIVES FOR THE LEEU-TAAIBOSCHSPUIT INDUSTRIAL COMPLEX SITUATED WITHIN THE VAAL BARRAGE CATCHMENT

Sponsor: Water Research Commission
ON Odume, NJ Griffin and AR Slaughter
February 2019 – September 2020

It is critically important that water quality standards in water use license (WUL) conditions are credible end scientifically defensible. This criticality arises because such standards are legally binding and enforceable, and are used as instruments for the realization of the objective of resource protection enshrined in the National Water Act NWA (Act No 36 of 1998). Without a transparent, scientifically credible and defensible process, for deriving water quality standards and for selection of water quality constituents included in a WUL condition, contestation may arise between stakeholders, particularly between resource users and regulators. Resource users may genuinely feel that standards are unrealistic and complying with such may have serious social-economic consequences. This project therefore arises out of the need to develop and/or refine existing approaches, methods and decision support system for linking water quality standards in WUL conditions to Resource Quality Objectives (RQOs) and/or site specific conditions taking into account chemical constituents of effluents being discharged by a water user. Such a system was attempted before (DWAF 2006a) but uptake and application was limited. The principles on which the NWA is based differed radically from the previous 1956 Water Act in terms of de-linking land ownership from the right to use water for either abstraction or waste discharges. The NWA moved to an administrative licensing process for the lawful use of water and for enabling continuing lawful use before the promulgation of the Act. At the same time, the NWA provide legally for resource protection through the Resource Directed Measures and methods exist for i) the classification

system ii) the classification iii) setting of the Reserve (Human and Ecological and iv) setting of the Resource Quality Objectives (RQOs) (DWAF 2006b; 2007). To realise the objective of resource protection, the DWS implemented Source Directed Controls (SDC) – and water use license are the primary SDC. Ideally, once, the instream Resource Water Quality. Objectives (RWQOs) are set, license conditions are derived on the basis of the RWQOs to meet the objectives. In reality however, while the RQOs provide numerical and/or descriptive statements about the biological, chemical and physical attributes that characterised a resource at a desired level of protection, taking into account the quantity, timing and pattern of instream flow as well as patterns of biota (riparian and aquatic) i.e. seasonal complexity; first, discharge standards, particularly water quality standards are set as single numeric limits per constituent without a clear indication to resource users whether such limits have taken into account seasonal variability inherent in instream conditions, captured in RQOs. Second, in sub-catchments and/river reaches where there are no RQOs, it is also not clear to all stakeholders how license conditions are derived, particularly on methods that are able to capture site specific conditions to inform license discharge standards. Third, it is also not clear to all resource users how upstream waste loads affect discharge standards for downstream users – this is particularly crucial for the Lower section of the Upper Vaal, where a number of upstream pollution sources impacts on downstream resource users. Fourth, while flow is a critical factor in instream resource quality, it is not clear how existing methods link flow (quantity) and quality in the process of deriving discharge standards in WUL. Fifth, in situation where a resource user discharges effluent of which the critical water quality variable of concern has no RQO description for the catchment of interest, it is also not clear how limits are set for such variable in WUL conditions. These obscurities in ways in which discharge standards in WUL conditions are derived have caused contestations between regulators and resource users – particularly within the Vaal Barrage catchment with regard to the scientific credibility, defensibility and transparency of methods used in deriving discharge standards in WUL conditions.

A further compounding factor is the real complexity of water quality as a multivariate issue with multiple data sources (e.g. biomonitoring, water chemistry and ecotoxicology), providing multiple and qualitatively and quantitatively different kind of information, and all of these expressed via waste loads in particular (and variable) flow conditions, resulting in an instream concentration – the unit of chemical compliance in WUL conditions. The complexity of water quality as a multivariate issue therefore requires systemic and careful consideration as to broader social-economic and ecological considerations/implication in the inclusion of specific water quality variable in license condition as well as the required frequency and location of monitoring, taking into account catchment dynamics. This study, which flows from an earlier study, therefore presents a unique opportunity for clearly linking water quality standards in WUL conditions to gazette RQOs, and site specific conditions, taking into account a range of complex interacting factors such as all components of flow (flow regime, timing, pattern, frequency etc.), land use types, and upstream waste loads. Thus in order to move towards both pragmatic use of water for waste discharge purposes, and real resource protection, the time is right for a careful study that will result in improved licensing conditions based on a better understanding of how to apply RWQOs, the South African Water Quality Guidelines or site specific conditions to improve resource class of a river reach.

To realize the very essence of the proposed project: i) any method/approach or decision support system developed or refined in the course of the project must be scientifically credible, defensible and transparent – on scientific assumptions, observed and modelled data, confidence, and limitations ii) the process of its development must be multi-stakeholder involved (regulators and resource users) iii) the tool/DSS developed must be embedded within a broader framework that gives guidance on setting and implementing water quality license conditions linked to RQOs and/or site- specific conditions for both point and diffuse emissions, iv) implementation must be successfully demonstrated with stakeholders (regulators and resource users) and v) capacity built both for regulators and resource users. The Vaal Barrage area and associated rivers serves as an ideal, but complex case study for the present study as regulators and resource users have indicated willingness to work together on the development of such a tool. Further, given the importance of the case study area of the proposed project, its success will contribute significantly to improving the resource quality and by extension the social-economics of the area.

Project objectives

- Undertake a comprehensive and thorough assessment of existing practices, data, approaches, methods and tools including relevant catchment literature, with regard to Source-Directed Controls (SDCs) and resource quality objectives (RQOs) in the proposed study areas. The assessment should include analysis of all current tools, practices, methods/approaches of setting water quality conditions and their scientific defensibility/or other uses within the proposed study area.
- Develop an approach that is robust and scientifically defensible but flexible method/tool/decision support system (DSS) (e.g. mass balance model) for transparently setting water quality license conditions (point and diffuse) taking account of receiving resource quality objectives/site specific conditions. The tool developed/refined should address issues of multiple users and competition as well as submission of data by water users to the regulators. Alternatively, guidance should be given on how to apply existing tools/models for setting and monitoring water quality license conditions, considering receiving site-specific conditions and RQOs. Issues relating to scientific assumptions, confidence, limitations and quality assurance/control should be addressed.
- Demonstrate and test the implementation and

applicability of the developed method. Tool/DSS under multiple water quality conditions, temporal/spatial, site-specific/RQOs scenarios (i.e. scenario analysis) with catchment stakeholders including the relevant units within DWS, catchment management forums, and water users e.g. Sasol, ESKOM, Rand Water, local government/municipalities. As part of the scenario analysis, demonstrate how the developed tool could be implemented such that a water user is able to determine the likely impacts on water quality objectives and/or site-specific conditions.

- Communicate widely with catchment stakeholders and build capacity of the relevant unit/sections within DWS, and water users through training on the use and application of the developed method/tool/DSS. The purpose of this objective is to ensure that the entire process is consultative and widely communicated to ensure that the outcome of the project is widely accepted by all stakeholders.

CONTRIBUTIONS OF AN ETHICALLY-GROUNDED AND VALUE-BASED APPROACH TO WATER GOVERNANCE – THE CASE OF TWO CONTRASTING CATCHMENTS

Sponsor: Water Research Commission
ON Odume
Collaborators U Okeja (Department of Philosophy, Rhodes University)
April 2019 – March 2022

Three top water governance challenges currently confront the water sector in South Africa. These are i) the regulatory system ii) accountability and iii) cooperative governance (Weston and Goga 2016). All three of these challenges have value and ethical dimensions. For example, an inefficient regulatory system has led to multiple incidences of illegal discharges of waste into rivers in most parts of the country, and these have negatively impacted on other users who have legitimate right of access to such water resources. An example in this regard is the Klip River catchment in Gauteng (Klip River Catchment Forum 2018). In the Lower Sundays River Valley Catchment (LSRVC) in the Eastern Cape, for example, an inefficient regulatory enforcement, poor accountability measures and a near absence of cooperative governance have manifested in the form of inequitable allocations of water between multiple user sectors, particularly between the privileged irrigated agriculture and the less privileged sections of the domestic users (Clifford-Holmes 2015). All these are matters of ethics in as much as they also border on the law. Ethical dimensions to water governance challenges manifest because different societal constituencies or groupings may hold different values with regard to water resources, and these values may come into conflict, thus requiring an ethically-grounded approach to bring them into balance or constructive trade-offs (Soderbaum. 2008; Brown and Schmidt, 2010; Odume and De Wet 2016). In this proposed project therefore, we seek to contribute to addressing specific identified water governance challenges in two contrasting catchments: the Klip River and the Lower Sundays River using an ethically-grounded approach – the systemic-relational (SR) perspective recently developed through a WRC funded project (Odume and De Wet 2016).

The Klip River catchment situated in one of the most urbanised catchment in the country faces a range of threats, particularly water quality deterioration arising from pollution, impaired river morphology and habitat alteration, abstraction challenges because of competing use demands and values. One of the main ethical issues in the Klip River catchment is pollution by some user sectors with significant negative impact on other users (Wepener et al. 2015). The lower Sunday's River valley catchment (LSRVC) situated in a largely rural part of the Eastern Cape faces significant water governance challenges, but of different nature to those in the Urban Klip River catchment. The main water governance challenges that border on ethics are those related to efficient and equitable allocation of water, particularly between domestic users and irrigated agriculture, which is further compounded by high levels of poverty, unemployment and inequality (Clifford-Holmes 2015; Stat SA 2017). In the LSRVC, even though water is supplied for irrigation almost uninterruptedly, the less privileged sections of the domestic users often experienced water cuts and in 2014, it led to serious violent protest that resulted in damages to properties (Clifford-Holmes 2015). Despite national and provincial governments' interventions from 2009 – 2014, a range of these challenges, which seriously border on ethics, still persist and deeply remained unresolved. In the context of these two sharply contrasting catchments with diverse challenges, it is therefore important that an ethically-grounded approach is brought to bear as values between water users' sectors come into conflict.

If the goal of managing water sustainably, efficiently and equitably is to be achieved, particularly in a pluralistic country such as South Africa, values associated with and derived from water whether, cultural, economic, ecological, spiritual, must be adequately taken into account and clarified in every decision- making process, and in governance systems (Brown and Schmidt, 2010; Pradhan and Meinzen-Dick 2010). In addressing 'wicked problems' such as water governance in South Africa (Weston and Goga 2016), value pluralism would imply that there will be times when multiple values clash, necessitating clarification regarding what ought to be done and balancing of constructive trade-off (Groenfeldt and Schmidt, 2013). How this constructive re-balancing and potential trade-off is achieved is the domain of ethics. We take values to mean what specific societal groupings or constituencies express at a generalised level to be good or bad conduct, and ethics as a systematic concern with the principles by which conducts, morals and values are clarified and justified, as we seek

to distinguish between right and wrong in our behaviour towards other people and towards nature (Odume and De Wet 2016).

While there is a growing body of knowledge in South Africa that supports the governance and management of water resources in the context of complex social-ecological systems (SES) (Folke et al. 2005; Pollard et al. 2011), there is little parallel research effort aimed at distilling ethical criteria and principles for navigating the array of complex issues such a systemic and holistic view of governance raises. It is therefore not surprising that a range of water governance challenges that border on ethics and values currently plague the water sector (Pegram et al. 2006; Sowman and Kapfudzaruwa 2009; Weston and Goga 2016). If we are to take seriously the idea of SES in practice, then it is not only the various kinds of components of the SES that may be seen to have intrinsic value. Value is also derived from the relationship between the components, (and their constituencies) and, in a dynamic complex system, from the emergent, and complexity-generated, properties of such a dynamic, interactive system (Pignatti, 2013).

This then raises the significance of the contribution of an ethically-grounded approach to water governance in South Africa. This is particularly true because when one engages with the three key values of equity, sustainability and efficiency, fundamental to the National Water Act, Act No. 36 of 1998 (RSA 1998), it appears that, if one pursues them in relation to each other with any rigour, one is – not surprisingly - likely to land up in situations where these values come into conflict, which may create ethical dilemma. For example, efficiency of delivery of water and sanitation services is directly influenced by whether or not service providers are able to afford to provide such services. This increasingly requires charging receivers for the supply of such services. Charging for services –even if a percentage of the service delivered (such as the first 6,000 litres of water) is free, or is charged at a pro rata rate proportional to income – does not impact equitably on all households across the income spectrum, and if services providers fail to provide such services efficiently across all water users sectors because of costs, then this raises ethical dilemma as water is a basic human right. Here the value of equity and efficiency even though they are fundamental to the Act come into conflict and may pose serious water governance challenges. What is required is an ethically-grounded approach to bring them into balance and constructive trade-off. In this proposed project, the systemic-relational (SR) approach to environmental ethics, which was recently developed by Odume and De Wet (2016) will be used in the case studies to investigate the contribution of ethics to addressing the identified water governance challenges.

The SR ethically grounded approach is innovative because it conceptualises the governance and management of water and associated values beyond the social domain, to include the wider SES, and recognises the mutually constitutive, on-going complementary and co-supportive interactions of the components (and their constituencies) of the SES. Eleven principles have been developed to help surface values associated with the components, clarify the implications of different claims and claimants, and courses of actions and to navigate the potentially difficult inescapable element of ranking and trade-off of values, and by implication, of rights related to those values in water governance. As the WRC begins to pay attention to the issues of ethics and water governance in South Africa, this proposed research contribute to the emerging field of water ethics in South Africa, and provide comparative data, which can inform ethically-grounded policy direction, practice and implementation.

Project objectives

- Together with stakeholders, surface key values informing water governance in the selected catchments, and undertake a value-based analysis of how the stakeholders go about reconciling/trading off conflicting values and the ethical implications.
- Explore whether an appeal to ethics level context-sensitive principles can foster greater equity, sustainability and efficiency in water governance in the selected catchments.
- Explore instances of polycentricity in water governance in the catchments, paying attention to whether/or not in such instances, it contributes to effective and cooperative water governance.
- Synthesize lessons of the value of ethically-grounded and value-based approach for policy, practice and implementation, while providing comparative data from the selected catchments.

ENHANCING URBAN WETLAND AND RIVER ECOSYSTEM HEALTH TO SUPPORT ENVIRONMENTALLY SUSTAINABLE URBAN DEVELOPMENT IN SELECTED AFRICAN CITIES – A SYSTEMIC-RELATIONAL (SR) ETHICAL PERSPECTIVE

Sponsor: Network of African Science Academies (NASAC), International Science Council and SIDA
ON Odume and CF Nnadozie
Collaborators BN Onyima (Nnamdi Azikiwe University, Awka), GO Omovoh (Federal Ministry of Environment, Nigeria), BO Omovoh (Federal Ministry of Environment, Nigeria), E Ogidiaka (Delta State School of Marine Technology).
Collaborating organization: Nelson Mandela Bay Metro
June 2019 – May 2022

Urban rivers and wetlands are often seriously degraded ecosystems, and in Africa, they are often used as sewage and storm water disposal pipes[1] (Winter 2017[1]). Heathy

urban rivers and wetlands can contribute to and support sustainable urban development through the provision of a variety of ecosystem services. The continuing degradation of urban rivers and wetlands presents an intractable challenge, and we argue that part of this intractability arises through insufficient appreciation by urban planners and policy makers in Africa of the interconnectedness and interdependence between ecological and social subsystems with a river/wetland catchment. To address this challenge, we propose a systemic-relational (SR) ethically grounded approach within the complex social-ecological system framework as an analytical perspective for investigating the ecological, economic and social as well as management and institutional dimensions of urban rivers and wetland health.

Our approach departs from the traditional assessment as it recognises that ecological and social-economic components together form an integrated and dynamic complex system of urban ecosystem health. We intend to recommend ways in which the health and functionality of these ecosystems can be enhanced to support sustainable urban development through the supply of valued and desired ecosystem services.

Our case studies are in Abuja Municipal Council in Nigeria and the Nelson Mandela Bay Metro in South Africa.

Project objectives

- To develop context-sensitive, holistic multi-dimension (ecological, social and economic) indicators of urban rivers and wetland health that can contribute to tracking the trajectory of urban development;
- To examine the consequences of polycentric, systemic and operational integration failures as major institutional impediments towards the realisation of healthy urban rivers and wetlands health in order to recommend a model of systemic integration that benefit the SES health;
- To use the SR ethically-grounded approach as an analytical perspective to examine the inextricable interactions and linkages between urban rivers and wetland health, and urban dwellers' social-economic well-being (i.e. people-river relationality) in order to contribute to shifting social and institutional practices in ways that can enhance ecosystem health and their services;
- To develop a framework for enhancing urban rivers and wetland health by taking account of the systemic-relational interactions, interdependence and potential trade-offs between ecological conditions, desired ecosystem services, institutional and social practices.

AFRICAN WATER RESOURCES MOBILITY NETWORK (AWARMN): BUILDING TRANSDICIPLINARY CAPACITY FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN AFRICA

Sponsor: European Commission Education, Audiovisual and Culture Executive Agency

ON Odume, CF Nnadozie, N Griffin, CG Palmer, J. Tanner

Collaborators BN Onyima (Nnamdi Azikiwe University, Awka), GO Omovoh (Federal

Ministry of Environment, Nigeria), BO Omovoh (Federal Ministry of Environment, Nigeria), E Ogidiaka (Delta State School of Marine Technology).

Collaborating organization: Nelson Mandela Bay Metro

January 2020 – December 2024

Achieving sustainable development, and inclusive growth within Africa would largely be undermined if its water resources are not sustainably managed, utilised, protected and governed. The continent is facing multiple water-related challenges, including declining water quantity and quality, inadequate governance and institutional structures, declining monitoring networks, increasing resource use in the face of a growing human population, and increasing resource variability associated with future changing climates. As the region strives toward improving political, economic and social stability, the importance of secure water supplies will assume increasing significance. If this is neglected, a potential for conflict exists: 1) within and between communities -through a lack of water- and sanitation-related access and services, and 2) between countries- through a lack of agreement on transboundary sharing of water resources and most importantly, 3) between societal constituencies through perceived non-inclusive and equitable sharing of water resources (distributive justice).

There is an urgent need to increase Africa's human capacity in the field of water resources to develop socially- relevant solutions to water resource problems on the continent. The shortage of trained, qualified and competent academics and professionals hinders Africa's efforts in addressing the challenges facing the water sector. 'Experts' from outside the continent are often called upon to address specific water-related challenges. This approach is not sustainable as it does not provide long-term capacity development for Africans. Some progress has however been made to address the region's skill shortages, e.g. through the Southern Africa WaterNet programme (http://www.waternetonline.org/) and the Carnegie-RISE-funded Sub-Saharan Africa Water Resources Network (SSAWRN).

The water challenges facing the region are inherently complex and systemic. It is now clear that addressing these challenges requires a fundamental and radical shift in the manner in which students and staff are trained. We argue

for a transdisciplinary, socially-engaged approach rooted in complexity and system thinking. We understand research contexts as complex social –ecological systems. This involves the co-production of integrative, socially meaningful and solution-oriented knowledge that transcends traditional disciplinary boundaries, and includes the widest range of knowledge sources: academic, professional, practice-based and local. This engaged participatory research style is rare in Africa, largely because a critical mass of practitioners is absent. In addition to the traditional specialist skills required within the water resources management sector (for example hydrology, ecology, economics, chemistry etc.), future graduates should be able to place their knowledge into a broader context – connecting meaningfully with other forms of knowledge. This skills-base will contribute substantially to sustainable, equitable, appropriate and developmentally effective water resource management in Africa. A critical outcome of transdisciplinary, socially-engaged training is that the learning pathways are seriously embedded in practice, and real-world challenges, so that by the time students graduate, they have been sufficiently expose to the challenges of the workplace, and society at large. This kind of meaningful training, thus prepared the students for employment, a critical envisaged outcome of the 2019 intra-Africa mobility call.

The overall aim of the partnership will be achieved through: 1) a transdisciplinary, socially-engaged training embedded in existing programmes within partner institutions, ensuring increases in the numbers of highly qualified and competent (MSc and PhD) graduates in the field of water resources in Africa; 2) develop and harmonise programmes and curricula, with a particular emphasis on disciplinary excellence and transdisciplinary capability; 3) build and sustain teaching and research capabilities among partner institutions; 4) design and implement research programmes based on collaboration and cooperation during, and beyond, the proposed funding; 5) facilitate student and staff mobility to promote multiculturalism and internationalisation among African institutions of higher learning; 6) contribute to innovation and water technologies that advance social-economic development of Africa and; 7) address the professional career development and employability of graduates by creating a direct interface between AWaRMN and industry partners.

ADAPTIVE WATER RESOURCE MANAGEMENT PROJECTS

THE TSITSA PROJECT: GOVERNANCE COMMUNITY OF PRACTICE

Sponsor: Department of Environment, Forestry and Fisheries: Natural Resource Management
CG Palmer, N Libala, M Ralekhetla, A Fry and N Mti
April 2019 - March 2021

The Tsitsa Project (TP) is an ongoing, 10-year (2015-2025) project funded by the National Department of Environment Forestry and Fisheries: Natural Resource Management Directorate (DEFF:NRM) to restore the landscape, so as to ensure both improved livelihood options for residents, and the sustainability of ecological infrastructure that supports livelihoods. The Tsitsa River catchment is the source of water for the proposed Ntabelanga dam in the Eastern Cape, and is a rural landscape including private and communally owned areas. The TP started as a natural science based project focusing on sedimentation and rehabilitation, in realising the interconnectedness between humans and nature. Prof Tally Palmer facilitated the shift of the TP to adopting a Complex Social Ecological Systems (CSES) approach, where good governance is seen as having potential to bring transformation towards sustaining the outcomes of the project – a sustainable landscape supporting livelihood and human well-being. Participatory governance research was initiated as a core process undertaken by the Institute for Water Research (IWR), Governance Community of Practice. The Governance CoP is working towards empowering communities to engage in participatory natural resource governance as an investment into the sustainability of both livelihoods and ecological infrastructure.

Our key research questions are:

1. How can interventions, and especially those that involve government, research and stakeholders, including local residents, result in sustainable outcomes that persist beyond the intervention, and move towards sustainable behavior-change in the practice of all participants? 2. Can development of local governance capacity contribute to sustainable landscapes: people and environment?

Within the 2019 academic year, the Governance CoP' objectives were to:

1. Write a detailed literature-based plan of how to integrate the various bio-physical methods, data and

results and with social-science and humanities-based methods, data and results

2. Report on developing epistemic justice through a "knowing" programme (Figure 1), where participants become comfortable with the vocabulary associated with the restoration project, and also understand the benefits of the project to themselves and their community. This is pertinent to the development of Community Liaison Officers and their development as informed participatory governance agents.
3. Report on participatory governance community work sessions (e.g induction, roadshow and capacity development) to indicate progress towards informed participatory governance agents.

The focus of the work this year was the development of the capability pathway (Figure 1), which will guide the way engagement is done by the Governance CoP towards empowering participatory governance agents. The capability pathway was initially envisaged as a linear step-by-step of processes that ended with capacitated participatory agents; and the steps were: co-knowing, co-listening and co-speaking, co-planning, co-influencing and co-decision-making. Epistemic justice research completed by the governance team (Ralekhetla 2018) that shown that it is fundamental for people to have knowledge – of both content and context, and once you know you can establish speaking and listening relationships. Then you can start talking about co-development of plans. It's only once you know, and can listen and speak and have been part of the planning and you are able to get into influencing and deciding.

Of course the capability development process is not linear, and the Governance CoP has collaborated with the Systems Praxis CoP (within the TP) to expand the linear concept into a systemic conceptualization that accounts for different internal and external forces that will possibly impact on the realisation of the pathway. Following the capability pathway the focus for this year was co-knowing, through a workshop process named 'Learning Words'. 'Learning Words' develops a common vocabulary and understanding of TP activities, processes and benefits for local people. In 'Learning Words' workshops a word related to natural resource management is chosen and participants develop a word cloud of their association with the word. The word Home/Ikhaya has been used as an icebreaker of the exercise.

We started with a large workshop aimed at local residents with knowledge of the Tsitsa Project; this workshop was conducted in Maclear, the small farming town at the centre of the catchment. Aligning our work with the broader Tsitsa Project, we moved progressively further out into the harder to reach villages in the catchment. Thus far five Learning Words workshops have been conducted in three out of the six project nodes, allowing in-depth interactions with approximately one hundred and fifty people. Importantly, the six newly appointed Community Liaison Officers helped with the facilitation and running of the last three workshops.

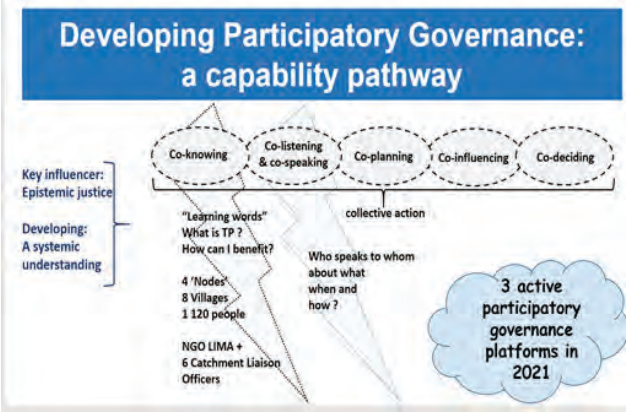


Figure 1: The Capability Pathway

Participants at the Learning Words workshop

EVALUATING TRADE-OFFS FROM INTENSIFIED PRACTICES IN COMMUNAL LIVESTOCK SYSTEMS IN SOUTH AFRICA USING AN INTEGRATED FARMING SYSTEMS APPROACH

Sponsor: Coventry University
Dr AR Palmer
April 2019 – March 2021

This interdisciplinary research project, funded by the UK's BBSRC, involves researchers from Coventry University, Rothamsted Research (UK), with partners from three separate institutions in South Africa namely Conservation SA, the Institute for Water Research and Stellenbosch University. The project aims to better understand the socio-ecological systems (SES) of communal grazing areas in SA for the past 20 years, focusing on governance of communal grazing systems as common property regimes and the links between governance and degradation of communal rangeland. Using a large aperture scintillometer, Prof. Tony Palmer from IWR, has been determining the water use of the wattle trees which have invaded the hill-slope seeps of the Drakensberg foothills. The grasslands associated with these seeps have historically been a very important grazing resource, but this has been replaced by un-palatable wattle

trees. In addition, the water used by these trees has radically altered catchment run-off, reducing the water available to the communities living in the villages. The project aims to quantify the volume of water being lost to wattle invasion, and to explore alternative livelihood strategies that should be considered in the affected villages.

Prof. Tony Palmer installing the larger aperture scintillometer, with wattle invasions of hillslope seeps clearly visible in the background.

CAPACITY DEVELOPMENT IN THE TSITSA PROJECT

N Mti

Ms Mti has been working closely together with the Governance group that works on the Tsitsa project in Maclear. She has been assisting in the project as a translator and researcher. She also contributed in organizing and planning in terms of logistics of the workshops. This year she became a member of the Makana Water Forum and has taken up the secretarial duties of the forum. The Makana Water Forum has been involved in building awareness on matters relating to water resource management, water supply and strategies in the Makana Local Municipality.

IWR CITIZEN SCIENCE GROUP

Ms Khaya Mgaba is a leader of the IWR Citizen Science Group with other members. David Gwapedza, Bawinile Mahlaba, Bukanani Mdludla and Asanda Chili helped during field trips. This year the group demonstrated and taught Kingswood College students how to use mini-SASS and measure water quality variables. The learners were taken to the Palmiet River and engaged in mini-SASS demonstration, showcasing the value of water resources and how resident biota are able to respond to changes in water quality. The learners were also taught important macroinvertebrate identification skills.

Saint Andrews Round square circle conference 2019

Saint Andrews College hosted a Round square conference on the 12th-16th of April 2019. The conference theme was 'Embracing Our Realities, Growing Our Opportunities'. IWR citizen science group Ms Khaya Mgaba, Dr Neil Griffin, Dr Matt Weaver and Ms Ntombekhaya Mti were demonstrating water quality testing, aquatic invertebrate adaptations and the use of mini-SASS for assessing water quality.

Ms Ntombekhaya Mti building a word cloud with participates in Lower Sinxako.

Ms Khaya Mgaba helping the students to identify freshwater invertebrates.

Ms Asanda Chili and Kingswood college students during their field trip.

COMMUNITY ENGAGEMENT AT THE IWR 2019

SciFest Africa is South Africa's largest science festival. The theme for 2019 was "Discover your element" and celebrated the International Year of the Periodic Table of Chemical Elements as proclaimed by the United Nations. SciFest Africa promotes public awareness, understanding and appreciation of science, technology and innovation in South Africa. The Institute for Water Research (IWR) uses this opportunity to give back to the community and share the knowledge gained through scientific studies. IWR staff and students showcase the work conducted by the institute. Biomonitoring, water quality testing, and hydrology where the key features of the IWR exhibit demonstrated water processes and explained the use of aquatic insects as indicator of water quality to the visiting scholars.

Primary school students identifying macroinvertebrates to understand the status of the water.

BUILDING CAPACITY THROUGH INTERNSHIP TRAINING IN ENVIRONMENTAL WATER QUALITY

Science Faculty Open Day

IWR participated in the Rhodes University Science Faculty open which was held on the 8th of March. The open day is an annual attempt by the faculty to engage high school learners and prompt their interest in science-related issues as well as showcase the numerous science program offered by the university. This year, the Institute ran a mini-workshop centred around building a water supply system and highlighting good citizenship for water resources. The workshop activities included:

- A water-wise quiz which addressed current issues such as drought. The quiz allowed contributors to engage meaningfully with the leaners and get a sense of how members of the broader Makhanda community view and respond to water issues. It also made the learners aware of their own water consumption and prompted discussions around water conservation.
- Demonstration of the Grahamstown water supply cycle and the South African catchment management. Leaners used maps to locate their homes and then trace how they fit into the water supply system in terms of where their water comes from, how it is cleaned and transported to them as the end users. Learners responded quite positively to this activity and there were some lively discussions around this topic.
- Overview of the research and activities carried out in the institute including, the kinds of careers the leaners could explore in the water sector that matches with their interests.

IWR MSc students Mr Sinetemba Xoxo and Ms Asanda Chili interacting with learners.

POST DOCTORAL FELLOW ACTIVITIES

AN EXPLORATION OF SOCIAL-BIOPHYSICAL KNOWLEDGE INTEGRATION IN THE TSITSA PROJECT

Sponsor: Department of Environmental Affairs (DEA), Chief Directorate
Natural Resource Management (NRM)
Post-doctoral Fellows: N Libala and A Copteros
Supervisor: CG Palmer

The Tsitsa Project (TP) is a science-based social-ecological land restoration and livelihoods development programme. It has evolved over time from being the Ntabelanga and Lalini Infrastructure Project in 2014 to the Tsitsa Project in 2018 (Matthews, 2019). As part of its evolution, it has shifted from being a more biophysically-centred sedimentation and rehabilitation plan to acknowledging the social-biophysical linkages and the need to work with social and contextual considerations (van der Waal et al., 2018). Two of the seven guiding principles of the TP are 'polycentric governance' and 'equitable participation by multiple stakeholders' (Cockburn et al. 2019). TP is a collaborative venture into polycentric governance with the main proponents and sponsors being: The Department of Environmental Affairs (DEA); The Department of Science and Technology (DST); the Water Research Commission (WRC) and the Department of Water and Sanitation (DWS) (van der Waal et al., 2018).

Participatory, polycentric governance landscapes are characterized by multiple centres of power and authority (Cleaver & Whaley, 2018). In these landscapes, polycentric governance is considered useful in managing complex, place-based, multi-scale, social-ecological systems (Palmer, Rivers & Fox, 2019). The governance structures of the TP have developed over time to represent the heterogeneity and complexity of the TP (van der Waal, 2018). Implementation has required a phased approach, due to the size of the catchment and the complexity of the total system. Research Communities of Practice (CoP) have been established to cover the breadth of activity and contribute to the systemic understanding of inter-relationships and the process links between biophysical, institutional and social elements. These include: Governance; Knowledge and Learning; Livelihoods, Sediment; Livestock; Grazing and Fire; Systems thinking and practice.

A strategic adaptive management approach has been adopted in which learning is based on an emergent, reflective and participatory practice (van der Waal, 2018). According to Walker and Salt (2012), natural resource management issues involve an inevitable level of 'irreducible uncertainty' due to the non-linear interdependencies occurring at multiple scales, as well as the unknown thresholds of systems change. According to Cilliers (2000), complex, adaptive systems comprise many interacting components with non-linear processes. There are feedbacks between components and processes, which are influenced by scale (temporal and spatial) where small changes can lead to large effects (and vice versa) (Clifford-Holmes, Palmer, de Wet, & Slinger, 2016). Complex adaptive systems are mutually influential, self-organise, develop and evolve (Tollemache, 2013).

The Governance CoP in the TP focuses on developing participatory governance. Governance is about institutional and political relationships that include those of power and knowledge (Leach et al., 2010). The Governance CoP focuses on the governance engagement capacity of residents in the communally owned landscape (Palmer, Rivers & Fox, 2019). It contributes to the TP vision of supporting sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services (Palmer, 2019). It also supports polycentric governance by strengthening the function of existing institutions through capacity development as part of creating a functional governance network (Cockburn et al. 2018).

If a range of healthy, workable institutions are operating at various scales in a collaborative fashion these are much more likely to support sustainable livelihoods that have equitable access to ecosystem services, while achieving resilient social-ecological systems. Two of the areas in which the Governance CoP contributes to institutional functionality is by nurturing adaptiveness, flexibility and learning within and between institutions and co-producing diverse knowledge streams (Armitage et al., 2012).

Considering the wide range of stakeholder (local residents, policy makers, scientists and natural resource managers) interests in the TP, van der Pol (2019) conducted research on the complexity of governance dynamics in restoration projects. In the TP he found that despite professionals adopting participatory approaches where: different stakeholders should all work together to co-produce knowledge; communities should be engaged in the decision-making to gain their support and reach long-lasting impact; the professionals that carry out this approach, need to be reflexive and need to work in a

transdisciplinary way, the reality is that diverse interests exist between many stakeholders, at many levels, and around different aspects within the TP. This makes it challenging to engage with the guiding principles of the project unless professionals involved in the project can be more transparent about their diverse interests and thus negotiate them better.

As part of negotiating these interests, this research focuses on the integration of various bio-physical and social-science data-sets into knowledge and understanding development in the TP. Wilson (2006) describes professionals in development practice as people who can have different theoretical backgrounds, work in diverse sectors, operate at various levels and within different institutional contexts but all combine theoretical knowledge and practical knowledge gained from professional practice to ensue possibilities for learning and change. The aim of this research is to actualise concurrent knowledge development across a range of disciplines and practices in the TP.

It aims to engage with the following research questions:
Has there been integration between biophysical, social-science and other engaged-research methods, data and results, from the TP, in support of achieving the TP vision?
What makes it possible to cross disciplinary framings and share learning in the TP?

What does knowledge creation and learning mean to the range of professionals involved in the TP?
What are the scale related drivers of change?

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INVESTIGATION OF THE OCCURRENCE AND RISK OF INFECTION OF PATHOGENIC AND ANTIBIOTIC RESISTANT *CAMPYLOBACTER* SPECIES IN SELECTED SOURCE WATERS WITHIN THE KOWIE CATCHMENT, EASTERN CAPE, SOUTH AFRICA

Post Doctoral Fellow: CF Nnadozie
Supervisor: ON Odume

Emerging pathogens and their strains whose human and environmental health risks remain poorly understood are serious concerns for the global health system. In the last decade, the discovery of *Campylobacter* spp., an emerging pathogen, is now a serious public health concern. Campylobacteriosis disease is caused by *Campylobacter* spp., is a gram negative bacterium, which is either spiral, curved or rod shaped. It either has two or one flagellum, or none, depending on the species. These infections are a main cause of gastrointestinal disease globally, and their occurrence rates are higher than those caused by *Salmonella* and *Shigella* in developed countries. Locally, diarrhoeal diseases pose a major public health problem in South Africa, and is the third leading cause of death in the country. Apart from gastrointestinal infections *Campylobacter* spp., has also been associated with other intestinal infections, such as, hepatitis, myocarditis myelitis, meningitis, haemolytic-uraemia syndrome, pancreatitis, as well as secondary complications, such as Guillain-Barr syndrome. The major concern with these infectious organisms (e.g. *C. jejuni* and *C. coli*) is the association with increasing resistance to first line antibiotics (fluoroquinolones, macrolides and tetracycline) that are used for treatment. Worse still, a vaccine by way of a preventative measure is not yet available. The impact cannot be overlooked particularly for South Africa with a high population of vulnerable individuals due to several reasons, including the HIV pandemic. In clinical settings, substantial surveillance data of *Campylobacter* isolates are available for many of the major areas in South Africa. However, environmental load of *Campylobacter* resistance is scarcely investigated. Yet, it is widely acknowledged that environmental bacteria are reservoirs of antibiotic resistance genes that can potentially be incorporated into human as well as pathogens with time. Environmental *Campylobacter* resistance gene pool is amplified by the inflow of antibiotic resistance genes from human waste

and livestock into water environment. For these reasons, *Campylobacter* is one health challenge, emerging at human-animal-environment interface. The Kowie River in Grahamstown, Eastern Cape Province is used by the community for recreational, irrigational and spiritual (e.g. baptism) purposes. However, this river system is subject to various kinds of microbial contamination that poses a health risk to human. Grahamstown and surrounding areas face a sewage treatment crisis and raw sewerage commonly flows into streams and rivers that eventually reach the Kowie River. Also, livestock farming is a common practice in the area, and much of the runoff containing manure from livestock from nearby farms flow into the river, thereby severely polluting it and affecting water quality. The extent to which human or animal inputs contribute to the pollution of the river with *Campylobacter* is unknown, and it influences the type and extent of protection required. This study investigates the potential of Kowie River system as a reservoir of antibiotic resistant *Campylobacter* spp. and as potential habitat where resistance genes are mobilised and transferred to susceptible cells. Furthermore, the study will apply the one health approach to identify the primary sources of the pathogen and the potential risks of gastrointestinal illness from human exposure to the Kowie river.

TRANSDISCIPLINARY RESEARCH AND PRACTICE FOR SUSTAINABLE WATER RESOURCE AND LAND MANAGEMENT, EASTERN CAPE, SOUTH AFRICA

Post Doctoral Fellow: MJT Weaver
Supervisor: CG Palmer

2019 has been a year of milestones for me, both from an academic and personal perspective. In April 2019 I graduated with my PhD in Water Resource Sciences concluding a five-year engaged research project entitled: Civil society engagement with water governance at the local government scale in South Africa. My postdoctoral fellowship continued my transdisciplinary journey of contributing to both theoretical and societal goals. On the theoretical front I published a two-part paper set in the international journal, Geoforum. These papers showcased PhD-gleaned insights on the process of emergence, practice (Weaver et al., 2019a) and learning (Weaver et al., 2019b) of a civil society organisation engaging with local water issues. Subsequently I have been collaborating with fellow academics in the Environmental Learning Research Centre in the development of a book entitled: Expansive Learning, Sustainability and the Common Good. I am developing a chapter that showcases the development of transformative agency (human action related to overcoming tensions, challenges or contradictions in order to transform their practice) during a change intervention to improve the function of a multi-stakeholder water governance platform, the Makana Water Forum. I presented this chapter at the 37th Environmental Education Association of Southern Africa (EEASA) Conference in Johannesburg (8 October 2019).

I also continued my goal of furthering societal goals through active involvement in the Makana Water Forum. I contributed to the development and facilitation of a city-wide stakeholder workshop: Makhanda - Water Works for Everyone (30 May 2019). Nearly 150 people gathered in the Makhanda City Hall and together learnt about and conceived concerted actions towards clean, reliable and fair water management in Makhanda. Building on this momentum and drawing on the knowledge and materials developed from the workshop I led a field trip for 35 UNESCO teacher trainers from the SADC region. Here, the Makhanda water situation served as a case study to explore the integration of environmental sustainability into teacher programs.

The second quarter of 2019 marked two huge milestones for me, becoming a father and securing a position as the Capacity Development Coordinator for the DEFF-funded Tsitsa Project. Capacity development is a key driver to empowering residents improve their livelihoods and sustainable natural resource management practices in the Tsitsa catchment. As coordinator my main focus for 2019-2020 will be to develop and run a series of four structured courses to build the capabilities of environmental and social monitors employed in the Tsitsa Project. In addition, I will be coordinating a multi-level and multi-stakeholder Social Learning Facilitation course to build capabilities of people conducting learning activities in natural resource management contexts.

South Africa has no shortage of catchments experiencing critical and complex social-environmental problems. I look forward to expanding and applying learnings from the transformative research conducted in my PhD and first year of this fellowship into new contexts.

Dr Matthew Weaver explaining the development of transformative agency in the Makana Water Forum at EEASA 2019 at the Kopanong Hotel in Johannesburg on 8 October 2019.

Dr Matthew Weaver explaining the complex networks of relationships hindering reliable water service delivery in Makhanda to UNESCO teacher educators.

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USING HIGH LEVEL EVAPOTRANSPIRATION FIELD EQUIPMENT TO REDUCE UNCERTAINTY IN THE MEASUREMENT AND UNDERSTANDING OF EVAPOTRANSPIRATION PROCESSES

Post Doctoral Fellow: G Ezenne
Supervisor: JL Tanner

Dr Gloria Ezenne's Rhodes University supported post-doctoral fellowship concludes in early 2020. Her focus has been primarily on working with the high-level field equipment for determining actual evapotranspiration (Large Aperture scintillometer and eddy covariance equipment) although there are a number of additional areas where she has contributed. Dr Ezenne received a research grant from Rhodes University which was used to carry out a geophysical investigation at the Fairview spring. The data from this investigation contributed to David Beirne's Honours student project on "Deciphering the inner workings of the Fairview spring in Makhanda. Dr Ezenne contributed to the WRC project "Critical catchment hydrological model inter-comparison and model use guidance development". The project started in April, 2019 and Dr Ezenne is applying the Soil and Water Assessment Tool (SWAT) model in selected catchments. Dr Ezenne also taught the evapotranspiration component of the Hydrology Honours course, and contributed to writing a number of proposals.

Dr Ezenne processed three years of Eddy covariance data from the Ezulu site in the Eastern Cape, and published new methods of data analysis based on the available data. Dr Ezenne together with Prof. Tony Palmer and Dr Jane Tanner also installed and conducted measurements on evapotranspiration at the Krom palmiet wetland. The Large Aperture Scintillometer (LAS) was installed at Krom wetland between 21st of May and 20th September, 2019 (Figure 1). It is an instrument designed for measuring the path-averaged structure parameter of the refractive index of air (Cn2) over a horizontal path between a transmitter and a receiver. Installed alongside with LAS were standard meteorological sensors which include: two net radiometers, HC2S3 temperature and relative humidity probe, 4 x soil heat plate, 2 x averaging soil thermocouples probe, fine wire thermocouples, 2 x water content reflectometer, wind monitor and Barometric pressure sensor. The LAS optically measures the Cn2 between transmitter and receiver which were 846m apart (figure 2) using a near infrared light source of 880 nm. Temperature fluctuations at this wavelength are dominant and measurements of Cn2 and standard meteorological observations can be used to derive the surface sensible heat flux (H) for the area. The recorded Cn2 data from the LAS together with other meteorological data was processed using 'EVATION' software developed by Kipp & Zonen. EVATION calculates and displays sensible heat flux, evapotranspiration and other parameters in a graphical environment.

Figure 1: Installation of Scintillometer at Krom wetland.

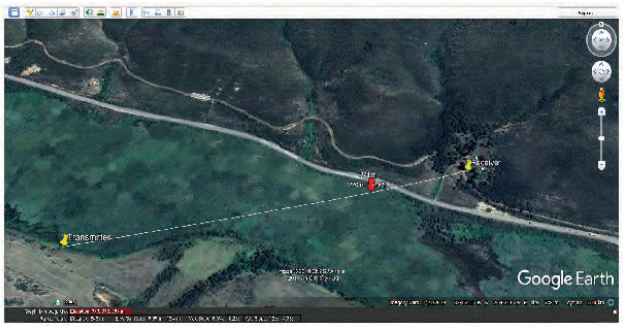


Figure 2: Position of transmitter and receiver at Krom wetland.

POSTGRADUATE ACTIVITIES

STAKEHOLDERS' CONTESTATION AND APPLICATION OF A SIMPLE DECISION SUPPORT SYSTEM FOR LINKING RESOURCE WATER QUALITY OBJECTIVES TO DISCHARGE STANDARDS IN WATER USE LICENCE CONDITIONS IN THE VAAL BARRAGE CATCHMENT

Student: A Chili
Supervisors: ON Odume and AR Slaughter
Degree: MSc (Water Resource Science)

Water resource management in South Africa is governed by the National Water Resource Strategy of which aids legal resource protection through the action of Resource Directed Measures. Resource Directed Measures include methods for: the classification system, setting of the Reserve (Human and Ecological) and setting of the resource quality objectives (RQOs). To realise resource protection, the DWS implemented Source Directed Controls (SDC), and water use license are the primary SDC. Ideally once, the instream Resource Water Quality Objectives (RWQOS) are set, license conditions are derived on the basis of the RWQOS to meet the objectives. However, in practicality there is no clear linkage between the RWQOS and SDCs. This has led to stakeholders contesting against the water quality standards in the Water Use Licence (WUL), which is including discharge standards. The resource users feel that standards are not realistic, and are questioning the scientific credibility and transparency in the methods used to develop the WUL. Specifically, the users of the Lower section of the Upper Vaal are contesting water quality standards in the WUL. The Vaal River supplies water to Johannesburg and industries and currently threatened by the excessive water pollution such as increased salinity, of which depletes water quality of the river. The deteriorating water quality is a threat to drinking water and to business because cost may be related to rectify the problems. This study is part of a WRC-funded project which is developing a decision support system for linking water quality licence conditions to resource quality objectives. For this study, the objectives are to (i) engage with stakeholders within the lower section of the Upper Vaal River to interrogate underlying value system underpinning water quality use and contestations of WUL; (ii) apply a simple water quality model and decision support system for linking instream water quality objectives and conditions in WUL in selected catchments within the lower section of the Upper Vaal River system.

This study will benefit the bigger project that aims to apply a WQSAM based Decision Support System (DSS), which will transparently link water quality standards in WUL conditions to (RWQOs) and site specific conditions taking into account the chemical constituents of effluent being discharged by water users. Data on the perception of stakeholders, which will be provided in this study, will serve as an input when formulating a Decision Support System (DSS).

MODELING IRRIGATION AND FERTILIZER MANAGEMENT PRACTICES FOR IMPROVED CROP YIELDS AND WATER USE IN THE EASTERN CAPE, SOUTH AFRICA

Student: DJ Choruma
Supervisors: ON Odume, S Pietsch and Dr J Balkovich
Degree: PhD (Water Resource Science)

Land use management and climate change are two important factors that significantly influence agriculture and water resources. Poor crop management can lead to decreased crop yields and a decline in surface water quality. Careful crop and land management practices can help maintain land productivity and improve the environmental sustainability of agricultural crop production. Changes in crop yields and future land use are hard to predict due to the complexity of factors involved however scenario modelling offers a way of exploring alternative future economic and environmental pathways of development. In general, my research uses the Environmental Policy Integrated Climate (EPIC) model and the Biogeochemistry Management (BGC-MAN) model to investigate how drivers of ecosystem change, such as climate and land use, affect the structure and function of ecosystems. Using scenario based simulations the study investigates the links between crop management practices, land use forms and water resources. The implications of the research will not only help farmers in making informed decisions at the farm level but also decision makers in developing sound water and land management policies and planning for future land use.

DEVELOPING A MACROINVERTEBRATE-BASED RIVER HEALTH BIOMONITORING PROTOCOL FOR WADEABLE STREAMS AND RIVERS IN NIGER DELTA REGION OF NIGERIA: APPLICATION AND MANAGEMENT IMPLICATIONS

Student: OA Edegbene
Supervisors: ON Odume and FO Arimoro
Degree: PhD (Water Resource Science)

Globally, the unabated degradation of water bodies due to increasing population growth is threatening sustainability and management. Increasing human population has led to food, housing, and other basic social amenities challenges. Therefore, urbanization and agriculture have become a way to meet the demands for food, housing and other basic social amenities for the increasing population. In turn, urbanization and agriculture negatively impact on water bodies (rivers/streams) and inhabitant resources by pollution. Urbanization and agricultural intensification may systematically increase natural land alteration, fragmentation of landscape, fertilizer/nutrient influx, sediment accumulation, all of which directly and indirectly impact aquatic systems. In Africa, Nigeria not exempted, there is a dearth of information on the effect of land use types on the community structure of aquatic biota in an ecosystem. Several biota e.g. fish, macroinvertebrates, plankton, etc. can be used to assess the ecological status of water bodies as a result of anthropogenic activities. Their responses to land use types are used in indicating the ecological state of water bodies. Among the biota in use as biomonitoring tools, macroinvertebrates are mostly used. Therefore, this study will (i) categorize selected rivers in Nigeria exposed to different land use activities into different impact groups, by measuring the physico-chemical properties of the rivers, (ii) develop a trait-based biomonitoring approach based on urban and agriculture/urban land use types for assessing the ecological health conditions of the selected rivers in Nigeria, (iii) develop a trait-based biomonitoring approach based on forested and forested/urban land use types to assess the ecological health conditions of the selected rivers in the Niger Delta ecoregion of Nigeria, (iv) develop a macroinvertebrate multimeric index for land use types for the selected rivers in Niger Delta ecoregion of Nigeria, (v) develop a macroinvertebrate multimetric index for forested and forested/urban land use types for the selected river in Niger Delta ecoregion of Nigeria.

EVALUATION OF ENDOCRINE-DISRUPTING COMPOUNDS IN THE FRESHWATER AND MUNICIPAL WASTEWATER OF EASTERN CAPE PROVINCE, SOUTH AFRICA

Student: AI Farounbi
Supervisors: NP Ngqwala and PK Mensah
Degree: PhD (Water Resource Science)

Surface water is critical to South Africa's development because about 77% of the needed water resources are from the surface water, which is under threat due to scanty rainfall (about 450 mm annually) with little runoffs to boost the rivers. The country is developing with increasing population and so the demand for the use and access to water resources. Expansion of industrial and agricultural activities and the population pressure had impacts on the water quality, availability and the state of aquatic ecosystems in the country. Other factors such as mine runoffs, eutrophication, salinization, and the emerging contaminants make water management a challenge in South Africa. Improperly managed water bodies are known to promote communicable and non-communicable diseases. Many developed nations of the world are taking steps to ensure that pollutants in water supplies are totally eliminated because of the problems associated with them. Endocrine-disrupting compounds (EDCs) are attracting attention worldwide because of their immediate and trans-generational effects on living things in the environment. This research investigated the presence of endocrine-disrupting compounds in the Eastern Cape Province of South Africa with the aim of determining their presence, concentrations and sources. Four Municipalities were selected for studies: Makana, Nkonkobe, Buffalo City and Nelson Mandela Bay. Bloukrans, Tyhume, Buffalo and Swartikops Rivers in these Municipalities were sampled with wastewater treatment plant (WWTP) in each Municipality. Wastewater and their treated effluents were sampled for the presence of heavy metals and EDCs. Each river was sampled at three different locations: upstream, midstream (after passing through a major town) and downstream (after receiving municipal wastewater treated effluents).

Fourteen physicochemical parameters of water quality were measured with modern equipment: Hanna HI9829 Multiparameter and ultraviolet spectrophotometer (UVmini-1240, Shimadzu Corporation, Japan). Fourier-transformed infrared (FT-IR) and nuclear magnetic resonance (^{1}H-NMR and ^{13}C-NMR) were used in the determination of chemical functional groups of organic compounds in the water samples, liquid chromatography coupled to mass spectrometry (LC-MS/MS) used in the determination of ten endocrine-disrupting compounds and inductively coupled plasma with mass spectrometry (ICP-MS) was used for the heavy metals analysis.

The result of the physicochemical analysis showed higher chemical oxygen demand and higher concentrations of phosphate, ammonium and chloride ions in the treated effluents and lower reaches of the rivers (midstream and downstream) than the recommended values. It also revealed salinization of the lower reaches of the Bloukrans and Swartkops Rivers. Functional group analyses show the presence of substituted aromatic compounds, alkyl halides, chlorobenzenes, vinylidenes, amides, amines, urethanes, cycloalkanes, acetonitriles, methenamine, imidazole and phenolic compounds among others. Proton NMR showed the chemical shifts of some target endocrine-disrupting compounds in some of the water samples. Analysis with LC-MS/MS confirmed the present of some EDCs in the samples with nonylphenol > dichlorophenol > bisphenol A > triclosan > octylphenol > imidazole > atrazine > triazole > estrone > estradiol. Metals concentrations in the samples were in the order of Cr > Ni > Mn > Cu > As > Pb > Cd > Hg > Zn. The concentrations of the metals were higher in the treated effluents, midstream and downstream samples than the DWAF recommended values. Likewise, lower reaches of the rivers had EDCs concentrations higher than the upstream samples. These pollutants were not totally removed from wastewater during treatment thereby reaching the rivers through the effluents. Multivariate analyses showed high positive correlations between wastewater, midstream and downstream samples with reference to the parameters tested. Some of the endocrine-disrupting compounds that are prohibited in developed countries such as atrazine, nonylphenols and bisphenol A, because of the pathological conditions traced to them, were observed in this study. This research has been concluded and the four journal articles generated from it have been sent to publishers.

LEVERAGE POINTS TO ENABLE PARTICIPATORY GOVERNANCE OF COMMUNAL LAND AND WATER RESOURCES IN THE RURAL EASTERN CAPE

Student: A Fry
Supervisor: CG Palmer and JK Clifford-Holmes
Degree: MSc (Water Resource Science)

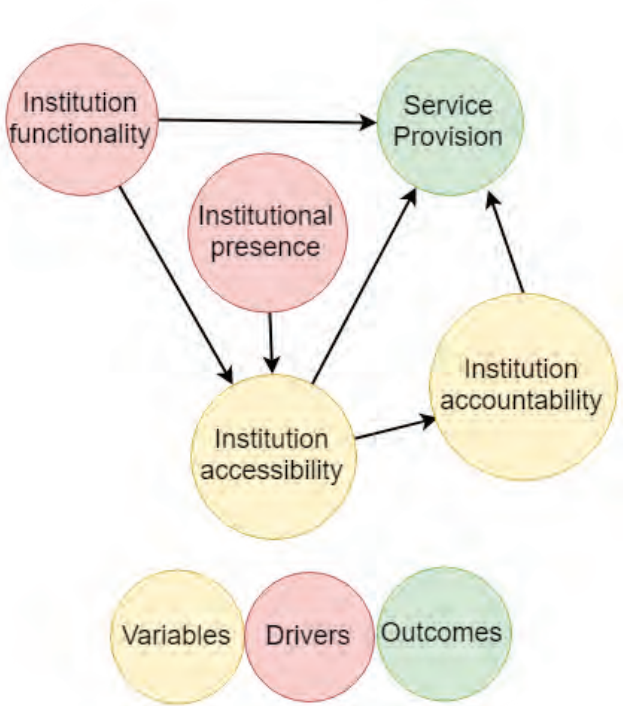
Research Overview

The goal of a substantive participatory democracy as described in the South African constitution, National Water Act and National Environmental Management Act has not yet been achieved; especially in the former homelands (areas enforced during apartheid along ethnic lines). This research asks the questions: What are the processes for participation that currently exist in the Tsitsa River Catchment? And how do different actors experience these processes? Through these investigations I hope to identify leverage points to improve these interactions.

This research is embedded in the Department of Environmental Affairs' Tsitsa Project (TP). TP arose when the Mzimvubu Water Project was proposed in the degraded Tsitsa River Catchment. TP aims to:

> *"support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services"* (Powell et al., 2018).

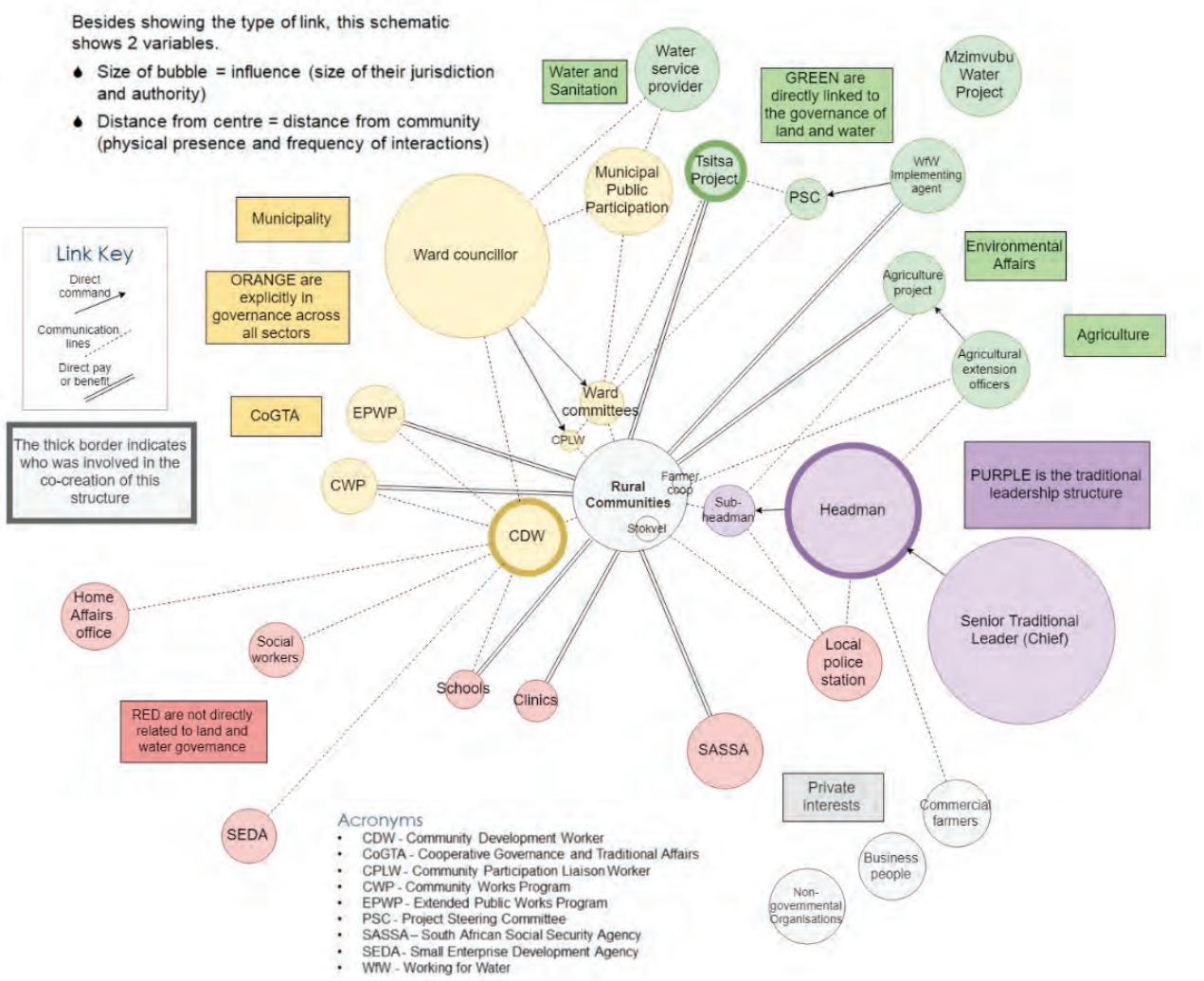
Whilst living in the catchment, I engaged in a series of interviews in order to co-create understanding and outcomes. The following diagrams are a samples from my preliminary results.



Part of my research involves co-developing diagrams to talk about different aspects of governance. The figure is an example of a simple influence diagram developed with local governance actors. In short, the presence and functionality of an organisation are two factors that influence how easy it is for rural communities to access formal organisations in order to hold them accountable and leverage assistance.

Discussion

This research is a step towards understanding how rural communities speak and listen to land and water governance institutions. The next step is to deepen this picture by co-mapping institutions with community groups. This local perspective will be compared with existing policy and planning in order to identify leverage points to enable rural residents to have a have a say in the governance of their land and water.



Interactions between governance organisations and communities living in the communal area of the Tsitsa River Catchment. The schematic was co-developed with Community Development Workers and Headmen; physically present actors who have the job of linking people and government. For reference when looking at the diagram:

- ***Influence - Senior Traditional Leaders and the Ward Councilors were articulated as the main actors with power in at this local level.***
- ***Distance - The villages I am working with are approximately a 1hour 30min taxi ride from town (and services) that costs R40 one-way.***

THE FURTHER DEVELOPMENT, APPLICATION AND EVALUATION OF A SIMPLE SEDIMENT YIELD MODEL (WQSED) FOR CATCHMENT MANAGEMENT IN DATA-SCARCE AFRICAN CATCHMENTS.

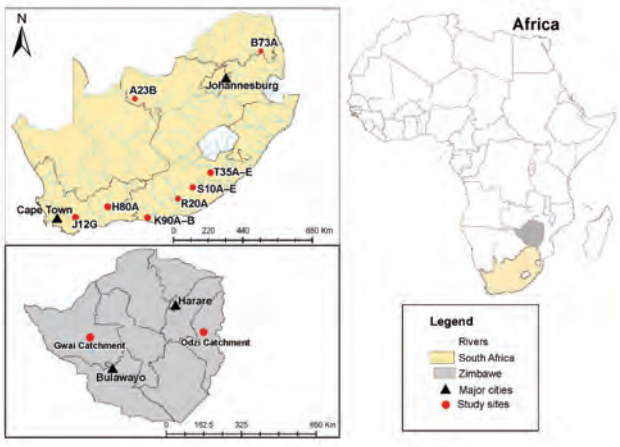
Student: D Gwapedza
Supervisor: AR Slaughter, DA Hughes and SK Mantel
Degree: PhD (Hydrology)

Erosion and sedimentation are some of the pressing global environmental problems. Human activities such as farming and deforestation have further increased the propagation of erosion. Erosion and sediment processes occur at a highly variable spatial and temporal scale making them difficult to quantify. Experimental plots have been used by researchers to attempt to understand erosion processes, models were also developed to represent and simulate sediment movement. However, translating the outcomes realised at a plot scale to a catchment scale have proved to be a challenge. The current study focused on further developing a simple model to simulate erosion and sediment transport. The estimation of soil erosion and sediment transport is important for catchment management. Quantification of reservoir sedimentation is crucial for determining the rate of reservoir storage loss, estimating reservoir lifespan and developing associated mitigation measures. The sediment transport model (WQSED) that was used in this study incorporates a hydrological model (Pitman) and the Modified Universal Soil Loss Equation (MUSLE).

The hydrological component of the model provides the daily flows that drive the erosion and sediment transport model. MUSLE was used to calculate the amount of sediment available for transportation. A regionalisation procedure to estimate the MUSLE model parameters was developed using GIS coverages. The model was tested on more than 15 quaternary catchments in South Africa and was proven capable of giving reasonable estimates.

The study was upgraded from an MSc to a PhD and has continued to further develop the model. Further developments included examining MUSLE scale dependency, considering temporal variations in vegetation cover, regional testing and evaluation. Scale dependency analysis revealed that the MUSLE is both spatially and temporally scale dependent. The spatial scale dependency is most associated with the erosivity factor and the temporal scale dependency is influenced by the vegetation cover factor. The study recommended applying MUSLE to a small (100 hectare) grid in order to avoid spatial scale effects and using a mean annual vegetation cover factor calculated using NDVI to avoid the temporal scale effects.

The model was calibrated and validated in the Tsitsa River Catchment (South Africa), Odzi Catchment (Zimbabwe) and Gwai Catchment (Zimbabwe) as observed sediment yield data was available for these catchments. The outcomes of the research included a framework for parameter estimation for the WQSED model and a simplified model that can estimate erosion and sediment delivery at broad spatial and temporal scales and that can be used by water resource managers with limited expertise in hydrological modelling. The sediment transport model will form part of the Water Quality Systems Assessment Model (WQSAM) and will be linked to other models routinely used for water resource assessments in South Africa.



Map of study catchments in the PhD study.

INTEGRATING BASIN SCALE HYDROLOGICAL MODELS WITH DETAILED FLOODPLAIN HYDRODYNAMIC MODELS IN THE CONGO BASIN

Student: PM Kabuya
Supervisors: DA Hughes, M Trigg and RM Tshimanga
Degree: PhD (Hydrology)

Introduction

The Congo River Users Hydraulics and Morphology (CRuHM) project is a joint programme between UK institutions (Universities of Bristol and Leeds) and sub Saharan African institutions (University of Kinshasa, University of Dar Es salaam and Rhodes University) funded by DFID. This PhD project fits within the CRuHM programme and the activities undertaken in 2019 have focused on the following:

- Developing confidence intervals of hydrological indices across different climate and physiographic regions of the Congo basin;
- Testing the confidence intervals of hydrological indices across different climate and physiographic regions of the Congo basin;
- Testing the DEM spatial resolution on the performance of the hydrodynamic models developed in 2018;
- Assessing the hysteretic patterns of channel- wetland exchanges;

Apart from the work done, there have been a number of capacity building activities such as workshops and fieldwork training, that were conducted during 2019.

Progress so far

Confidence intervals of hydrological indices provide the first estimates of hydrological indices and are able to capture the long-term characteristics of a sub-basin's hydrological behaviour and could be used in future scientific investigations and water resources decision making process.

This analysis has shown that the long-term hydrological characteristics of the Congo basin are dependent of sub-basin's climate and physiographic characteristics such as soil texture, average slope, curve number, topographic wetness index and aridity index. This dependency was evaluated with an affinity measure (Rand index) that showed about 85% affinity between the two pools of clusters and constitutes a strong basis for generalising hydrological indices from gauged to ungauged sub-basins of the Congo basin. It has been shown that the aridity index was a major control of hydrological indices such as the three fractions of the flow duration curve (Q10, Q50, and Q90) and the mean monthly flow (MMQ) expressed as runoff ratio.

Testing the impact of the spatial resolution of a DEM on the performance of the hydrodynamic models developed

in 2018 was one of the main outputs of this research. The initial results of the hydrodynamic models were based on the 90 m DEM. However, two other resolutions such as 270 m and 360 m were added to the analysis in order to evaluate whether the spatial resolution could affect the model performance for the three wetland systems namely Tshiangalele, Kundelungu and Ankoro.

Results have shown that the model resolution has a substantial effect on the model performance. For instance, the 270 m model resolution showed better performance compared to 90 m and 360 m model resolutions at the Ankoro and Kundelungu, while the 90 m model resolution yielded better performance at the Tshiangalele wetland system. This could be due to the fact that at the Ankoro wetland system, most of the channel reach has a width above 90 m, while at the Tshiangalele wetland system the majority of the channel reach has a width below 90 m. This might have contributed to a better representation of the flow dynamics between the channels and the wetland system. Additionally, the reduction of the floodplain vertical error, as a result of aggregating the 90 m DEM over 9 cells at the Ankoro and Kundelungu wetland systems, might have contributed to a better representation of floodplain topography and thus to the flow dynamics exchanges between both fluvial and wetland systems. It has been shown also that the model resolution did not bring a considerable effect on the spilling and return flow parameters of the Pitman wetland sub-model. The only noticeable effect of the model resolution was on the parameters of the power law of the storage volume-inundated area relationship.

Hysteresis have a long history in governing the functioning of natural systems in which values of the output do not only depend on values of the input at the same time, but also on the history of the input. This phenomenon was found in the inundated area, floodplain storage volume and river discharge relationships (Hughes, 1980). In addition, the hysteretic relationship in the inundation dynamics are controlled by the heterogeneity of the land surface and the time varying of flow exchanges between wetland and river systems passing through (Zhang and Werner, 2015).

It is, therefore, acknowledged that the degree of hysteresis can inform on the nature of the connections between the channel and the wetland (Hughes et al., 2014) systems. This activity has assessed the influence the hydrological characteristics and the wetland physical configuration have on the hysteretic patterns found between the channel and wetland systems. This understanding is necessary for estimating the spill and return flow parameters of the Pitman wetland sub-model in wetlands where running complex hydrodynamic simulations is not easy.

Future work

The future work will include the full thesis writing and submission during the 2020 academic year. It will also focus on paper writing and submission to international journals.

IN A NOVEL LANDSCAPE, IN THE EASTERN CAPE, SOUTH AFRICA, WHAT ARE THE KEY VEGETATION RESOURCES THAT SUPPORT LIVESTOCK PRODUCTION?

Student: W Liversage-Quinlan
Supervisors: CG Palmer and AR Palmer
Degree: MSc (Water Resource Science)

The Apartheid era 1913 Land Act concentrated millions of black citizens and their livestock into small land areas, attempting to establish self-governing and self-sufficient countries, separate from white South Africa. The concentrated land use and limited resources in these locations have led to some of the highest levels of land degradation in the country. Yet these previous homelands continue to support around 32% of the human population, highlighting their vital importance for sustaining livelihoods, as well as the present resilience to years of mismanagement. In the Tsitsa River catchment, the highly eroded soils and limited economic capacity are typical of many contexts seen in former homelands, highlighting the aftermath of these Apartheid policies.

The Tsitsa Project aims to restore and maintain the catchment ecological infrastructure, helping to sustain and improve livelihoods by reducing soil erosion and sedimentation and their associated risks, whilst improving soil quality and fertility around the catchment. This research examines the effects of historical land use change, livestock population trends and intensive selective grazing on the landscape condition, in an area with limited resources for adequate land management and livestock control.

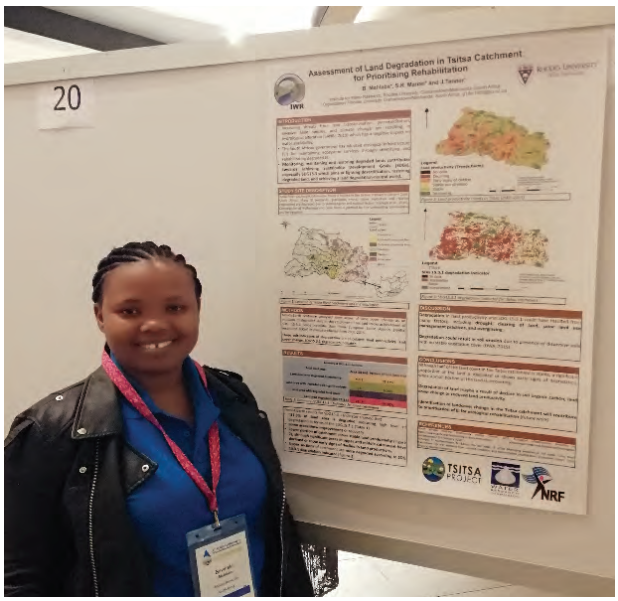
Degraded gullies and abandoned arable lands in the Tsitsa catchment.

ASSESSMENT OF ECOLOGICAL INFRASTRUCTURE (EI) PRESENCE, CURRENT STATE AND PRIORITIZATION FOR REHABILITATION AND DROUGHT MITIGATION IN TSITSA RIVER CATCHMENT

Student: B Mahlaba
Supervisors: SK Mantel and JL Tanner
Degree: MSc (Water Resource Science)

Ecosystem degradation is a serious concern in South Africa, with approximately 38% of its population living in ecologically degraded areas. Increasing threats from land transformation, overexploitation, invasive alien species, and climate change are resulting in changes in ecosystem goods and services, and hydrological alteration, which in turn has a negative impact on water availability. The benefits of ecological infrastructure (EI) have been recognized and there is an increase in investment in EI, as evidenced by the SANBI Framework for Investing in Ecological Infrastructure in South Africa. The rehabilitation and maintenance of EI sustains livelihoods for rural communities, through direct and indirect benefits and provide regulating and provisioning ecosystem services. Therefore, assessment, monitoring, maintenance and restoration of degraded lands is important for improving ecosystem services and while contributing towards achieving Sustainable Development Goals (SDGs).

Therefore, the study aims to identify recent land cover changes and the current state of degradation in the Tsitsa River catchment for prioritizing rehabilitation and ecological restoration in order to conserve and sustain the ecosystem services provided by natural resources and rehabilitation for drought mitigation. This study is primarily a desktop study, using various software to generate, extract and illustrate results. Trends.Earth has been used to analyze SDG15.3.1 degradation indicator in the Tsitsa catchment using sub-indicators of degradation productivity, land cover, and soil organic carbon. Satellite data from the European Space Agency's (ESA) Climate Change Initiative (CCI) is used by Trends.Earth to evaluate change from 2001-2015. Satellite imagery will be used to document the historical changes (2000-2019) in four targeted EI land cover categories (grasslands, riparian areas, wetlands and cultivated lands) in the Tsitsa catchment. Remote sensing data (NDVI trend and anomaly analyses using MODIS and Landsat datasets) will be used to quantify changes and degradation status of the targeted EI. By mapping out and identifying changes in the Tsitsa catchment, this study contributes to the prioritization of EI for ecological rehabilitation planning. Moreover, assessing the health of the Tsitsa catchment EI will contribute to the field of climate change adaptation for local communities, especially in times of drought.



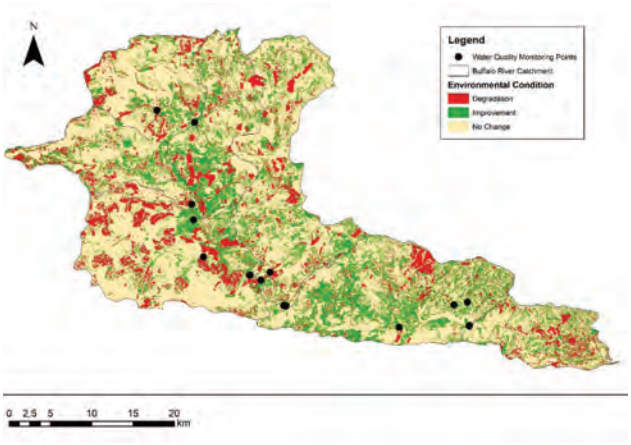
Ms Bwanile Mahlaba presenting at Society of Ecological Restoration SER conference 2019 Cape Town.

AN INVESTIGATION OF FACTORS CONTRIBUTING TO CHANGE IN WATER QUALITY IN THE BUFFALO RIVER CATCHMENT FROM 1980 TO 2018

Student: NB Masuku
Supervisors: NJ Griffin and GK McGregor
Degree: BSc Hons (Geography)

As the world progresses into the Anthropocene era, there is an increasing trend in unfavorable environmental phenomena such as the expeditious decline in water quality which is largely induced by human activity. Regardless of the imminent water quality issues experienced in South African catchments, studies have often overlooked the relationship between the changes in external factors and changes in water quality. The Buffalo River in the Eastern Cape has impaired water quality because of the decline in the available water supply exacerbated by nutrient loading, transformed land cover and land use in the catchment, mismanaged wastewater treatment works and the increase in population pressures.

This project aims to identify the spatial and temporal changes of the landscape which will allow us to understand how anthropogenic pressures have affected water quality in the Buffalo River catchment. In particular, this project aims to correlate historic water quality data with land cover change to provide a comprehensive and holistic analysis of the causes of deteriorating water quality.



Temporal and spatial changes in land cover between 1990 and 2013 in the Buffalo River catchment.

EXPLORING THE CONTRIBUTION OF AN ETHICS APPROACH TO WATER GOVERNANCE IN THE LOWER SUNDAY'S RIVER VALLEY CATCHMENT, EASTERN CAPE, SOUTH AFRICA.

Student: B Mdludla
Supervisors: ON Odume and CG Palmer
Degree: MSc (Water Resource Science)

In South Africa, there is a systemic water governance failure, which has led to an inefficient regulatory enforcement, low appetite for cooperation and a weak management system. These have resulted in deteriorating ecosystem health and impaired ecosystem services. There are three top water governance challenges which are currently confronting the water sector in South Africa. These are i) a weak regulatory system, ii) lack of accountability by stakeholders and iii) a near absence of cooperative governance. These challenges have implications not only for freshwater ecosystem health, but also the delivery of ecosystem services to people, such as the supply of domestic water to residents. In the Lower Sundays River Valley Catchment (LSRVC) in the Eastern Cape, these three challenges have led to inequitable distribution of water resources between societal constituencies, and wastewater treatment works discharging inadequately treated effluent into receiving rivers. Further, the governance challenges in the LSRVC have manifested in impaired freshwater ecosystem health, and inequitable allocations of water between multiple users, particularly between the privileged irrigated agriculture and the less privileged sections of the domestic users. The manifestation of these challenges are matters of ethics, in as much as they also concern the law. Ethical dimensions to water governance challenges manifest due to different societal groupings that hold different values with regards to water resources and these values may come into conflict. This study is a part of a WRC funded project which aims to better understand the water governance challenges in the LSRVC and explore solutions towards addressing identified challenges. The study will (i) surface key values informing water governance in the LSRVC (ii) undertake a value-based analysis of how stakeholders go about reconciling conflicting values and their ethical implications (iii) apply an ethically-grounded approach – so called the Systemic Relation (SR) approach, as an analytical lens to explore whether ethics can contribute to realizing the three fundamental values, in water governance, which are equity, sustainability and efficiency. The SR ethically-grounded approach is innovative because it conceptualizes the governance and management of water and associated values beyond the social domain, to include the wider Social Ecological Systems (SES), and recognizes the mutually constitutive, on-going complementary and co-supportive interactions of the components of the SES. This study will deploy a range of data collection techniques including interviews with the relevant stakeholders, various sources, especially from published water policy statements, attending workshops and workshop participation, the participant's observations and semi structures interviews.

ASSESSMENT OF THE PITMAN MODEL SUITABILITY FOR USE IN GROUNDWATER DROUGHT PREDICTION

Student: K Mokoena
Supervisors: JL Tanner and SK Mantel
Degree: MSc (Hydrology)

Africa's water resource distribution varies strongly with spatial and temporal geographies, where large areas in Africa are subjected to a series of prolonged and extreme cases of droughts (Taylor et al., 2009). In many cases, these droughts are often followed by extreme flood events, placing society and the environment at risk due to climatic variability. South Africa is a water stressed country which faces further external pressures such as temperature increases due to climate change resulting in a high evaporation rates affecting surface and groundwater resources (Levy and Xu, 2011). With increasing need for fresh reliable water resources, it is inevitable that alternative sources will be explored. Therefore, constant monitoring and management of current water resources and the development of new methods to determine the available quantities of freshwater resources, at both surface and groundwater levels for future use and resource management, has become of great importance.

Groundwater is a popular alternative resource and due to the rise in groundwater extractions there has been great interest/an increasing need to locate, understand and sustainably manage our groundwater resources. It has been noted by Kind et al., (2016) & Hughes, (2001) that the processes for evaluating the Ecological Reserve for surface

water bodies have been well established. However, this has not been the case for groundwater. Due to limited information and databases that provide hydrological and hydrogeological data for South Africa, it has been difficult to fully understand the impacts of climatic and anthropogenic factors on groundwater resource quantities and quality. Therefore, it is important to look into groundwater drought monitoring and prediction by comparing historical data to current data, modern satellite observations and indices.

This study applies the Thomas et al., (2017) methodology by using the GRACE-derived Groundwater Drought Index (GGDI) in South African catchments, with the aim of identifying whether drought characterisation can be carried out using data from GRACE satellites. The results are compared to Pitman hydrological model groundwater simulations, although the groundwater routines are simplistic, it serves as a good water balance perspective on the split between runoff into dams (SW), soil moisture/interflow and groundwater. The Pitman Model, using groundwater level data from the NIWIS, rainfall, streamflow and GRACE data, will be used to determine whether it can represent the propagation of the groundwater droughts identified. The findings of this study will benefit and promote research and sustainable management of groundwater resources in South Africa, and further feed into the development of an integrated system for adaptation and mitigation to hydrological drought in South Africa.

Apart from the conventional Masters curricular, Kopano is currently part of the first cadre of the GreenMatter Water Fellows and the Grahamstown Nodal Co-ordinator for the Young Water professionals (YWP) South Africa. She is also a recipient of the Investec Rhodes Top 100 Student Leadership award.

TRADITIONAL ECOLOGICAL KNOWLEDGE IN CONTEMPORARY RURAL SOUTH AFRICA: OPPORTUNITIES, CHALLENGES AND IMPLICATIONS

Student: C Murata
Supervisors: AR Palmer and G Thondhlana
Degree: PhD (Environmental Science)

This study explores the knowledge of holders of indigenous knowledge system (IKS) regarding their natural environments. In particular, it focuses on how local people understand and deal with problems of degradation, what they know of the economic values of the resources they use for their day-today lives, as well as the challenges and opportunities that confront use of IKS in contemporary South Africa. The study is situated in the broader context of the growing voice being made by highly reputable global publications enjoining contemporary societies including research institutions to include IKS in the mainstream ecological programs and knowledge systems. This global call has come against the backdrop of increasing environmental problems especially degradation and unsustainable harvesting of natural resources across the globe.

Indigenous knowledges are understood as the common-sense ideas and cultural knowledges of local peoples concerning the everyday realities of living. They encompass the cultural traditions, values, belief systems, and world views that, in any indigenous society, are imparted to the younger generation by community elders. They also refer to world views that are products of a direct experience of nature and its relationship with the social world.

However, the imposition of colonialism and its allied knowledge system in science, have done a lot of damages on IKS. Colonialism in South Africa and elsewhere broadly, was as much a project of domination of local people, who by nativity, had right to claim ownership of and belonging in the land, as it was a system of knowledge imperialism. The system involved destabilization, inferiorization, illegitimating and displacement of the knowledge systems of the colonized (IKS), while simultaneously valorising and privileging the knowledge of the colonizer. One major implication of this is that IKS is no longer what it used to be before colonialism and imposition of science. With the benefit of state-support starting from colonialism to democracy, science has been used as the dominant source of environmental knowledge in South Africa. State recognition of IKS is a recent phenomenon that was set in motion in the late 1980s by the publication of *Our common future* (1989). One major recommendation from the publication is that harnessing of IKS can significantly contribute to finding solutions to contemporary environmental problems.

However, very few studies have been conducted in South Africa on IKS in relation to environmental problems and practices. The major aim of the study was to explore local people's knowledge about the ecological resources in their landscapes and find how they apply their traditional knowledge to understand and manage these resources with the idea to unravel some of the opportunities and challenges confronting efforts to apply the knowledge system in contemporary South Africa. The study was conducted in five villages in north-eastern Eastern Cape Province of South Africa. This area is part of what formerly was the Transkei homeland scheduled by the former apartheid government for settlement by Xhosa speaking tribes. The Transkei homeland was reincorporated into South Africa at attainment of democracy in 1994 and became part of the Eastern Cape Province.

The study used qualitative case study approach in order to both understand application of IKS in context and allow for intense engagement with informants. By using an intense case study approach, the work unravels some of the

nuances, limitations and strengths of TEK that rarely get mentioned in large-scale survey studies.

Findings and implications

One central finding of this study is that holders of IKS struggle to give adequate knowledge many elements and process of environmental functions and degradation. This inadequacy has been variously alluded to explanations such as that IKS is not capable of reading and making connections between minuscule and that it struggles to deal with foreign induced problems such as spread of alliance invasive plants.

What this study does not answer is whether or not the weaknesses found in IKS, for example its failure to deal with modern ecological problems such as alien invasive plants are inherent or just an incident of historical circumstances. In South Africa, just like in many other former colonies of the West, IKS were sidelined and their truth claims were rejected as superstition and myth over centuries. IKS has just re-emerged in the past three decades following growing calls for its recognition as a legitimate source of knowledge by global institutions. Over these centuries of suppression, IKS was denied institutional support such as research and teaching necessary for its growth.

On the other hand, ecological problems were developing both in magnitude and complexity. In the case of South Africa, some problems that previously were not there such as invasive alien plants, emerged over this period. The implication is that while ecological problems were growing in South Africa, TEK was mainly stagnant. The growth of IKS has been overtaken by events in development and emergence of new ecological problems because it did not grow side by side with development of problems we are now asking it to solve, or find answers to.

There is need for serious state investment efforts in IKS in South Africa. Research centers, faculties and departments in universities need to be established to teach and conduct research in IKS. If this is not done, IKS will continue to be treated as a political tool useful to silence and appease indigenous communities and their claims for recognition. It will be difficult to take it as serious knowledge tool because it lacks capacity to provide answers to contemporary problems.

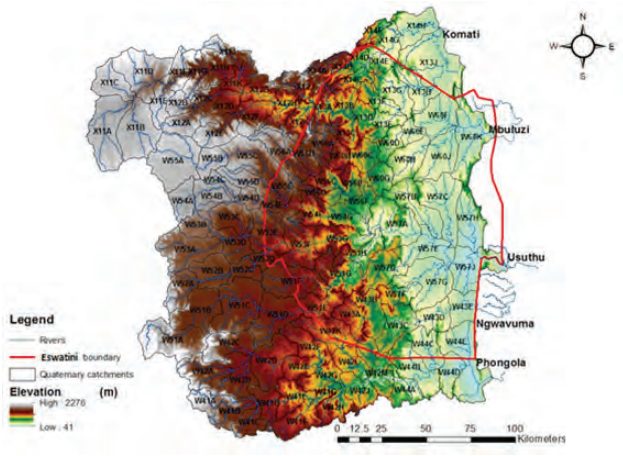
Figure 1 shows the researcher on a fieldwork trip collecting data on provisional ecosystem services such as medicinal plants and wild fruits that households at Colana village use.

Figure 2 shows the researcher crossing Umzimvubu River during data collection at Nozitshena using a locally designed technology called gangangile. There are no bridges in close vicinity.

ESTABLISHING A WATER RESOURCES ASSESSMENT SYSTEM FOR SWAZILAND INCORPORATING INFORMATION AND MODELLING UNCERTAINTY

Student: C Ndzabandzaba
Supervisor: DA Hughes and JL Tanner
Degree: PhD (Hydrology)

This research is influenced by the current advances and trends in hydrological modelling. It has been noted that most basins of the world, more especially those in developing countries are ungauged and/or poorly gauged resulting in inconsistent and inadequate data and information. This precludes sustainable water resources management and informed policy making. Therefore, this project is aimed at developing a water resources information system for Eswatini that is based on both observed and simulated information and that incorporates uncertainty. The basis of the system is the uncertainty version of the Global Options threaded version of the Pitman model. Some observed and simulated datasets (local and global) have been collated. The regional constraints on hydrological response have been quantified and revised to establish behavioural but uncertain parameter sets. Water use and other modifications to the natural hydrology have been incorporated for the Mbuluzi, Phongola and Ngwavuma basins, in which acceptable simulations have been achieved. The study will then apply the similar approach to the Komati, Usuthu and Komati basins. Key regions and data sources where existing uncertainties might impact adversely on water allocation management decision-making will then be identified. Eswatini is shown in the figure below (red border) with the head water catchments of many of the river basins found in South Africa.



TAXONOMIC AND TRAIT-BASED MACROINVERTEBRATE RESPONSES IN SEDIMENT IMPACTED RIVERS, EASTERN CAPE, SOUTH AFRICA.

Student: Ms P Ntloko
Supervisor: Dr O.N Odume and Prof C.G Palmer
Degree: PhD (Water Resource Science)

Sediment is a freshwater ecosystems stressor, and the accumulation in rivers results in alteration of streams and rivers. Major contributors to elevated fine sediment input to rivers include agriculture, deforestation and clear-cut practices, mining activities, road construction, damming and river flow regulation. Regardless of the source, fine sediment in the form of suspended solids or settled material, can negatively impact on all components of lotic ecosystems. Sediments negatively impact on water quality by affecting macroinvertebrates diversity and assemblage structure. Suspended sediment particles impair gills and filter feeding apparatus of biological communities through the sediment mechanism of clogging. Alternatively, settled sediment particles result to burial of biological communities, and can indirectly impact on macroinvertebrates assemblage by changing the habitat by filling interstitial spaces in bed substrate, and reducing food availability. Thus, macroinvertebrates have become attractive tool for assessing the impact of fine sediment entry in rivers, and biomonitoring fine sedimentation due to significant sensitivity to sediments. There is a remarkable interest in developing taxonomic-based diagnostic indices that serve as a surrogate for conventional sediment measurements techniques. Specifically, there is need to have sediment index that is stream type specific to indicate sediment loads.

A prerequisite for developing multimetric index is a classification of macroinvertebrate taxa according to their sensitivity to increased fine sediment deposition. Therefore, aims of this project are to (i) use taxonomic and trait-based macroinvertebrate responses to assess macroinvertebrates vulnerability to elevated sediments in the Tsitsa River and its tributaries, in Eastern Cape, South Africa; (ii) develop sediment mulmetric index for Tsitsa River to assess sensitive of macroinvertebrates taxa to fine sediment loads (iii) explore the patterns of ecological and trait relation to fine sediment stress in Tsitsa river and its tributaries (iv) to identify traits and ecological performance based on tolerance and sensitive macroinvertebrates-trait indicators of sediment loads.

Honours student, Bukanani Mdludla, assisting in the field filtering water samples for chlorophyll analysis in Tsitsa River.

THE PRICE OF COAL?: THE POLITICAL ECOLOGICAL ECONOMICS OF COAL MINING AND WATER MANAGEMENT IN CAROLINA, SOUTH AFRICA

Student: N Nzimande
Supervisors: D Fryer and CG Palmer
Degree: MCom (Economics)

The research focuses on the political and ecological issues of coal mining in South Africa. These issues are discussed in alignment with the economic valuation methods used to value the impacts of the coal mining sector. Coal mining is viewed as a driving force in the development and advancement of South Africa's economy. Alongside the positive economic and energy benefits of coal mining, a number of negative externalities exist environmentally, socially and often politically. The mining sector is regulated by a number of policies and laws which are dependent on

economic valuation. Various economic valuation methods have assisted in placing value on the positive and negative activities by mining companies allowing for better regulation. However, we have found resource or economic Coal mining pollutes neighbouring river systems and groundwater systems in the grasslands valuation often being limited to monetary values. Moreover, this valuation approach incorporates mainly environmental attributes leaving out the social and political aspects. New developments have arisen that view economic activities such as mining as part of a greater Complex Ecological System (CSES) involving both social and environmental attributes.

I explore mining activities and the aligning valuation methods used as part of a complex social ecological system. These approaches acknowledge that coal mining takes place in a space that includes both the environment and various stakeholder groups or institutional arrangements. Analysing coal mining as part of a CSES allows for the incorporation of social, political and environmental aspects into economic natural resource valuation. Mining often takes place in a mixed land use area which consist of various stakeholders who may value the same resource differently. I developed a framework that incorporates key concepts such as CSESs into resource valuation allowing for a more holistic approach in valuing the costs of economic activities such as mining. Our study area is the mining town of Carolina. There have been a number of contestations over the impact of mining on other land uses like agriculture. Water quality depletion has also been linked to coal mining as the source due to the pollution released.

A resource valuation study has been done in Carolina which produced numerical values which were not representative of the various stakeholders in the area. In developing the framework, I analysed the extent of mining impacts in the area, the stakeholders involved, the valuation method used and whether the values presented were representative of the various stakeholders. Overall, research provided critiques and alternatives to the economic natural resource valuation approaches in a political ecological economic context that realises the interplay of the environment and the political, economic and social factors.

Many coal mining sites are situated along rivers in Mpumalanga. Coal mining waste can end up in the rivers which are also used by farmers, communities and other stakeholders. The polluted water resources often result in contestations between the different stakeholders.

EXPLORING THE NATURE AND MEANING OF PARTICIPATION IN ENGAGED NATURAL RESOURCE-RELATED PROJECT

Student: M Ralekhetla
Supervisor: CG Palmer
Degree: PhD (Natural Resource Management)

The Tsitsa Project is a government-funded project with the aim to restore the Tsitsa River catchment to improve livelihoods and the sustainability of environmental infrastructure. In the TP, some researchers engage with different stakeholders in the quest to achieve meaningful participation. Participation has been described it in terms of giving a voice to those in communities who will be affected by the institutional decisions concerning resources in their living and earning space (Chess, 2000; Yang, 2016). Another useful definition for this study is that participation is the redistribution of power (Arnstein, 1969; Reed et al., 2009). Goals of participation include increasing knowledge, building consensus, and improving agency of decisions, generating acceptance of actions, to increase trust and empower citizens.

While the concept of participation was initially positively received by many in the field of natural resource management, some concerns have been raised, particularly relating to the practicality of the promises made in the theory of stakeholder participation. These concerns include: There is no framework that is universally accepted to apply in many situations, leading to difficulties in the practice of participation. It is over advertised as the answer to many problems, based on assumptions that it offers sustainable solutions and empowers vulnerable people in society. Yet there is little, or not enough, evidence to prove its usefulness. Issues of power and control, sharing power and control equally between stakeholders and professionals are difficult to address. Another unclear aspect is the question of 'who really benefits?

Problem statement

So, the status of participation as a 'hurrah' word, which brings warm glow to its users and hearers, blocks its detailed examination, conceals the competing frames of meaning, masks the fact that participation can take on multiple forms and serve many different interests. Many conflicts between indigenous people and scientists revolve around fundamental differences in their respective systems of thought, particularly as these concern knowledge and experiences that are relevant to understanding the natural world. These epistemological differences, in turn, heavily influence the formation of public policy, and can operate to cause forms of epistemic injustice for the affected groups.

Epistemic injustice

Epistemic injustice, as coined by Fricker (2007), means a wrong done to someone in his or her capacity as a knower.

In other words, a person becomes belittled in their capacity as a knower, or have their credibility as a knower undermined (Anderson, 2012; Glass and Newman, 2015; Paphitis, 2018). This is mostly an unintentional outcome of participatory approaches in natural resource governance and therefore, management. Epistemic injustice can take two forms i) testimonial injustice and ii) hermeneutical injustice (Fricker, 2007; Glass and Newman, 2015). Social forms of injustice, such as epistemic injustice, are usually a result of power dynamics that become the primary challenge to sustainable participation (Fricker, 2007).

Narratives of Participation

Therefore, I suggest the collection of narratives of participation because they reveal the reality of participatory processes in a more encompassing, complex and nuanced way. They do this because they reveal a human story, a developmental trajectory, and a narrative is much more than the sum of its parts. Can the participation narrative tell us something about the process that we might not get from looking at the process in other ways? YES, because of the way, it is constructed, through lived experiences and the meanings created, and can therefore give meanings that the different people who engage in the Tsitsa Project attach to the concept of participation based on their lived experiences. Addressing experience issues across the competing frames could mean avoiding tokenism, and lead to more meaningful and ethical ways to understand participation.

Participants in a Learning Words workshop held in Maclear by the Governance community of practice. Learning words workshop is one of the participatory processes used to advance participation in the Tsitsa project.

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INTEGRATED HYDROLOGICAL MODELLING FOR GROUNDWATER DROUGHT IN SOUTH AFRICA

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Degree: MSc (Hydrology)

The strategic role of groundwater (GW) resources for water security in South Africa has been widely discussed; particularly, in relation to extreme droughts projected under changing environmental scenarios such as diminishing surface water supplies, drought proneness because of dry climate and climate change induced variabilit. Especially at a regional scale, it has been determined that the physical characteristics of the catchment play a significant role in regulating hydrological variable. However, in the case of groundwater systems this has not has not yet been adequately described. This work aims to advance the understanding of the logical propagation of drought through groundwater aquifer systems by applying an integrated hydrological modelling approach that looks at the propagation of drought through meteorological, hydrological and hydrogeological systems. The research is part of a Water Research Commission project that aims to design an early warning drought forecasting system in South Africa, which includes a groundwater drought component. As a repository of water resource intelligence, an early warning system will facilitate timely identification and interpretation of droughts. This will encourage implementation of favourable actions that address challenges associated with groundwater resources in South Africa under a continuously and rapidly changing environment.

The research builds on an existing methodology (Peters *et al.*, 2005), which applies commonly used surface water reservoir performance indicators (resilience, reliability, vulnerability and endurance) to groundwater aquifer systems (recharge, GW levels and discharge). An important variant to this approach is the use of the Pitman model which, simulates both surface water and groundwater systems together. The research will look at how the model

represents drought propagation features predominantly influenced by aquifer characteristics; pooling, lag, attenuation, and lengthening (figure 1). The assessment will be done by comparing a time series of observed data with a time series of simulated data based on visual assessment (hydrograph and flow duration curve (FDC)) as well as statistical assessment (Nash-Sutcliffe coefficient of efficiency (CE) and percentage bias (% bias). Finally, storage- draft relationships of aquifers will be evaluated using mass curve analysis approach in order to determine the aquifer yield reliability and explore the consequences of various abstraction scenarios.

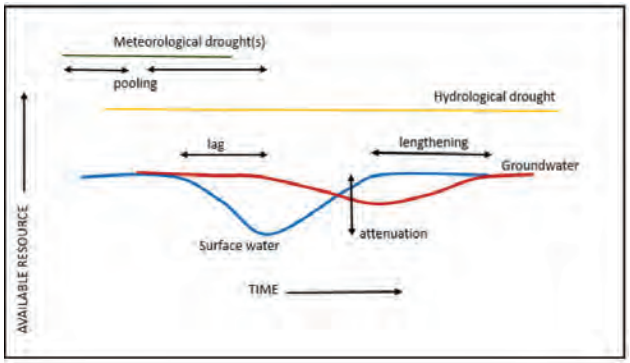

Figure 1: Hydrological drought propagation with respect to meteorological drought (adapted from Van Loon, 2013)

Research case studies for this work are selected on the basis of data availability, aquifer type and rainfall region such that there is even representation of typical South African aquifer environments. Of particular interest is Lake Sibaya which, is an attractive case study for several reasons. Firstly, Lake Sibaya is part of the iSimangaliso Wetland Park which, is a Ramsar world heritage site. The lake is an important groundwater source area (figure 2) and has a traceable history of being a dependable source of freshwater to communities around the lake. However, of late, the lake has experienced declining water levels and has attracted the attention of many researchers. This research will contribute to an all hands on deck campaign that is required in order to develop sustainably sound interventions for rehabilitation of the lake particularly, under the context of drought. The second case study is yet to be confirmed.

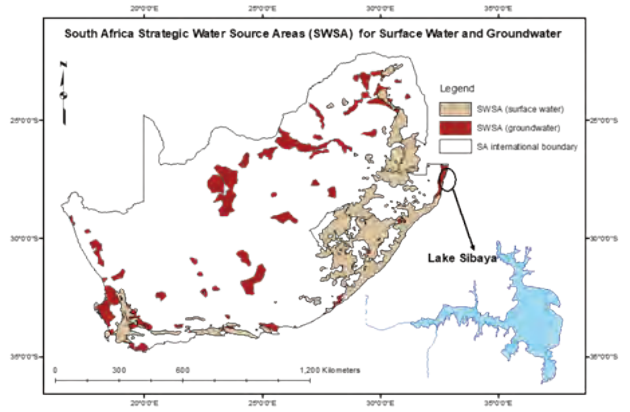

Figure 2: Map highlighting the location of Lake Sibaya as a strategic water source area for groundwater (LeMaitre et al., 2018)

We expect to have some contrast in the performance levels since aquifers with different hydrogeological characteristics have varying responses (slow and quick responding) (Peters *et al.*, 2005). It is not clear how sensitive the Pitman model is to drought signal, as the groundwater routines applied by the model are simple. It will particularly be interesting to see how the model will differentiate between a predominately groundwater driven system (like Lake Sibaya) and a surface water one as we explore drought propagation in the varying environments. It is hoped that this work will contribute to an improved understanding of drought propagation in groundwater systems thereby, enhancing drought preparedness and mitigation in South Africa.

ASSESSMENT OF HOW ECOLOGICAL INFRASTRUCTURE PLAYS A ROLE IN DROUGHT MITIGATION AND WATER SECURITY: CACADU AND CROCODILE RIVER CATCHMENTS AS CASE STUDIES

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Degree: MSc (Water Resource Science)

Background

Water scarcity is recognised as a major challenge in many countries including South Africa, threatening over 4 billion people globally. Close to 70% of global water budget is allocated for irrigation, while 20% goes to industry and 10 % to domestic needs, both with a projected global increase of 10 – 24% by 2050 globally. In Africa, the domestic water demand figure is projected to increase by three times the global projections. These figures present a pressing need for intervention on challenges related with freshwater shortages in South Africa and elsewhere in the world, including in developed countries, as targeted by Sustainable Development Goal 6 (SDG 6) (United Nations 2015)planet and prosperity. It also seeks to strengthen universal peace in larger freedom. We recognise that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development. All countries and all stakeholders, acting in collaborative partnership, will implement this plan. We are resolved to free the human race from the tyranny of poverty and want and to heal and secure our planet. We are determined to take the bold and transformative steps which are urgently needed to shift the world onto a sustainable and resilient path. As we embark on this collective journey, we pledge that no one will be left behind. The 17 Sustainable Development Goals and 169 targets which we are announcing today demonstrate the scale and ambition of this new universal Agenda. They seek to build on the

Millennium Development Goals and complete what these did not achieve. They seek to realize the human rights of all and to achieve gender equality and the empowerment of all women and girls. They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environment al.","author":[{"dropping-particle":"","family":"United Nations","given":"","non-dropping-particle":"","parse-names":false,"suffix":""}],"container-title":"Sustainable Development Goals","id":"ITEM-1","issued":{"date-parts":[["2015"]]},"number-of-pages":"1-40a","publisher-place":"New York, USA","title":"Transforming our world: the 2030 Agenda for Sustainable Development. United Nations Sustainable knowledge platform","type":"report"},"uris":["http://www.mendeley.com/documents/?uuid=a7202a42-a2dd-4708-b4cc-94f393a7efd6"]}],"mendeley":{"formattedCitation":"(United Nations 2015.

The United Nations SDGs are a set of global targets for guiding environmental protection, reducing inequality, and stimulating economic growth. SDGs related to land management (SDG 15) and water security (SDG 6) are central to the current study. In South Africa, SDGs are closely linked with the 2030 agenda for National Development (NDP) – a South African framework to address poverty and inequality.

Recognising the impacts of droughts and anthropogenic modifications, Cohen-Shacham et al. (2016)sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters proposed a concept for "adapting to climate change disaster risks and improving the welfare of social-ecological systems by working with ecosystems". The Nature-based Solutions concept (NbS) is defined as a suite of actions that are directly targeted at protecting, sustainably managing and rehabilitating, intact or altered ecosystems. The NbS concept is closely linked to that of Zero Net Land Degradation, but the NbS concept goes a step further to clearly include the process of implementation, the type of land uses and management practices to be included, features which the Zero Net Land Degradation conceptual framework leaves obscure. Meanwhile, within the South African context, a holistic framework to foster and advocate understanding for maintaining and restoring systems was developed (SANBI 2014). The framework is for investment in ecological infrastructure (EI) which is defined as *"*a naturally functioning social-ecological system that can deliver ecosystem services as a way of supporting the country's economy, reducing inequalities and alleviating poverty by supporting the national and global development agenda". The utility of the SANBI framework is based on the fact that the framework embodies the restoration of degraded ecosystems and maintaining ecosystem structures and functions (SANBI 2014).

In contributing to the EI growing area of study, this research uses the SANBI framework for EI investments (SANBI 2014). This study will highlight the importance of healthy EI for flow regulation in catchments during dry periods and times of drought, especially for communities. As a strategic source for ecosystem services, catchments need constant monitoring and protection. Through catchment management, drought development can be mitigated. This study will focus on five key EI categories (wetlands, riparian zones, rangelands, plantations, and cropland areas) in two identified catchments. The main purpose of this work is to provide an assessment of how ecological infrastructure can play a role in drought mitigation and during dry seasons to enhance community water security?

Preliminary results

To date, stakeholder discussions to identify priority rehabilitation areas in Macubeni have been conducted using the direct-to-digital approach as shown in image 1. Following is a summary of some of the results from the workshop. The most prioritised rangelands for rehabilitation were chosen by the community based on grassland health status (i.e. intactness) and proximity from the homesteads (i.e. not more than 2 km away). Springs were prioritised based on year-round seepage ability. The community members indicated that the vegetation that grows in wetlands that emerge from these springs acts as supplementary fodder especially during dry seasons. These results will be used together with spatial data to come up with final priority locations for rehabilitation using the analytic hierarchy process as a multi-criteria decision model.

A stakeholder discussion for the participatory GIS exercise in Macubeni using the direct-to-digital approach was conducted in May 2019 to prioritise key resource locations for rehabilitation.

RESEARCH OUTPUTS

PEER REVIEW JOURNALS AND CONFERENCE PROCEEDINGS

Akamagwuna FC, Mensah PK, Nnadozie CF and **Odume ON** (2019) Evaluating the responses of taxa in the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) to sediment stress in the Tsitsa River and its tributaries, Eastern Cape, South Africa. Environmental Monitoring and Assessment, 191: 664. https://doi.org.10.1007/s10661-019-7846-9

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