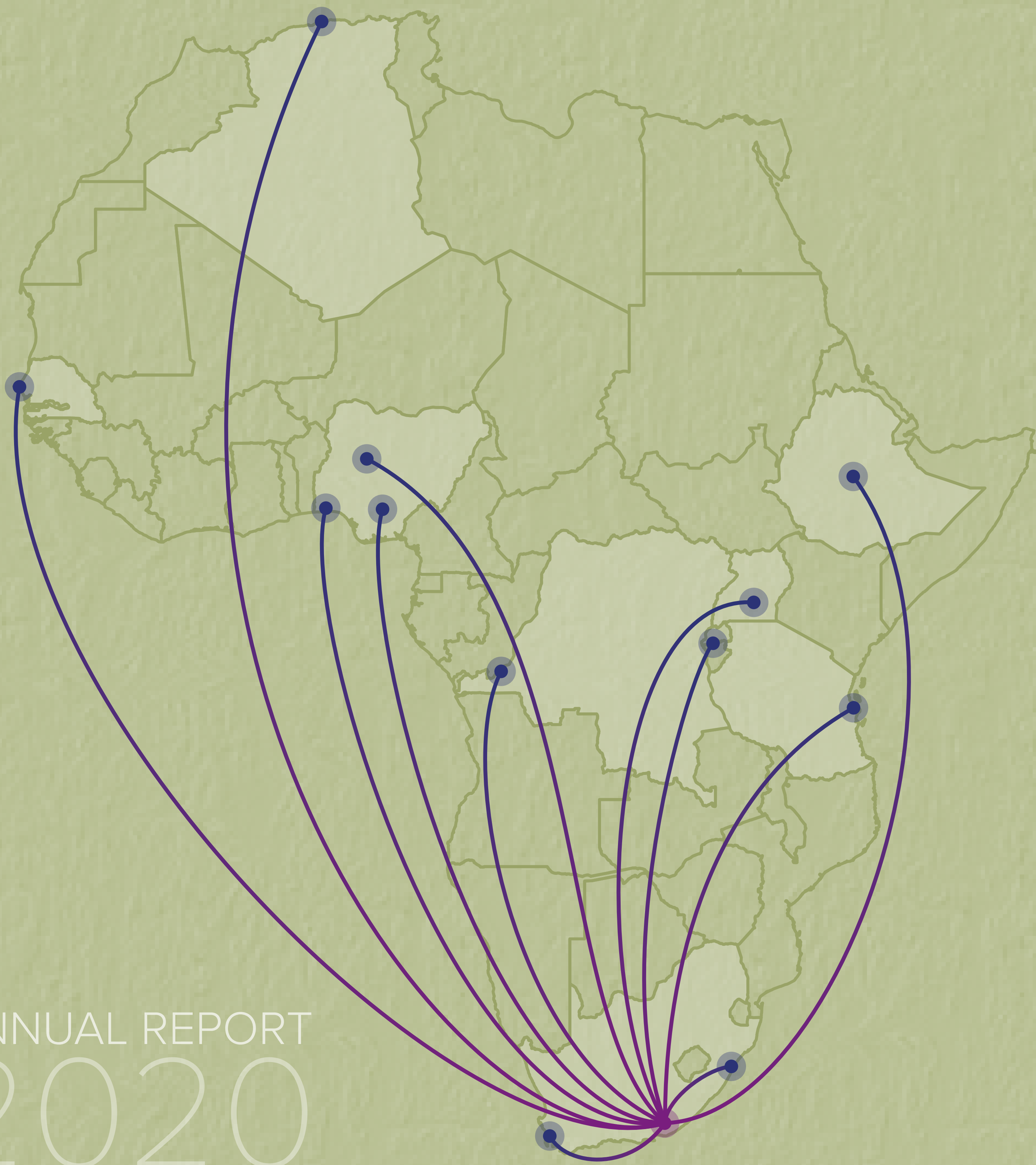
RHODES UNIVERSITY
Where leaders learn

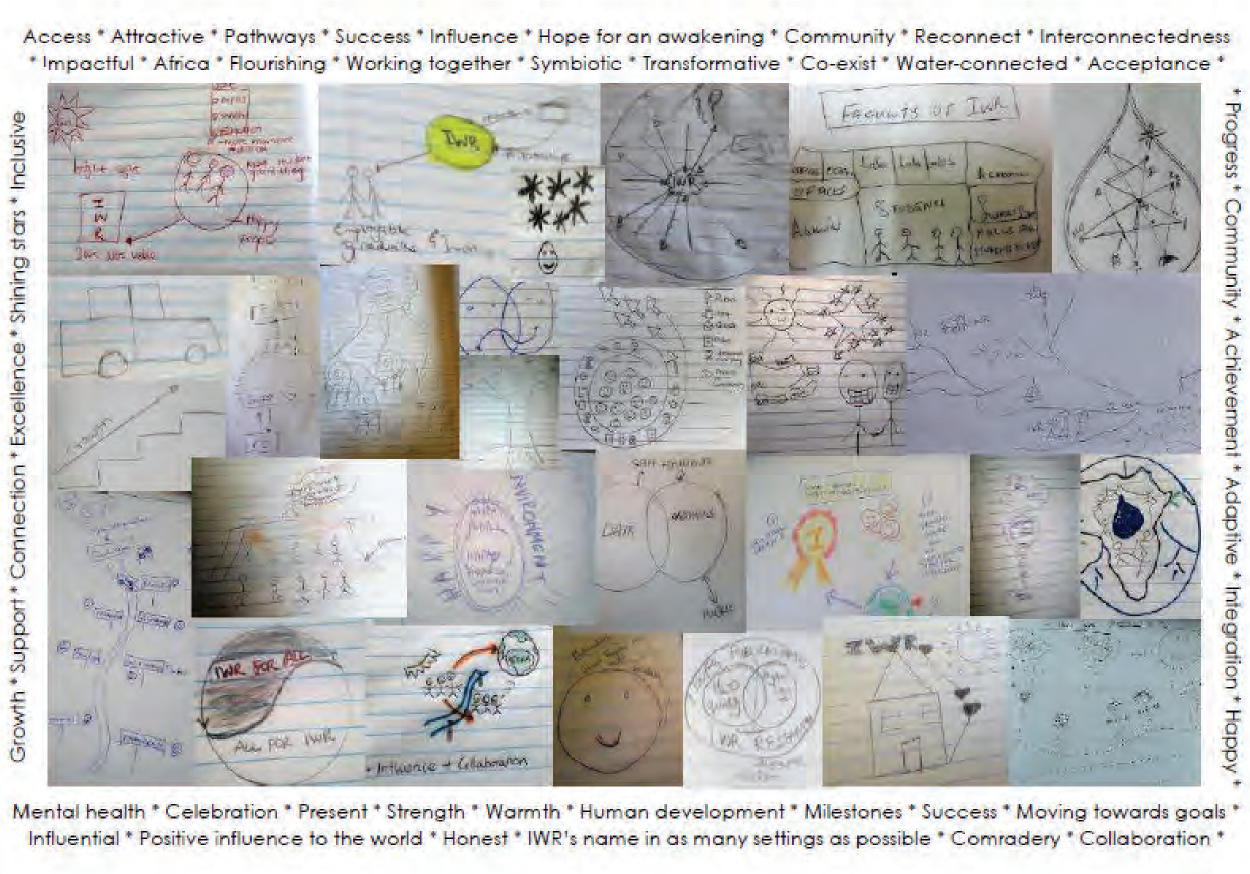
IWR

Institute for Water Research



ANNUAL REPORT
2020

CONTENTS



The IWR could not gather for a photograph this year. Here are pictures drawn by IWR participants during the 2020 Strategic Adaptive Management, Adaptive Planning Process, workshop. They illustrate the visions we have of the IWR we would like to see, surrounded by the words that describe this.

STAFF AND MEMERS OF THE INSTITUTE

STAFF

Dr Athina Copteros	Postdoctoral Fellow
Mr David Forsyth	Principal Technical Officer
Dr Bukho Gusha	Postdoctoral Fellow
Dr Neil Griffin	Research Officer
Dr Notiswa Libala	Postdoctoral Fellow
Dr Sukhmani Mantel	Senior Research Officer
Ms Juanita McLean	Administration Manager, Manager: ARUA Water Centre of Excellence
Ms Ntombekhaya Mgaba	Senior Technical Officer
Ms Ntombekhaya Mti	Research Assistant
Dr Chika Nnadozie	Postdoctoral Fellow
Prof Nelson Odume	Associate Professor; Director: UCEWQ
Prof Tally Palmer	Professor; Director: IWR, Director: ARUA Water Centre of Excellence
Dr Jane Tanner	Senior Research Officer, Co-Director: ARUA Water Centre of Excellence
Honorary Prof Tony Palmer	Research Officer
Dr Matthew Weaver	Postdoctoral Fellow

ASSOCIATES

Prof Brian Allanson	Honorary Research Fellow
Dr Jai Clifford-Holmes	Research Associate
Prof Chris de Wet	Professor Emeritus
Prof Denis Hughes	Professor Emeritus
Dr Paul Mensah	Research Associate
Dr Nikite Muller	Research Associate
Dr Eric Igbinigie	Research Associate
Dr Andrew Slaughter	Research Associate
Dr Jill Slinger	Visiting Professor

REGISTERED POSTGRADUATE STUDENTS

Ms Asanda Chili	MSc (Water Resource Science)
Mr Anthony Fry	PhD (Water Resource Science)
Mr David Gwapedza	PhD (Hydrology)
Mr Pierre Kabuya	PhD (Hydrology)
Mr William Liversage-Quinlan	MSc (Water Resource Science)
Ms Bawanile Mahlaba	MSc (Water Resource Science)
Ms Bukanani Mdludla	MSc (Water Resource Science)
Ms Kopano Mokoena	MSc (Hydrology)
Ms Zintle Mtintsilana	MSc (Water Resource Science)
Ms Nandipha Ngoni	MSc (Water Resource Science)
Mr Coli Ndzabandzaba	PhD (Hydrology)
Ms Pindi Ntloko	PhD (Water Resource Science)
Ms Anele Ntshangase	MSc (Water Resource Science)
Ms Mateboho Ralekhetla	PhD (Water Resource Science)
Ms Phatsimo Ramatsabana	MSc (Hydrology)
Ms Noleen Tavengwa	MSc (Water Resource Science)
Mr Sinethemba Xoxo	MSc (Water Resource Science)

REGISTERED POSTGRADUATE STUDENTS CO-SUPERVISED IN PARTNER DEPARTMENTS

Mr Frank Akamagwuna	PhD (Zoology)
Ms Regina Dakie	BSc Hons (Environmental Water Management)
Ms Amy Freeman	MSc (Geography)
Mr Sakikhaya Mabohlo	BSc Hons (Environmental Water Management)
Mr Yanga Njiva	BSc Hons (Environmental Water Management)
Ms Sibuyisele Pakati	MSc (Geography)

2020 GRADUATED STUDENTS

Mr Dennis Choruma	PhD (Water Resource Science)
Mr Augustine Edegbene	PhD (Water Resource Science)

MEMBERS OF THE BOARD

Turning to One Another

There is no power greater than a community discovering what it cares about.
Ask: “What’s possible?” not “What’s wrong?” Keep asking.
Notice what you care about.
Assume that many others share your dreams.
Be brave enough to start a conversation that matters.
Talk to people you know.
Talk to people you don’t know.
Talk to people you never talk to.
Be intrigued by the differences you hear. Expect to be surprised.
Treasure curiosity more than certainty.
Invite in everybody who cares to work on what’s possible.
Acknowledge that everyone is an expert about something.
Know that creative solutions come from new connections.
Remember, you don’t fear people whose story you know.
real listening always brings people closer together.
Trust that meaningful conversations can change your world.
Rely on human goodness.
Stay together.

By Margaret Wheatley

IWR DIRECTOR'S REPORT

IWR Vision 2020

> The IWR provides a nurturing environment for students and disciplinary specialists working collaboratively on the complex and interconnected water-related challenges facing humanity in the 21st century. We catalyse the emergence of globally relevant approaches for Africa from within the African context.

Introduction

In common with the whole world, 2020 has been an extraordinary, and bruising year for the IWR. Our staff and students have suffered illness, bereavement, isolation, gender-related violence and mental health stress. Field and laboratory work have been interrupted, and everyone has had to adapt to online communication. In this context I am hoping that my experience of the IWR community has been common: kindness, consolation and unstinting support.

We have also been successful and fruitful, securing a large international competitive grant, which, with those from last year, provides a sound grounding for the immediate two-to-five-year future.

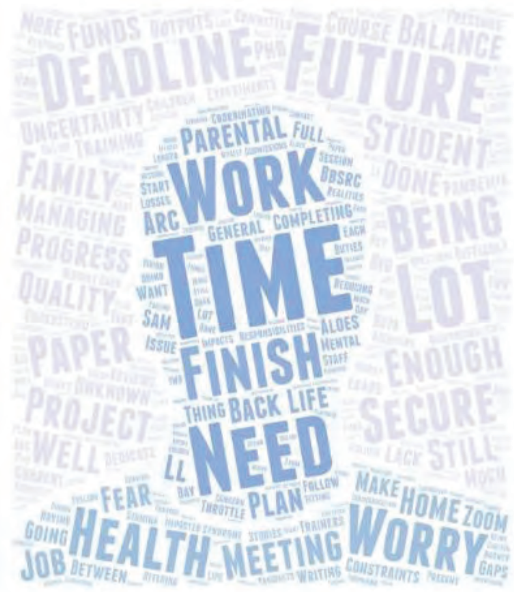
A 2020 research highlight is the listing of Associate Professor Nelson Odume in the top 15 researchers at Rhodes University in the annual institutional Research report. Congratulations to Nelson.

Over recent years succession-planning has been a focus. Aligned with this, we are delighted to report that Jane Tanner has been promoted to Senior Researcher, and Nelson Odume to Associate Professor, and we congratulate both of them. These are well-deserved promotions, and both Jane and Nelson are fully engaged in the collaborative leadership processes in the IWR. Jane is the lead researcher in the Hydrology Group and a Co-Director of the African Research Universities Alliance (ARUA) Water Centre of Excellence (CoE). Nelson is the lead researcher in environmental water quality and aquatic ecology, and is the Director of the Unilever Centre for Environmental Water Quality (UCEWQ).

Strategic Adaptive Management (SAM)

The IWR operates using collective, co-operative Strategic Adaptive Management – the process we teach in Adaptive Water Resources Management, and practice in our engaged research projects. SAM comprises Adaptive Planning, Adaptive Implementation, Reflection and Review, and cycles back to planning in the light of change. We engage in a full Adaptive Planning Process biennially, and adaptive reflection and adjustment in the alternate years. Our weekly meetings include review and reflection on implementation progress through the year. 2020 saw the full Adaptive Planning Process repeated for the third time, facilitated on-line by Lucy O'Keeffe over three days. I encourage readers to look at the SAM report on our website.

In this Covid-dominated year we began by checking in on everyone personally. These were our preoccupations:



After a session sharing ideas about values, and behaviours that reflect values, we reframed the IWR statement of values:

> We uphold excellence and ethics in our work, and collaboration for social-ecological justice.

We recognised that key behaviours that support this value-statement include: hosting and participating in workshops and seminars; taking conscious action in reducing environmental impact: submitting funding applications that support this value, and designing MSc and PhD projects that include this value; being generous in including students in publications whenever possible; expressing ideas with courage, trusting others will be generous. fighting for justice beyond the thesis / paper; creating spaces for resource sharing: funding opportunities, research opportunities and networking; taking care that participants genuinely benefit from their research participation; taking ethics applications seriously and being willing to work out of academic hours to contribute in the wider community. The process included sharing stories about each other as we have experienced people acting out these values.

Out of the consideration of values, we revised the IWR vision to:

> The IWR provides a nurturing environment for students and disciplinary specialists working collaboratively on the complex and interconnected water-related challenges facing humanity in the 21st century. We catalyse the emergence of globally relevant approaches for Africa from within the African context

The principles that guide us towards this vision are: prioritising relationships; valuing all forms of knowledge: local, place-based, academic, practical, and insightful – together comprising transdisciplinarity; being sensitive to context: social, economic and the widest range of biophysical factors; living our values and ethics: paying attention to fair outcomes and who benefits; paying attention to learning and reflection; acknowledging and learning from tensions: power imbalances, race and gender, academic and practice, 'give it a whirl' and patient perseverance, brave and cautious; enabling access to, and use of, the best available technology; striving for research excellence and productivity; being competitive in securing of funding.

We plan to work out of our strengths:

We ended with a set of clear objectives, with associated personal and collective commitments to action and implementation, in six key areas: Human capability, Outputs, Funding, Partnerships, Technical capacity and Visibility. While we understand 2021 will remain challenging, we have re-engaged with our identity and purpose, and we are ready to progress.

ARUA Water CoE

The IWR is the hub and lead node of the ARUA Water CoE. Our node partners are Addis Ababa University, Ethiopia; University Cheikh Anta Diop, Senegal; Dar es Salaam University, Tanzania; Makerere University, Uganda; University of Rwanda, Rwanda; Lagos University, Nigeria; University of Cape Town, University of KwaZulu-Natal. Dr Sukhmani Mantel was appointed as the Water CoE Academic Manager and Ms Ntombekhaya Mti as a Research Assistant in March 2020, while Dr Rebecca Powell will join the team as Large Grants Manager in January 2020.

A highlight of 2020 was the March 2020 announcement by UK Research and Innovation (UKRI) that the Water CoE is one of four ARUA Centres awarded a £2M Research Excellence Grant, to undertake a project entitled: *Unlocking resilient benefits from African water resources (RESBEN).* Six such grants were available, so we were particularly proud to be one of the four successful projects. This success is associated with a substantive annual supporting grant of $50K, for three years, from Rhodes University. This commitment to ARUA is hard to honour in current financial circumstances and we will take care to use the funds to secure and grow the CoE.

The UKRI Capacity Development Grant for the project *Water for African SDGs* awarded in 2019, is closely linked *RESBEN*. In a covid-19 adaptation, *Water for African SDGs* has moved from a plan for each node to run an in-person course related to their RESBEN research, to nodes collaborating to prepare six OpenCourseWare on-line courses that will be uploaded in early 2022. In January 2020 we were able to successfully run an in-person Adaptive Systemic Approach course, hosted by Addis Ababa University (see *Water for African SDGs* project report). Lead and early-career researchers from all the nodes, and from our partner Universities Sheffield and Lancaster, have collaborated actively in on-line meetings and training in the preparation of on-line courses. We were commended by the funder, UKRI, at the first project board meetings in October for excellent progress.

Nelson Odume continues to lead two large, internationally funded, cross-continental projects that are an integral part of the Water CoE profile: Leading Integrated Research for Agenda 2030 in Africa (LIRA) and the African Water Resources Mobility Network (AWaRMN) project, where IWR Visiting Professor, Jill Slinger is the European partner. These projects will increase the IWR post-graduate school and will provide African students with international experience. Nelson is also pioneering an African presence in the USA Society for Fresh Water Science by establishing an African Branch.

The Water CoE has established strong links with the N8 (Northern Eight Group) Universities in the UK. Sheffield and Lancaster Universities are partners in the UKRI project, and Professor Frances Cleaver (Lancaster University), and Drs Vanessa Speight (Sheffield University), Claire Walsh (Newcastle University), and Jed Stevenson (Durham University) serve on the UKRI project boards. Tally Palmer was an invited speaker at the Newcastle University *Global Water Security Symposium*, that celebrated both *70* years of *water* and environmental health research, and the establishment of the UKRI Global Water Security and Development Hub. Preceding the symposium, the N8 hosted a Water CoE-N8 Colloquium that included in-person and on-line CoE participants across Africa, on the theme*: Research for development as catalyst of change towards social-ecological justice.* From that, Tally Palmer was an invited panellist for a Universities UK International and UK ODA (Official Development Assistance) webinar that attracted more than 300 participants on: *Research and Innovation for international development: a focus on impact.*

Zoom: the iconic 2020 communication experience. Participants in the ARUA Water CoE -N8 colloquium: Research for development as catalyst of change towards social-ecological justice

Zooming again: a selection of IWR participants in the Preventing Harm (Safeguarding) training.

The Water CoE is evidently growing into a thriving cross-continental research community of practice.

Congratulations and Acknowledgements

Drs Augustine Edgebene and Dennis Chorumna graduated this year, both having received excellent examiner's reports, after supervision with Nelson Odume.

Lucy O'Keeffe has been a vibrant and inspiring facilitator and trainer for the IWR this year.

The IWR has been productive in ways beyond the professional realm. We welcome into the world, and into IWR families new children: Kananelo Ntsiki, Isaac Perry Fry, James Roi Weaver, Seth Mukundi Choruma, Lakheke Lala Mahlaba and Tariro Chloe Tavengwa. In 2021 we look forward to welcoming new small people into the families of Zintle, Notiswa and Matthew.

The IWR emeritus and visiting professors, researchers, post-doctoral fellows, support staff and students have worked hard and bravely in 2020. We have continued, through innumerable zoom meetings, to work and collaborate actively with external and internal partners, including the Departments of Geography and Environmental Science, and the Environmental Learning Research Centre. 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, appreciative guidance, and we continue to receive valuable strategic and financial support from the University.

Prof CG Palmer
Director: IWR and ARUA Water Centre of Excellence

UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY (UCEWQ) REPORT

Introduction

After 20 years of funding from Unilever South Africa, this year mark the end of this anchor funding to the Centre. We are indeed very grateful to Unilever for the decades of support. The Centre will continue to be branded as Unilever Centre for Environmental Water Quality until a replacement funding is secured. Unilever SA has agreed to assist in brokering relationship with a new funder. The Rhodes University Communication and Advancement Division is also assisting the Centre in identifying possible replacement anchor funders.

The African Water Resources Mobility Network (AWaRMN), a multi-partner project funded with a grant of 1.39M Euro by the Intra-Africa Academic Mobility Scheme of the European Union successfully took off this year. AWaRMN is comprised of five African Universities and one European University as partners. The partners are the University of Kinshasa, Democratic Republic of Congo; Federal University of Technology, Minna, Nigeria; Makerere University, Uganda; National Higher School of Hydraulic, Algeria; and TuDelft Netherlands (European, Technical partner). Rhodes University through the Institute for Water Research is the Lead Partner, coordinated by Prof ON Odume and assisted by Dr CF Nnadozie. AWaRMN aims to strengthen capacity for research and teaching, promote internationalisation, multiculturalism, and multilingualism through postgraduate student training and exchanges as well as collaborative research programmes and projects.

AWaRMN delegates at the project flag off meeting in Brussel Belgium. From left: Prof Jill Slinger, Prof Mohamed Meddi, Dr Unique Keke, Dr Chika Nnadozie, Prof Francis Arimoro, Prof Raphael Tshimanga and Prof Nelson Odume.

The partnership has already recruited 12 PhD and 6 Masters students for the 2021 academic year. The Institute will host 4 of those PhD students and 2 MSc students. We are very excited about this development as AWaRMN is a good replacement for RISE (Regional Initiative in Science and Education), which comes to an end few years ago.

During the 2020 virtual graduation, 2 PhD students, Dr Ovie Augustine Edegbene and Dr Dennis Junior Choruma were awarded their doctoral degrees. I would like to congratulate them for this achievement. Other students who are affiliated with the Centre are making steady progress and we expect to graduate 2 PhD students and 2 Masters students in 2021.

UCEWQ is the lead partner for two LIRA (Leading Integrated Research for Agenda 2030 in Africa) projects funded by the International Science Council and the Network of the African Science Academies (NASAC). The first project is a collaborative project between Rhodes University, Nnamdi Azikiwe University, Awka, Nigeria; Federal Ministry of Environment, Nigeria; Delta State School of Marine Technology, Nigeria; Nelson Mandela Bay Metro and the Port Elizabeth Office of the Department of Water and Sanitation, South Africa.

The second project is a partnership between Rhodes University, CSIR-Water Research Institute, Ghana; Mnandi Azikiwe University, Nigeria; Kwame Nkrumah University of Science and Technology, Ghana; Stellenbosch University and Institute for Health Research, Epidemiological Surveillance and Training (IRESSEF), Senegal. Both projects focused on the Sustainable development goals, their interlinkages and the role of science-policy-society interactions in the achievement of the SDGs. We are excited that the Centre is extending its footprint solidly into the rest of the African continent and globally.

Two years ago, I reported that Dr Nnadozie was joining the Centre as a postdoctoral fellow, opening the Centre to microbial water quality and ecology research as well as the link to human health. Dr Nnadozie is the leader of a four-year WRC-funded project on antibiotic resistant restrains of *Campylobacter* spp. in water sources. I am delighted with her progress thus far, attracting one Master student as the primary supervisor, and one PhD student as the co-supervisor. Beginning 2021, she will be supervising additional PhD student as the primary supervisor and 2 PhDs as the co-supervisor. Dr Choruma who was supervised in the Centre will join us in 2021 through a postdoctoral fellowship funded by the African Study Centre through the African Multiple Clusters of Excellence of which Prof Odume is part.

Research and projects within the Centre

The Centre has been very active over the past 3 years implementing various research projects and establishing new research areas. Dr Griffin and Dr Libala have successfully led a WRC-funded project on localisation of SDG 6, the indicators and targets for South Africa. Ms Khaya Mgaba, has courageously taken on the leadership of the microplastic project under the mentorship of Prof Odume, Drs Mensah and Griffin. For the first time in South Africa, a Decision Support System (DSS) was developed to link the resource quality objectives (RQOs) and water quality standard in water use licences. The outcome of this project, which was led by Prof Odume, Dr Slaughter and Dr Griffin will assist both the DWS and resource users on water quality licensing and protection of the water resource. Our project on ethics and water governance is providing innovative and insightful ways of navigating the complexity of ethical challenges water governance and management in South Africa. We are delighted to announce that in 2020 we have secured another WRC project on the Revision of the 1996 South African Water Quality Guidelines for Aquatic Ecosystems. This project is being implemented in partnership with the University of South Africa (UNISA). Details of these projects and others are provided in the Project section of this report.

Ecophysiological experimental equipment in the UCEWQ stream lab

Ms Pindiwe Ntloko collecting samples in the field.

National, regional and international influence

The coronavirus pandemic (COVID-19) is perhaps the greatest disruptor in modern human history. But it also provides us an opportunity to reflect and innovate. Despite the COVID-19, which bring international travel to a complete standstill, UCEWQ maintained a high national, regional and international profile. In January 2020, Prof Odume, together with the LIRA team in Nigeria organised a workshop on urban river ecosystem health and water quality governance. The workshop was aimed at exploring ways of improving urban river ecosystem health and water quality by looking at institutional, governance practices as well as barriers. Building on the success of the first workshop, the team organised a second workshop focusing on water quality practices in Nigeria and available tools, methods and approaches for monitoring river health as well as the linkage to relevant policies. Both workshops attracted participants from various Nigerian Federal Ministries, Departments and Agencies (MDAs). Representative MDAS include the Federal Ministries of Environment, Water Resources; the Nigerian Hydrological Services Agency, Abuja Environmental Protection Board, Abuja Municipal Council, National Environmental Standards Regulatory and Enforcement Agency, University of Abuja, among others. A similar online workshop was also organised in South Africa, which was aimed at exploring ways to improve the Swartkops River water quality, ecosystem health and governance practices. Through the LIRA project, the Swartkops River catchment management forum is being established. Earlier in the year, Prof Odume also attended the LIRA structured programme in Addis Ababa, Ethiopia. The LIRA programme was aimed at capacity building for project principal and co-principal investigators on transdisciplinary research and other research skills and leadership.

LIRA workshop participants in South Africa.

LIRA workshop participants in Nigeria.

Prof Odume and other African Freshwater Scientists are in the process of establishing the African Chapter of the Society for Freshwater Science (SFS). The Chapter once fully established should provide a solid platform for trans-Atlantic Scientific collaboration and cooperation between African and North American Scientists. It is hoped that the platform will offer opportunity for exchanges of scientific ideas, project collaboration, student exchange and access to equipment and other resources, which are ordinarily not available to African Scientists on the continent. One of the objectives is to provide our North American colleagues a network to those interested in carrying out research on some of our iconic freshwater systems on the continent. Earlier in the year before the COVID-19 lockdown, Prof Odume attended and presented at the African Water Association (AFWA) conference in Kampala as part of the AfriAllaince Group on social innovation to climate and water related challenges in Africa. Dr Ngqwala from the Faculty of Pharmacy who is part of the AfriAlliance Project also attended and presented alongside Prof Odume. AFWA conference is one of the biggest gathering of water scientists/researchers, policy makers, practitioners, and international and multilateral organisations on the continent. After four years, the AfriAlliance Project is coming to an end, and the Action Groups within the project are exploring collaboration beyond the AfriAlliance project lifespan.

The Centre is a key partner in the transformational learning project jointly led by the Rhodes University Environmental Learning Research Centre (ELRC) and the Institute of Environmental Systems Research at the University of Osnabruck, Germany. Staff and students of the Centre including Prof Tally Palmer, Dr Matthew Weaver and Prof Odume participated in an online workshop on the role of transformative learning. We are excited to be part of such international initiatives.

Ms Zintle Mtintsilana (left) and Kingswood college students (right) during biomonitoring outreach programme.

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. Due to the restrictions arising from the COVID-19 pandemic, we could not undertake more community engagement programmes for the year.

Partnerships and linkages

For 20 years, Unilever South Africa was the founding partner of the Centre and we remain grateful for their support. In 2018 the Centre and Unilever SA signed a two-year MOA (2019–2020) with a 50% cut in funding. The MOU, which comes to an end in 2020 has not been renewed, heralding an end to a 20-year funding from Unilever SA to the Centre. The Centre remains profoundly grateful to Unilever SA for the years of support, and the long and good relationship we have enjoyed. As I have already indicated, we are in the process of approaching other potential funders via the Rhodes University Communications and Advancement Division. Unilever SA has offered to support this process.

AWaRMN and the ARUA Water Centre of Excellence are platforms the Centre will continue to use to deepen and strengthen its partnerships and linkages within Africa and beyond.

The African Studies Centre at Rhodes is one of the Africa Multiple Clusters of Excellence funded by the University of Bayreuth, Germany. UCEWQ is a lead partner of the Rhodes University African Studies Centre (RASC). RASC is a space for disciplinary, interdisciplinary and transdisciplinary scholarships and we are very excited to be part of this initiative. Dr Choruma who joins UCEWQ in 2021 as a postdoctoral fellow is funded by RASC. Assured Turnkey Solutions (PTY) LTD and Scherman Environmental CC remain key strategic industry partners. We are exploring strategic relationship to grow our water quality research with Dr Scherman.

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

Finally, I am truly grateful to all staff and students of UCEWQ who have remain committed to research excellence. I would like to single out Ms Khaya Mgaba and Ms Zintle Mtintsilana who continue to maintain our cultures and run experiments during the lockdown. Their commitment and dedication to duty was unwavering. Thank you! I would also like to thank the Water Research Commission that fund most of our research projects.

Prof ON Odume
UCEWQ Director

HYDROLOGY REPORT

Introduction

Although it has been a challenging year, the Hydrology Group has continued to remain active and grow. There were two graduates in 2020 at Honours level, and nine students working towards graduation in 2021: three PhD students (David Gwapedza, Coli Ndzabandzaba and Pierre Kabuya), four MSc students (Phatsimo Ramatsabana, Sinetemba Xoxo, Bawinile Mahlaba and Kopano Mokoena) and two Honours students (Regina Dakie and Sakikhaya Mabohlo). Two additional students are co-supervised by Dr Jane Tanner in Geography.

Mr David Gwapedza submitted his PhD towards the end of 2020, and is awaiting the examiner reports. In the meantime, he has been awarded a Rhodes University Post-Doctoral Fellowship which will begin once his PhD thesis has been finalised. Mr Gwapedza has also been awarded a WRC project as project lead working with Dr Sukhmani Mantel and Dr Jane Tanner. This project works with IRSTEA Research Institute in France, and the Freshwater Research Centre in the Western Cape, and will include three student projects (two MSc and one PhD). The post-doctoral fellowship and WRC project will contribute much needed capacity to the Hydrology Group and we are grateful to the University for the additional support.

Mr David Gwapedza who will be a new post-doctoral fellow and new WRC project lead

International collaboration

In 2019, 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. This collaboration has continued into 2020 with two publications between the institutions (one of these is under review). One of these publications was as a result of PhD Hydrology student David Gwapedza's visit to Germany on exchange in late 2019 where he assisted in setting up a hydrological model for the Buffalo City Municipality.

The Royal Society-DFID Africa Capacity Building Initiative CRuHM (Congo River User Hydraulic and Morphology) project continues to be a large active project led by Emeritus 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. Pierre submitted his PhD thesis at the end of 2020 and is awaiting the examiner reviews.

Aerial view of the braided channels of the Congo River at the entrance of the Cuvette Centrale. Camera is attached to floating plane (Picture was taken during a previous CRuHM fieldwork campaign)

Dr Mantel has continued to collaborate with Dr Januchowski-Hartley (since they served as Board members of the Freshwater Working Group of the Society for Conservation Biology) on a paper focusing on a global review of methods and evidence used to determine environmental and ecological responses of small instream infrastructure. In the same vein, she is currently volunteering on a project that is mapping small infrastructure in UK such as culverts, small dams, weirs and fords using remote satellite imagery (https://firelaboratory.uk/author/srjanuchowskihartley/). If you want to know more about why this work is important, look at this article on how culverts threaten fish (https://bit.ly/3iEqRhv).

In 2019, Prof Denis Hughes was invited by Stellenbosch University to participate in the African Union - NEPAD African Network of Centres of Excellence on Water Sciences and Technology - ACEWATER phase 2 project, specifically for the purposes of applying their experience of hydrological modelling in the sub-Saharan Africa region to establish a hydrological model for the whole Zambezi River basin. Dr Mantel accompanied Prof. Hughes and presented a brief overview of her previous work on setting up the WEAP model for Zambezi. Subsequently, through an expert contract with the European Commission, Joint Research Centre (and with their participation through the third author), the study was expanded to include running future scenarios of both climate change and water use. A couple of papers are expected to come out of this collaboration, one of which has been submitted to the Journal of Hydrology: Regional Studies.

The Hydrology Group continues to be heavily involved in ARUA with Dr Tanner as Co-Director of the CoE, and a Co-Investigator on both ARUA grants. Dr Mantel was appointed as part-time Academic Manager for the Water CoE on the UKRI Excellence Grant project: Resilient benefits from African Water Resources, in July 2020. She has been leading the development of Capacity Development Grant: Water for African SDGs online courses since mid-August 2020 with the assistance of David Gwapedza and Dr Bukho Gusha. The creation of online courses was initiated as a replacement for the in-person courses by the nodes that were originally conceptualised under the Water for African SDGs proposal. Four new Hydrology students supervised by Dr Tanner and Dr Mantel will work on the natural science aspects of the ARUA RESBEN grant in Senegal, Tanzania and Ethiopia. This is going to be exciting work looking at a variety of hydrological issues in the case study basins.

Students

Honours: Two honours students supervised by Dr Jane Tanner and Dr Sukhmani Mantel in 2019 graduated in 2020. This year two more interesting hydrology honours projects were supervised in Hydrology. This included a project by Ms Regina Dakie on the impacts of small dams and alien invasive vegetation on the Howisonspoort and Settlers dams in Makhanda, and Mr Sakikhaya Mabohlo who worked towards a better understanding of the aquifer beneath the Waainek wellfield. The honours course ran successfully for its third year and was held completely online besides a day field trip to Mountain Drive. Unfortunately, a field school run by the Groundwater Division of the Geological Society of South Africa which was planned this year was cancelled due to Covid-19. We are hoping the course will be able to go ahead next year with the 2021 Honours group.

MSc projects: The Hydrology Group is currently supervising seven MSc projects (see student projects in this report for details) with five MSc students expecting to submit before April 2021.

PhD projects: The hydrology group is currently supervising three PhD students (see student projects in this report for details). All PhD students have submitted (end 2020) and are awaiting the examiner reports.

Conferences

PhD student Mr Pierre Kabuya presented a paper on "Understanding factors influencing the wetland parameters of a monthly rainfall-runoff model in the Upper Congo River Basin" at the EGU General Assembly 2020 Online, from 4–8 May 2020. MSc students Mr Sinetemba Xoxo and Ms Phatsimo Ramatsabana both presented at the Water Institute of Southern Africa (WISA) online conference, from 7- 11 December 2020. Ms Ramatsabana's paper was titled, "Integrated hydrological modelling for groundwater drought in South Africa" and Mr Xoxo's paper was titled, "Assessment and prioritisation of ecological infrastructure for water security: Cacadu Catchment in Eastern Cape". Dr Jane Tanner was a co-author on a paper presented at the 42nd Fynbos Forum online from 9-11 September 2020. The paper was titled, "Connectivity clues: Hydrological monitoring to understand surface and groundwater flows in the Baviaanskloof and Kromme catchments, the eastern end of the Table Mountain Group".

Participants at the workshop on Groundwater Standards hosted by Stellenbosch University including Dr Jane Tanner and MSc student Mr Jaco Greef

Dr Tanner and MSc student Mr Jaco Greef attended a workshop run by the local chapter of the International Association of Hydrogeologists titled, "Groundwater: Setting the standards – Borehole Drilling; Pumping Tests and Monitoring" in Stellenbosch from 11-13 November 2020. The course was run by top groundwater professionals in South Africa and is key for the groundwater work currently ongoing in Makhanda. The workshop was successful with positive discussion, well-spirited debates and technical knowledge sharing (see picture above).

Consulting

The hydrology group continues to actively consult with both Prof Hughes and Dr Tanner contributing to international and local consultancy projects. Many of these projects have emerged from the partnership between the IWR and Mr Andrew Johnstone of GCS (Pty) Ltd, and the partnership has been incredibly valuable for the Hydrology Unit. The main hindrance to increasing the consulting work is the lack of capacity within the Institute.

Courses attended

As part of improving the staff supervision skills, Dr Mantel and Dr Tanner attended a five-week Postgraduate Supervision Development Course run by Creating Postgraduate Collaborations, an EU funded initiative (co-funded by ERASMUS) "to nurture research-rich environments necessary for quality postgraduate education". The course was run by various Institutes including Prof Chrissie Boughey and Dr Sioux McKenna from Rhodes University. The course was attended by over 100 participants from nine universities across five countries.

Dr Mantel and Dr Tanner are attending the Training of Trainers course which is run by the Environmental Learning and Research Centre at Rhodes University as part of a larger ARUA group of participants. The course comprises four Modules to inform and strengthen the existing and future learning and stakeholder engagement facilitation practice of educators, trainers, facilitators in Natural Resource Management. It is a six-month course which runs into 2021.

Community Engagement

The hydrology group continues to monitor groundwater levels in Makhanda both at Waainek wellfield, Rhodes University and in town. The monitoring was scaled back in 2020 due to Covid-19 but is gradually increasing in areas as lockdowns are lifted. The monitoring continues to be carried out by Mr Mzwanele Mkatali under the supervision of Dr Tanner. In addition to this, the Hydrology Group has entered into a partnership with Makana Municipality to assist with the setup of a new water analysis laboratory at Waainek Water Treatment Works. This partnership is specifically working with Water and Sanitation Manager Mr Gubevu Maduna and involves Mr Mkatali who is going to be responsible for the laboratory set up and running.

Dr Mantel continues to be part of the Makana Plastic Action Group committee (https://www.facebook.com/MakanaPlasticAction) which organised a clean-up at the Makhanda Spring with support of the local Rotary and Rhodes University students (SOAR and SRC Environmental representatives) and also was part of the Plastic-Free July social media event.

Spring cleanup organised by Makana Plastic Action Group

Proposals and concluding projects

The Hydrology Group submitted four Water Research Commission proposals in 2020, and only one of these was selected for funding (lead by David Gwapedza). We are also still waiting to hear about a number of international proposals submitted. The hydrology group also submitted a proposal with Dr Kathleen Smart which proposed to set up a research catchment in the Bedford/Endwell area focused on thicket vegetation work and a semi-arid hydrology site. This proposal was unfortunately unsuccessful but we are still working towards establishing this research site through other funding opportunities. In terms of hydrology, Prof Hughes set up a semi-arid research site in Bedford in the late 1980s which installed significant infrastructure but which did not continue beyond 1993 after the funding concluded. This infrastructure remains largely intact (see recent image of one of the gauging weirs installed, below) and given the severe lack of semi-arid hydrological data, represents a good opportunity to reinvigorate the site. In addition to this, the site falls within the region of the Karoo aquifer, also with a serious lack of understanding. Mr Andrew Johnstone has secured funding to install groundwater level monitoring equipment in the area (data will be available in real time and hosted on the IWR website) and we hope to gradually increase the equipment on the site in the future through various opportunities.

One of five gauging weirs installed by Prof Denis Hughes in the late 1980s

Three hydrology WRC projects (see details in hydrology projects below) conclude in 2021 with some great outputs including new methodologies, publications, guidance documents, fact sheets etc (see picture below). The group's focus is shifting to the ARUA grants and the management of the natural sciences component of the projects which Dr Tanner and Dr Mantel are leading.

Image from the fact sheet produced by Dr Sukhmani Mantel on the value of investing in ecological infrastructure

Dr Tanner continues to serve on the EFTEON Hydrology scientific advisory committee, the Rhodes University Environmental Committee and the Rhodes University Water Task Team. Dr Tanner has also recently been appointed to serve on the advisory board for the ARUA Centre of Excellence in Notions of Identity hosted by Makerere University.

Lastly a big thank you to all the staff and students contributing to the hydrology group which is gratefully growing in capacity, particularly Prof Hughes who continues to provide invaluable guidance and support.

Dr JL Tanner

HYDROLOGY PROJECTS

CONGO RIVER USERS HYDRAULICS AND MORPHOLOGY (CRUHM)

Sponsor: Royal Society-DFID
DA Hughes
Collaborators: 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
January 2016 – September 2021

A major research and capacity building project, the Congo River users Hydraulics and Morphology (CRuHM) project, funded under the Royal Society-DFID Africa Capacity Building Initiative of the United Kingdom, is being implemented in the Congo River Basin. The main aim of this research initiative is to carry out large scale hydraulic 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. Under this research, led by a consortium of partner institutions from 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, a number of research activities have been undertaken, including:

- Large scale annual site focused fieldworks involving application of relatively new approaches to data collection on large rivers and predictions in ungauged basins,
- Hydrological science research covering a large spatial scale with the objective of collecting a number of fundamental data sets related to river hydraulics and geomorphology,
- Testing and applying a methodological framework of fluvial sediment sampling to understand source to sink processes of sediment transport in the Congo basin,
- Development of hydrological and hydrodynamic modelling frameworks that incorporate new data with the objective of understanding hydraulic behaviour of the river, accounting for wetland processes in large scale hydrological modelling of the basin, quantifying the poorly understood water fluxes between the main channel and the floodplain, and investigating impacts of possible future climate changes and human influences in the basin

This research comes at a time where key decisions are needed for major options of water resource development in the basin, including the African hydropower grid from the Inga Dam, river navigation to connect riparian countries, water supply, large scale irrigation as well as inter-basin water transfer options. It is therefore important to foster a framework of knowledge management and information sharing in support of science-based decision making that will complement the economic, social and environmental dimensions of water resources to support sustainable development in the Congo River Basin.

Traffic on the single channel of the Congo River before entering the braided region. (Picture was taken during a previous CRuHM fieldwork campaign)

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

Sponsor: Water Research Commission
SK Mantel
Collaborators: JL Tanner (IWR), D le Maitre (CSIR), A de Vos (Department of Environmental Science, Rhodes University)
April 2019 – March 2021

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 (Figure 1), 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 has experienced a severe and continuing 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 fibre and to establish settlements. 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 Figure 1) 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.

South African National Biodiversity Institute's (SANBI) 2014 framework for investing in ecological infrastructure (EI) promotes a range of approaches, including the following four that link with the focal EI land cover types that our project is investigating:

- Improvement of practices used for rangeland management

- Clearing invasive aliens from catchments and riparian areas
- Maintaining / restoring natural vegetation buffers in riparian zones
- Rehabilitation of wetlands

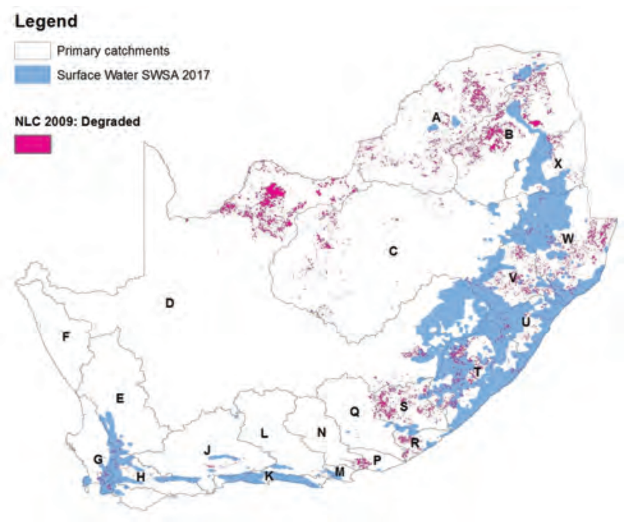


Figure 1 showing the location of degradation areas in South Africa (2009 National Land Cover) relative to the surface water strategic water source areas (SWSA) by primary catchments

The project focuses on four target ecological infrastructures whose maintenance and restoration will support flow regulation ecosystem services in the catchment: grasslands/rangelands, riparian zones, wetlands, and abandoned croplands. The last category has been added as previous research has identified them as focal areas for invasive alien plant invasion, which are well known for their large water use as well as source and cause of erosion. Figure 2 shows an example of a spatial map generated by the project. See the reports by the two MSc students under this project, Mr Sinetemba Xoxo and Ms Bawinile Mahlaba for results generated for the Tsitsa, Cacadu and Crocodile River catchments.

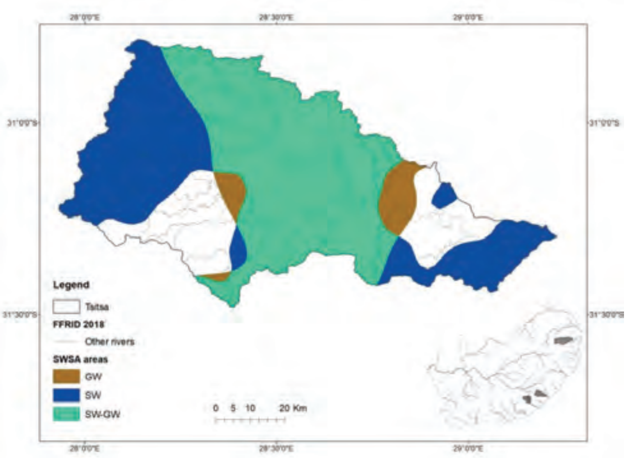


Figure 2 Flagship and free-flowing rivers derived from National Biodiversity Assessment 2018 overlaid on surface water (SW) and groundwater (GW) Strategic Water Source Areas (SWSA) for the Tsitsa River catchment

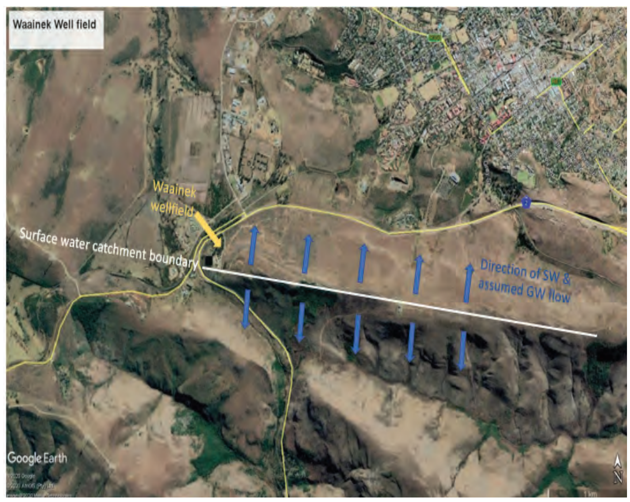
MONITORING GROUNDWATER IN MAKHANDA

Sponsor: Hydrology Group

M Mkatali & JL Tanner

Mr Mzwanele Mkatali is currently working as a Research Assistant in the Institute under Hydrology. Some of his responsibilities are to oversee the groundwater monitoring programme in the Makhanda area. This involves the monitoring of private boreholes, the Waainek well field, and boreholes at Rhodes University. Mr Mkatali communicates with borehole owners regarding access to their land and information, measurement of the groundwater levels as well as sample processing, and finally analysis and reporting of the data. He has taken on this role completely, independently and with assurance. In addition to managing the groundwater programme, he as assisting with various field trips in the collection of samples when needed and measures water quality variables (pH, temperature, DO, EC, Chloride, Chlorine, Ammonia, Ammonium Chloride, Iron, Nitrate and Phosphate). He has also taken on monitoring of the Fairview spring and assists with chemical analysis of spring water samples. Mr Mkatali is also busy writing a paper focused on the identification of the major controlling factors of groundwater chemistry, and the potential of using groundwater chemistry as a tracer.

Mr Mkatali measuring the groundwater level in a borehole



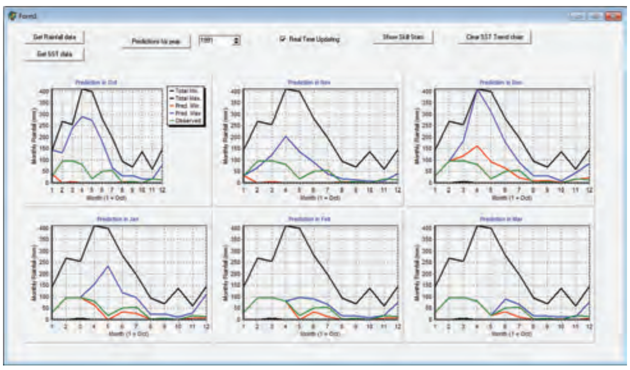
Conceptualisation of the groundwater system at Waainek Water Treatment

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 – March 2021

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 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 months 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 improve.



The project has been delayed due to Covid-19 so progress has been limited in 2020. The next stage of the project focuses on testing the system in other case study areas, including particularly winter rainfall regions. This phase is ongoing.

CRITICAL CATCHMENT MODEL INTERCOMPARISON AND MODEL USE GUIDANCE DEVELOPMENT

Sponsor: Water Research Commission
JL Tanner, DA Hughes and D Gwapedza
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

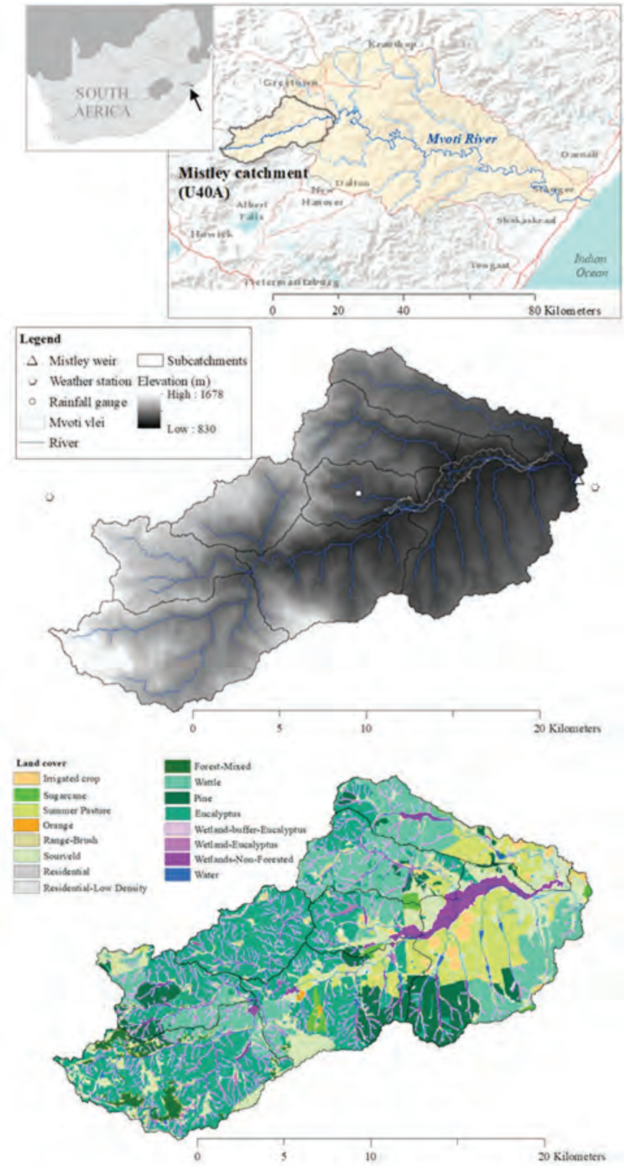
In response to the growing use of hydrological modelling in water resource and catchment management in South Africa, this project aims to provide modeller guidance that can facilitate wise-use of the diversity of modelling software tools available. This is achieved by exploring the structural differences across several commonly used tools in South Africa and the implications of these differences for application in different settings.

Project objectives

1. Review and compare the structures and structural options in a selection of commonly used catchment modelling software tools in South Africa.
2. Apply a selection of catchment modelling software tools to a set of case study catchments and scenarios of change across a diversity of settings to allow for more quantitative exploration of the implications of structural differences.
3. Capture and document user experiences with the different tools being compared and reviewed through workshops, interviews, and surveys.
4. Synthesise the resulting data and information to produce guidance materials for modellers.

The modelling tools and versions selected for inter-comparison in this project are:

- ACRU, Agricultural Catchment Research Unit model, ACRU 4 version (Schulze, 1986, 1995; Schulze and Davis, 2018)
- Pitman model (Pitman, 1973) application tools:
  - WRSM-Pitman, Water Resources System Model, WRSM2000 version (Bailey, 2015; Bailey and Pitman, 2015)
  - SPATSIM-Pitman, modified Pitman Model run through the SPatial And Time Series Information Modelling platform, SPATSIM v3 version (Hughes, 2013, 2019)
- SWAT, Soil and Water Assessment Tool, implemented with ArcSWAT2012 (Arnold et al., 1998; Neitsch et al., 2011)
- MIKE-SHE, Système Hydrologique Européen, MIKE 2019-2020 versions (Abbott et al., 1986; DHI, 2017; Refsgaard and Storm, 1995)



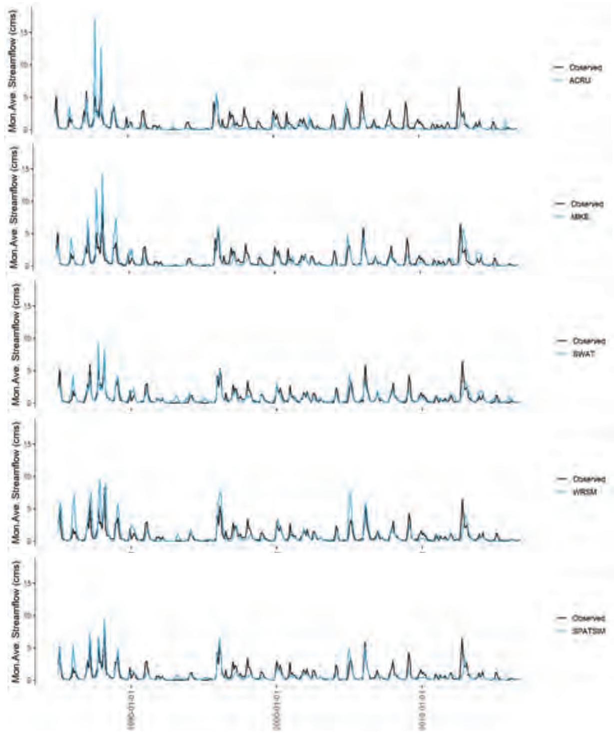
Regional location, topography and gauging stations, and land cover of the Mistley catchment on the upper Mvoti River, KwaZulu-Natal

The intention is to model case study catchments that cover a variety of climate, geomorphological, and land cover settings across and to look at multiple common modelling applications, such as estimating the hydrological impacts of invasive alien tree species, wetland loss or restoration, or other land or water management scenarios (See figure below). The goal of this exercise is to gain a deeper understanding of the capabilities of the tools and the practical implications of tool choice on the modelling process and it outputs.

Province	Catchment	Climate type	Geology, geomorphology, natural vegetation	Scenario types	Highlighted representation issues
KZN	Mistley, upper Mvoti	Summer rain, sub-tropical	Shale & dolerite, rolling hills, Grassland	Commercial forestry extent & riparian/wetland buffers	Riparian zone processes
WC	Upper Berg	Winter rain, sub-humid / semi-arid, Mediterranean	TMG quartzite, steep mountain, Fynbos	Invasive alien tree extent & location	Interflow in steep, rocky mountains
EC	Upper Kromme	Bimodal rain, semi-arid	TMG quartzite - steep mountain + floodplain alluvium, Fynbos	Invasive alien tree extent, Wetland extent	Spatial rainfall distribution & flow connectivity interact with subcatchment delineation Valley bottom wetland representation
LM	Middle Letaba	Summer rain, semi-arid, temperate	Gneiss & granite, relatively flat, Woodland	Irrigation amount & irrigation from groundwater	Irrigation from groundwater, from multiple sources Numerous small farm dams Channel transmission loss

Case study catchments, use-case demonstration scenario types, and highlighted process representation issues encountered in model building

When building models for the case study catchments using the different modelling tools various challenges were encountered, some of which were particular to a single tool while others applied to multiple. Some of the hurdles were primarily due to the process conceptualisation strategies in the tools. Others were directly linked to the software interface and the ways that inputs are added and outputs are exported; however these aspects could result in process representation issues as well. It would benefit modelling tool users to be aware of some of the challenges encountered during this project. The Mistley and Berg catchment case studies are complete, and the Krom and Letaba case studies are in progress. The project has produced some very interesting comparisons and guidelines for hydrological model selection and use.



Monthly modelled and observed hydrographs for the Mistley catchment 1986-2016

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

In South Africa, resource directed measures (RDM) and source directed controls (SDC) are two complementary strategies designed to ensure that water resources are both used and protected. The RDM are directed at water resources to ensure their protection and they include the water resources classification system, the classification of every significant water resource, determination of the Reserve and setting of resource quality objectives (RQOs). On the other hand, the SDCs are measures impose to restrict and control the use of water resources not only in terms of ensuring water resource protection, but also ensuring that water resources are equitably allocated and use efficiently. Water use licencing (WUL) is an example of an SDC instrument.

To be able to use the two complementary strategies effectively, it is important that the link between them is clarified. Stakeholders within the Vaal Barrage catchment have indicated that the link between the water quality component of the resource quality objectives (RQOs) and discharge standards in WUL are often not clear. Even when the links between the RQOs and discharge standards in WUL are clear, the way in which standards in WUL are derived, considering catchment baseline conditions, imperative for social-economic development as well as scientific credibility need to be clarified. It has also been argued that in sub-catchments and/river reaches where there are no RQOs, the way in which site-specific condition inform the derivation of water quality discharge standards in WUL, and the risk posed to the resource by the discharge standards in WUL needed to be explored and clarified. It is also not clear to all resource users how upstream waste loads affect discharge standards for downstream users as well as the downstream RQOs. This is particularly crucial for heavily utilised catchments such as the Vaal Barrage catchment and associated rivers such as the Klip, Suikerbosrand, Taaiboschpruit and Blesbokspruit, where several upstream pollution sources impact on downstream resource users and RQOs. This study was thus aimed at developing a decision support system (DSS) for clearly linking water quality standards in WUL conditions to gazetted RQOs, and/or site specific conditions in the Vaal Barrage catchment, taking into account a range of complex interacting factors such as all components of flow (flow regime, timing, pattern, frequency and magnitude), land use types, upstream waste loads, diffuse and point effluent emitters.

Project aims

The specific aims of the projects are as follows:

1. Undertake a comprehensive and thorough assessments of existing practices, data, approaches, methods, and tools including relevant catchment literature, regarding 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 standards in WUL and their scientific defensibility.
2. Develop an appropriate, robust and scientifically defensible but flexible decision support system (DSS) for transparently setting water quality standards in WUL conditions (point and diffuse) taking account of receiving resource quality objectives/ site specific conditions.
3. Demonstrate and test the implementation and applicability of the developed 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 As part of the scenario analysis, demonstrate how the developed DSS could be implemented such that a water user is able to determine the likely impacts on RQOs and/or site-specific conditions.
4. Communicate widely with catchment stakeholders and build capacity of the relevant unit/sections within Department of Human Settlements Water and Sanitation (DHSW&S), and water users through training on the use and application of the developed DSS. This is to ensure that the entire process of developing the DSS is consultative and widely communicated, and project outcome acceptable to all stakeholders.

Project results and discussion

The desktop study of current practices regarding RDM and SDC revealed that the current method used by DHSW&S of determining end of pipe discharge standard can be considered as quite robust as it considers critical parameters such as the flow mixing ratio (dilution), management class, attainable treatment in setting end-of-pipe discharge standards, and receiving resource in-stream concentrations. However, several shortcomings in the approach are recognised:

1. There is no consideration of the differences between conservative and non-conservative variables. While

the mixing ratio is of relevance to conservative water quality variables which are predominantly affected by dilution, non-conservative variables are affected by a myriad of additional processes such as chemical speciation and algal uptake.

2. There is no consideration of upstream waste loads. This disadvantage is of particular relevance for heavily impacted catchments such as the Vaal Barrage and associated rivers;
3. The potential contribution of diffuse sources to the waste loads is not considered. This is a major oversight in a catchment such as the Vaal where diffuse sources contribute significantly to the system waste loads.
4. The receiving stream concentration for toxic substances is set at zero (0) for toxic substances and reference condition for system variables. These criteria may be considered unrealistic in a heavily used catchment, where gazetted Recommended Ecological Category is set below category B.

The DSS is based on a calibrated version of WQSAM (a water quality model) and is able to simulate important water quality variable of management concern such as nutrients nitrate (NO_3-N), nitorite (NO_2-N), Ammonium (NH_4-N) and Phosphate (PO_4-P); sulphate salts ($SO_{4)}$, total dissolved solids (TDS), calcium, chloride, fluoride, potassium, magnesium and sodium, and metals such as iron, aluminium, cadmium, chromium, copper, lead and zinc. Observed data for metals were sparse to allow for model calibration.

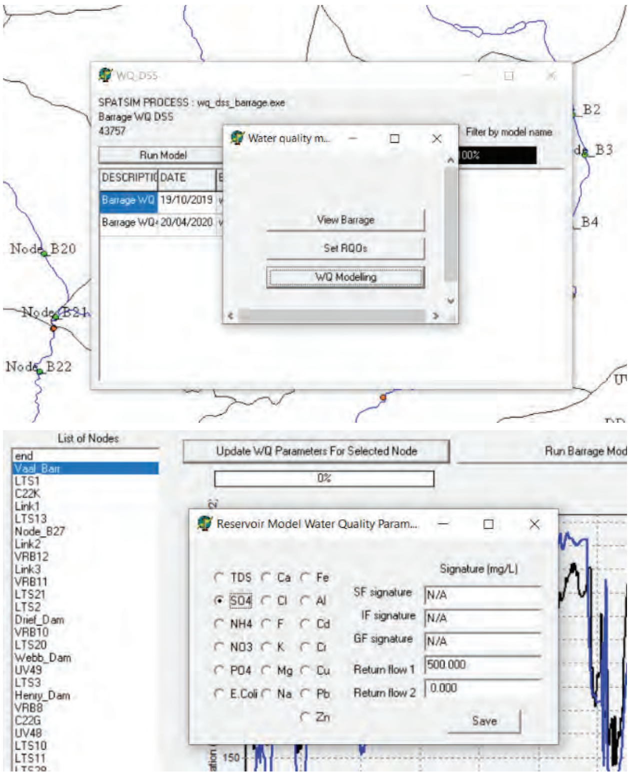


Figure A: Launch screen of the DSS (top) and the screen for setting the water quality signature for both point and non-point sources (bottom).

The "Set RQOs" button on the launch screen (Fig A, top) opens a panel with which it is possible to set RQOs for each node (Fig B, top)

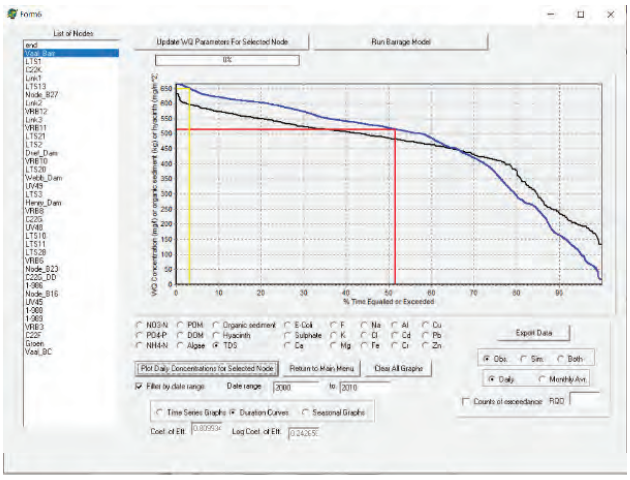


Figure B: Screen within the DSS for setting Resource Quality Objectives for particular nodes (top) and the frequency distribution curve relating the model return flow signature to the RQOs (bottom).

The user can then set either numerical limit and 95% RQO for each node and for each water quality variable simulated. It was decided to allow users to set RQOs themselves to maximise the flexibility of the model. As shown in Figure B, left, as an example (these are not the official RQOs), the numerical limit and 95% TDS RQOs (mg ℓ^{-1}) have been set to 650 mg ℓ^{-1} and 514 mg ℓ^{-1}, respectively. The interpretation of water quality simulations in relation to the RQOs is facilitated through the water quality modelling screen. Using the same RQO example, Figure B right, shows the frequency distribution of TDS for the Vaal Barrage in relation to the numerical limit and 95% RQO. From the frequency distribution of simulated TDS for the Vaal Barrage shown in Figure B, right panel, the yellow and red lines show where the numerical limit and 95% RQOs cross the frequency distribution. The percentage of time that the simulated water quality exceeds either of the RQOs can be determined by where the vertical line crosses the X-axis of the frequency distribution graph. In this hypothetical example, the vertical line of the numerical limit RQO (yellow line) crosses the X-axis of the graph at around 3%. The vertical line of the 95% RQO (red line) crosses the X-axis of the graph at around 52%, indicating that simulated water quality exceeds the RQO around 52% of the time. For the TDS of the Vaal Barrage to fall within the 95% RQO, the red line should cross the X-axis at 5%. This results therefore shows that the simulated TDS data for the Vaal Barrage exceeds the hypothetical TDS 95% RQO.

Possible applications of the DSS include investigating the effects of upstream waste loads on downstream users and RQOs, scenario modelling of effects of water quality standards in WUL on the RQOs, and also simulating whether the receiving river system has capacity for additional emitters given waste loads from current emitters. The DSS is downloadable here https://www.ru.ac.za/iwr/research/software/spatsim/ . User would need to follow the instruction and then use the manual (project report volume 2) on how run the DSS for various applications.

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

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

Good water governance is increasingly being recognised as a process that can address critical water challenges such as those of scarcity, risk, service delivery, infrastructure maintenance, ecosystem degradation, deepening citizen participation and negotiating multiple values associated with water resources and related services (Pahl-Wostl 2015a, b; 2019; Berg 2016). The growing call for the governance of water resources within complex social-ecological system (CSES) perspective amount to explicit recognition of the interconnectedness, interdependence and cross-scale dynamics between the ecological and human (social) subsystems. This also amounts to explicit recognition and taking account of values within the components and relationships of the CSES and their emergent properties (Folke et al. 2007; Pollard et al. 2011; de Wet and Odume 2019). However, the governance of water resources within CSESs raises complex ethical challenges as water is not only viewed through the lenses of society alone, but also that of the environment and thus the imperative for balancing the use and protection of water ecosystems. Values are said to underpin water governance processes, decisions and institutional arrangements.

It is increasingly being recognised that values play a significant role in the way water is governed, managed, used and protected (Brown and Schmidt,2010; Odume and de Wet 2016; de Wet and Odume 2019). Some authors such as Schulz et al (2017) have argued that many of the conflict around water are indeed values-based conflicts, in which the actors or stakeholders involved are unable to reconcile their different value standpoints. In South Africa for example, the three values of equity, sustainability and efficiency are enshrined in the National Water Act (Act No. 36 of 1998) as though they were principles, assuming the level of "*de facto*" status in the way water is viewed, managed, protected and governed (RSA 1998). We take values to mean what specific societal groupings or constituencies express at a generalised level to be good or bad conduct (de Wet and Odume 2019). This definition of value is akin to what Schulz et al (2017) refers to as fundamental values, underpinning our attitude and behaviour towards other people and the rest of nature.

This project which seeks to explore the link between water governance and ethics is being carried out in the Lower Sundays River catchment and the lower section of the Upper Vaal. For example, an inefficient regulatory system in the lower section of the Upper Vaal catchment has led to multiple incidences of illegal discharges of waste into rivers, negatively impacting on other users who have legitimate right of access to such water resources. 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 and emerging farmers. 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). This project therefore, seek to contribute to addressing specific identified water governance challenges in two contrasting catchments: The Klip River and the Lower Sundays River and exploring their ethical dimensions, while developing an ethic framework for thinking about values, their interactions and implications in specific cases.

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.
- Synthesise 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 – LEADING INTEGRATED RESEARCH FOR AGENDA (LIRA) 2030 IN AFRICA

Sponsor: Network of African Science Academies (NASAC), International Science Council and SIDA
ON Odume and CF Nnadozie
June 2019 – May 2021
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; Uku Jude (Private).

Collaborating Organisation: Nelson Mandela Bay Metropolitan Municipality; Port Elizabeth office of Department of Water and Sanitation

Urban rivers and wetlands are often seriously degraded ecosystems, and in Africa, they are often used as sewage and storm water disposal pipes. 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 present an intractable challenge, and we argue that part of this intractability arises of insufficient appreciation of 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.

Workshop participants work on exploring ways to improve the Swartkops River water quality

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: Funded by the Intra-Africa Academic Mobility Scheme of the European Union
ON Odume and CF Nnadozie
January 2020 – December 2024
Collaborator Organisations: Federal University of Technology, Minna, Nigeria; University of Kinshasa, DRC; Makerere University, Uganda; National Higher School of Hydraulics, Algeria; TU Delft, Netherlands

Project website for additional details: https://www.ru.ac.za/intra-africa-awarmn/

This multi-partner EU-funded project aims to develop African capacity for sustainable water resource management through the training and exchange of MSc and PhD students as well as staff exchange among partner institutions across Africa. This objective is founded on the realisation that achieving sustainable development, and inclusive growth within Africa would largely be undermined if its water resources are not sustainably managed, utilised, protected and governed by competent and qualified professionals. 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).

The African Water Resource Mobility Network (AWARMN), which is a project of the Intra-Africa Academic Mobility Scheme, is a set up to address the water-related pressing needs on the African continent. The main objective of addressing these pressing needs are 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 AWARMN 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.

AWARMN is funded by the Intra-Africa Academic Mobility Scheme of the European Union (https://eacea.ec.europa.eu/intra-africa_en)

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 threat 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 in 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, the has the following specific objectives:

- Evaluate the potential toxicity of microplastics as chemical stressors (plasticisers) 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.

PATHWAYS, CONTEXTUAL AND CROSS-SCALE DYNAMICS OF SCIENCE-POLICY-SOCIETY INTERACTIONS IN TRANSDISCIPLINARY RESEARCH IN AFRICAN CITIES.

Sponsor: LIRA; Network of African Science Academies; International Science Council
ON Odume
April 2020 - March 2021
Collaborators: Dr. Fati Aziz, Water Research Institute, Ghana; Dr Sokhna Thiam, Institute for Health Research, Epidemiological Surveillance and Training, Senegal; Dr Sandra Boatemaa, Stellenbosch University, South Africa; Dr. Akosua B.K. Amaka-Otchere, Kwame Nkrumah University of Science and Technology, Ghana; Dr. Blessing Nonye Onyima, Nnamdi Azikiwe University, Nigeria.

The global Sustainable Development Agenda (SDGs) are inherently complex as do their interactions (Nilsson et al. 2016). Strengthening science-policy-society interaction has been conceptualised in the literature as one way of navigating the complexity of sustainability challenges, and of accelerating the achievements of the SDGs (Bernard et al. 2019). Conceptual models e.g. the Triple Helix model (Saviano et al. 2019), framework (Steg, 2008) and typologies (e.g. Sundquist et al. 2018) have been developed to analyse, reflect and integrate the triad of science, policy and society in projects, but the extent to which these are supported by empirical evidence, particularly in an African context remain largely unexplored.

Our LIRA integrative projects, which have been conceptualised to contribute to the achievement of the SDGs in Africa, and to accelerate specific project outcomes, provide a rare opportunity not only to interrogate and critique these models, frameworks and typologies, but to further develop them as a contribution from the global South. The proposed project thus explores ways in which the interactions between science-policy-society were foregrounded in small integrative projects concurrently addressing multiple SDGs in Africa. The project will address the following:

1. critique existing models, frameworks and typologies of science-policy-society interactions, drawing on empirical evidence from the African contexts;
2. draw on experiences of implementing integrative projects in Africa, and meta-analyses, to explore and showcase pathways and scales (space and time) of interactions, and associated principles;
3. analyse and reflect on systemic and contextual obstacles to, and opportunities for interactions, drawing on our specific project experiences and empirical evidence;
4. reflect on the specific contributions of foregrounding science-policy-society interactions to the SDGs as manifested in the individual projects.

MAPPING WATER AND SANITATION INTERLINKAGES ACROSS THE SUSTAINABLE DEVELOPMENT GOALS

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

Following the conclusion of the Millennium Development Goals (MDGs) in 2015, the United Nations (UN) adopted the 2030 Agenda for Sustainable Development. The 2030 Agenda consists of 17 Sustainable Development Goals (see Figure 1) as well as a monitoring framework of 69 targets and 230 indicators to track achievement of the SDGs. The SDGs build on the MDGs and present a significantly broader context for tackling universal developmental challenges. The SDGs provide a unique opportunity for multilateral stakeholders to triangulate and confront pressing challenges in a coordinated and integrated manner. This is because the SDGs are indivisible, in a sense that they must be implemented as a whole, in an integrated rather than a fragmented manner, recognising that the different goals and targets are closely interlinked. As a result, the SDGs offer a platform for the effective and deliberate positioning for leaving no one behind, eradicating poverty, increasing access to education, combating climate change and reducing inequality.

Since the adoption of the SDGs, South Africa has made great strides in unlocking opportunities and devising mechanisms that support the effective implementation of the SDGs. Despite the commendable efforts that have been made, the 2019 reporting period revealed that significant work is still required in order for South Africa to achieve the 2030 Agenda within the allotted time. A particular gap was recognised in the country's knowledge and understanding of interlinkages across the goals and how the interactions can be mapped out to provide comprehension on possible trade-offs between goals, opportunities amongst goals that can to accelerate progress as well as support improved programmatic planning, implementation and monitoring. This knowledge gap is acutely noted in relation to SDG 6, which focuses on water and sanitation.

The Water Research Commission (WRC) is cognisant of the limited body of knowledge that examines SDG 6 interactions with other SDGs. The scarcity of information is even more severe at a national scale. To this end, the WRC together with the Department of Water and Sanitation have commissioned a study to analyse the extent to which SDG 6 indicators demonstrate interactions or interlinkages with other SDG indicators in a South African context.

The purpose of the study is to address the existing knowledge gaps by identifying interlinkages between SDG 6 indicators and other SDG indicators across the 2030 Agenda. As a result, the study examines the key dimensions within which interactions occur and assesses vertical coherence and horizontal integration in the implementation of interlinked indicators. The project also identifies research needs for interlinked indicators as well as tables recommended means of implementation for interlinked indicators, which have been identified to have strong network connection. The specific aims of the research study are as follows:

- To critically assess interlinkages between SDG 6 indicators and other SDG indicators in order to determine dependencies, trade-offs and implications for implementation
- To present research needs and recommendations on how to improve the institutionalisation, localisation and implementation of interlinked water related SDGs
- To provide recommendations on the development of appropriate systems and platforms to monitor and evaluate progress on SDG 6 linked indicators.

Figure 1: SDG Diagram

ADAPTIVE WATER RESOURCE MANAGEMENT PROJECTS

ANDREW W. MELLON FOUNDATION PROGRAMME TITLE: "SOUTHERN EPISTEMOLOGIES: THINKING BEYOND THE ABYSS FOR A TRANSFORMATIVE CURRICULUM"

IWR contribution: Colloquium: Chasms affecting southern participatory research, a question of epistemic justice
Chairperson: Emeritus Professor C de Wet
Panel: Prof CG Palmer: IWR, Rhodes University
Dr Nomzamo Dube: Centre for Transdisciplinarity, University of Fort Hare
Reverend Gina Gcebile: College of the Transfiguration, Makhanda
Dr Nicola Palmer, Law School, Kings College, London.

Introduction
When we consider De Santos' work, beyond abyssal thinking, it raises the question of 'what is an abyss?'. It's a huge enormous chasm, abyssal is an unimaginably deep chasm. He is talking about those things that we don't manage to bridge easily. The things that very seriously divide us. There isn't a person that is South African or that has lived in SA that doesn't understand the profound divisions, or in Africa, as a continent. The profound divisions that separate us. Here we consider chasms that affect participatory research.

Dr Nomzamo Dube
Life, Knowledge & Action: Fort Hare's Transdiciplinarity first year course - a compulsory course for all first year students'. The course has now been duplicated at University of Zululand. At the time of UFH 90th Anniversary the university held incoko (dialogue / self-critiquing) with academic staff and students. A problem identification study found that students struggle to connect their studies to the wider purpose and academics felt there was a social isolation of the academic project (staff worked in silos). Out of this came the plan for a transdisciplinary course for first years that paid attention to: decolonisation of the curriculum such that it makes sense to the realities of the students; a humanising pedagogy (a kind of education that humanises students and giving them a voice); and the promotion of transdiciplinarity. Dr Dube went on to present the focus, aspirations and outcomes of the course

Reverend Gina Gcebile
Most of you are probably familiar with Desmond Tutu. Desmond Tutu in apartheid SA advocated for Ubuntu as a way in which me might begin to think about each other and about the world as people. Since Desmond Tutu, theological work has been interested in Ubuntu. Most theological work coming out of southern Africa has, in a sense said that Ubuntu is compatible with Theology. However I think Ubuntu is not compatible with theology or justice or the Christian teaching of grace or any other Christian teaching. Reverend Gcebile went on to provide a compelling argument for this contention.

Dr Nicola Palmer
How do we draw out some of the connections that unsettle the comfortable assumptions of global south and global north ? I think that this requires us to not only look south but to be southern. Epistimologies of the south are built on two main concepts. The first is about developing ecologies of knowledge and the second is about embracing intercultural translation.

The first step we want to explore is how the development of wider ecologies of knowledge can lead us toward greater epistemic justice. Ignorance of a particular type of knowledge can disqualify people from participating in decision making that affects their everyday lives. Scientific and legal knowledge are good examples. The solution to epistemic injustices cannot be found in the more equal distribution of scientific and legal knowledge alone. The challenges of participating in, for example, catchment management or complex legal processes, cannot be achieved through outreach or education alone. It is not simply a question of providing more people with scientific or legal knowledge. There requires a level of humility from those who hold that knowledge to recognize their own ignorance. What is this ignorance? As with all ways with which we know our world, scientific and legal knowledge have limitations. They are necessarily and unavoidably constrained. There is knowledge that cannot be known through science or law, and some interventions are only going to be rendered possible through other ways of knowing the world. Dr Palmer went on to apply this thinking to post-genocide Rwanda.

ARUA WATER COE-ADAPTIVE SYSTEMIC APPROACH (ASA)

Ms Mti joined the ARUA CoE team who travelled to Ethiopia in February this year. The team organised an Adaptive Systemic Approach course at Addis Ababa University. Ms Mti assisted in the planning of the course and organizing the materials needed for the course. She is also assisting Ms Mclean in the writing of the minutes within the ARUA CoE meetings.

Group photo at Addis Ababa University

THE TSITSA PROJECT: GOVERNANCE COMMUNITY OF PRACTICE

Sponsor: Department of Environment, Forestry and Fisheries: Natural Resource Management
N Libala, A Fry, M Ralekhetla, N Mti and CG Palmer,
April 2020 - March 2021

The Tsitsa Project (TP) is an an initiative by the South African government's Department of Environmental Forestry and Fisheries: Natural Resource Management (DEFF: NRM). An ongoing, 10-year (2015-2025) landscape restoration project that aims to ensure 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 Mzimvubu Water Project. in the Eastern Cape, and is a rural landscape which includes private commercial farming and land administered by traditional councils. TP started as a natural science-based project focusing on sedimentation and rehabilitation, in realising the interconnectedness between humans and nature TP has adopted a Complex Social Ecological Systems approach, where good governance is seen as having the 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 (Gov. CoP). The purpose of the Governance CoP is to leave a catchment where local people listen and speak knowledgeably and contribute to decisions, in governance spaces that affect their lives.

Within the 2020 academic year, the Governance CoP' objectives were to:

1. Conduct training on listening and speaking for monitors in order for them to be able to participate in decision-making and implementation regarding land and water, which affect their livelihoods and well-being
2. Write a paper that recognizing the capability pathway as a theory of change, and deepening it into a systemic understanding of participatory governance development processes, with Systems CoP.
3. Roll out report on the learning words.

In 2019, the Governance team in the Tsitsa Project developed capabilities for a wide range of local stakeholders and residents to be able to meaningfully participate in planning and decision-making processes pertaining land use, restoration and livelihood activities in the Tsitsa Catchment. Five capabilities (Figure 1) have been identified as pathway for the achievement and sustainability of catchment management:

- *Co-Knowing*: common understanding of key terminology and concepts related to the process.
- *Co-Listening and co-speaking:* establish speaking and listening relationships.
- *Co-Planning:* meaningfully participate in planning processes.
- *Co-Influencing and co-deciding*: influencing decision making through active participation engagements, ownership of initiatives and agency thus promoting equity and social justice in such processes.

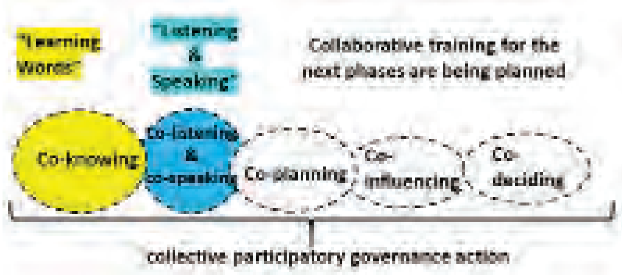


Figure 1: The Governance Capability Pathway: Learning Words workshops have been undertaken in twelve villages, and initial Listening and Speaking training has been initiated with Catchment Liaison Officers.

Last year, we worked on the first Capability "Co-knowing" where we facilitated several "Learning Words" workshops in various villages, with three main purposes: i) embedding a vocabulary and understanding of the Tsitsa Project across the catchment – including and understanding of how the project can benefit individuals and communities, ii) providing a foundation for the confidence, understanding and vocabulary to engage with the development of Listening and Speaking capabilities; and iii) providing a context for community engagement with restoration implementation and livelihood development planning. This resulted in enhancing people's understanding of the project aim and scope, developing village-level plans, implementing relevant restoration interventions, and strengthening local governance structures.

In 2020 we focused on second capability "Co- Listening and speaking" The training of speaking and listening is building on "learning words" process. This Listening and Speaking capability is focusing on introducing ways of listening and speaking to other actors in the catchment, and relationship mapping knowing where to speak and listen. We conducted a training for 16 monitors. The training took place in Maclear on the 16th and 17th September 2020 in LIMA offices. The training was facilitated mainly via zoom but some Governance members, the TP Catchment co-ordinator and LIMA officials were physically in Maclear to assist participants with the technical issues.

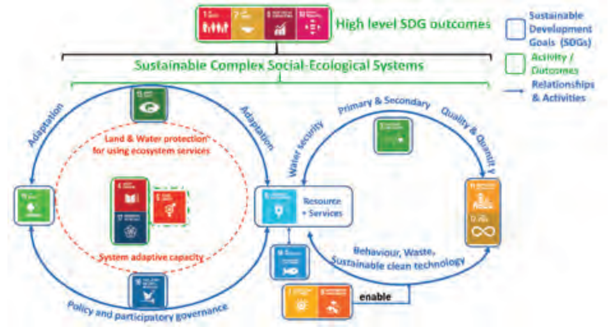
Listening and speaking training in Maclear LIMA offices

ARUA WATER CENTRE OF EXCELLENCE (COE) WATER FOR AFRICAN SDGS (CAPACITY DEVELOPMENT GRANT)

Sponsor: UKRI-GCRF
Prof CG Palmer (Director and Principal Investigator) and Dr JL Tanner (Co-Director and Co-Investigator)
Collaborators: Prof Z Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof N Banadda (Makerere University, Uganda), Prof S Faye (Cheikh Anta Diop University, Senegal), Prof E Longe (University of Lagos, Nigeria), Prof J Nobert (Dar es Salaam University, Tanzania), Dr N Venuste (University of Rwanda, Rwanda), Prof K Winter (University of Cape Town, South Africa), Prof S Gurmessa (University of KwaZulu-Natal, South Africa)
September 2019 – August 2023
Project website: https://www.ru.ac.za/iwr/aruacoe/

The ARUA-UKRI research programme Capacity Development Grant supports 13 ARUA Centres of Excellence, with the Water CoE project, ***Water for African SDGs***, being one of them. The ***aim of the project is to establish and develop the ARUA Water CoE as an effective, high-performance, hub and network of nine African Universities' researchers and post-graduate students***. The CoE plans to use research to catalyse change towards social and ecological justice and sustainability, paying attention to African community water and sanitation needs. The project team brings together diverse strengths in the area of water, so the nodes can flexibly link and respond innovatively to research funding calls, and effectively apply research. To support the administrative demands of the project, Ms Juanita McLean was appointed as Centre Manager.

Project progress
The Water CoE has developed a systemic image of the SDGs as a planning, practice and evaluation tool (Figure below). The image has SDG 6, Clean water and sanitation, at the centre, linking two primary water cycles: i) Water in a Catchment (rainfall, run-off, ground water recharge, evapotranspiration, evaporation); and ii) Water Services – supply and sanitation (raw water from the natural resource, often in dams, pipes and pumps to water treatment works, treated potable water to households, waste water to treatment works and discharge into the natural resource). Each CoE node has strengths in different parts of these cycles for effectively applying research.



A conceptual model/image was developed of water-centred SDGs, within a complex social-ecological understanding.

The Capability Grant proposal includes capacity-building, exchanges and mentorship and this was envisioned primarily through the development and delivery of a 3-day in-person course by each node, to 14 participants from 3-5 other nodes. The first of these training courses was delivered in February 2020.

Foundation training course on the Adaptive Systemic Approach: 10-13 February 2020
A 3-day training course titled Addressing Complex Water and Land Problems: Applying the Adaptive Systemic Approach, was held in Addis Ababa, Ethiopia in February 2020. The course was hosted by the University of Addis Ababa, Land and Water Resources Centre (WLRC-AAU), and presented and facilitated by the CoE Director Professor Tally Palmer. Dr Gete Zeleke (Director WLRC-AAU) and Professor Zerihun Woldu (Water CoE Co-Director) opened the course and welcomed participants from all nine nodes, and four UK participants, funded by the UK N8 Universities. Each node sent a senior or mid-career researcher, an early career researcher and a post-graduate student. The course focussed on applying the novel Systemic Adaptive Approach, which forms the foundation of the research carried out under the Grants.

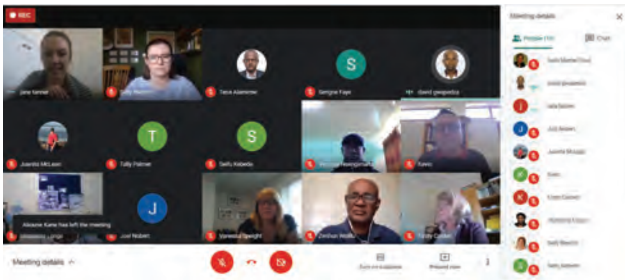
Participants at the ARUA Water CoE foundation course, funded by UKRI:GCRF Capacity Building Grant: Addressing Complex Water and Land Problems: Applying the Adaptive Systemic Approach.

On Day 2 of the course participants practiced running the Adaptive Planning Process Step of the Adaptive Systemic Approach (ASA). The goal was to develop a Strategic Plan for the Water CoE 2020-2024. As part of the Adaptive Planning Process, participants developed a set of common values. These were used as the basis for reviewing the Principles of Ethical Practice first drafted at the launch workshop. Jo Rose from the University of York then facilitated a session on developing an Ethical Code of Practice. The emerging Water CoE Ethical Code of Practice was agreed upon and it will be reviewed annually. The Safeguarding training conducted in 2020 (see below) and beginning of 2021 is contributing to this first review. Another important outcome of the ASA workshop was the approval of University of KwaZulu Natal (UKZN) as a new node member. UKZN has found additional funds to participate in the Capacity Development project.

Participants working on course activities

Updated plans for Capacity Development grant due to COVID-19

Following the Foundational course delivery, the changed situation across the world due to COVID-19 has put most travel to a halt. This has impacted the delivery of the planned in-person courses for the next 2.5 years. Thus, we have conceptualised a shift in the delivery of the project through transferring of in-person courses to online open courseware courses. This change of plans was discussed with the node leaders during a Zoom meeting on 23rd July 2020 (image below).



Participants of the first Zoom meeting on 23rd July 2020 to discuss updated plans for course delivery

The courses decided upon for delivery as Open Courseware by the nodes are as follows:

- Rhodes University: Adaptive Systemic Approach (ASA)
- Makerere University, University of Lagos, University of Cape Town: Adaptive Systemic Approach for Urban Water Pollution Management
- Addis Ababa University and University of KwaZulu Natal: Sustainable Land Management and Landscape Restoration for Ecosystem Services and Water Security
- Cheikh Anta Diop University: Biodiversity and Social Economic Benefits of large dams in African Rivers
- University of Rwanda: Biodiversity, NRM and the water-energy-food nexus
- University of Dar es Salaam: Hydrological modelling for water resources analysis, planning and management in data scarce catchments

All the courses will include the Rhodes University ASA course and all the courses will feed into each other.

This alternative way of delivery of courses using online courseware will not only build the capacity of the nodes but will additionally leave behind a legacy for future learners using case studies and contexts from Africa. As part of this adaptation, the Water CoE has been regularly meeting the Early Career Researchers (ECR) / postgrads (PGs) group appointed by the African nodes, together with node researchers, since August 2020 (initially once a week and then every other week). In between the meetings, the ECR/PGs interact with the node leader and researchers who are contributing lectures into each course. The group meetings have provided training and guidance to the ECR/PGs on developing online courses - in line with the capacity-development aim of the grant. The training has also included creation of videos for the courses by Mr David Forsyth (IWR IT specialist). In order to prepare for this training, Mr David Gwapedza (ECR at Rhodes University until March 2020) and Dr Sukhmani Mantel (Academic Manager, Water CoE) attended a Rhodes University course on developing online resources. This course was adapted to share skills with the nodes.
The organisation and management of the courses by ECRs and postgraduates (under the supervision of a node researcher) is resulting in the capacity development of the junior researchers in various areas including scientific knowledge, technical skills, and course delivery. For final assembling of the courses, we are planning that one person from each node will travel to Rhodes University in 2022 to finalise and upload the course on the Rhodes University platform.

Safeguarding Training

As noted under the IWR Director's Report, safeguarding practices need to be in place at each University of the Water CoE. A local consultant, Lucy O'Keeffe, has been appointed to conduct the training on Zoom. Lucy is a South African-based organisational development consultant and a qualified coach with experience of organisational leadership, programme design, implementation and management, primarily in the NGO sector. Lucy works with Arusha Sturgeon who is a UK-based psychiatric nurse and specialist safeguarding practitioner. Due to the COVID-19 pandemic regulations which started in March/ April 2020, it was decided to provide online safeguarding training for all nodes via the same service provider. Lucy has conducted safeguarding workshop with three of the nodes, including Rhodes University, University of Rwanda and University of Lagos. The other nodes will be engaged for Safeguarding Training in February-March 2021.

ARUA WATER CENTRE OF EXCELLENCE (COE) UNLOCKING RESILIENT BENEFITS FROM AFRICAN WATER RESOURCES. (RESEARCH EXCELLENCE GRANT)

Sponsor: UKRI-GCRF

Prof CG Palmer (Director and Principal Investigator) and Dr JL Tanner (Co-Director and Co-Investigator)

Collaborators: Prof Z Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof N Banadda (Makerere University, Uganda), Prof F Cleaver (Lancaster University, UK), Prof S Faye (Cheikh Anta Diop University, Senegal), Prof E Longe (University of Lagos, Nigeria), Prof J Nobert (University of Dar es Salaam, Tanzania), Prof V Speight (Sheffield University, UK), Dr N Venuste (University of Rwanda, Rwanda), Prof K Winter (University of Cape Town, South Africa), Prof S Gurmessa (University of KwaZulu-Natal, South Africa)

April 2020 – December 2023

Project website: https://www.ru.ac.za/iwr/aruacoe/

ARUA Water CoE is one of four multidisciplinary and multinational projects addressing the UN's SDGs that are supported by UKRI-GCRU Research Excellence Grant. The four joint research excellence projects that have been awarded under this award scheme will help forge new relationships and synergies between the ARUA Centres of Excellence and UK-based GCRF researchers. They together will build on existing activities to develop new proposals and projects aligned to the Sustainable Development Goals (SDGs). The ARUA Water CoE project is titled ***Unlocking Resilient Benefits from African Water Resources***. The ***aim of the project is to apply transformative, transdisciplinary, community-engaged research, to shift water development outcomes towards achieving the SDGs, with focus on continental water development priorities: water supply and pollution***.

The project consists of six proposed project Case Studies (Figure 1) that exemplify water-related challenges across Africa, and support progress towards SDG 6, the core water-related goal. In addition to the six Case Studies, there are three South African learning sites (University of KwaZulu-Natal, University of Cape Town and Rhodes University) that will provide insights and learning opportunities related to Case Studies. The research impact will be measured against contributions to SDG 6 Goals (G) & Indicators (I). Two city-based, water services Case Studies (led by University of Lagos and Makerere University) aim to catalyse change towards: G6.3 Improved water quality, reduced pollution & proportion of untreated wastewater, I: Evidence of increased safe wastewater treatment, recoveries from wastewater & urban water bodies with improving water quality. Three landscape/catchment Case Studies (led by Addis Ababa University, University Cheikh Anta Diop, and University of Dar es Salaam) will catalyse change towards: G6.4 Reduced water stress and increased water-use efficiency I: proportion water-use in relation to availability. All Case Studies will contribute to G6.5: Implement IWRM. I: Evidence of IWRM using governance & institutional development indicators. The cross-cutting biodiversity Case Study (conducted by University of Rwanda) will contribute to G6.6: Protect and restore water–related ecosystems, I: Evidence of

Collaborators and funders of the Research Excellent Grant ecosystem monitoring. All Case Studies will contribute towards G6.8 Support & strengthen participation by local communities in improving water & sanitation management. I: Evidence of governance process & institutional change towards participatory governance, especially by women. Each case study will report on the progress towards relevant SDG goals and targets: SDG6 and other indirectly related goals, many of which are influenced by water. The project team's vision is to change the approach to water development, for Africa, by Africans.

The project objectives are:

1. To apply a novel Adaptive Systemic Approach to six country-based case studies (Figure 1) that shifts developmental research outcomes towards greater equity and sustainability.
2. To address equitable sharing of water supply benefits arising from contested water use, in three catchment-based case studies.
3. To establish the sources, pathways and impact of selected pollutants and to develop community pollution resilience in two city-based case studies.
4. To develop participatory governance to support resilient water supply, water quality, and ecosystem protection in all case studies (Figure1).
5. To build an effective, excellent, partnered African water research network.

All the case studies will be conducted as four ASA steps, and there will be two aspects that they will research: the local water problem science question of the case study, and a social science question relating to researching the actual ASA process.

Figure 1: The main research questions being targeted under the Research Excellence Grant using the Adaptive Systemic Approach for transformative developmental research

Project progress

The project was launched with the participation of all node leaders and researchers (including UK partners Prof V Speight and Prof F Cleaver) in a Zoom meeting on 17 September 2020. The ASA foundation course in Addis Ababa in February 2020 for the Capacity Development grant supported the Research Excellence Grant as it provided the nodes with the understanding and adoption of the Adaptive Systemic Approach. During the launch, the team discussed the way forward with agreement of an internal set of Deliverables, the first of which has been submitted by the nodes.

A number of staff and post-doctoral researchers have been appointed to allow successful delivery of this large grant, including: Dr Rebecca Powell (Large Grants Manager), Dr Sukhmani Mantel (Academic Manager), Mr David Forsyth (IT Manager), Dr Bukho Gusha, Dr Matthew Weaver and Dr Notiswa Libala (postdocs starting in 2021), Dr Sally Weston and Dr Ana Porroche-Escudero (UK University postdocs at Sheffield and Lancaster). Dr Bukho Gusha has joined the team supported by her NRF post-doc.

Since the ASA approach is novel, Prof Palmer's NRF Community Engaged Research account has been used to support the participation and training of one Research Assistant from each node in the Train the Trainers' course being run by the Environmental Learning Research Centre (ELRC) at Rhodes University. The course is headed by Dr Matthew Weaver in collaboration with Prof Heila Lotz-Sisitka.

Updated plans for Research Excellence Grant due to COVID-19

UKRI provided the Water CoE with the option to have a no-cost extension of nine months and extend the original deadline to the end of December 2023. The CoE has accepted this option. This extension has allowed the project team to delay the start of first set of workshops to February-April 2021. The nodes are currently in the process of identifying and appointing Research Assistants (two per node, with the exception of one for UKZN). The CoE has also provisionally considered a way forward if no international travel is possible in 2021. Under such a scenario, the on-ground team will be critical to project progress, and the CoE will consider use of online IIASA model

Way forward in 2021

During the launch in September, the team discussed holding periodic two monthly meetings to consider project progress and any issues. In addition, each node will be asked to fill out quarterly reports using a GoogleForm that is based on the information requirements of the ResearchFish platform used by the funder. We also hope that each node will submit an interesting progress story every quarter to be posted on the CoE ARUA website and we will share these highlights using the Water CoE Twitter account.

ASSESSING PERFORMANCE OF LIVESTOCK PRODUCTION IN COMMUNAL RANGELANDS OF THE EASTERN CAPE, SOUTH AFRICA.

Sponsor: National Research Foundation
Post-doctoral Fellow: B Gusha
Supervisor: AR Palmer

In South Africa, communal rangelands are in the brink of ecological collapse because they are vastly overstocked compared to commercial agricultural enterprise. In the traditional areas of the Eastern Cape, livestock continue to supply many different products and services, making a significant contribution to rural livelihoods. People are known to invest heavily in livestock production of which cattle production alone accounts for 80–90 % of assets value. Rural- and urban-based people continue to have considerable high livestock numbers in these communal areas, which is perhaps mostly related to the absence of other saving method such as banks that leads to thousands of rural people to use livestock as store wealth. However, the apparent excessive number of livestock in these communal areas are blamed to have a deleterious effect on the condition of communal grazing resources through overstocking and overgrazing leading rangeland degradation, which saw communal famers faced with mandatory destocking in the past. This was hoped to have an effect on the quality of livestock and their reproduction rates, production and their market value. While, food security can be improved by maximizing the production efficiency of livestock production, the production inefficiencies are limiting livestock productivity and sources of inefficiencies are diverse. The most important requirement to improve productivity is to use production inputs more effectively.

Cattle after they have been measured for body weight.

It is important to understand the production strategies, socio-economic characteristics and determinants of efficiency among farmers. Therefore, this study assesses the performance of livestock production in communal rangelands where every member has an equal access to the available grazing resources. This study will help provide knowledge of production efficiencies in order to improve the potential of a communal livestock system thus, increased economic growth and decrease poverty in livestock dependent rural households in South Africa.

EXPLORING PARTICIPATORY GOVERNANCE AS A KEY LEVER IN REALISING LONG TERM SUSTAINABILITY OF LANDSCAPE AND LIVELIHOODS IN THE TSITSA RIVER CATCHMENT

Sponsor: National Research Foundation
Post-Doctoral fellow: N Libala
Supervisor: CG Palmer

South Africa is a country experiencing both land degradation and water-related crises. In the Tsitsa Catchment many people, livelihoods and landscapes are vulnerable and natural resources have been eroded. Despite numerous research and/or development interventions there is still no clearly successful process for restoring natural resources while ensuring thriving communities. One recurring omission in interventions is the involvement of the local community in every stage of the intervention; right through to the sustainability of the process once intervening agencies exit and the involvement of the local people in decision making about the land and water resources. My research is nested within a large restoration and research intervention in the Tsitsa River Catchment (Eastern Cape) by the Department of Environment, Forestry and Fisheries. The Tsitsa project vision is to: "To support sustainable livelihoods for local people through integrated landscape management that strives for resilient through a social-ecological systems approach which fosters equity in access to ecosystem services".

I am also the Governance Coordinator for the Tsitsa Project and our research focuses on Participatory governance, empowering communities to engage in participatory land and water governance as an investment into the sustainability of both livelihoods and ecological infrastructure. In attempt to address the issues of local people being excluded in projects, the Governance Community of practice (GovCop) in the Tsitsa Project developed a Capability Pathway (more details in the Tsitsa project-Governance report), which acts as both a process guide and a theory of change for participatory governance development in the catchment. By focusing on capability development the GovCop inputs and support are geared towards allowing those whose development is at stake to deliberate and communicate their view and aspirations and ultimately influence how the project activities should be designed and investments allocated as a joint endeavour with the project implementers, managers and partners. A capability pathway provides a framework that goes beyond the focus on achievement of people's welfare or economic development but also a tool for the promotion of equity, agency and empowerment. With this in mind, the GovCop aims to open up new opportunities for the improvement of the catchment's natural resources as well as for the advancement of human development so dependent on these ecosystems and the services they provide.

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.

Sponsor: Water Research Commission
Post-doctoral Fellow: CF Nnadozie
Supervisor: ON Odume

Campylobacter spp. are the main cause of gastrointestinal disease globally. A high prevalence of resistance to first-line antibiotics useful for treatment exists in clinical isolates of *C. jejuni* and *C. coli*. 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. While there are no documented waterborne outbreaks of *Campylobacter* gastroenteritis in South Africa, small-scale local studies demonstrate that the rates of infections might be underestimated in South Africa. Consumption of contaminated water is a principal risk factor for *Campylobacter* infection. Poultry, domestic animals, and livestock are reservoirs for *Campylobacter* and contaminate surface water by shedding their feces. Transmission from the environment to humans and animals is possible. Therefore, *Campylobacter* is a typical example of a "One-Health challenge", which has emerged at the human-animal-environment interface. The Kowie River in Grahamstown Eastern Cape Province is used by the community for recreational, irrigational, and baptism purposes. Grahamstown and surrounding areas face a sewage treatment crisis and raw sewerage commonly flows into streams and rivers that eventually reach the Kowie River. In addition, livestock farming is a common practice in the area, and much of the runoff containing manure from livestock from nearby farms flows into the river, thereby severely polluting it and affecting water quality. Despite its public health significance and the potential to cause widespread infections within the Kowie catchment, the major source of antibiotic-resistant *Campylobacter* contamination to Kowie River, the antibiotic resistance, and virulence genes they harbor, and the risk they pose to public health remain unexplored. Thus, this study applies 'one health' approach to identify the potential risks of *Campylobacter* infection from human exposure to the Kowie River. This study will develop and apply a combination of wet lab, next-generation sequencing, and machine learning algorithm risk-based modeling to investigate the source of antibiotic-resistant *Campylobacter* spp in the Kowie River, and the risk they pose to the public.

CAPACITY DEVELOPMENT COORDINATION AND RESEARCH IN THE TSITSA PROJECT, EASTERN CAPE SOUTH AFRICA

Sponsor: Department of Environment, Forestry and Fisheries: Natural Resource Management
Post-doctoral Fellow: MJT Weaver
Supervisors: CG Palmer and E Rosenburg

Overview of my role in the Tsitsa Project

My primary role as a post-doctoral fellow is as the Capacity Development Coordinator of the Tsitsa Project. In addition, I am leading or contributing to a number of transdisciplinary research processes related to governance, capability expansion, sustainable livelihoods and integrated landscape rehabilitation planning.

Activities in 2020

The Covid-19 pandemic has required us to innovate new ways of working and providing value through our work. I will use this report to share some of the successes my collaborators and I have achieved in the Tsitsa Project this year.

We have made significant progress in the development and launch of the online certificate course (NQF Level 5): Facilitating Social Learning and Stakeholder Engagement in Natural Resource Management Contexts - Introductory Course (Training of Trainers). The name of the course speaks to its purpose, however if you wish to find out more click or follow this link to access an introductory video about the Course: https://youtu.be/YQbWjbqUX74). Adapting what initially was planned to be a face-to-face course of 30 participants to be gully online with three times the number proved to be a significant challenge and learning curve. However, several success factors contributed to getting the Course off the ground. Regular, vibrant and rich online meetings and individual effort has seen this course develop from concept to outline and now in this quarter, to a fully subscribed, accredited, online course that launched in October 2020. The course has over 100 participants from all corners of South Africa. Fifteen Tutors and 22 Dual-Participant Tutors are collaborating in small tutorship circles to enable and mediate online learning. Contributing factors to the progress of the course has been the formation of a vibrant and talented core team of course facilitators, the generous insight and contributions from Prof Rosenberg and the hard work of the Tutors and Dula-participant Tutor in mediating learning and managing their participant groups.

Successful Gov CoP and KL CoP collaboration on other Capacity Development processes has been led and driven by Dr Notiswa Libala and I (both of us are early career coordinators), drawing on advice from senior members (the professors). This leadership structure has allowed space for the us, as young leaders, to experiment, grow and optimise the already constrained time that the senior thought leaders have on the Tsitsa Project. This rich collaboration has seen the design and coordination of a Monitor Capacity Development Short Course for the different forms of environmental monitors employed bt the Tsitsa Project. The course comprised 3 highly interactive Modules, each contributing to building overall capacity towards becoming a well-rounded and empowered Monitor.

Generative collaboration between the Governance, Livelihoods and Capacity Development working groups have resulted in integrated inputs, related to social processes required for restoration, into the evolving Enhanced Restoration Planning Approach for the Tsitsa Project. This output will serve as guidance through case study examples, lessons learnt and effective principles of practice to restoration processes in other catchments and contexts in Africa.

I am also leading and contributing to various applied research processes and supervising a 1st-year MSc Student Ms Anele Tshangase with Prof. Tally Palmer. Anele is based at the IWR and conducts her research within the Tsitsa Project. She is exploring the value of ecological infrastructure related to participatory governance processes in the Tsitsa River catchment. The subjects of my research outputs include: systematising the governance capability development in the Tsitsa Project (paper); exploring causal mechanisms of transformational processes in the Tsitsa Project (paper); and showcasing transformative agency development in a multi-stakeholder water governance platform in the Makana Local Municipality (book chapter). My research outputs are still in the publication pipeline and are listed in the publications section of this report.

The Training of Trainers course seeks to build the capacity of facilitators, trainers, applied researchers and students, educators and anyone else interested in the practice of learning facilitation and stakeholder engagement in Natural Resource Management Contexts.

Participants discuss the the veld condition assessment method during the second Module of the Monitor Capacity Development Course in the Tsitsa Project.

Researchers learning about the impacts of sediment on ecosystems in the Tistsa River catchment

APPLICATION OF MACROINVERTEBRATE-BASED BIOMONITORING AND STABLE ISOTOPES FOR ASSESSING THE EFFECTS OF AGRICULTURAL LAND-USE ON RIVER ECOSYSTEM STRUCTURE AND FUNCTION IN THE KAT RIVER, EASTERN CAPE PROVINCE, SOUTH AFRICA

Student: FC Akamagwuna
Supervisor: ON Odume and N Richoux
Degree: PhD (Zoology)

Project Synopsis

Land use activities, including agricultural practices, are a threat to ecological integrity and biodiversity of freshwater ecosystems as they affect both the structure and function of river systems (Li *et al.*, 2019; Scotti *et al.*, 2020). A direct consequence of land use is the input of sediment, nutrients and pollutants such as heavy metals, resulting in severe water quality problems in many rivers in South Africa (Lerotholi, Palmer and Rowntree, 2004; Mgaba, 2018). The Kat River in the Eastern Cape Province drains a catchment characterised by intensive commercial agricultural practices that represent the primary sources of pollution affecting this river system. The Kat River is a fundamental asset to the surrounding communities, who depend on the river for drinking water, subsistence and commercial agriculture, and recreational and cultural activities (Soviti, 2016). Ecologically, the river provides resources and habitat for both aquatic and terrestrial organisms that represent biologically diverse communities. Despite the importance of every river system, anthropogenic disturbances continue to cause water quality degradation, with severe adverse effects on aquatic biota and human communities (Soviti, Oche and Ntshanga, 2003). This study aims to investigate the ecological consequences of agricultural land-use activities on the structure and functioning of the Kat River system in the Eastern Cape of South Africa. Gaining an understanding of the ecological implications of pollution on the system is an essential step towards the development of an effective biomonitoring tool for long-term monitoring and management of agricultural pollution. The study aim was addressed through the following objectives.

1. To examines the spatial and temporal response patterns of macroinvertebrate communities to agricultural and the development of a macroinvertebrate-based index for monitoring agricultural pollution in the Kat River.
2. To explore the distribution patterns of traits, ecological preferences and functional diversity of macroinvertebrate communities to an agricultural disturbance in the Kat River.
3. To evaluate the responses of the trophic structure of Ephemeroptera, Plecoptera and Trichoptera to a gradient of agricultural disturbance in the Kat River.
4. To assess the spatial and temporal changes in food resources and trophic diversity of macroinvertebrate consumers along a gradient of Agricultural Pollution.

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 resources management in South Africa is governed by the National Water Resource Strategy, 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 licenses are the primary SDC. Ideally, once the instream Resource Water Quality Objectives (RWQOS) are set, license conditions are derived based on the RWQOs to meet the objectives. However, in practice, 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 includes discharge standards. The resource users feel that the 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 including many industrial areas and the River currently threatened by excessive water pollution such as increased salinity. The deteriorating water quality is a threat to drinking water and to business as significant costs are associated with rectifying the water quality problems. This study is part of a larger 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 contribute to the larger project that aims to apply a WQSAM based Decision Support System (DSS) and 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.

Initial results indicate that inadequate institutional capacity may be significantly contributing to the contestation on water quality instruments such as RQOs and WUL conditions, as the inefficiencies indicate the lack of appropriate scientific methodologies and knowledge. Other significant challenges include unrealistic licence conditions, a lack of distinction between RQOs and WUL and unregulated and unlawful water use, especially by industries.

THE EFFECTS OF LAND COVER AND LAND USE ON CATCHMENT RUNOFF: A CASE STUDY OF THE IMPACTS OF SMALL DAMS AND INVASIVE ALIEN PLANTS ON MAKHANDA WATER SUPPLY

Student: R Dakie
Supervisor: SK Mantel and JL Tanner
Degree: BSc Hons (Environmental Water Management)

Land-use and land cover changes have been shown to have impacts on the environment and water resources of catchments. The impacts of land cover changes such as displacement of natural vegetation by invasive alien plants and land-use changes such as the increased number of small dams on water resources have been investigated in recent years in South Africa. This study aimed to determine the role of cumulative small dams and invasive alien plants on water shortages for Makhanda, a University town in the Eastern Cape of South Africa. The study was based in the P30A quaternary catchment, which is located just outside Makhanda. This catchment hosts two water supply dams (Settlers and Howieson's Poort) which are responsible for supplying a greater part of Makhanda with water, each providing 77% and 11% respectively. The catchment has a total of 88 dams (82 small and six major dams), and alien plants also invade it. The catchment areas for major dams were determined using ArcGIS. Invasive alien plants were mapped along the riparian areas, and their evapotranspiration determined using EEFLUX platform. The invasive alien plants had mean actual evapotranspiration higher than that of grassland. Pitman's hydrological model was run for 30 years (1991-2020) to simulate volumes and flows for Settlers Dam under different scenarios of the presence of small dams and invasive alien plants: "small dams only"; "invasive alien plants only"; "both small dams and invasive alien plants present" and "no invasive alien plants and small dams". The results show that a maximum volume of Settlers Dam will be exceeded more often when there are small dams only in the catchment as compared to when there are invasive alien plants only. The results show that Settlers Dam had lower volumes when the model was run with small dams only as opposed to when ran with invasive alien plants only in the catchment and that invasive alien plants will have a greater impact on runoff as opposed to small dams. We can see that there would be a much lower flow in Settlers Dam when there are invasive alien plants only as opposed to when there are small dams only in the catchment.

Analysis of maximum flows for the different scenarios showed that Settlers Dam would have a higher maximum flow (46.74 Mil.m^3) when there are small dams only in the catchment as opposed to when there are invasive alien plants only (43.52 Mil.m^3). Analysis of the simulated low-flows showed that Settlers Dam has zero-flows 64% of the time (19 years of the 30 years) when there are invasive alien plants only as compared to when there are small dams only in the catchment, which is only about 63% of the time (18 years of the 30 years). Therefore, these findings suggest that invasive alien plants have a greater impact on runoff to Settlers Dam as compared to small dams. Invasive alien plants in the catchment may need to be removed while the building of small dams should be halted so that there will be greater runoff into Settlers Dam which will alleviate water shortages of Makhanda.

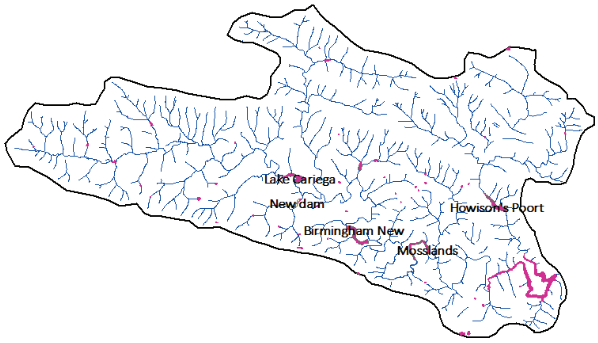


Figure 1: Major dams for which the catchment areas were delineated in ArcGIS.

THE INFLUENCE OF ALLUVIAL FANS ON THE GEOMORPHOLOGICAL STRUCTURE AND HYDRO- LOGICAL FUNCTIONING OF THE KROM RIVER WETLAND, EASTERN CAPE, SOUTH AFRICA

Student: A Freeman
Supervisors: F Ellery and JL Tanner
Degree: MSc (Geography)

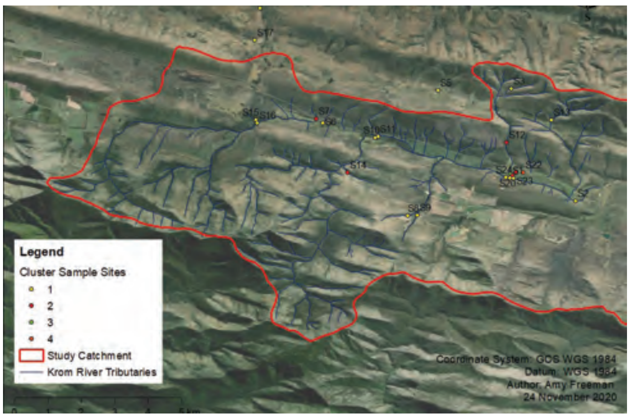
Wetlands are amongst the most important ecosystems on the planet as they provide invaluable ecosystem services, such as flood attenuation and drought prevention, water purification, providing habitats for various animal and plant species, as well as recharging groundwater aquifers. Palmiet wetlands are endemic to the Cape Fold Mountain belt of the Western and Eastern Cape. Despite a growing body of research devoted to understanding palmiet wetlands, huge knowledge gaps remain in terms of their structure and functioning, particularly with regards to their hydrology.

The Krom River Wetland is situated in the southern part of the Eastern Cape, approximately 20 km east of the town of Joubertina. The wetland is an unchannelled valley-bottom wetland that is situated in the intensely folded Cape Fold Mountain Belt, between the Suuranys Mountains to the north and the Tsitsikamma Mountains to the south. The Krom River catchment experiences rainfall evenly throughout the year, however, drought is common in the area, with the catchment receiving anywhere between 500 and 800 mm of rainfall per year. The Krom River catchment is located within the quartzitic sandstones and non-quartzitic shales of the Table Mountain Group (TMG) and Bokkeveld Group of the Cape Supergroup. The valley occupies a syncline such that the wetland itself is largely immediately underlain by rocks dominated by clay-forming minerals – the Baviaanskloof and Gydo Formations. The valley-floor on which the Krom River Wetland is situated, is comprised of less-resistant shales, while the steep valley-sides of the Suuranys and Tsitsikamma Mountain consist of highly-resistant quartzitic sandstone. Land cover within the catchment has been transformed significantly by livestock agriculture, deciduous fruit orchard farming and the presence of alien invasive species such as *Acacia mearnsii* (Black Wattle), and the integrity of palmiet wetlands has declined significantly over the last century.

The hydrological functioning of the Krom River Wetland is highly complex. The presence of palmiet in this system is thought to be linked to sustained flows from the Table Mountain Group aquifer system. It is conceptualised by hydrologists that palmiet wetland of the Krom functions as a result of water that enters the wetland via preferential flow paths in the tributary alluvial fans, which then flows consistently down the length of the valley.

This study aims to untangle the complex hydrological functioning of the Krom River Wetland through four specific objectives:

- Examine variation in water chemistry of surface and groundwater in and adjacent to the trunk valley-floor
- Measure spatial variation in elevation of surface and groundwater in and adjacent to trunk valley-floor
- Determine variation in soil particle size and major soil chemical characteristics opposite and between alluvial fans
- Construct a conceptual model of water flow in the Krom River wetland, and consider implications for surface-groundwater interactions



The study is in its first year of research. Analysis of water chemistry showed four distinct clusters of samples in the Krom catchment. Solute concentrations were analysed for each sample cluster to determine behaviour of solutes under evaporative processes. The results showed that solutes such as chloride, sodium and calcium to a lesser extent increased systematically with increased evaporative losses, while magnesium and silica appear to be lost. Field trips to the Krom catchment that were cancelled in 2020 are scheduled for early 2021.

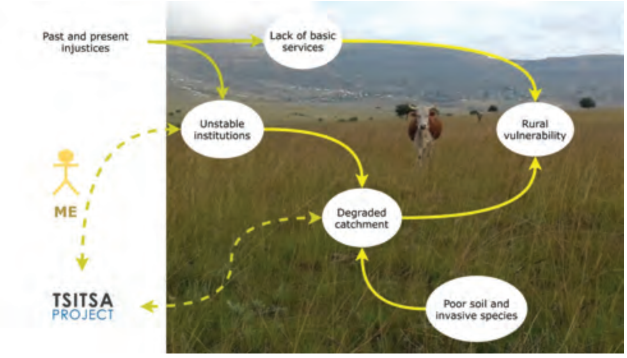
LEVERAGE POINTS TO ENABLE PARTICIPATORY GOVERNANCE OF LAND AND WATER RESOURCES IN THE RURAL EASTERN CAPE

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

The Tsitsa River forms part of the Mzimvubu River which is a key water source for future development of the rural Eastern Cape and particularly the former Transkei homeland. In order to realise the potential developmental benefits of the Tsitsa River, the catchment needs to be managed in a way that builds resilient social-ecological systems. I am embedded the Tsitsa Project which is trying to achieve these aims.

I am conducting an in-depth case study of land and water governance in the catchment by spending time in the area with people who have been living and working there for many years. The diagram shows a systems diagram which I have used to contextualise my work. Like many of the systems diagrams I have used throughout my research, it is a simplification which is a useful communicative and analytical tool.

The past and present injustices associated with colonisation, apartheid and continued unequal distribution of resources have contributed to a lack of basic services throughout the former Transkei. The lack of basic services contributes to the vulnerability of people living in these rural villages as they continue to rely on rivers, grasslands and forests for part of their livelihoods. The injustices have also destabilised formal and informal institutions. Unstable institutions, such as non-existent grazing management, disempowered traditional leaders or unresponsive government departments, also contribute to degradation in the catchment. There are many other factors, such as those related to poor soil and invasive alien vegetation – these factors have been widely researched by many of my colleagues. The Tsitsa Project is shown bottom left of the diagram and has two-way links with the governance institutions as well as directly with the ecological systems in the catchment.



A simple systems diagram contextualising this research. The yellow arrows show how factors influence each other. The two-way dotted arrow shows how the Tsitsa Project interacts with people and ecosystems. The grasslands and cattle in the background highlight the importance of these resources to residents in the Tsitsa River Catchment. My position in the research is shown by the stick figure.

Land and water governance research have shown that new initiatives cannot be implemented as if on a blank page, rather, they interact with the context in complex ways. A new initiative needs to be able to integrate itself into an existing governance system in order to have long term impacts. As is indicated by the stick figure in the diagram, I am investigating how the Tsitsa Project can interact with the disrupted institutions – those consisting of local people and existing institutions. This involves understanding structurally how institutions interact and how residents interact with them. This also involves an understanding of process, how processes in the governance system manifest in the real world. My hope is that by supporting new and existing institutions for participation and collaboration in land and water governance, institutions can work together to reduce the vulnerability of people living in the Tsitsa River Catchment.

INTEGRATING MULTIPLE EARTH SCIENCE METHODS TO DEVELOP AN OVERVIEW MODEL TO BE USED IN GROUNDWATER EXPLORATION

Student: PJ Greeff
Supervisor: JL Tanner and S Büttner
Degree: MSc (Hydrology)

During the year, a broad research goal was developed: *Integrating multiple earth science disciplines to develop an overview model to be used for groundwater modelling.*

A focus area has been earmarked for the development of the model: Starting from the Southwell turnoff in the east, the site is the whole mountain drive range with the Weltevrede Formation to the south being the southern boundary and the Kweekvlei Formation to the North being the northern boundary. The site then carries on across the N2 to the west of Waainek, totalling approximately 12km of mountainous terrain.

Work done
Literature: The predominant portion of the year was spent on studying literature which focused on geological processes linked to aquifer development and groundwater movement. The first literature review draft was submitted to Dr Tanner in August. Subsequent online discussions were held between Dr Tanner and myself in an attempt to define the research and come up with some realistic goals and ways to achieve them. The literature review is an ongoing document, where changes are made after every discussion.

Fieldwork
A week was spent in the mountain drive mountain range stretching from the Southwell turnoff to the N2 in an attempt to get familiarised with the overall lithology and structural geology. Time was spent with Prof Steffen Büttner in the field to fast-track my understanding of the underlying geological processes that contributed to the rock features seen today. A broad structural evaluation was done through localised geological mapping, which included taking approximately 100 base-line strike/dip readings spread throughout the Mountain Drive mountain range. A close-out meeting was held to discuss the weeks results and plan a way forward.

Once a specific area of interest for geophysics has been identified, arrangements will be made for an electromagnetic survey. Figures below show key geological features.

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

Student: D Gwapedza
Supervisors: 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 processes. Quantification of sediment yield is important for water quality assessments and estimating reservoir sedimentation. 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 storage and channel module are integrated for sediment delivery and channel routing. The model was tested on more than 15 quaternary catchments (Figure 1) selected in varying regions of South Africa and was proven capable of giving reasonable long-term estimates when compared to previous studies.

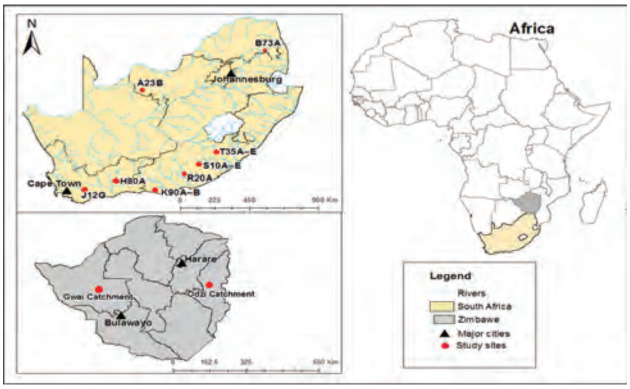


Figure 1. A map of all the selected study sites in South Africa and Zimbabwe.

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 (Table 1; Figure 2) in the Tsitsa River Catchment (South Africa), Odzi Catchment (Zimbabwe) and Gwai Catchment (Zimbabwe) (Figure 1) as observed sediment yield data was available for these catchments.

Table 1. Calibration and validation performance for selected catchments

Catchment	Country	Calibration			Validation		
		R2	NSE	PBIAS	R2	NSE	PBIAS
Inxu	ZA	0.97	0.89	4	0.72	0.76	36
Tsitsa	ZA	0.64	0.62	-12	0.60	0.55	-35
Gwai (A38)	ZW	0.91	0.90	-5	0.81	0.53	55
Gwai (A36)	ZW	0.89	0.84	-22	0.02	-0.91	6.5
Odzi	ZW	0.81	0.71	-2	0.67	0.66	-1.5
Grand Cane	USA	0.58	0.56	-11	0.61	0.58	-31
San Patricio	USA	0.60	0.59	-38	0.69	0.66	-34

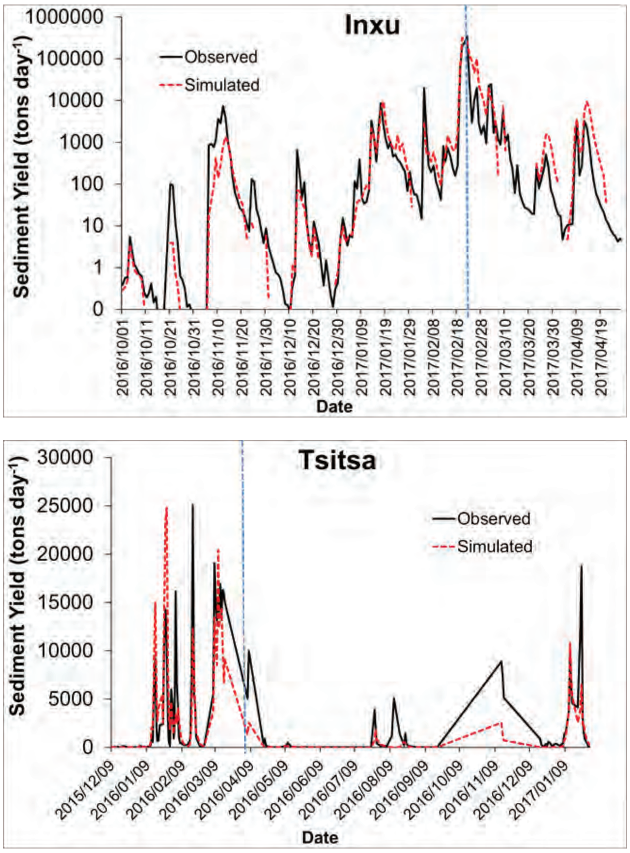


Figure 2. Graphs showing the observed and simulated sediment for the Tsitsa and the Inxu sub-catchment (the blue line separates the calibration and validation period).

Additional calibration and validation was conducted in catchments selected from the USA states of Louisiana (2) (Table 1) and Puerto Rico (1). 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.

CONSTRAINING HYDROLOGICAL MODEL'S UNCERTAINTY WITHIN A COMBINED MODELLING APPROACH ACCOUNTING FOR CHANNEL-WETLAND EXCHANGES IN THE CONGO BASIN

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

The Congo River Basin plays an essential role in the regional water cycle, global carbon sequestration and the economies of the nine basin countries. The basin is the second-largest in the world in terms of both discharge and drainage area after the Amazon and has the potential to affect sea surface salinity and temperature, contributing to regional and global ocean circulation and climate. The ecosystem of the Congo Basin is extremely important for food security, river navigation, trade, hydroelectric power generation, mining and logging activities, supporting the livelihoods of about 100 million people. These livelihood activities together with climate change and variability exert considerable pressure on the dynamics of water resources. Understanding the link between these activities and the hydrology of the basin is therefore indispensable to sustainable development.

The use of hydrological and hydrodynamic models is central to the understanding of hydrological processes and prediction of future impacts due to environmental changes. However, the use of such tools is often challenging because of the heterogeneity in parameters and state variables, nonlinearities and scale effects in process dynamics, complex or poorly known boundary conditions and initial system states. In addition, the basin is characterised by high heterogeneity in climate and physiographic characteristics, resulting in highly and spatially variable hydrological processes, making the prediction highly uncertain if traditional model calibration approaches are used. It is therefore vital to resort to modelling practices that account for different sources of uncertainties inherent to data-scarce regions such as the Congo Basin.

This PhD project aims at improving the hydrological predictions of the Congo Basin using modelling approaches accounting for the uncertainties due to climate and discharge data, effects of wetlands, model structure and parameters under natural hydrological conditions. It is difficult to quantify individual sources of uncertainty, but the use of the indices of hydrological behaviour offers an opportunity to include these uncertainties by computing the uncertainty ranges of these indices, which are then used as filters to constrain the outputs of hydrological models in the ungauged sub-basins of the Congo Basin.

The activities that have been undertaken during the 2020 academic year mainly focused on the:

- Testing of the uncertainty ranges of constraint indices in selected sub-basins of Sangha, Oubangui, Kasai and Lualaba drainage systems of the Congo Basin;
- Simulation of wetland downstream impacts on the flow regime of the lower Lualaba drainage system;
- Reporting of research outputs for final thesis writing.

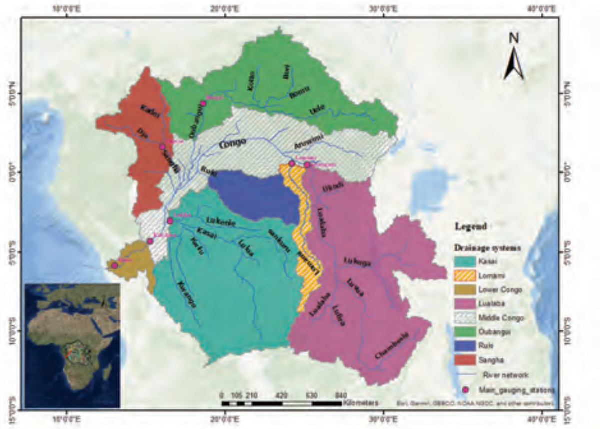


Figure: The geographical location of the Congo River Basin and its major hydrographic network.

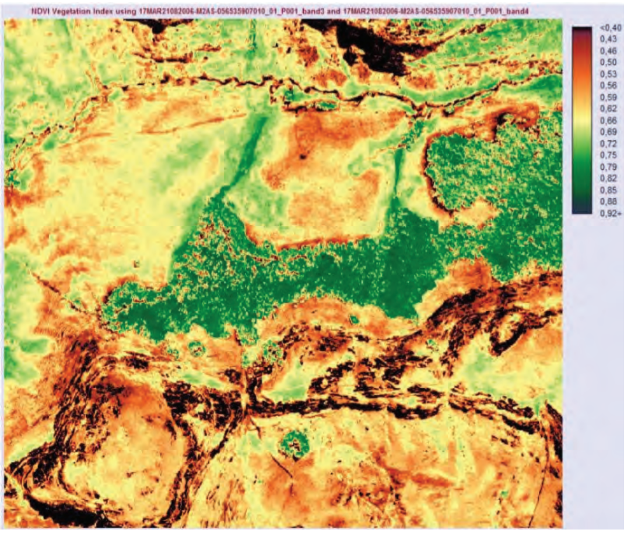
IN A NOVEL LANDSCAPE, IN THE EASTERN CAPE, SOUTH AFRICA, WHAT ARE THEY KEY VEGETATION RESOURCES THAT SUPPORT LIVESTOCK PRODUCTION?

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

In the Tsitsa River catchment, land degradation, overstocking of livestock, and concentrated settlements show the environmental aftermath of Apartheid policies, and this altered state affects the future of proposed dams, the landscape condition, and communities impacted by these issues. The aim of this research is to identify the key vegetation resources used in livestock grazing in the Tsitsa River catchment, determine their condition and annual production, and to ascertain the potential economic benefits that can arise from their conservation. It is thought that by recognising the most productive vegetation resources and determining their relative contributions, the limited resources for rehabilitation and management efforts can be focused on threatened, productive landscape elements. Livestock farming continues to sustain a large population of people and provide vital economic benefits in these rural areas. The Tsitsa Project has been established by the Department of Environmental Affairs as an implicit to restore and maintain the ecological infrastructure of the catchment to an optimal condition. This research is situated within the context of this project, and will help to identify productive areas of vegetation that can be utilised by livestock. This will inform the management and conservation of these areas with the ultimate goal of rehabilitation. The intention is to use this knowledge to empower rural communities in their own decision-making.

Livestock supported by diverse areas of vegetation production.

Primary areas of vegetation production have been shown to supply essential Ecosystem Services that support substantial livestock herds. Particular vegetation types are favoured over others, and so grazing habits are not uniform throughout the catchment. Hill slope seep wetlands, riparian meadows, contour banks and road side edges are examples of productive vegetation resources that have been recognised as common feeding areas. Rates of Evapotranspiration have been shown to be strongly linked to the vegetation type that is found on a landscape. Natural rangelands are the predominant type of uncultivated land use in semi-arid and arid environments. There is a strong relationship between desertification and land management in these climates. The off-site effects of erosion caused by defoliation of vegetation include the mobilisation of sediments within aquatic systems, causing large-scale degradation to these ecosystems.



Example of seep wetland identified using MODIS NDVI.

In this research, vegetation types were identified in a pilot area of 5x5 km^2 using high-resolution satellite imagery in order to determine and distinguish their spectral signatures. These signatures were then be used to distinguish these vegetation types in a larger spatial area with a lower resolution (25x25 km^2). MODIS indices including the Normalised Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and the Photosynthesis Net time series (PSNnet ts) were used to determine the average condition and annual production of these vegetation types.

DETERMINING AQUIFER CHARACTERISTICS OF THE WAAINEK WELL FIELD IN MAKHANDA, EASTERN CAPE, TO IMPROVE UNDERSTANDING OF THE MOUNTAIN DRIVE AQUIFER

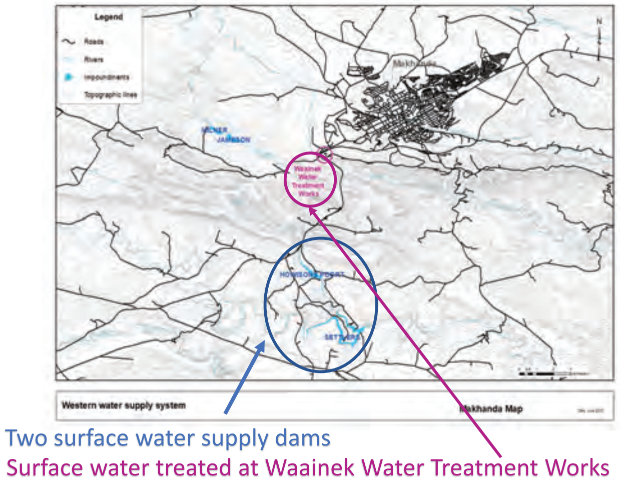
Student: S Mabohlo
Supervisor: JL Tanner
Degree: BSc Hons (Environmental Water Management)

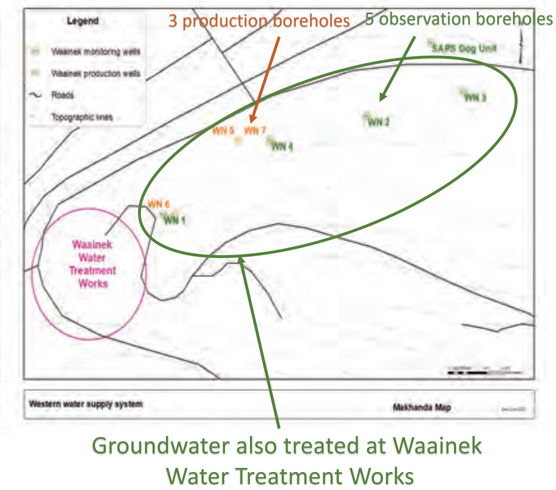
Makhanda is one of the areas in the Eastern Cape Province facing regular water supply issues. This is because Eastern Cape is drought prone with variable rainfall, and low rainfall runoff ratios. This means that a significant amount of rainfall is needed to generate runoff into the dams. As a result of the recent drought, together with increasing-water demand, the levels of water in dams supplying the town have dropped. This necessitated groundwater development to supplement water supply system thereby minimise water supply issues. Early in 2019, groundwater development (well field drilling) was executed next to the Waainek Water Treatment Works (WWTW), where 8 boreholes were drilled. However, this well field was drilled in a rush and therefore no feasibility study was undertaken, resulting in limited knowledge of the groundwater system and unknown sustainable management (pumping) rules. Due to that, it is unknown how much this well field can supplement the Makhanda surface water system. To improve knowledge about groundwater systems requires an understanding of the aquifer and its characteristics. Hence this study sought to improve this understanding for the Waainek well field as a foundation for designing a sustainable management system in the future.

Specifically, three objectives below were followed to achieve the main aim of the study:

- To compare pump tests undertaken by Gift of the Givers to assess heterogeneity of the Waainek aquifer
- Using all available data, to identify the correct geological conceptual model for the Mountain Drive aquifer
- Using the pump test curves, to determine inner and outer boundary conditions for the boreholes of the Waainek well field.

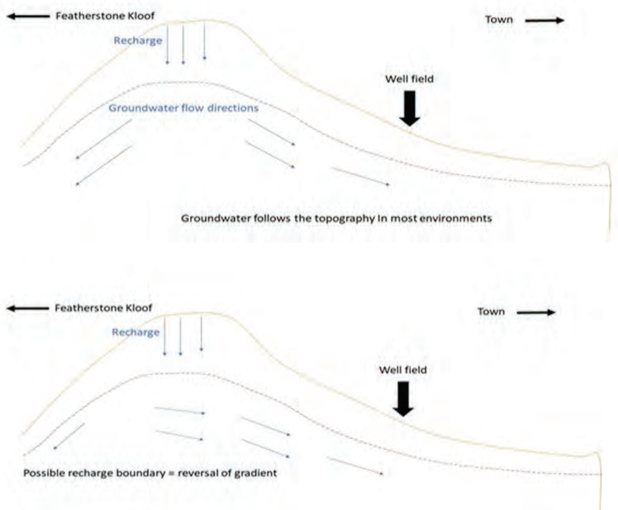
The data used for this study includes pump test data (conducted by Gift of the Givers), borehole geological logs, abstraction amounts for 2 production boreholes and geological maps. Pump tests data were used to determine aquifer characteristics and prevailing boundary conditions in the Waainek wellfield. Borehole geology logs were used to verify the results from the analysis of the pumping test data and to understand the heterogeneity of the aquifer. All the data obtained were also used to build a build a conceptual picture of the Mountain Drive aquifer.





The transmissivity values determined by Gift of the Givers indicate that the Waainek well field has generally low transmissivity with an average of 7.27 /day although variability between the boreholes was high. Pump test data analysis indicates that there is a recharge boundary, and the aquifer exhibits semi-confined conditions. This is likely due to numerous shale lenses behaving as small aquitards which was confirmed by borehole logs. The well field is situated close to the contact between the Witpoort quartzite and the Upper Witterberg shale, with the shale layers increasing in thickness the closer to the contact the borehole was located.

The overall conclusion based on pump tests data and geological information, is that the Mountain Drive aquifer has the potential to provide water for longer periods. The water level recovery data plotted with water level drawdown data, shows that the groundwater levels fall quickly once pumping starts but also recover very quickly when pumping stops. The pumping tests show that after 100 to 200 minutes of pumping the drawdown stabilises with the same pumping rate. Currently, the well field is being managed through short pumping sessions, followed by a longer period of recovery. This is to compensate for the sharp drawdown once pumping starts. This project demonstrated that longer pumping times would be a preferable management system as the water levels will stabilise fairly quickly after pumping begins.



Conceptual model indicating possible effects of pumping on the quartzite aquifer

THE ASSESSMENT OF DEGRADATION STATE IN ECOLOGICAL INFRASTRUCTURE AND PRIORITISATION FOR REHABILITATION AND DROUGHT MITIGATION IN THE TSITSA RIVER CATCHMENT

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

The benefits of Ecological Infrastructure (EI) have been recognised and there is an increase in investment in EI, as evidenced by the South African National Biodiversity Institute (SANBI) framework for Investing in EI in South Africa. The rehabilitation and maintenance of EI sustain livelihoods for rural communities, through direct and indirect benefits and provide regulating and provisioning ecosystem services.

The study adopts the (SANBI) framework of investing in EI to prioritise the restoration of degraded ecosystems and maintain ecosystem structures and functions. This study aims to assess how Ecological Infrastructure (EI) (specifically wetlands, grassland, abandoned cultivated fields, and riparian zone) can facilitate drought mitigation: to assess land degradation status and identify priority EI areas that can be restored to improve the drought mitigation capacity.
This study is primarily a desktop study, using various

software to generate, extract and illustrate results. The study focusses on the assessment of degradation status in the catchment. Trends.Earth tool was used to assess the current state of degradation and change since the year 2000 in Tsitsa catchment, through assessment of SDG15.3.1 degradation indicator at a resolution of 300 m. The land degradation indicator uses information from three sub-indicators: Productivity, Landcover and Soil Organic Carbon. Degraded ecosystems need to be restored in order to sustain essential ecosystem services provided by EI. The Analytical Hierarchy Process (AHP), a type of multi-criteria decision analysis (MCDA) approach that integrates stakeholder inputs in the AHP process, was used to prioritise suitable areas for restoration, which can increase streamflow. The land degradation indicator showed that approximately 54.3% of the catchment is stable, about 40.5% of the land is degraded and 5.2% of the land area improved. The AHP analysis results identified approximately 63% (17703 out of 28317 ha) for wetlands, 16% (19214.1 ha) of grasslands, 93% (10911.6 ha) abandoned cultivated fields and 46% (1016 ha) riparian zone as suitable high priority areas for restoration to improve flow regulation. The current degraded and prioritised EI in the T35 catchments should be restored and maintained to improve livelihood and reduce drought impacts.

Through mapping, identification of degraded areas in the catchments and prioritisation of suitable areas for restoration to increase stream flow contributes towards ecological rehabilitation planning. Furthermore, the study contributes to climate change adaptation for local communities, especially during drought periods.

Figure 1: Bawinile Mahlaba explaining her project to local communities at T35A-Sigoga village during community mapping of natural resources (wetland, grassland, riparian zones and abandon cultivated fields) for prioritisation.

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)

Brief overview

In South Africa, there is a systemic water governance failure, which has led to weak regulatory enforcement, low appetite for cooperation and a weak management system. These have contributed to deteriorating ecosystem health and have impaired ecosystem services. There are three significant water governance challenges which are currently confronting the water sector in South Africa. These challenges are i) a weak regulatory system, ii) lack of accountability by stakeholders and iii) a near absence of cooperative governance (Weston and Goga, 2016). 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, for example, an inefficient regulatory enforcement environment, low accountability measures and a near absence of cooperative governance have led to the inequitable distribution of water resources between societal constituencies. Weak regulatory enforcement has also led to failures of wastewater treatment works, and the discharge of inadequately treated effluent into receiving rivers (Molony, 2014). 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 (Clifford-Holmes, 2015). 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. Despite national and provincial government’s intervention from 2009 to 2014, the problems that border on ethics persist and remain unresolved. Therefore, an ethically grounded approach to water governance is required to bring interventions into balance or constructive trade-offs. In this project, I seek to contribute to addressing the specified water governance challenges in the LSRV using an ethically-grounded approach, the Systemic Relation (SR) approach, developed by Odume and De wet (2016). 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 broader Social-Ecological Systems (SES). Also, the SR approach recognises the mutually constitutive, on-going complementary and co-supportive interactions of the components 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 inescapable and challenging element of ranking and trade-off of values. Therefore, this study aims to explore the potential contribution of an ethical approach to water governance in the Lower Sunday's River Valley catchment.

This project is a WRC funded project which aims to understand better the water governance challenges in the lower Sunday's River Valley with a view to co-exploring solutions towards addressing specific difficulties identified.

Aim
To explore the potential contribution of an ethics-based approach to water governance in the Lower Sunday's River Valley catchment

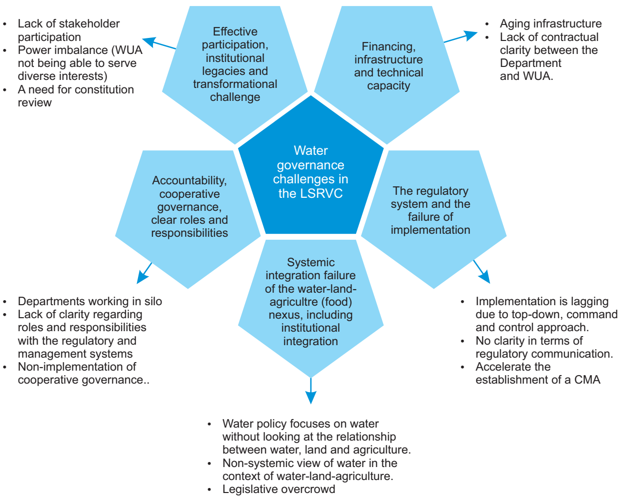
Objectives
1. To explore the key water governance challenges and their ethical dimensions in the Lower Sunday's River catchment.
2. To surface key values informing water governance in the Lower Sunday's River catchment and undertake a value-based analysis of the interactions between selected values.
3. To synthesise lessons of the value of an ethics-based approach to water governance in the Lower Sunday's River Valley catchment.

Methodology
The study uses a range of qualitative data collection techniques and methods to achieve the desired objectives. Qualitative data reflect how reality is socially constructed and allows researchers to achieve a greater understanding of the meaning they give to social experiences. The qualitative method enables researchers to gain a detailed description of the informants' feelings, thoughts and views. The study also employs focus group discussions, key informant interviews, document analysis and workshops for data collection.

Due to COVID-19 regulations, one out of two workshops have been conducted. The workshop consisted of 15 participants, which were divided into two focus groups to discuss water governance challenges in the Lower Sundays River Valley. The workshop included various stakeholders such as the LSR municipal manager, farmers in the LSR, the L-WUA, people from the Department of Water and Sanitation and students. The workshop provided information that helped me construct questionnaires which were used for one on one zoom interviews with selected stakeholders. A summary of the challenges that were raised from the workshop was sent to all participants via email as form of feedback.

Interviews have been conducted to gain a better understanding of the water governance challenges that decision-makers face as well as the water users, the underlying values which influence water governance and ways in which stakeholders go about reconciling values when they led to conflicts. Data from the interview is taken as a perspective rather than a fact, due to the outcomes of interviews being the subjective views of the interviewee. Interviews are also prone to bias and there are high chances of the interviewee having a poor recall and an inaccurate representation (Clifford-Holmes, 2015). Interviews are designed for 15-20 stakeholders; this has provided a deeper understanding of the challenges in LSR. One on one interviews are crucial as some of the stakeholders might have felt uncomfortable to point out some issues. Interviews were held via zoom meetings and the interviews recorded with permission from the participants. The zoom interviews were designed to be not longer than 40 minutes, however, as this is a discussion and more issues arise, the interviews took no more than two hours. Data from the interviews was transcribed and saved on google drive for future reference and as a form of archival documents.

Results



SOUTH AFRICAN GROUNDWATER DROUGHT: CASE STUDY EXPLORING UITENHAGE ARTISAN BASIN

Student: KN Mokoena
Supervisor: JL Tanner
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 has become 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. 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 several methodologies in determining groundwater levels and eventually groundwater drought using the Pitman model in the Uitenhage Artesian Basin. The results are compared between Pitman hydrological model groundwater simulations and observed groundwater levels. 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, and streamflow 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, a WRC Water RDI Roadmap student support programme funded by DST, WRC and DEA supporting postgraduate students. She is also Vice-Lead for the Young Water professionals (YWP) Eastern Cape, South Africa, a recipient of the Investec Rhodes Top 100 Student Leadership award and part of the WISA 2020 Virtual Conference YWP Rapporteur Forum.

DEVELOPING ECOTOXICOLOGICAL METHODS FOR EVALUATING THE POTENTIAL EFFECTS OF MICRO-PLASTICS AND PLASTICIZERS AT ENVIRONMENTALLY REALISTIC CONCENTRATIONS IN SOUTH AFRICAN FRESHWATER SYSTEMS

Student: Z Mtintsilana
Supervisor: NJ Griffin
Degree: MSc (Water Resource Science)

Plastic production and pollution have increased drastically worldwide over the last 50 years. Larger plastic pieces in the environment can break down over time to form smaller plastic particles called microplastics. Plasticizers are additives incorporated into plastics to give them particular properties. They are not covalently bonded to the plastic and consequently can leach out from the plastic into the environment and act as chemical stressors. Microplastic exposure is also a physical stressor and can be associated with a number of negative effects on organisms from multiple trophic groups, such as; reduced food consumption, excessive weight loss, reduced growth rate, blockage of gills, decreased energy and negative impacts on successive generations. There is a lack of research on the impact of microplastics and their plasticizers, especially so in South Africa. This research aims to contribute to the development of methods for assessing the potential ecotoxicity of microplastics and plasticizers in South African freshwater systems.

Toxicological experimental setup assessing the chemical impact of calcium stearate on adult Melanoides tuberculata

The microplastics chosen for the study are polyvinyl chloride, polyethylene and polypropylene, and the selected plasticizers are dibutyl phthalate, calcium stearate and bisphenol A. In a series of lab experiments, the effects of selected plasticizers on different endpoints such as; growth, egestion, reproduction and hatching rate are being tested. Test taxa are the snail *Melanoides tuberculata,* the shrimp *Caridina nilotica,* and the fish *Danio rerio* and *Tilapia sparrmanii*. Each experiment has three replicas and most run for 21 days. To date chronic tests have already been completed using plasticizers as stressors. Experiments using microplastics as stressors are still being run.

Toxicological experimental setup assessing the chemical impact of dibutyl phthalate on embryos of Danio rerio

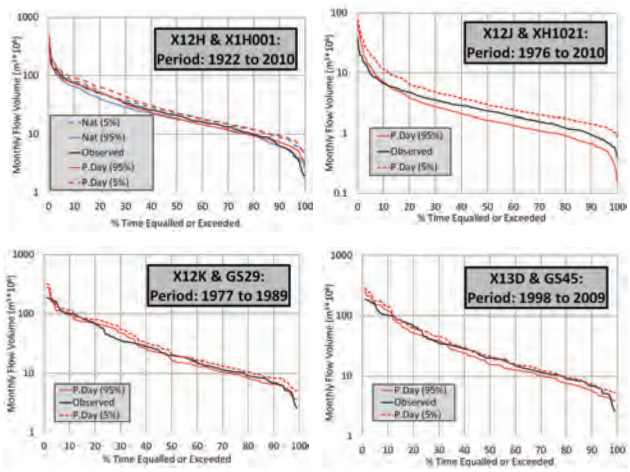
Toxicological experimental setup assessing the chemical impact of dibutyl phthalate and bisphenol A on juvenile Tilapia sparrmanii.

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

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

The research project develops 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. A 2-step uncertainty modelling approach was applied to all the transboundary basins of Eswatini where the first step establishes behavioural, but uncertain, model parameter ranges for natural incremental sub-basin hydrological responses, while the second step links all the sub-basinoutputs to generate cumulative sub-basin outflows and allows for water use parameters to be included.

Catchments of the Eswatini Basin



FDCs comparisons between model outputs and observed data for the sub-basins in the mid-section of the Komati catchment

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 were incorporated for all the basins. The model was run under near-natural as well as impacted streamflow conditions and acceptable simulations have been achieved. Key regions and data sources where existing uncertainties might impact adversely on water allocation management decision-making were identified. The results demonstrated that the approach is appropriate for the estimation of available water resources in Eswatini, partly due to it being a simple approach which incorporates uncertainty in the hydrological modelling process. The study has provided more insight into the spatial variability of the hydrological response and existing development impacts than was previously available.

INVESTIGATION OF METHODS OF DETECTION AND RISK FACTORS FOR *CAMPYLOBACTER* CONTAMINATION IN KOWIE RIVER, EASTERN CAPE.

Student: N Ngoni
Supervisors: CF Nnadozie and C Knox
Degree: MSc (Water Resource Science)

Campylobacter species are slender, Gram-negative, rod-shaped, spiral, and curved-shape bacteria with single or pair of flagella. These organisms are significant to study due to the increasing number of human and animal infections. Contact with River water that is contaminated with feces is a major risk factor for transmission to human. Specific and sensitive methods to detect *Campylobacter* in river water samples are lacking. Detection of Campylobacter in river water samples is important to collect sufficient occurrence data for risk assessment. Furthermore, risk ranking is an integral part of risk identification during a risk assessment. It is critical to identify and rank major sources with high *Campylobacter* pollution risk, to prioritise mitigation. This study is a part of a larger study investigating the risks of Campylobacter infection from human exposure to the Kowie River. The Kowie river system is selected because it is potentially contaminated with raw sewerage flowing from the nearby Belmont Vally Wastewater Treatment Plant, runoffs containing manure from nearby livestock farm, and shedding from domestic animals drinking from the river. The aims of this study are to: (i) evaluate different methods to detect *Campylobacter* spp. from environmental water, (ii) enumerate viable *Campylobacter* bacteria in Kowie River water samples ,(iii) identify the major risk sources for *Campylobacter* contamination of the Kowie River, and (iv) analyze the probability of occurrence and impacts of these risks.

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

Student: P Ntloko
Supervisor: ON Odume and CG Palmer
Degree: PhD (Water Resource Science)

Degradation of freshwater ecosystems and loss of biodiversity is a major concern worldwide (Strayer and Dudgeon 2010). Human-induced factors including urbanization, industrialization, and a growing human population are the main drivers of the degradation of freshwater ecosystems (Vörösmarty et al., 2010; Kopf *et al.,* 2017). There is an expected growth of the human population up to 8.6 billion by 2030, 9.8 billion by 2050, and 11.2 billion by 2100 (NEP, 2011; UN, 2017). The projected population growth implies increased demand for food and consequent increased pressure on water resources, which may manifest in the form of increased abstraction and pollution, impacting both water quantity and quality (Strayer and Dudgeon, 2010; Steffen et al., 2015; Zhang *et al.,* 2017). A critical water quality stressor is excessive input of fine sediments into freshwater ecosystems from anthropogenic activities in the catchments (Larsen *et al.,* 2011; Tiecher *et al.,* 2017). Freshwater quality is deteriorating due to fine sediment inputs (Van der Merwe-Botha, 2009), reducing ecosystem services that benefit humankind, for socio-economic development and prosperity. Fine sediment is composed of both suspended and settled fine sediment grain sizes and are defined as materials <2 mm in size and encompassing sand (<2000 to >62 μm), silt (<62 to >4 μm), and clay (<4 μm) (Wood and Armitage, 1997; Owens *et al*., 2005; Jones *et al*., 2012; Vercruysse *et al.,* 2017).

Although fine sediments are natural components of river systems, levels beyond the natural background levels are a major stressor of riverine ecosystems (Walling and Fang, 2003; Conroy *et al.,* 2016; Doretto *et al*., 2017; Vercruysse *et al.,* 2017). For example, elevated fine sediments in freshwater ecosystems change channel morphology, reduce water flow, and increase turbidity in freshwater ecosystems (Mathers *et al.,* 2017), thereby affecting biodiversity and ecosystem functioning (Jones *et al.,* 2012). Elevated levels of fine sediments can potentially lead to several biological and ecological effects including gill clogging, smothering of eggs, filling up of interstitial spaces, disruption of fine feeding organs, the burial of less motile species, and depletion of dissolved oxygen, while leading to an increase in turbidity causing visual impairment and reducing light penetration (Dallas and Day 2004; Extence *et al.,* 2011; Gordon *et al.,* 2013; Turley *et al.,* 2016). These effects impact aquatic biodiversity by affecting respiration, food and feeding behaviour, mobility, habitat stability, and reproduction of aquatic organisms. The effects may manifest at the species, population, community, and even ecosystem levels (Bona et al. 2016). Fine sediments clog the habitats, increases macroinvertebrates drift, and reduces available habitat for organisms (Schalchi, 1992; Jones *et al.,* 2012). Fine sediments have been reported to differentially affect macroinvertebrates. For example, species of the orders Ephemeroptera, Plecoptera, and Trichoptera have been reported to be vulnerable to sedimentation, and their species richness is reduced in fine sediment impacted habitat (Jones *et al.,* 2012; Beermann et al., 2018). However, the abundance and richness of some species of Chironomidae have been observed to increase about fine sediments increases because they have adaptive traits that allow them to withstand sediment stress (Kreutzweiser *et al.,* 2005).

The input of excessive fine sediment can have important hydrological, geomorphological and ecological implications, changing the physical and biological environment and causing lotic ecosystem degradation (Owens *et al*., 2016; Laceby *et al*., 2017; Mathers *et al*., 2017; Stopps, 2018). For example, elevated sediments in freshwater ecosystems affect channel morphology, water flow and turbidity (Mathers *et al.,* 2017). The transport of fine sediment in the water column increases turbidity and reduces light penetration, thereby reducing primary production and the availability of high-quality habitat for macroinvertebrates (Wilbur and Clarke, 2001; Collins *et al*., 2010b; Stopps, 2018). Many changes occasioned by fine sediment inputs are detrimental to instream biota through effects on respiration, micro-habitat, Physico-chemical characteristics, food web and food quality, and availability (Bryce *et al*., 2010; Kemp *et al.*, 2011).

A growing number of studies have investigated the impact of important water quality stressors such as fine sediments, eutrophication, flow reduction, pesticides and climate change and their effects on aquatic biotic communities and ecosystem functionality (Matthaei et al., 2010; Piggott *et al.,* 2015b; Bruder *et al.,* 2016; Piggott et al., 2015a). Also, in recent years, there has been great concern regarding the levels of fine sediment being delivered to and transported by rivers and streams. River bank erosion is known to contribute greatly to fine sediment delivery in freshwater ecosystems (Herlihy *et al.,* 2005; Stott, 2005) and adversely affects habitat compositions (Dunbar *et al.,* 2010a). Poor land management practices such as agricultural practices (Jones and Schilling, 2011; Zhang *et al*., 2014; Collins *et al*., 2016; Naden *et al.,* 2016), forestry operations (Negishi *et al*., 2008; Futter *et al*., 2016), construction (Angermeier *et al*., 2004; Lachance *et al*., 2008) and mining (Brown *et al*., 1998) contribute greatly to sedimentation processes. Landscape degradation can accelerate the input and delivery of fine sediments into the stream and riverine ecosystems (Zhang *et al.,* 2017). For example, landscape degradation resulting from agricultural activities accounts for 48% of stream pollution from excessive fine sediment loads in the United States of America (USA) (Sutherland *et al.,* 2012). In South Africa for example, landscape degradation is considered to be the major source of fine sediment delivery (Le Roux & Sumner, 2013). South African rivers deliver sediment in the excessive amount to the ocean, with the Orange River delivery the most (Gordon *et al.,* 2012). Sedimentation of South African rivers is one of the leading causes of water quality degradation (Le Roux & Sumner, 2013), exacerbated by other interacting factors, which include soil erosivity, slope steepness, flow, and rainfall variabilities (Msadala *et al*., 2010). The major sources of fine sediment load in South African rivers can be classified into in-channel and non-channel sources, where channel sources are those derived from the beds and banks of rivers and streams as a result of widespread erosion (Basson *et al.,* 2010). Non-channel sources originate from the wider landscape and may include activities such as logging, agricultural activities, and urban development (Le Roux *et al.,* 2008; Lorentz *et al.,* 2012; Gordon *et al*., 2013). Over 70% of South Africa's surface area has been affected by various degrees of soil erosion (Le Roux *et al.,* 2007; Le Roux *et al.,* 2008; Collins *et al.,* 2016), making most riverine systems in South Africa, and in particular in the northern part of the Eastern Cape province, vulnerable to fine sediments loads as soils in these areas are considered duplex and dispersive.

The Eastern Cape province of South Africa, where this study was undertaken, is currently classified among the most severely impacted by soil erosion in the country (Le Roux *et al.,* 2007; Foster *et al.,* 2017). The Mzimvubu catchment, which includes the Tsitsa River and its tributaries in the Eastern Cape where this study was undertaken consists of highly erodible duplex soils, placing it among the highest sediment yielding regions in South Africa (Msadala *et al*., 2010). The Tsitsa River is subject to excessive fine sediments input through the effects of gully erosion (Re Loux, 2013). Sediment loads derived from gully erosion and other forms such as rill and sheet erosion could possibly affect the overall integrity and ecosystem health of the Tsitsa River system. The trait-based approach (TBA) is rooted in theoretical ecological concepts such as the habitat template concept (HTC), habitat filtering concept (HFC), functional diversity, redundancy and uniqueness (Schemera *et al*., 2017, Odume *et al.,* 2018). The trait-based approach expands biomonitoring beyond the traditional taxonomy-based assessments by providing mechanistic linkages between the composition of the macroinvertebrate community and the environmental conditions. The presence of specific traits has the potential to indicate how different stressors influence the macroinvertebrate communities (Culp *et al.,* 2011; Van den Brink *et al.,* 2011, Beeckman, 2017). The trait-based approaches could provide very simple tools that could particularly be useful in less well-studied areas, including developing countries because in some instances one may not need to identify macroinvertebrates specimens to recognise their traits e.g. body shape, body size, and possession of certain structures such as gills (Van den Brink *et al.,* 2011). South Africa, is among the developing countries where the approach has not gained popularity in terms of applying it to biomonitoring (Odume, 2014; Odume *et al.,* 2018), and therefore the present study is among the first few to explicitly apply the approach to a specific freshwater stressor. The trait-based approach is an adaptation of the standard biomonitoring approach, the sampling strategy remains the same, but the taxonomic composition of macroinvertebrates is translated into a trait composition through a trait database, observation, measurements and the literature (Culp *et al.,* 2011).

Therefore, the study of the interactions between traits and elevated fine sediments can lead to the potential identification of trait-based indicators of fine sediments in rivers, which can provide a basis for mechanistic insights into how fine sediments drive macroinvertebrate communities to change. Further, given that traits mediate organism-environmental interactions, it is also possible to develop a trait-based approach for identifying potentially vulnerable and resilient macroinvertebrates taxa to elevated fine sediments. In this study trait-based indicators are developed, and an approach for predicting the potential vulnerability and resilience of macroinvertebrates communities to effects of fine sediments is also developed. This is the first study in South Africa to develop explicit trait-based indicators of elevated fine sediments as well as an approach for predicting macroinvertebrate's vulnerability and resilience to sediment effects, thus advancing the science and practice of freshwater biomonitoring.

Aim of the study
The overall aim of this study was to develop novel taxonomic and trait-based approaches for assessing macroinvertebrate responses to elevated fine sediments in Tsitsa River and its tributaries, Eastern Cape, South Africa.

Objectives

- To characterise suspended and settled fine sediments grain sizes and their distribution in the Tsitsa River and its tributaries.
- To develop and validate a macroinvertebrate-based sediment specific multimetric index suitable for monitoring effects of elevated fine sediments in the Tsitsa River and its tributaries.
- To explore macroinvertebrate ecological preferences and traits with a viewing to identifying possible trait-based indicators of fine sediment stress in the Tsitsa River and its tributaries
- To develop a novel trait-based approach for assessing and predicting the potential vulnerability and resilience of South African macroinvertebrate families to fine sediment stress in the Tsitsa River and its tributaries**.**

THE VALUE OF ECOLOGICAL INFRASTRCUTRE RELATED TO PARTICIPATORY GOVERNANCE PROCESSES IN THE TSITSA RIVER CATCHMENT, EASTERN CAPE, SOUTH AFRICA

Student: AK Ntshangase
Supervisors: MJT Weaver and CG Palmer
Degree: MSc (Water Resource Science)

South Africa is facing high levels of environmental degradation which has resulted to some of its population living in ecologically degraded areas. The environmental degradation in the country is prevalent as a result of both human and climatic factors. An example of human-induced factors contributing towards environmental degradation is poor land use and management practises. These poor practices are causing ecological infrastructure in catchments to deteriorate. The degraded ecological infrastructure is having significant consequences on people's livelihoods and the economy of the country at large. In South Africa, ecological infrastructure supports the country's development objectives related to poverty alleviation, rural development and job creation.

It is acknowledged that most key ecological infrastructure elements are located in rural areas. In rural areas, ecological infrastructure normally mediates built infrastructure to support local livelihoods. However, despite the importance of ecological infrastructure to rural communities, the most deteriorated ecological infrastructure is located within these areas. The main factors driving the deteriorating ecological infrastructure are human-induced activities. These activities include but are not limited to, inappropriate land use, poor land management practises, proliferation of invasive alien plants and overpopulation. Therefore, it is important that rural communities become aware of the interrelationship between them and the functioning of ecosystems in their landscapes.

This study will be using the Tsitsa River Catchment to explore how the interrelationship between people and ecological infrastructure can be used to develop participatory land and water governance in the catchment. Firstly, the study will provide a desk-top-based integrated analysis of biophysical and social elements and their relationships from the Tsitsa Project's research output repositories, in order to develop the current understanding of local people in relationship with ecological infrastructure. Following, will be to use the integrated analysis to reflect the findings to the communities in the catchments and enrich the understanding of the social-ecological relationships. Lastly, this study will investigate the value of ecological infrastructure as a basis from which to enhance participatory landscape governance.

Figure 1: Degrading rangelands in Tsitsa River Catchment.

DETERMINATION OF SEDIMENT BUFFERING FUNCTION OF THE GATBERG FLOODPLAIN WETLAND IN THE UPPER TSITSA RIVER CATCHMENT, SOUTH AFRICA

Student: SS Pakati
Supervisor: JL Tanner, B Van der Waal and S Grenfell
Degree: MSc (Geography)

Floodplain wetlands are important components of river systems that provide various ecosystem services such as sediment buffering. These wide and often expansive storage areas have a substantial impact on downstream water quality by trapping in sediments and storing 'contaminants' adhered to sediment thus improving water quality. A planned construction of the Ntabelanga and Lalini Dams on the Tsitsa River Catchment has been proposed; however due to the steep landscapes, this promotes high erosion rates that can potentially reduce the lifespan of the proposed dams. The existing wetlands in the Tsitsa Catchment have therefore been identified as key sediment buffers that can reduce sediment transport. The study attempts to investigate the current sediment buffering function of a floodplain wetland over a wet season.

Time integrated samplers were installed above and below the wetland to determine sediment coming in and leaving the wetland. Five transects were conducted across the wetland to evaluate the topography. Sediment samples were taken at key morphological features along each transect and in the longitudinal profile to determine organic content, particle size and type. Astro turf mats were deployed on targeted transects and on key floodplain features to determine sediment accumulation.

Field measurements of vegetation parameters (height, density and stem diameter) were taken to calculate roughness values. Bed particle size does show a poor correlation with distance downstream. A poor correlation was also shown by elevation above water level with particle size. Flood benches and banks had the coarser d50 particle size than the floodplain surface, backswamps and oxbows. Coarser sediment in banks and on benches may be associated with frequent inundation with high velocities while finer material may be due to low velocities and because of the type of morphological feature such as oxbows, backswamps and floodplain surface which are regarded as potential sediment buffers. Vegetation roughness showed a negative relationship with particle size; however the overall estimation was that high roughness values induces finer particle size and low roughness induces larger particle size. Differences in roughness values shown by each vegetation type are due to vegetation geometry i.e. shape, flexibility and distribution. Sediment particle size is inversely proportional to organic content; finer particle size are more cohesive and more capable to carry 'pollutants'. Sediment particle size decreases away from the channel with finest sediment found in deeper depositional environments.

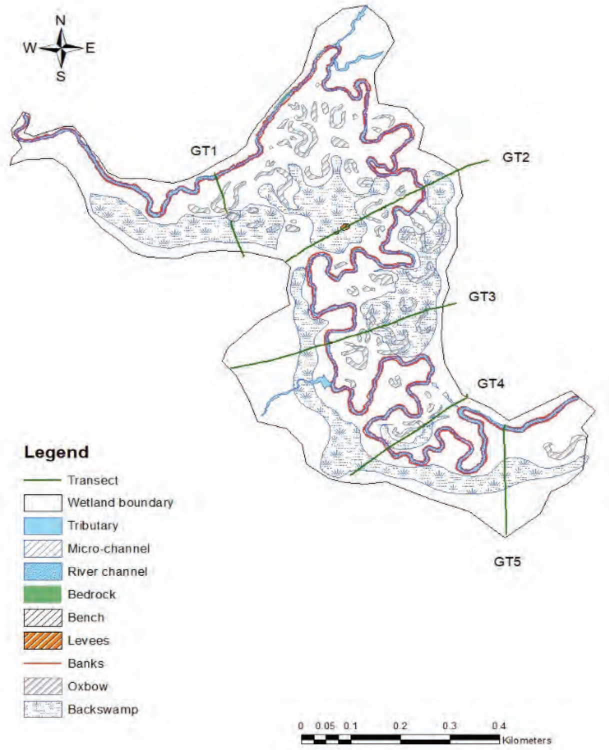


Figure 1 : Gatberg floodplain wetland features and where the transects were conducted.

EXPLORING THE NATURE AND MEANING OF PARTICIPATION IN A LAND RESTORATION PROJECT IN THE TSITSA RIVER CATCHMENT: A QUESTION OF EPISTEMIC INJUSTICE?

Student: M Ralekhetla
Supervisor: CG Palmer and S Paphitis
Degree: PhD (Water Resource Science)

Some projects start with a participatory intention, but rarely define the nature of participation they hope to bring, which may sometimes make it difficult to track progress. We need to consider the fact that even though everyone is working together towards project goals; people hold different backgrounds, and therefore different interests and values, which also influence their perception of the world. It is therefore important to explore the competing ways in which participation is framed by those who participate so as to avoid unmet expectations. Unmet expectations could lead to tokenism and failure to experience benefit (tokenism in this case means the act of doing something because it is expected, but the person doing it does not believe it is necessary, so they do it just to tick their boxes).

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 refers to a wrong done to one in their capacity as a knower. In other words, people are belittled in their capacity as a knower. 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). It becomes important to unpack the underlying epistemic injustices that are already in place as they may influence the marginalisation of the collective resources of other groups.

Tsitsa Project offers an interesting context within which to explore critical questions of participation because some researchers engage with stakeholders in the catchment, at different scales, with a 'participatory intention'.

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. Addressing experience issues across the competing frames could mean avoiding tokenism, and lead to more meaningful and ethical ways to understand participation.

This broad context leads to my aim and objectives.

The aim of this research is to build narratives of participation, to deepen the conceptual and theoretical understanding of stakeholder participation, drawing on practice-based experiences in the Tsitsa River catchment.

- To collect narratives of what it means to participate in the restoration of the landscape from Tsitsa Project stakeholder-participants qualitative narrative approach.
- To analyse the narratives to find out how epistemic (in) justice influenced people's experience and meaning of participation qualitative narrative approach.
- To develop a conceptual framework/framing of participation, for mutually beneficial and sustainable stakeholder participation.

The objectives then led to the use of a qualitative narrative approach, which is where raw data consists of stories. It relies on the basis that stories can reveal the identity of the narrator, and give a context of how they view the world or how they construct meaning of the world. This is useful in the TP context because understanding the stories of the different stakeholders within the project will lead to a better understanding of the factors that motivate the way they do things and better buy-in for the suggested environmental/ restoration solutions, which could lead to sustainability of the TP efforts in the long term.

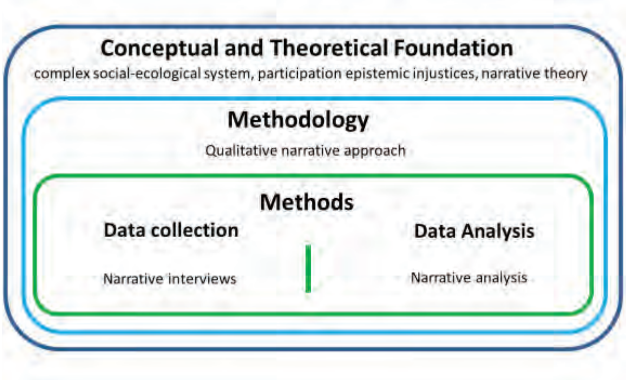


Figure 1 Conceptual and theoretical framework

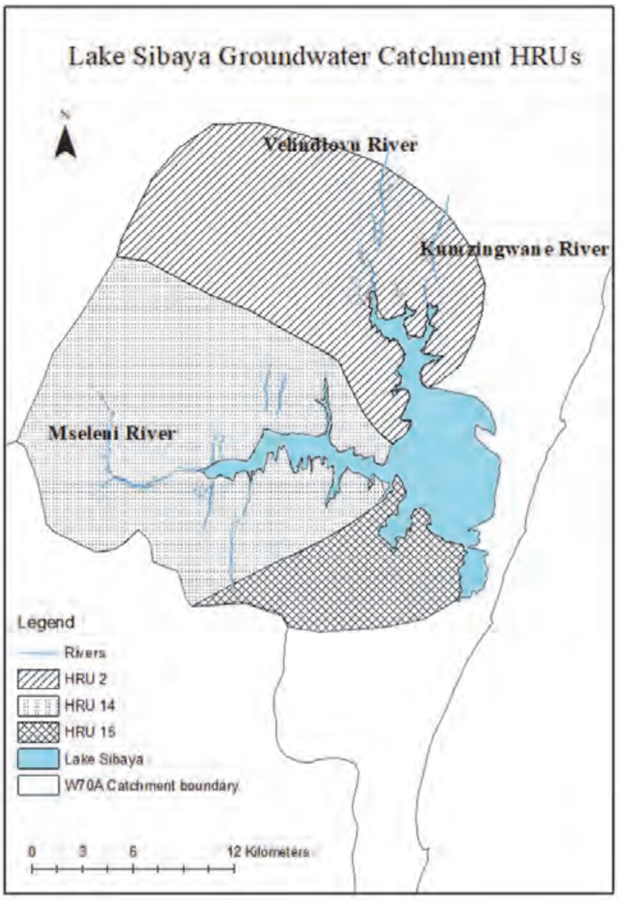
I hope that my research informs future participatory processes, both within the Tsitsa catchment, and other similar contexts.

INTEGRATED HYDROLOGICAL MODELLING FOR GROUNDWATER DROUGHT IN SOUTH AFRICA- A CASE STUDY OF LAKE SIBAYA

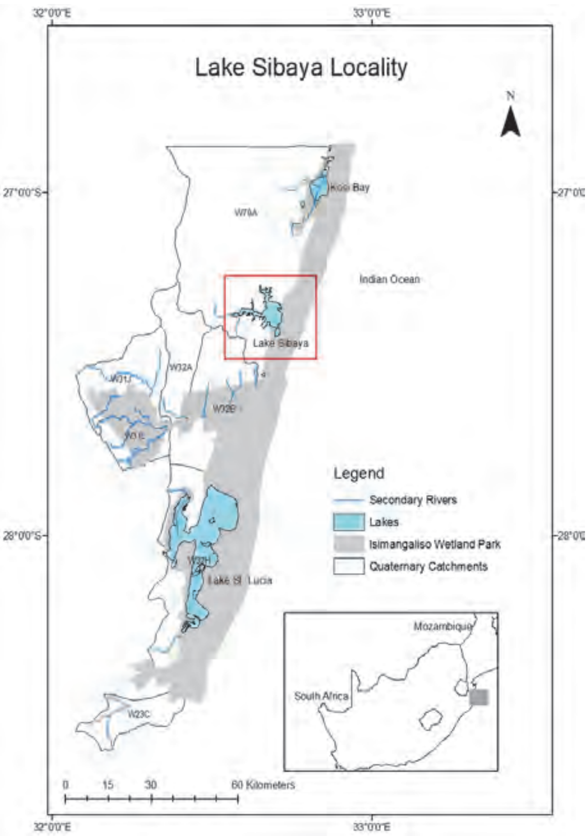
Student: P Ramatsabana
Supervisor: JL Tanner and SK Mantel
Degree: MSc (Hydrology)

Globally, drought has been extensively researched (Calow et al., 2010; Mishra and Singh, 2010; Sheffield and Wood, 2008). However, the emphasis is mostly on meteorological and soil moisture drought, much uncertainty still exists about the processes underlying the development of hydrological drought. Hydrological drought is important because it directly affects the availability of surface and groundwater resources that are required for vital day-to-day human and ecosystem functions (Dai; Santos et al., 2011).

In South Africa much of the research on the subject of drought and water resources tends to focus on the development of hydrological drought of surface water with scant consideration for groundwater. This is related to the fact that drought conditions in surface water are observed at an earlier stage of the drought, and surface water resources such as rivers and lakes are easier to study compared to groundwater systems, which are not easily observed (Kath and Dyer, 2017). Consequently, there is significant uncertainty concerning the characterisation, monitoring and forecasting of groundwater drought due to precipitation deficit (meteorological drought) (Department of Water Affairs, 2010; Weitz and Demlie, 2013). Where research has been carried out with a direct focus on the development of groundwater drought, the discussions tend to be limited to analyses of groundwater level fluctuations (Bloomfield et al., 2019) without tracing the complete propagation of the drought signal.

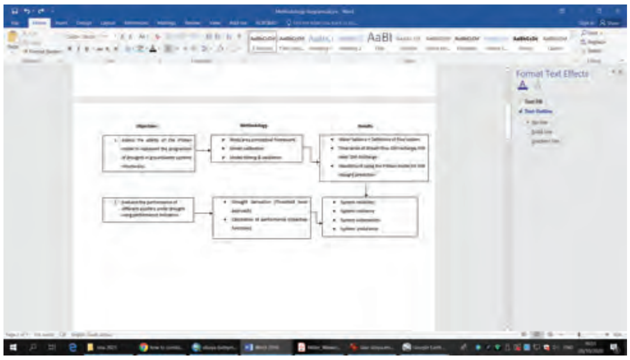


Catchments of Lake Sibaya



Locality map of study site

This study makes an original contribution to this discussion by adopting a holistic approach that, in addition to groundwater levels, takes into account other critical components of the groundwater system (recharge and discharge). Assessing the total aquifer situation in this way will assist in developing a clearer understanding of the propagation of meteorological drought to groundwater systems and therefore reduce uncertainty in predicting future outcomes. The methodology is a variation of the approach adopted by Peters et al. (2005), the main difference being the use of the Pitman model (Hughes, 2004) which, simulates both surface and groundwater systems in an integrated way. Developing an understanding of the processes underlying the propagation of meteorological drought to groundwater systems can assist in properly framing the extent of the challenge of ensuring water security in South Africa.



Research methodology overview

AN ASSESSMENT OF ECOLOGICAL INFRASTRUCTURE ROLE AND BENEFIT FOR DROUGHT MITIGATION IN RURAL SOUTH AFRICAN CATCHMENTS (CACADU AND UPPER CROCODILE RIVER CATCHMENTS AS CASE SITES)

Student: S Xoxo
Supervisors: SK Mantel, JL Tanner and A De Vos
Degree: MSc (Water Resource Science)

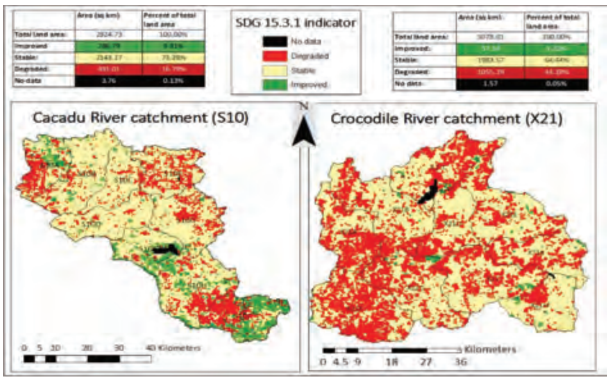
Background

Water scarcity is recognised as one of the significant challenges many countries, including South Africa, are facing. The threat to water scarcity is exacerbated by the coupled impacts of climate and anthropogenic drivers. Perturbing droughts and continued land cover change influence the ability of catchments to partition rainwater runoff, thereby affecting streamflow returns. Despite some availability of funds to reverse ecosystem degradation, achieving adequate ecosystem recovery still remains a challenge.

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" following their recognition of combined the impacts of droughts and anthropogenic modifications. 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). Thus, this study sought to assess the consequences of human actions to catchment health status using the SDG 15.3.1 degradation indicator as a surrogate.

The study further developed a prioritisation plan for restoration to improve drought mitigation for four focal ecological infrastructure (EI) categories (i.e. wetlands, riparian margins, abandoned agricultural fields and grasslands). The focal EI categories were selected for their importance in delivering water-related ecosystem services when sustainably managed. Finally, hydrological modelling was used to assess how ecological infrastructure enables drought mitigation.



Human-induced degradation indicator in the two focal catchments over 15 years (2000-2015). The human-induced degradation indicator was derived using the Rain-Use Efficiency climate adjustment.

The study used the recently released global GIS toolbox (Trends.Earth) for tracking land change and for assessing the land degradation indicator of two focal catchments (i.e. Cacadu and Upper Crocodile River catchments) over 15 years at a 300 m resolution (Conservation International 2018). Next, a GIS-based multi-criteria decision analysis (MCDA) based on community stakeholder priorities, open-access spatial datasets and expert opinions, was used to identify EI focal areas that are best suitable for restoration to increase the drought mitigation capacity of the focal catchments. The collected datasets provided three broad criteria (ecosystem health, water provision and social benefit) for establishing the MCDA model using 12 spatial attributes. Lastly, the study used the Pitman rainfall-runoff conceptual model to simulate the catchment runoff response in modified vs intact catchments.

Outcomes

Results from the ecosystem health assessment revealed a moderate (17% degraded land) and severe (34% degraded land) human-induced degradation in the Cacadu and Crocodile catchments, respectively (Figure 1). Dynamics in land productivity dominated degradation in both catchments, while no significant changes were observed for soil organic carbon and land cover change at a coarse scale.

Community stakeholder discussions were conducted to identify priority rehabilitation areas in Macubeni have been conducted using Google Earth 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.

Twenty-two experts were approached to rank twelve spatial attributes for their relative importance in improving the flow regulation service of catchments (Table 1). These results were 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. MCDA model results show priority areas for restoration to improve flow regulation service and consequently the drought mitigation in focal catchments.

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.

The hydrological regime in the focal catchments is expected to be mainly influenced by significant changes in land cover and climate over the past 30 years. Rainfall runoff changes in headwaters may have spill-over impacts in the lower parts of the catchment, therefore urgent land-use change and climate adaptation planning is necessary to improve water security and other local livelihoods.

Table 1: Hierarchical structure of the 12 spatial attributes and three main criteria used in the prioritisation of focal ecological infrastructure for drought mitigation.

Main criteria	Criteria weights	Attributes	Attribute weights
Ecosystem health	0.33	Present ecological status	0.31
		Ecosystem protection	0.29
		Degradation indicator	0.26
		Stream order	0.08
		Recently cleared	0.06
Hydrologic functionality	0.33	Surface water runoff	0.27
		GW contribution to streamflow	0.25
		MAR reduction due to IAPs	0.20
		Wetland size	0.14
		Wetland type	0.14
Social benefit	0.33	Population density	0.50
		Accessibility	0.50

Closing remarks

Combining the outcomes from the three assessments allowed the study to highlight the role and benefits of ecological infrastructure in terms of drought mitigation. Study findings were interpreted to make recommendations for the role and benefit of ecological infrastructure for drought mitigation at a landscape scale and tertiary catchment level, within the context of available management options.

The results support the notion that multiple science data sources can be useful for promoting investments in ecological infrastructure. However, better spatial and temporal resolution datasets at a national level are still needed to improve the accuracy of studies such as the one outlined in this thesis.

The study recommends better ecosystem protection approaches at multiple levels to reduce the vulnerability of communities to drought impacts.

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 - December 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, Dr 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 unpalatable 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.

RESEARCH OUTPUTS

PEER REVIEW JOURNALS AND CONFERENCE PROCEEDINGS

Akamagwuna FC and Odume ON (2020) Ephemeroptera, Plecoptera and Trichoptera (EPT) functional feeding group responses to fine-grain sediment stress in a river in the Eastern Cape, South Africa. *Journal of environmental monitoring and assessment.* https://doi.org/10.1007/S10661-020-8187-4

Bester R, Blignaut JN and van Niekerk PH (2020) The cost-effectiveness of water augmentation and management: Assessing the Unit Reference Value. *Journal of the South African Institution of Civil Engineering*, *62*(2), 39-44.

Cockburn J, Rosenberg E, Copteros A, Cornelius SF, Libala N, Metcalfe L and van der Waal B (2020) A relational approach to landscape stewardship: towards a new perspective for multi-actor collaboration. *Land*.

Eckardt FD, Bekiswa S, Von Hold JR, Jack C, Kuhn NJ, Mogane F, Murray JE, Ndara N and Palmer AR (2020) South Africa's agricultural dust sources and events from MSG SEVIRI. *Aeolian Research*. 47 https://doi.org/10.1016/j.aeolia.2020.100637

Edegbene OA, Arimoro FO and Odume ON (2020) Exploring the pattern of distribution of macroinvertebrate signature traits and ecological preferences and their responses to urban and agricultural pollution in selected rivers in the Niger Delta ecoregion, Nigeria. Journal: *Aquatic Ecology*. 1-21.

Edegbene AO, Arimoro FO and Odume ON (2020) How does urban pollution influence macroinvertebrate traits in forested riverine systems. *Water 12, 3111.*

Edegbene OA, Arimoro FO and Odume ON (2020) Exploring the pattern of distribution of macroinvertebrate signature traits and ecological preferences and their responses to urban and agricultural pollution in selected rivers in the Niger Delta ecoregion, Nigeria. Journal: *Aquatic Ecology*.

Ghali H, Osimen EC, Akamagwuna FC, Keke UN and Edegbene AO (2020) Preliminary assessment of the deteriorating state of north-western Nigeria dam using phytoplankton structural-assemblage and environmental factors. *Water Science* 10.1080/11104929.2020.1816152

Gwapedza D, Nyamela N, Hughes DA, Slaughter AR, Mantel SK and van der Waal B (2020) Prediction of sediment yield of the Inxu River catchment (South Africa) using the MUSLE*, International Soil and Water Conservation Research*. doi: https://doi.org/10.1016/j.iswcr.2020.10.003.

Hughes DA and Farinosi F (2020) Assessing development and climate variability impacts on water resources in the data scarce Zambezi River basin. Simulating future scenarios of climate and development. *Journal of Hydrology: Regional Studies*. https://doi.org/10.1016/j.ejrh.2020.100763

Hughes DA, Mantel SK and Farinosi F (2020) Assessing development and climate variability impacts on water resources in the Zambezi River basin. Initial model calibration, uncertainty issues and performance. *Journal of Hydrology: Regional Studies*. https://doi.org/10.1016/j.ejrh.2020.100765.

Janssen S, Vreugdenhil H, Hermans L and Slinger J (2020) On the nature based flood defence dilemma and its Resolution: A game theory based analysis. *Science of the Total Environment, 705*. doi*:* https://doi.org/10.1016/j.scitotenv.2019.135359

Januchowski-Hartley SR, Mantel SK, Celi J, Hermoso V, White JC, Blankenship S and Olden JD (2020) Small instream infrastructure: comparative methods and evidence of environmental and ecological responses. *Ecological Solutions and Evidence* 1(2), 1-7. https://doi.org/10.1002/2688-8319.12026

Kabuya PM, Hughes DA, Tshimanga RM, Trigg MA and Bates P (2020) Establishing uncertainty ranges of hydrologic indices across climate and physiographic regions of the Congo River Basin, *Journal of Hydrology: Regional Studies*, 30. https://doi.org/10.1016/j.ejrh.2020.100710.

Keke U, Arimoro F, Ayanwale A, Odume ON and Edegbene A (2020) Biodiversity patterns along seasonality and environmental factors of stream macroinvertebrate communities. *Egyptian Journal of Aquatic Biology and Fisheries* 24 (4) 521 – 534.

Libala N, Palmer CG and Odume ON (2020) Using a trait-based approach for assessing the vulnerability and resilience of hillslope seep wetland vegetation cover to disturbances in the Tsitsa River catchment, Eastern Cape, South Africa. Journal: *Ecology and Evolution* 10 (1) 277-291.

Lidzhegu Z, Ellery F, Mantel SK and Hughes, DA (2020) Delineating wetland areas from the cut-and-fill method using a Digital Elevation Model (DEM). *South African Geographical Journal*, 102(1), 97-115. https://doi.org/10.1080/03736245.2019.1638825.

Muñoz-Carpena R, Batelaan O, Willems P and Hughes DA (2020) Editorial – Why it is a blessing to be rejected: improving science with quality publications. *Journal of Hydrology: Regional Studies, 100717*. https://doi.org/10.1016/j.ejrh.2020.100717

Mwedzi T, Siziba Q, Odume ON**,** Nyamazana E and Mabika I (2020) Responses of macroinvertebrate community metrics to urban pollution in semi-arid catchments around the city of Bulawayo, Zimbabwe. *Water SA* 46 (4 October.

Odume ON (2020) Searching for urban pollution signature and sensitive macroi9nvertebrate traits and ecological preferences in a river in the Eastern Cape of South Africa. Journal: *Ecological Indicators* 108: 105759.

Palmer AR, Ezenne GI, Choruma DJ, Gwate O, Mantel SK and Tanner JL (2020) A comparison of three models used to determine water fluxes over the Albany Thicket, Eastern Cape, South Africa. *Agricultural and Forest Meteorology* 288, 107984.

Scheihing KW, Tanner JL, Weaver MJT and Schöniger M (2020) A strategy to enhance management of free basic water via communal taps in South Africa. *Utilities Policy, 64. ISSN 0957-1787, https://doi.org/10.1016/j.jup.2020.101043*

IN PRESS AND SUBMITTED ARTICLES

Gusha B, Palmer AR and Villano RA (Under review) A stochastic frontier analysis of the performance of livestock in the north -Eastern Cape communal rangelands. Agrekon.

Gusha B and Palmer AR (Under review) Assessment of household livestock-based livelihoods in the north Eastern Cape communal rangelands, South Africa. Cogent Food and Agriculture.

Hughes DA and Farinosi F (2020) Unpacking some of the linkages between uncertainties in observational data and the simulation of different hydrological processes using the Pitman model in the data scarce Zambezi River basin. *Hydrological Processes*, Under Review.

Libala N, Clifford-Holmes JK, Bester R, Ralekhetla M, Mti N, Fry A, Weaver MJT and Palmer CG (in prep) A systemic view of the Governance Capabilities Pathway.

Libala N, Odume ON and Palmer CG (under review) Engaging with communities to develop an understanding of livestock grazing practices in relation to hillslope seep wetlands in the Tsitsa River catchment, Eastern Cape *Anthropocene on Restoration Ecology*.

Libala N, Odume ON and Palmer CG (under review) The use of biological indices to assess the condition of hillslope seep wetland in the Tsitsa River Catchment, South Africa. *Rangeland ecology and Management*.

Nolte A, Eley M, Schöniger M, Tanner JL, Gwapedza D, Mantel SK and Scheihing K (2020) Hydrological modelling of a regional dam system for assessing spatio-temporal variations in groundwater recharge in a water stressed metropolitan region of Eastern Cape, South Africa. *Hydrological Processes* (Submitted).

Tramblay Y, Rouché N, Paturel J-E, Mahé G, Boyer J-F, Amoussou E, Bodian A, Dacosta H, Dakhlaoui H, Dezetter A, Hughes DA, Hanich L, Peugeot C, Tshimanga R and Lachassagne P (2020) ADHI: The African Database of Hydrometric Indices (1950-2018). *Earth System Science Data*, submitted.

Weaver MJT, Cockburn J, Mtati N and Palmer CG (in prep) Transformative processes in a WEF nexus landscape: a case study of two vignettes from the Tsitsa Project.

CHAPTER IN BOOK

Weaver MJT (completed, awaiting publisher) Breaching the gap: Translating commissive talk to action in multi-level water governance arrangements.

Mushi CA, Ndomba PM, Tshimanga RM, Trigg MA, Neal J, Bola GB, Kabuya PM, Carr A, Beya J, Hughes DA and Bates P (2020) Design and Implementation of a Sediment Sampling Program on the Kasai River, a major tributary of the Congo River. Chapman Congo Conference Monograph, AGU Books.

Tshimanga RM, Bola GB, Kabuya PM, Nkaba L, Neal J, Hawker L, Trigg MA, Bates P, Hughes DA, Laraque A, Woods R and Wagner T (2020) Towards a framework of catchment classification for hydrological predictions and water resources management in the ungauged basin of the Congo River: An a priori approach. Chapman Congo Conference Monograph, AGU Books.

Tshimanga RM, Trigg MA, Neal J, Ndomba P, Hughes DA, Carr AB, Kabuya PM, Bola GB, Mushi CA, Beya JT, Ngandu FK, Mokango GM, Mtalo F and Bates P (2020) New measurements of Congo River water dynamics and sediment transport. Chapman Congo Conference Monograph, AGU Books.

Trigg MA, Tshimanga RM, Ndomba PM, Mtalo FA, Hughes DA, Mushi CA, Bola GB, Kabuya PM, Carr AB, Bernhofen M, Neal J, Beya JT, Ngandu FK, and Bates P (2020) Putting river users at the heart of hydraulics and morphology research in the Congo Basin. Chapman Congo Conference Monograph, AGU Books.

REPORTS

Cockburn J, Weaver MJT, Kotschy K and Mvulane W (2020) Quarterly Progress Report, Knowledge and Learning Community of Practice. Reporting Period: Quarter 2 of 2020-2021: June, July, August 2020. Tsitsa Project.

Cockburn J, Weaver MJT, Kotschy K and Mvulane W (2020) Quarterly Progress Report, Knowledge and Learning Community of Practice. Reporting Period: Quarter 1 of 2020-2021: March, April, May 2020. Tsitsa Project.

Cockburn J, Weaver MJT, Kotschy K and Mvulane W (2019) Quarterly Progress Report, Knowledge and Learning Community of Practice. Reporting Period: Quarter 4 of 2019-2020: December 2019, January 2020, February 2020. Tsitsa Project.

Fry A (2020) Quarterly Student Report, Governance Community of Practice. Reporting period: Quarter 1 of 2020-2021: March, April, May 2020. Tsitsa Project.

Fry A (2020) Quarterly Student Report, Governance Community of Practice. Reporting period: Quarter 2 of 2020-2021: June, July, August 2020. Tsitsa Project.

Fry A (2020) Quarterly Student Report, Governance Community of Practice. Reporting period: Quarter 3 of 2020-2021: September, October, November 2020. Tsitsa Project.

Fry A (2020) Quarterly Student Report, Governance Community of Practice. Reporting period: Quarter 4 of 2020-2021: December 2020, January, February 2021. Tsitsa Project.

Libala N (2020) Quarterly Progress Report, Governance Community of Practice. Reporting period: Quarter 1 of 2020-2021: March, April, May 2020. Tsitsa Project.

Libala N (2020) Quarterly Progress Report, Governance Community of Practice. Reporting period: Quarter 2 of 2020-2021: June, July, August 2020. Tsitsa Project.

Libala N (2020) Quarterly Progress Report, Governance Community of Practice. Reporting period: Quarter 3 of 2020-2021: September, October, November 2020. Tsitsa Project.

Libala N (2020) Quarterly Progress Report, Governance Community of Practice. Reporting period: Quarter 4 of 2020-2021: December 2020, January, February 2021. Tsitsa Project.

Libala N, Ralekhetla MM, Fry AS, Mti N, and Palmer CG (2020) Learning Words roll-out, Governance Community of Practice. Reporting period: Quarter 1 of 2020-2021: March, April, May 2020. Tsitsa Project.

Libala N, Ralekhetla MM, Weaver MJT, Fry AS, Mti N, and Palmer CG (2020) Development of listening and speaking capabilities for participatory land and water governance in rural South Africa, Governance Community of Practice. Reporting period: Quarter 4 of 2020-2021: December 2020, January, February 2021. Tsitsa Project.

Mantel SK, Xoxo S, Mahlaba B, Tanner JL and Le Maitre D (2020) Spatial database and prioritization of ecological infrastructure in three focal catchments. Deliverable 2 for WRC Project K5/2928/1&2. Water Research Commission, Pretoria, South Africa.

Mantel SK, Xoxo S, Mahlaba B, Tanner JL and Le Maitre D (2020) The value of investing in maintaining and restoring ecological infrastructure. Deliverable 3 for WRC Project K5/2928/1&2. Water Research Commission, Pretoria, South Africa.

Mgazy A (2020) Biannual Student Report, Governance Community of Practice. Reporting period: March to August 2020. SANBI.

Xoxo S and Mantel SK (2020) A follow-up progress report indicating the rationale, methods and degradation status of Machubeni ecological infrastructure at 250 m resolution. Deliverable 3 for Rhodes University GEF5 Sustainable Land Management Project, Department of Environmental Science, Makhanda, South Africa.

Xoxo S and Mantel SK (2020) A final map showing ecological infrastructure, community confirmed priority rehabilitation areas and key resources and change analysis. Deliverable 4 for Rhodes University GEF5 Sustainable Land Management Project, Department of Environmental Science, Makhanda, South Africa.

CONFERENCE PRESENTATIONS

Banadda N and Palmer CG (2020) Practicing the Adaptive Systemic Approach: research that enables just and sustainable water resource development. Geographical Science for Resilient Communities, Ecosystems and Livelihoods under Global Environmental Change (GORILLA) December 2020, Makerere University, Kampala

Gusha B and Palmer AR (2020) Deriving an evidence-based estimate of livestock water productivity in communal rangelands of the north Eastern Cape Province, South Africa. Special edition of the Animal Production Science Journal.

Kabuya P, Hughes DA, Tshimanga RM and Trigg M (2020a) Understanding factors influencing the wetland parameters of a monthly rainfall-runoff model in the Upper Congo River Basin. EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-642, https://doi.org/10.5194/egusphere-egu2020-642.

Palmer CG (2020) The Adaptive Systemic Approach to water resource research that supports social-ecological justice. Global Water Security Symposium. Newcastle University, January 2020.

Palmer CG (2020) Development research as catalyst of change towards social-ecological justice. ARUA Water CoE-N8 Colloquium. Newcastle January 2020.

Palmer CG (2020) Invited panellist for a Universities UK International and UK ODA (Official Development Assistance) webinar: *Research and Innovation for international development: a focus on impact.*

Ralekhetla M, Palmer CG and Paphitis SA (2020) Exploring the nature and meaning of participation in a land restoration project in the Tsitsa river catchment: a question of epistemic injustice? (Tsitsa Project Research Policy colloquium 2020).

Ralekhetla M, Palmer CG and Paphitis SA (2020) Exploring the nature and meaning of participation in a land restoration project in the Tsitsa river catchment: a question of epistemic injustice? (3 minute thesis Rhodes University online conference).

Weaver MJT (2020) Overview of the Training of Trainers Course. Reconnect and Reflection Workshop, Tsitsa Project. Online Zoom Workshop, 26 August 2020.

Weaver MJT (2020) Breaching the gap: Translating commissive talk to action in multi-level water governance arrangements. Cultural Historical Activity Theory Research School, Moving from the edges of Third Generation CHAT into Fourth Generation CHAT. ELRC, Rhodes University. 17 - 20 February 2020.