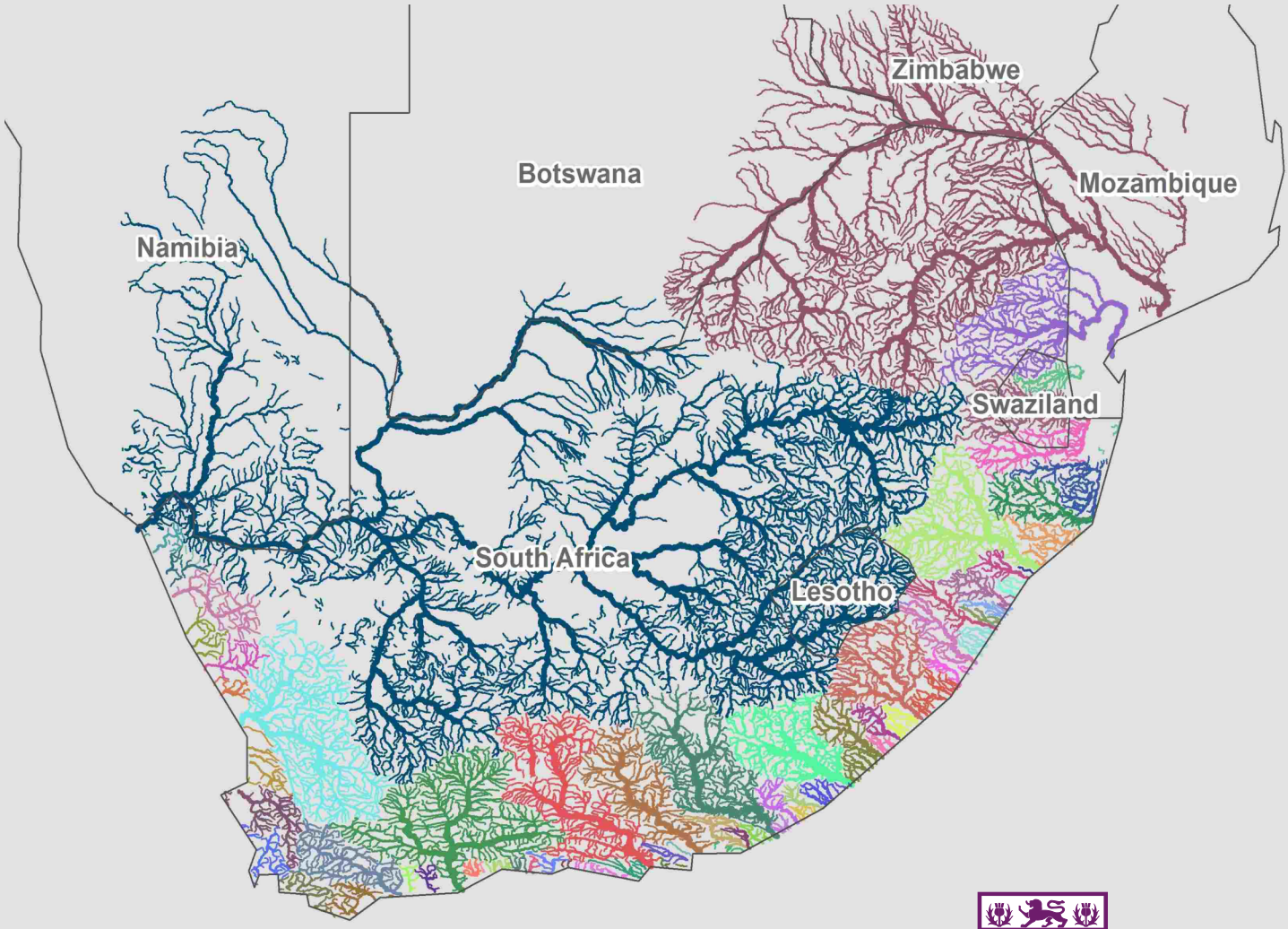
Institute for Water Research

Annual Report 2018



RHODES UNIVERSITY
Where leaders learn

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RHODES UNIVERSITY
Where leaders learn

RHODES UNIVERSITY
INSTITUTE FOR WATER RESEARCH
2018

IWR

Back Row: Dr T Palmer, Mr M Weaver, Mr E Greyling , Mr W Liversage, Prof D Hughes, Mr G Bola
Third Row: Mr C Hale, Ms J McLean, Ms B Mdludla, Mr D Forsyth, Ms N Mgaba, Dr S Mantel, Ms T Zondani
Second Row: Ms N Ndzimande, Ms M Ralekethla, Ms C Smith, Ms N Ngantweni, Ms M Wolff, Ms B Mahlaba, Dr C Nnadozie, Dr G Ezenne
Front Row: Ms A Chili, Ms M Mosekili, Ms Q Mkhabile, Dr N Odume, Prof C Palmer, Dr J Tanner, Ms A Bulunga , Ms Phindiwe Ntloko, Ms K Mokoena, Ms N Libala
Inset: Dr P Mensah

STAFF AND MEMBERS OF THE INSTITUTE

STAFF

Ms Rozanne Bester	Research Assistant
Dr Gloria Ezenne	Post Doctoral Fellow
Mr David Forsyth	Principal Technical Officer
Dr Neil Griffin	Research Officer
Ms Bawinile Mahlaba	Intern
Dr Sukhmani Mantel	Senior Researcher
Mr Sbongiseni Mazibuko	Research Assistant
Ms Juanita McLean	Administration Manager
Dr Paul Mensah	Senior Researcher
Dr Chika Nnadozie	Post Doctoral Fellow
Ms Ntombekhaya Mgaba	Senior Technical Officer
Ms Ntombekhaya Mti	Intern
Dr Nelson Odume	Senior Researcher, Director UCEWQ
Prof Tally Palmer	Professor, Director IWR
Dr Jane Tanner	Researcher IWR
Ms Margaret Wolff	Junior Researcher

ASSOCIATES

Prof Brian Allanson	Research Fellow
Dr Jai Clifford-Holmes	Research Associate
Prof Chris de Wet	Professor Emeritus
Mr Greg Huggins	Research Officer Nomad Consulting
Prof Denis Hughes	Professor Emeritus
Dr Eric Igbinigie	Research Associate
Ms Delana Louw	Rivers for Africa
Mr Stephen Mallory	IWR Water Resources
Dr Victor Munnik	Research Associate
Prof Jay O' Keeffe	Research Associate
Dr Tony Palmer	Research Associate
Dr Andrew Slaughter	Research Associate
Dr Patsy Scherman	Research Associate
Dr Jill Slinger	Visiting Professor

REGISTERED POSTGRADUATE STUDENTS

Mr Frank Akamagwuna	MSc (Water Resource Science)
Mr Bongile Bhomela	PhD (Water Resource Science)
Mr Dennis Choruma	PhD (Water Resource Science)
Ms Pumza Dubula	PhD (Water Resource Science)
Ms Asanda Chili	BSc (Hons)
Mr Augustine Edegbene	PhD (Water Resource Science)
Mr Adebayo Farounbi	PhD (Water Resource Science)
Mr Edwin Greyling	BSc (Hons)
Mr David Gwapedza	PhD (Hydrology)
Mr Christopher Hale	BSc (Hons)
Mr Pierre Kabuya	PhD (Hydrology)
Ms Notiswa Libala	PhD (Water Resource Science)
Mr Zwidofhelangani Lidzhegu	PhD (Water Resource Science)
Mr William Liversage-Quinlan	MSc (Water Resource Science)
Ms Eunice Makungu	PhD (Hydrology)
Ms Bukanani Mdludla	BSc (Hons)

Ms Qawekazi Mkabile	MSc (Water Resource Science)
Ms Bawanile Mahlaba	BSc (Hons) Environmental Water Management
Ms Kopano Mokoena	BSc (Hons)
Ms Matseleli Mosikili	BSc (Hons)
Mr Siyabongu Ndlovu	MSc (Water Resource Science)
Ms Pindiwe Ntloko	PhD (Water Resource Science)
Ms Mateboho Ralekhetla	MSc (Water Resource Science)
Mr Dionis Rugai	PhD (Hydrology)
Mr Kyle Smetherham	MSc (Hydrology)
Ms Caitlin Smith	MSc (Hydrology)
Mr Matthew Weaver	PhD (Water Resource Science)
Ms Margaret Wolff	MEd
Ms Thantaswa Zondani	MSc (Hons)

REGISTERED POSTGRADUATE STUDENTS CO-SUPERVISED IN PARTNER DEPARTMENTS

Ms Ancha Bulunga	MA (Community Engagement)
Ms Nqobile Nzimande	MEcon (Economics)

2018 GRADUATED STUDENTS

Ms Caleena de Carvalho	BSc (Hons)
Mr Onalenna Gwate	PhD (Hydrology)
Ms Tia Keighley	MSc (Water Resource Science)
Mr Mzwanele Mkatali	BSc (Hons)
Ms Ntombekhaya Mgaba	MSc (Water Resource Science)
Ms Sinako Mtakati	BSc (Hons)
Ms Vuyelwa Mvandaba	MSc (Hydrology)
Ms Nadia Oosthuizen	MSc (Hydrology)
Mr Gareth Thomson	MSc (Water Resource Science)
Mr Emmanuel Vellemu	PhD (Water Resource Science)

MEMBERS OF THE BOARD

Prof Tony Booth	Dean of Science, Rhodes University
Prof Peter Clayton	Chairman, Rhodes University; Deputy Vice Chancellor: Research & Development
Prof Julie Coetzee	Botany Department, Rhodes University
Dr Alta de Vos	Environmental Science, Rhodes University
Mr Fekile Guma	Department of Water & Sanitation, Pretoria
Dr Eric Igbinigie	Assured Turnkey Solutions, Johannesburg
Mr Andrew Johnstone	GCS Water & Environmental Consultants, Johannesburg
Dr Evison Kapangaziwiri	CSIR, Pretoria
Ms Juanita McLean	Secretary to Board and Administration Manager Institute for Water Research
Prof Ian Meiklejohn	Geography Department, Rhodes University
Mr Daluxolo Mlenzana	Director of Technical Infrastructure and Engineering, Makana Local Municipality
Dr Nelson Odume	Institute for Water Research, Rhodes University
Prof Tally Palmer	Institute for Water Research, Rhodes University
Dr Angus Paterson	SAIAB (South African Institute for Aquatic Biodiversity)

Emeritus Professor Jay O'Keeffe

It is with sadness that we record the death of Emeritus Professor Jay O'Keeffe, a founding Director of the IWR. Jay graduated with his PhD from Imperial College London, and joined Rhodes University in 1983 as a post-doctoral fellow in the then Institute for Freshwater Studies (IFWS), led at the time by Emeritus Professor Brian Allanson. Jay went on to become the Director of the IFWS, and in 1991, together with Emeritus Professor Denis Hughes, founded the IWR. Jay was a fine academic with an extensive international reputation.

He was President of the Southern African Society for Aquatic Scientists, and a Programme Manager of the Kruger National Park Rivers Research Programme. Jay was awarded the SASAQS Gold Medal in 2004, an award made rarely, in recognition of an exceptionally high standard of research in the aquatic sciences, and an exceptionally valuable contribution to the management, conservation or development of aquatic ecosystems over an extended period.

Moreover Jay was a charming and charismatic person who was one of the global pioneers of the science of environmental flows(E-flows). His collaboration with Denis Hughes brought hydrology, hydrological modelling and aquatic ecology together, and Jay became a catalyst around whom hydraulic modellers, geomorphologists, water quality specialists and a variety of aquatic ecologists grappled with how to use (E-Hons) science to protect rivers while still using them.This research became a prime motivating factor for water resource protection in the South African National Water Act of 1998, the first legislation globally to provide a legal right for E-flows.

In 2004 Jay moved to the Netherlands, taking up the WWF Freshwater Chair at the UNESCO-IHE Institute for Water Education (2004 to 2010). It was in this position that Jay became a global leader in E-flows training and implementation, and escalated his mentoring and post graduate supervision. He worked notably in East Africa and India, where he contributed substantively to the complex, multi-disciplinary initiative of establishing E-flows for the Upper Ganga River, taking account of the socio-cultural value of India's holy river. He retained a research associate relationship with the IWR.

Jay's great gift - to family, friends, colleagues, and students - was to be attentive and really interested in the other person, and to give generously of his vibrant and positive view of the world. He was an important mentor within the South African Aquatic Science community, and has an ongoing lineage of attentive post-graduate supervision in the IWR.

Jay will be remembered and missed.

Emeritus Professor J O'Keeffe

Holding the Course

2018 was the most demanding and vulnerable year the Institute has faced. The 2017 Annual Report presented a thriving Institute with excellent research activity post-graduate completions, publications, engaged research processes and the establishment of partnerships in the consulting world. We were particularly gratified by the formation and functioning of a participatory Makana Water Forum, formally institutionally linked to the Makana Local Municipality and the Department of Water and Sanitation.

At the 2017 Board meeting we noted with concern that competitive income for 2018 year was low, the Unilever commitment was wavering, and we anticipated a hard year. The reality of this uncertainty emerged as Dr Paul Mensah left us to take up an academic position at his *alma mata*, the University of Cape Coast, Ghana. Paul had made a substantive contribution to the IWR and UCEWQ. He was promoted to Senior Researcher during 2018, successfully supervised students, lead Ecotoxicology research and co-ordinated our honours teaching programme. We wish him success and look forward to future collaborations. Rhodes University provided bridging funds to enable staff retention in the second half of 2018. The University expressed concern as to the probable efficacy of their support, as it was uncertain what would change by January 2019.

I am therefore delighted to report that the hard work, strategic planning and activity particularly among the IWR leadership team has enabled us to turn the corner. 2019 has brought a full portfolio of research contracts from the Water Research Commission, and we still have international proposals being adjudicated. We will sorely miss Paul's skills and will be looking to recruit an Ecotoxicology post-doctoral fellow as soon as possible, hopefully in 2020. In 2019 Ms Khaya Mgaba will be undertaking research as well as supervising the laboratories. Dr Nelson Odume was Acting Director for the last quarter of 2018, and it is his determined presence among funders and clients, and his active profiling of the IWR, that has been a key factor in "holding the course" and achieving a turn-around. On the international front Dr Jane Tanner established a strong collaboration with the Monpellier University and will be visiting Dr Olivier Barreteau then in January 2019. We will continue to submit international applications with them. I have established contact with Professor Frances Cleaver at Sheffield University – bringing a social science dimension to the existing strong Rhodes collaboration with Sheffield. Professor Cleaver is a global leader in catchment and water governance processes.

We start 2019 with a strong sense of purpose and optimism.

Sustainable Development Goals

In January 2018 the IWR hosted a successful Open Day event in East London. The theme was water in relation to the United Nation's Sustainable Development Goals (SDGs). The Open Day was organised as an interactive "Conversation Cafe", and responses were contributed by all participants, including IWR staff and students, established, and potential IWR partners. The SDG focus was used in a range of grant proposals through the year.

African Research Universities' (ARUA) Water Centre of Excellence

The most important development in 2018 was the recognition of the IWR as the African Research Universities' (ARUA) Water Centre of Excellence host (http://arua.org.za/arua-centre-of-excellence-coe-in-water/), with Professor Tally Palmer as the Director of the CoE, and Dr Jane Tanner as the IWR lead researcher. ARUA comprises 16 African Universities recognised as offering continental research leadership. The Vice Chancellors of the respective Universities founded the Alliance in 2015, and 2017 saw member Universities motivate to host the Centres of Excellence. We have been awarded an NRC Knowledge Interchange and Collaboration grant as seed funding to launch the CoE.

Dr Jane Tanner, Prof Ernest Aryeetey (Secretary of ARUA) and Prof Tally Palmer at ARUA Workshop organised by CoE Energy

In ARUA: "Centre of Excellence (CoE) has been defined as "a team, a shared facility or an entity that provides leadership, best practices, research, support and/or training for a focus area

The ARUA CoEs are intended to be focal points for aggregating world-class researchers from member universities to undertake collaborative research in priority thematic areas while providing opportunities for graduate students from the region and elsewhere to work with the researchers. The CoE is therefore an assembly point for good and committed researchers and students seeking to do cutting-edge work."

ARUA Centres of Excellence Document

The Water CoE partners are: Rhodes University, Addis Ababa University, University of Dar es Salaam, Lagos University, University of Rwanda, Makarere University and University of Cape Town. The ARUA Water CoE has a research agenda related to the SDGs, and will be officially launched in the first half of 2019

The ARUA Centre of Excellence for Water: Africa's water-centred approach to the SDGs
SDG 6 – Clean Water and Sanitation *is at the centre. We recognise water as intrinsically being 1) water in the landscape – the catchment/watershed) and 2) the delivery of water services (water supply and sanitation.*
These two are encircled in blue.

On the left is a blue circle focused on water resources in the landscape.

- Water resources involve three key SDGs: i) SDG 6 – Clean Water and Sanitation, ii) SDG 15 – Life on Land and iii) SDG 13 – Climate Action. The water resource (SDGs 6 and 15) is linked to Climate Action – SDG 13 through Adaptation. These three are supported by SDG 16 – Peace, Justice and Strong Institutions through policy and good governance, including participatory governance.
- Together this suite of SDGs (6, 13, 15, 16) provide a research focus on the protection of land and water (catchment) ecosystem services, leading to an understanding of system adaptive capacity. Intrinsically this means we see people in the landscape as a social-ecological system.
- At the centre of this water resource view research, three SDGs are supported: i) SDG 4 – Quality Education through the development of ARUA researchers and their post-graduate students AND the communities with whom they will engage; ii) SDG 5 – Gender Equality through mainstreaming gender into all ARUA Water CoE activities and outcomes; and iii) SDG 17 – Partnerships for the Goals though a recognition that engaged action research always brings patterns, and therefore the co-creation of knowledge into the process.

The blue circle on the right focuses on water services and their delivery.

- Here, water service delivery is fundamentally essential to SDG 3 – Good Health and Well-being which requires research attention on primary and secondary water scarcity in terms of both the quantity and quality of water. Water security is necessary for i) SDG 11 – Sustainable Cities and Communities and

ii) SDG 12 – Sustainable Consumption and Production. Research into human behaviour, waste management and sustainable clean technologies related to water are also drivers of SDGs 11 and 12.

Linked to, but not the focus of, research within the ARUA Water CoE are:

i) SDG 7 – Affordable Clean Energy, and ii) SDG 9 – Industry Innovation and Infrastructure as critical enablers of water service delivery; and iii) SDG 14 – Life below Water links to SDG 6 mainly through multiple aspects of estuaries.

The Water CoE uses the concept of complex, adaptive social-ecological systems as the integrating framework to channel water-related research into resolving and addressing the challenges associated with SGS 1, 2, 8 and 10: SDG 1 – No Poverty, SDG 2 – Zero Hunger, SDG 8 – Decent Work and Economic Growth, and SDG 10 – *Reduced Inequalities*.

Environmental Water Management Honours

Seven students will successfully graduate with an Environmental Water Management Honours degree taking a majority of courses offered with the IWR. This innovative course was initiated with a foundational module on Adaptive Integrated Water Resource Management, included new specialist courses in Aquatic Ecology and Hydrology, and retained the long-standing Environmental Water Quality module. However the uncertainties of 2018 led to the course being strongly retained by the Geography Department in 2019, with IWR researchers offering service modules, instead of the increasing leadership and developmental role we had hoped for. It is an advantage to the IWR staff to teach several of the modules in terms of additional income and teaching experience, and for students to be exposed to a wider range of IWR ideas and expertise.

Strategic Adaptive Management

During 2018 the IWR has continued to work adaptively to advance in the four key strategic areas identified in February 2017, for the 2017-2019 period.

Act to diversify income streams and increase income and savings so that:

1) Rhodes University is assured that contracts to IWR staff can be offered beyond immediate project time-frames.
2) Reserve funds are built up for emergency salaries for long-standing

- productive staff in the case of a funding gap.
- Improve skills training for staff and post-graduate students.
- Improve research outputs.
- Improve the reputation and profile of the IWR at different scales: within the University, provincially, nationally and internationally.

Some of the 2018 Graduates and Supervisors: Left to Right: Dr Sukhmani Mantel, Dr Onalenna Gwate (PhD) , Ms Ntombekhaya Mgaba (MSc), Dr Nelson Odume, Mr Mzwanele Mkatali (BSc), Dr Emmanuel Vellemu (PhD) and Dr Paul Mensah

In 2018 these four primary strategic areas were addressed:

Diversified income: Despite all efforts, the financial circumstances of the IWR did not improve during 2018. Positive outcomes included: i) success in securing ongoing funding from the Department of Environment Affairs to continue participating in the innovative Tsitsa Project; ii) retaining Margaret Wolff as a researcher on that project; and iii) research associate Dr Jai Clifford Holmes also secured funding to

be part of the IWR Governance Community of Practice within the Tsitsa Project. In July, Rhodes University agreed to provide additional support to the IWR in the form of a seven month mornings-only contract to retain staff in the hope of new funding becoming available in 2019.

Proposal submission rate to a wide range of potential funders increased, with Drs Nelson Odume and Jane Tanner leading this drive. We have been substantively successful with the WRC, with the award of seven projects, five of which are led by the IWR. We have been awarded an NRF Community Engagement project with running costs and a student bursary. We are fortunate to have retained funding from Unilever in 2018, although with a 50% reduction. This means all contract research staff are secure for 2018. However, Technical IT Support remains insecure. We are some way from achieving the diversified Income goal set in 2017.

Skills Development
The IWR provides students with focussed training in writing, presentation delivery, and the use of data analysis tools, programming tools and models. We have a seminar series, and we make use of the courses offered by the Centre for Postgraduate Studies. David Forsyth has taught a course in Python – a high level computer language throughout the year.

Research output
The focussed writing morning every second Friday has been intermittent, and will be resumed in 2019 to ensure a writing commitment and habit. The productive publication output of the IWR is lower than 2017 with 18 reports and 19 papers. It was particularly gratifying to have a paper in a high ranking journal, in the final stages of acceptance that is co-authored by IWR student and staff participants of the Transdisciplinary (TD) Research Group. The paper is based on TD research undertaken in the IWR over the last decade.

IWR reputation and profile
In addition to the academic reputation and profile accrued from academic output, the IWR participates actively within the University in the Science Faculty Open Day and in "Water World" at the Science Festival. Within Makhanda (Grahamstown), doctoral student Matthew Weaver, together with Notiswa Libala and Mateboho Ralekhetla, have supported and provided leadership within the Makana Water Forum, which has had increasing traction with the Department of Water and Sanitation and the Makana Local Municipality. International partnerships have been deepened with Montpellier, Coventry and Sheffield Universities, and Professor Jill Slinger at the Delft University Technology continues to be an active partner. Professor Tally Palmer presented an invited keynote paper at Climate Change 2018, in London.

The IWR continues to operate as a cohesive whole across all areas of academic expertise and with the actively involved participation of support staff. Leadership is shared, and this report is followed by reports from the Director of the Unilever Centre for Environmental Water Quality, Dr Nelson Odume, and the Hydrology group research leader, Dr Jane Tanner.

Everyone at the IWR works extremely hard in a good spirit of collegiality. Emeritus Professor Denis Hughes continues to make substantive contributions. The Departments of Geography and Environmental Science, and the Environmental Learning Research Centre, are much appreciated as key partners. The Dean of Science, Professor Tony Booth, the Deputy Vice Chancellor Research and Chairperson of the IWR Board, Dr Peter Clayton and the IWR Board members offer good guidance, and we continue to receive excellent strategic and financial support from the University.

Prof CG Palmer, Director: IWR

Introduction

The Centre remains committed to undertaking cutting edge research and training postgraduate students. Staff and students of the Centre continue to play active roles in this regard. Dr Griffin was seconded as an Ecology Lecturer on an international training programme by the Tropical Biology Association. His participation in this programme is likely to open new collaborative opportunities in the future. In 2018, the Centre was contracted by the Department of Environmental Affairs: Oceans and Coast, to provide water quality training to new recruits responsible for monitoring the quality conditions of beaches and estuaries across the country. Through Dr Odume, the Centre has also been involved in providing training on Environmental Water Requirements and Ecostatus Models to Staff of the Biodiversity and Environment Unit of the Lesotho Highlands Development Authority.

Thomas Alty and Vice-Chancellor's Award being presented to Ms Ntombekhaya Mgaba by the Deputy Vice-Chancellor: Academic and Student Affairs Prof Chrissie Boughey

I would like to congratulate Ms Khaya Mgaba, a Senior Technical Officer within the Centre for being awarded the Rhodes University Thomas Alty and Vice-Chancellor's Award for 2018. The Thomas Alty Award is made to a member of staff who is awarded a Masters or PhD degree (or equivalent qualification) while in the service of the University. This year, Ms Mgaba earned her MSc degree in Water Resource Science from within the Institute.

This year, the Centre welcomes Dr Nnadozie as a postdoctoral fellow. Dr Nnadozie is a Microbiologist by training, specialising in metagenomics and computational microbiology. Dr Nnadozie is working closely with Dr Odume to develop a research niche in microbial water quality within the Centre. The Centre currently does not undertake microbiological research and we see her coming as critical in expanding our research frontiers.

Dr Paul Mensah (front row, second from the left) immediately after a farewell gathering organised by the IWR.

Sadly, we also say goodbye to Dr Mensah who has been the anchor for our Ecotoxicology Research Group. Dr Mensah was instrumental in preparing the IWR for running the Environmental Water Management Honours programme in 2018. He has since relocated to Ghana to pick up an academic position at the University of Cape Coast. We wish him well in all of his future endeavours. Students within the Centre have remain extremely dedicated to their academic projects. Mr Frank Akamagwuna completed his MSc and will be graduating in the 2019 graduation ceremony, while Ms Notiswa Libala, Mr Matthew Weaver, Ms Margaret Wolff and Ms Qawekazi Mkabile have all reached advance stages of their research, nearing completion. I would like to congratulate Mr Dennis Choruma for being selected to attend and present at the summer school on Sustainability in the Food-Water-Ecosystem Nexus jointly organised by Makerere University and University of Bonn. The summer school was a great opportunity for Mr Choruma to network and meet with fellow PhD students, postdocs and senior academics in the field of sustainability research.

In 2017, we took a strategic decision to actively contribute to the training of professionals who are already working in the water sector. In 2018, the short courses programme did not happen because efforts were directed towards ensuring that the Environmental Water Management Honours programme ran smoothly within the IWR (details in the IWR Director's report). However, we are in the process of securing University's accreditation of a number of short courses for 2019. The short courses, including Environmental Water Quality, Adaptive Integrated Water Resources Management, Ecoclassification and Environmental Water Requirement, and linking RDM and SDC to Water policy and strategy will all be available in 2019. Interested students and professionals should watch out for the advert and/or approach the Centre as to exact date when these courses will be available. Drs Nnadozie and Ezenne are our short courses coordinators and have played leading roles in ensuring that the course materials are prepared and submitted for university's accreditation.

National, Regional and International influence

The Tsitsa Project remains a strategic entry point for UCEWQ research to contribute to addressing critical sustainability challenges in South Africa. UCEWQ staff and students through Prof Tally Palmer are leading the governance research group within the DEA-funded and led Tsitsa Project. They have been very active and have participated in a number of workshops and Science Management meetings where ideas regarding the project are shaped. Ms Wolff and Dr Palmer are members of the Tsitsa Project Strategic Advisory Committee.

On the international arena, UCEWQ continues to deepen her collaborative relationships with a number of strategic partners. This year, Dr Odume and his PhD student, Mr Dennis Choruma visited and spent two weeks at the International Institute for Applied Systems Analysis (IIASA). They used the period to receive training on two IIASA models: The Biogeochemistry BGC-MAN model and the Environmental Policy Integrated (EPIC) model.

Delegates at the Tsitsa Project Science Management Meeting, Hogsback, May 2018.

Mr Choruma is now able to apply these models to his PhD research project. The AfriAlliance Action Group on Ethics and IWRM led by Dr Odume is negotiating a special edition slot with the editor of the Water International journal to publish the Action Group's work on ethics and integrated water resource management. Such a special edition will allow the group to put forward some of the conceptual and practical work being done by the group. Last year, the Centre was invited to participate in a transformational learning workshop by the Institute of Environmental Systems Research at the University of Osnabruck, Germany. Following this invitation, in 2018 the Centre together with other partners in Germany and South Africa put together a proposal for a training workshop on transformational learning to be held in 2019.

As with previous years, our community engagement initiatives led by Dr Paul Mensah and supported by Ms Mgaba continue to flourish. The Centre took learners from Kingswood College on a mini-SASS5 demonstration in the Palmiet River just outside Makhanda (Grahamstown). Learners were exposed to the complexity of water quality challenges, and the responses of aquatic biota to water pollution. Our staff and students were also committed to the 2018 Scifiest Africa festival. Learners and visiting scholars were exposed to the research being undertaken within the Centre. I would like to express my gratitude to our staff and students who have remain committed to ensuring that we give back to the larger society.

Kingswood College students during Mini-SASS field trip

Partnerships, linkages and performance

Unilever South Africa remains the core founding partner of the Centre and we remain grateful for their support. The three-year MOA we had with Unilever SA comes to an end in 2018 and is now replaced by a two-year donation MOA from 2019-2020, with almost 50% funding cut. Nevertheless, we do appreciate this donation as this will strengthen the Centre's capacity to deliver on its research and postgraduate students training mandate. In the coming year, the Centre and Unilever SA will work collaboratively to address a number of water related challenges, particularly in the Klip River catchment in Gauteng. The Klip River faces serious water quality challenges, and we are happy that we will be able to work to contribute to addressing some of these challenges. Already, a baseline study has been completed. Last year, I indicated that we submitted a bid to host the ARUA Centre of Excellence in Water. The bid was successful and the IWR has been awarded the right to host the centre (see IWR Director's report for details). Our partnership with our industry partners remain strong. Assured Turnkey Solutions (Pty) Ltd and Scherman Colloty & Associates CC remain key strategic industry partners. Our staff and students continue to attend and present papers at both local and international conferences and workshops. Dr Odume presented a paper at the 2018 Annual conference of the Society for Freshwater Science in Detroit, USA. Ms Margaret Wolff attended and presented a paper at the 4th Global Change Conference in Polokwane, and Prof Tally Palmer presented a paper at the Adaptation Futures conference in Cape Town and an invited paper at the 2018 Climate Change conference in London.

Ms Notiswa Libala gave a presentation at the National Indaba on Ecological Infrastructure for Water Security jointly hosted by the South African National Biodiversity Institute (SANBI) and the Development Bank of Southern Africa. The Environmental Water Management Honours students all attended and presented at the 2018 conference of the Society of South African Geographers (SSAG). In 2018 the Centre graduated one PhD student, Dr Emmanuel Vellemu and three MSc students: Ms Khaya Mgaba, Ms Tia Keighley and Mr. Gareth Thomson. We expect the number of students graduating in 2019 to more than double. We continue to attract students from within and outside South Africa. However, we are unable to take all interested and qualified students because of limited supervisory capacity. Our intern programme has become a flagship programme for capacity development. In 2018, we welcomed an NRF-funded intern Ms Bawinile Mahlaba. Ms Mahlaba was with the Centre in 2017 as an intern sponsored by Prof Palmer. We are happy to have her back. While undertaking her internship, Ms Mahlaba was offer the opportunity to enrol for the Environmental Water Management Honours programme on a part-time basis. She has so far been commendable both as an intern and as a part-time student within the Centre. Ms Ntombekhaya Mti joined the Centre in 2016 and remained with us. She has acquired new skills in shrimp culture, water quality testing and Microsoft Excel. This year, we say goodbye to one of our previous interns, Mr Mzwanele Mkatali after obtaining an Honour degree in Chemistry from Rhodes. Our laboratories and cultures are in excellent condition and we continue to participate in the National Laboratory Proficiency Testing Scheme. I would like to express my deepest appreciation and gratitude to all staff and students of the Centre who have worked tirelessly to make 2018 a success.

Dr ON Odume, Director: UCEWQ

HYDROLOGY REPORT

Introduction

This year has been another busy year for hydrology within the IWR with some interesting projects undertaken and a few notable achievements from staff and students. Dr Jane Tanner has been working on a number of WRC projects on drought prediction, wetland restoration, and climate change, in addition to some interesting international collaborations with the University of Leeds, UK, and the Ben Gurion University of the Negev, Israel. Dr Sukhmani Mantel has been working on a large grasslands project together with Dr Anthony Palmer, as well as on a climate change project. Prof Denis Hughes remains active as professor emeritus, and, as well as working on numerous projects, has been documenting detailed guidelines for the models he has developed over the years. Dr Andrew Slaughter remains on his two-year visiting professorship at the University of Saskatchewan in Canada but continues to retain links to the IWR, both through student supervision and through contributions to projects.

Interesting achievements included Dr Mantel's South African rivers map (see annual report cover), which has been very well received with requests for a high-resolution map for professional use for Business Insider and a book on molluscs coming out next year. The Business Insider article on how the map came about can be read at the following link:

https://www.businessinsider.co.za/survey-to-figure-out-why-map-of-south-african-rivers-captivates-people- 2018-9

Soil and water resources specialist Dr Gloria Ezenne joined us on a post-doctoral fellowship from the University of Nigeria in April 2018. Dr Ezenne's expertise on evapotranspiration is assisting us in developing capacity within the Institute in the use of high-level field equipment that measures actual evapotranspiration and carbon fluxes (scintilometer and two eddy covariance systems). Purchased from an equipment grant applied for by Dr Anthony Palmer and Dr Mantel, the field equipment is highly specialised and the Hydrology group aims to expand their current research on evapotranspiration using this equipment.

The hydrology group ran a five-week honour's module on hydrology starting in September 2018 as part of the Environmental Water Management (EWM) Honours course. The course included surface water and groundwater hydrology, as well as the basics of hydrological modelling and uncertainty assessment. The course went remarkably well with Dr Tanner, Dr Mantel, Dr Ezenne and Prof Hughes all contributing. Four of the EWM honours students selected hydrology research projects and two of them will continue with further post graduate studies within the IWR. Dr Tanner, Dr Mantel and Dr Ezenne completed the University offered Catalyst course in May 2018 to prepare for the honours teaching. The course was remarkably helpful and without a doubt improved the quality of the hydrology module offered.

Capacity Building and Advocacy in Africa

The Hydrology Group continues to contribute towards building hydrological capacity in Africa, largely through the high volume of students from Sub-Saharan Africa. Although the Carnegie RISE programme for the Sub- Saharan Africa Water Resources Network (SSAWRN) came to an end in December 2016, the remaining programme funds still support five students from South Africa, Tanzania, Swaziland and Botswana. The programme has so far resulted in three MSc graduates and nine PhD graduates from Rhodes University, with a further two PhD students expected to graduate in 2019.

The Royal Society-DFID Africa Capacity Building Initiative CRuHM (Congo River User Hydraulic and Morphology) project continues to move forward. 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. Annual field trips focusing on carrying out large scale hydraulic and geomorphological science research on the main navigable channels of the Congo River are undertaken,

with the aim of addressing the severe lack of basic scientific knowledge and understanding in these water engineering fields for the world's second largest river.

This year the field trip was unfortunately cancelled due to concerns over Ebola, but a field trip training exercise was held instead.

Honour's field trip to the mountain drive catchment

The IWR currently hosts two PhD candidates from the DRC as part of this project, Mr Pierre Kabuya and Mr Gode Bola. In addition, the CRuHM project hosted IWR PhD candidate Mr David Gwapedza who attended and presented at a CRuHM workshop during March 2018 in Moshi-Tanzania. CRuHM project members agreed that that Mr Gwapedza also apply his sediment model (developed by Dr Slaughter) to the Congo River Basin and compare results with another CRuHM student. The workshop was also attended by Prof Hughes and PhD candidate Mr Kabuya.

As part of the African Research Universities Alliance (ARUA), the IWR has formed partnerships with other hydrology Centre's in Africa. In particular we are working on proposals with the University of Dar es Salaam, and Makerere University in Uganda.

PhD candidate Mr David Gwapedza at a filed trip training in Tanzania

Conferences attended

Dr Tanner and Dr Ezenne attended the biennial South African National Chapter of the International Association of Hydrological Sciences local conference at the Kruger National Park in September 2018. The theme of the conference was "The hydro-illogical cycle: predicting and managing droughts." Dr Tanner presented a paper on her work on groundwater drought as part of a Water Research Commission project on drought prediction, while Dr Ezenne presented work from Nigeria on increasing soil infiltration in rural small-scale farms using various types of mulches.

Field work training as part of CRuHM project

MSc student Ms Caitlin Smith attended the National Wetland Indaba in Kimberley, Northern Cape in October 2018 and presented a poster on her research into the hydrological functioning of palmiet wetlands in the Eastern and Western Cape of South Africa.

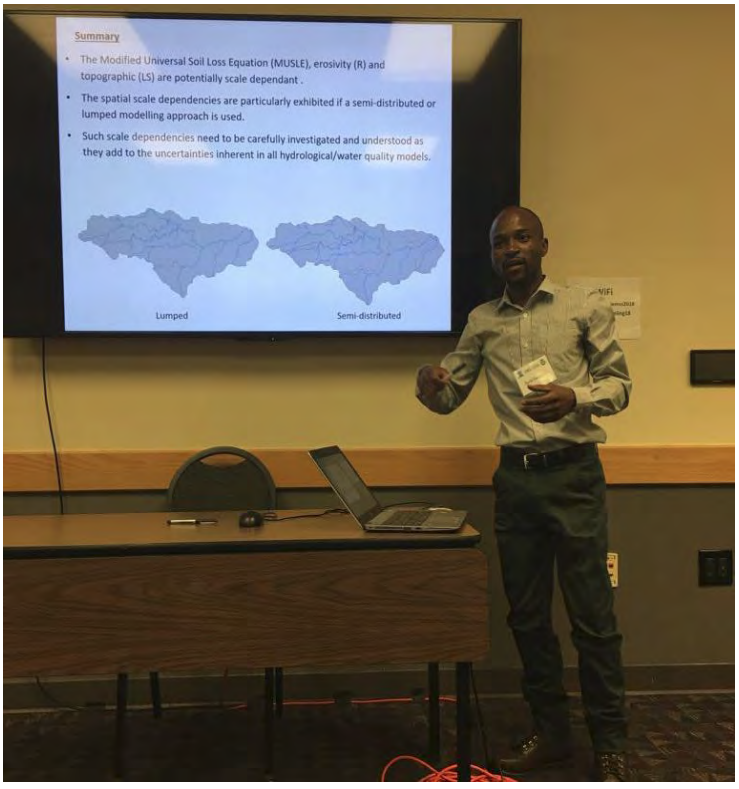
The theme of the conference was "Drylands and Wetlands: connecting and managing heterogeneity across landscapes". Endemic palmiet wetlands were a popular topic of research at the conference and Ms Smith's work has significantly contributed to changing perspectives on palmiet system functioning. She submitted her thesis in November 2018 and will graduate in 2019.

Dr Anthony Palmer, Dr Mantel and Ms Buhle Qawe Mkabile attended the 53rd Annual Congress of the Grassland Society of Southern Africa in Pretoria in August 2018 and presented on their work on the restoration of grasslands. Dr Tanner and Dr Mantel attended the Ecological Infrastructure Workshop which occurred after the Grassland Congress as they have a new project on Ecological Infrastructure starting in 2019.

Dr Mantel and Ms Margaret Wolff attended the Rhodes University Environmental Colloquium organised by Dr Rosa Klein in March 2018 and presented on the work that the IWR undertakes within the University. This Colloquium aimed to build collaboration between departments by identifying research streams that cut across departments.

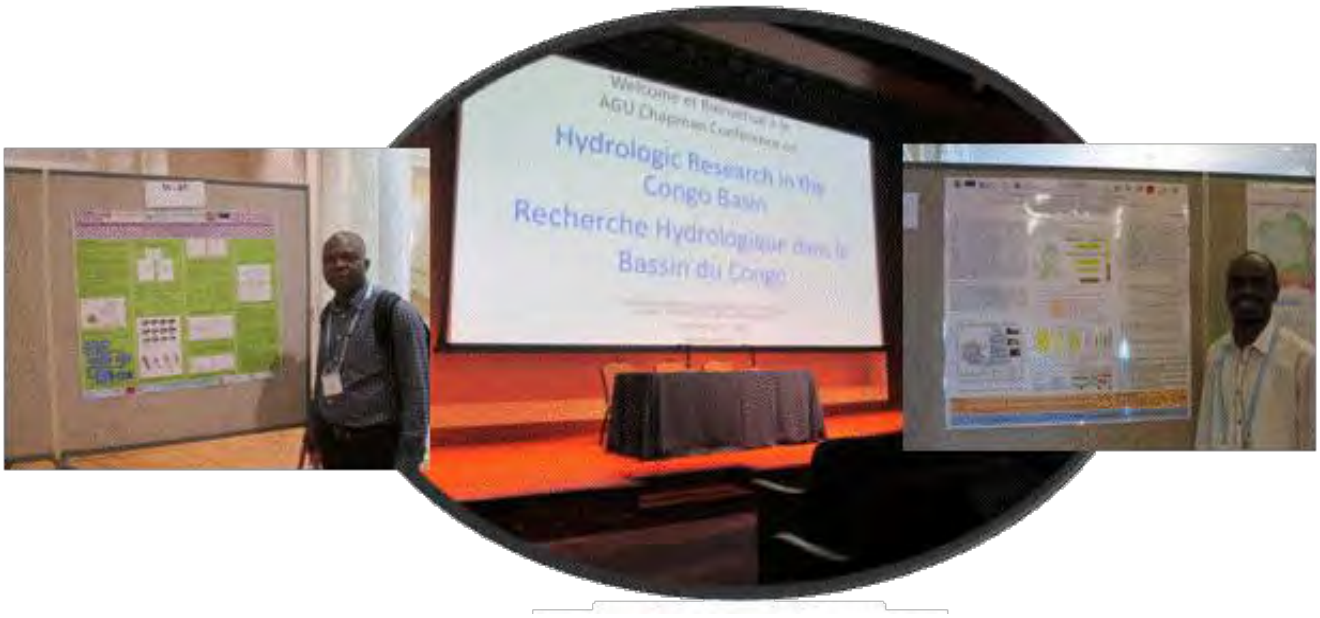
This is the last year that Dr Mantel is serving as the Vice President of the Freshwater Working Group (FWWG) of the Society for Conservation Biology (SCB). During the ICCB 2017 Congress, Dr Mantel and Dr Helen Barber- James of Albany Museum (a FWWG board member) developed CV guidelines for students and early career researchers and hosted a CV clinic at the 28th International Congress for Conservation Biology (ICCB) in Cartagena, Colombia. The informal feedback received from the students led them to work with the President of the FWWG (Dr Stephanie Januchowski-Hartley) to design a survey to gather feedback from students who attended the ICCB. The survey results generated some useful insights which are being converted into an article focusing on needs of graduate students and young professionals.

In June 2018, PhD candidate Mr Gwapedza attended the 9th International Congress on Environmental Modelling and Software (IEMS) at Colorado State University Fort Collins, USA. At the conference, he presented a paper titled 'Spatial scale issues associated with the application of the MUSLE'. The paper was subsequently accepted for publication in September. Mr Gwapedza attended the conference with his supervisor Dr Andrew Slaughter.



David Gwapedza presenting at the the 9th International Congress on Environmental Modelling and Software (IEMS

PhD candidate Mr Pierre Kabuya presented his work on the Congo River Basin at the 3rd International Conference on African Large River Basin Hydrology (ICALRBH) which was held in Algiers, Algeria from 6 to 9 May 2018. The conference hosted a special session on the CRuHM project, where Mr Kabuya, presented his work on the use of hydrological indices to constrain a rainfall – runoff model in the data scarce environment of the upper Congo River Basin. The conference also presented opportunities for various research collaborations in the Congo Basin including the development of data sharing protocols within the Congo Basin research communities and the implementation of the



PhD candidates Mr Pierre Kabuya (left) and Mr Gode Bola (right) presenting at th AGU/Chapman Conference on Hydrological Research in the Congo Basin held in Washington DC, USA.

Unesco FRIEND programme for the Congo Basin.

Lastly, both Mr Kabuya and Mr Bola attended the AGU/Chapman Conference on Hydrological Research in the Congo Basin held in Washington DC, USA from 25 to 27 September 2018. Mr Kabuya presented his work on the parameterisation of the hydrodynamic processes of the Kamalondo wetland systems in the upper Congo Basin, while Mr Bola presented on his research on constraining hydrological model outputs for the upper Kasai in the Congo Basin.

Notable contributions and achievements

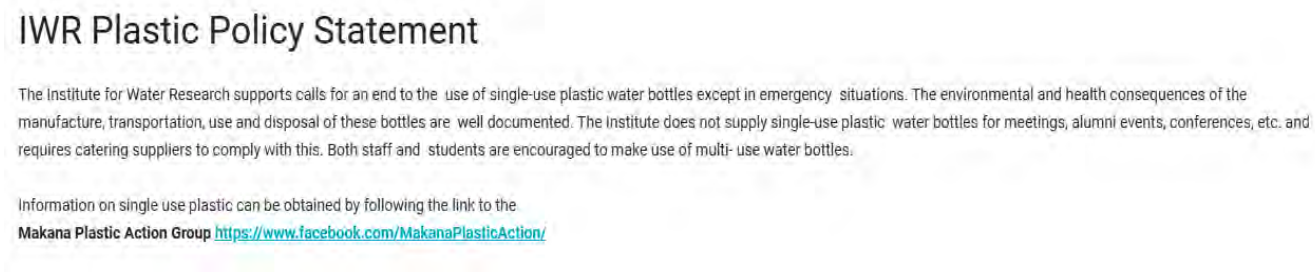
Dr Tanner was awarded a grant by the University of Montpellier to visit the IRSTEA Centre (National Research Institute of Science and Technology for Environment and Agriculture) in Toulouse, France. Dr Tanner will be travelling in February 2019 and will learn about agent-based modelling, and discuss potential future collaboration with the Centre.

Dr Jane Tanner presenting at the CatchX workshop

The hydrology group has been working with the University of Leeds on a project called CatchX which aimed to translate global hydrological data into easily downloadable information online. The IWR was responsible for testing the hydrological information which yielded some interesting results on commonly used global datasets (see project report). At a CatchX workshop in Cape Town Prof Hughes and Dr Tanner presented their findings to potential users of the platform.

Prof Eilon Adar from Ben Gurion University in Israel visited the IWR to give two talks and assist Ms Caitlin Smith in her modelling work. Ms Smith is using a mixing cell model developed by Prof Adar for her MSc research. Prof Adar holds the Alain POHER Chair in Hydrogeology and Arid Zones and is one of Israel's leading researchers in water sources, use and technology. Prof Adar has developed a mixing cell model which uses water chemistry information to trace/identify sources of water recharging/discharging from groundwater aquifer systems. At the IWR we have been successfully using the model to trace both surface water and groundwater movement into wetland systems and are looking forward to taking this work forward in 2019.

This year also saw the birth of the Makana Plastic Action Group (MPAG; headed by Mr Tim Bull of Grahamstown Residence Association, Dr Harold Gess of Journalism and Media Studies [JMS], Ms Margaret Wolff and Dr Mantel of IWR, and Ms Sarah Hanton of VG School, amongst others). MPAG is a sub-committee of WESSA (Wildlife and Environment Society of South Africa) Grahamstown and its mission is to reduce the use of single-use plastic in Makana through education and by highlighting businesses in the area who are using substitutes to reduce plastic waste or giving refunds to people who are bringing in their own take away containers (https://www.facebook.com/MakanaPlasticAction/). Ms Margaret Wolff and Dr Mantel have been involved in spreading the message at Rhodes and the IWR have followed through in the footsteps of JMS to adopt a Plastic Policy Statement to reduce single-use plastics particularly during events organised by the Institute.



IWR Plastic Policy Statement

The Institute for Water Research supports calls for an end to the use of single-use plastic water bottles except in emergency situations. The environmental and health consequences of the manufacture, transportation, use and disposal of these bottles are well documented. The institute does not supply single-use plastic water bottles for meetings, alumni events, conferences, etc. and requires catering suppliers to comply with this. Both staff and students are encouraged to make use of multi- use water bottles.

Information on single use plastic can be obtained by following the link to the
Makana Plastic Action Group https://www.facebook.com/MakanaPlasticAction/

Mr David Forsyth has been running a python course for staff and students the entire year which has been very valuable for the hydrology group, in terms of data management and use. In addition, Mr Forsyth has been producing online videos in the use of the various models the IWR has produced. This has been hugely valuable in increasing support for the use of the models worldwide.

Hydrology PhD candidate Mr David Gwapedza is the IWR student representative and has been nominated and elected to be the president of the RUSDASM society - a society of Adventist students at Rhodes University.

On the Horizon

The Hydrology Group submitted a number of proposals in 2018, and while we have not yet had a response from all of them, we will be starting two new WRC projects on Ecological Infrastructure (led by Dr Mantel), and on model comparison (led by Dr Tanner). In addition, a new collaboration with the Fresh Water Research Centre (FRC) in Cape Town has resulted in one successful project on the ecological Reserve, and we are through to the second stage for a large UK funded Darwin proposal with the XFRC. In addition to our ongoing existing projects, we will be continuing to run the honours hydrology module and hope to welcome back Dr Slaughter once his visiting professorship has concluded.

Once again, a big thank you to all the staff and students within the Hydrology Group who have contributed to such a successful year with their hard work, enthusiasm and loyalty.

Dr JL Tanner: Head of Hydrology

HYDROLOGY PROJECTS

DETERMINING THE HYDROLOGICAL FUNCTIONING OF THE PALMIET WETLANDS IN THE EASTERN AND WESTERN CAPE OF SOUTH AFRICA

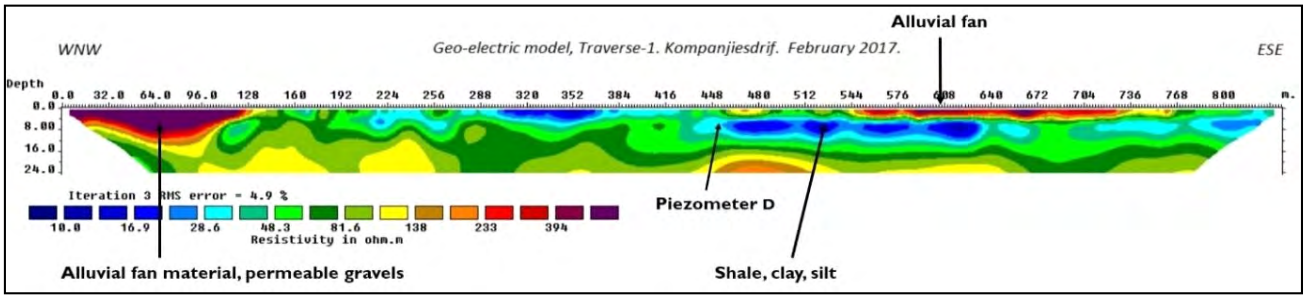
Sponsor: Water Research Commission
JL Tanner and F Ellery
Project dates: April 2016 to November 2018

This project successfully concluded in November 2018 with some interesting outcomes. The WRC have requested policy and ministerial briefs be drafted as the study outcomes indicate that current restoration efforts of palmiet wetlands are actually having a detrimental effect on long term wetland health and rehabilitation. The project was commissioned as endemic palmiet wetlands in the Eastern and Western Cape are particularly threatened wetlands, and due to their high water and sediment retention abilities, this has potentially serious consequences for water security in many towns in their catchments, including cities such as Port Elizabeth. Key threats to the wetlands includes gully erosion, clearing for agriculture and alien vegetation. Despite large investments by the State in wetland restoration, serious knowledge gaps in our understanding of their wetland structure and function remain, particularly in the hydrological functioning of these systems.

Prionium serratum (Palmiet) is a robust plant with stems up to 2 m tall (Boucher and Withers, 2004). Palmiet is endemic to the nutrient poor Table Mountain Group (TMG) sandstones and Natal Group sandstones and grows in dense stands that impede river flow, forming wetlands. It is thus known as an ecosystem engineer. This project took a multidisciplinary approach which looked at the geomorphological, hydrological and ecological factors that underpin and sustain these wetland ecosystems.

An instrumented study site within a relatively pristine Palmiet wetland located on the upper Krom River catchment within the Eastern Cape was set up. Piezometers were installed and monitored along with boreholes, and river water quality. Geophysics (Electrical Resistivity Tomography) was carried out and a number of models were set up.

The downstream part of the Krom River Kompanjies wetland showing the erosion control structure and the severe erosion downstream of the structure.



Results of ERT survey demonstrating preferential flow paths (in red/purple) that contribute groundwater to the wetland from the steep sided mountain aquifers.

The conclusions of the study can be summed up in the following paragraphs. The hydrological functioning of palmiet wetlands is closely linked with high sub-surface discharges typically found within TMG aquifers. The palmiet wetlands appear to be sustained by significant amounts of sub-surface water (both groundwater and interflow) moving through preferential flow paths in the alluvial fans, which are in turn sustained by groundwater discharge from the surrounding sandstones and quartzite's of the Nardouw Subgroup and Peninsula Formation. This conceptual model indicates that a consistent water supply is a palmiet system driver, and a key component of palmiet wetland formation. The wetlands clearly retain a significant amount of water, leading to the maintenance of prolonged flows, and a larger baseflow. However, we suggest that the occurrence of palmiet as the dominant species in this wetland is due to the sustained low flows related to catchment geology and high hydrological connectivity between the catchment and the wetland that is enabled by flow paths that allow the free flow of water from the catchment to the wetland.

Palmiet has a thick system of fibrous roots that grow significantly deeper than other similar wetland plants (sometimes up to five metres deep). Its deep rooting system appears to play an important role in the ecosystem functioning of the plant and its ability to withstand heavy floods that are characteristic of the TMG geology. The palmiet plant is able to trap significant quantities of sediment and the long palmiet stem can withstand being buried in metres of sediment as the crown of the plant will emerge.

A key feature of Palmiet wetlands is that they generally have high slopes for their discharges, and therefore are vulnerable to collapse via erosion. The geomorphological component of this investigation lead by Prof Fred Ellery from the Geography Department, demonstrated that collapse may be a result of natural processes which departs radically from the widely held perception that wetland degradation in the form of gully erosion is due to anthropogenic influences alone. Extrinsic factors such as poor land management may accelerate natural gully formation, but erosion through gullying may also result from intrinsic factors. The volume of sediment found within the wetlands (numerous sand lenses and filled gullies) indicates that palmiet traps sediment during high flow events, creating deposits of sediment which has freshly moved from the catchment and is protected from dissolution diagenesis within the wetland (Pulley et al., 2017). The study demonstrated that stream power (modelled using CAESAR-Lisflood), in addition to localised longitudinal slope increases (due to sediment deposition by numerous alluvial fans), can result in the initiation of natural erosion gullies.

Pulley et al. (2017) dated sediment from these gullies at between 470 and 7060 BP indicating that these gullies were a part of system functioning prior to the introduction of European farming. Pulley et al. (2018) also identified that palmiet wetland erosion is key to establishing new wetland habitats downstream of the eroded wetland reach, by reducing the longitudinal slope of the river. A large portion of the eroded sediment therefore is deposited just downstream of the original erosion point and does not travel far downstream (therefore the erosion is not a significant risk to the Churchill dam).

In summary, the research concluded that gully erosion, is a natural and important part of the Palmiet System functioning, and that high groundwater discharge typically found within the Cape fold belt geological environment is key for Palmiet formation.

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

Sponsor: Water Research Commission
JL Tanner and DA Hughes
Project dates: April 2017 - March 2020

Effective drought early warning systems are an integral part of efforts worldwide to improve drought preparedness. This project is aimed at developing an early warning system with the objective of providing catchment-based assessments of developing drought situations for southern Africa. Triggers for specific mitigation and response actions are often unreliable because of the inadequacy of detection tools and inadequate linkages between indices and impacts. Integrated assessment products are preferred, but few attempts have been made to integrate meteorological and hydrological information into a single product for purposes of detecting and tracking drought conditions and development, hence this project will attempt to integrate the information and present it in an accessible manner.

Specific aims include:

1. Identify primary sources of hydrological (streamflow and groundwater) predictability and their relative influence on seasonal and annual hydrological predictability,
2. Develop a hydrological monitoring system that provides consistent and reliable national information on daily or weekly time scales,
3. Identify and develop hydrological drought indicators and thresholds for major dams, rivers and aquifers for different drought phases, and link these to the early warning system,
4. Develop an operational integrated early warning (real-time or near real-time) system for hydrological drought monitoring and prediction.

A Drought Early Warning System (DEWS) is important since it will allow for early drought detection, improved and proactive response to drought, trigger actions within a drought management plan, act as a critical mitigation action and provide foundation for a drought plan. The project is using the modified Pitman Model together with forecasted climate data (3 to 6 months in advance) to predict hydrological drought for both surface water and groundwater resources. Currently the project is in its second year and we are grappling with ensuring the climate data provided is reliable and useable. An MSc student (Phatsimo Ramatsabana) supported by RISE is contributing to the project by focusing on the prediction of groundwater drought.

ESTABLISHING RESEARCH GROUP: ONE RESOURCE

Sponsor: The Carnegie Corporation of New York through the Science Initiative Group's (SIG) Regional Initiative in Science and Education (RISE) program.
JL Tanner
Project dates: August 2016 ongoing

The SIG RISE program is focused on enabling sustainable research groups in Africa with the capacity to pursue collaborative projects that make unique and impactful contributions to the advancement of scientific and engineering knowledge. The grant has contributed towards a new research group focused on increasing the awareness of the importance of surface water and groundwater interactions in Africa.

The groups' specific aims include:

1. Foster stronger links between surface water and groundwater hydrologists,
2. Education and capacity building in the field of surface and groundwater interactions,
3. Identify key research sites and potential funders to undertake large scale investigations into significant and regionally important sites with strong interactions between surface water and groundwater.

A group launch and workshop was held in Entebbe, Uganda in August 2017. The research group was named "One Resource" and is made up of hydrologists, hydrogeologists and vadose zone specialists who aim to carry out research on the interactions between surface water, the unsaturated (vadose) zone and groundwater. Research partners are located throughout Africa to ensure that the research is focused on Africa and its unique environments and issues. Since the group's launch, additional key members have joined and Dr Gloria Ezenne, a Rhodes University post-doctoral fellow has taken over some management functions of the group. A review paper on the current status of surface water and groundwater interactions in Africa is currently being written by the group.

CATCHX PLATFORM

Sponsor: UK NERC-Innovations
JL Tanner and DA Hughes
Project dates: January 2017- November 2018

CatchX is a NERC-Innovations project which has translated existing scientific data from global models and remote sensing products into a web platform. CatchX aims to enable decision makers at a river catchment level to have access to the latest cutting-edge information to address urgent water resource challenges faced all over the world. The project is in collaboration with the Earthwatch Institute, whose aim is to engage people worldwide in scientific field research and education to promote the understanding and action necessary for a sustainable environment.

The platform will improve access, or provide access for the first time, to standard water balance information at a local catchment level globally, without the need for complex GIS or hydrological modelling skills. This will not only allow non-expert users access to hydrological information, but also provides meaningful, locally relevant, visualisation of these data for decision making.

The platform will deliver catchment characterisation reports, annual and seasonal water balance information and natural stream flow estimates. These can be used to; inform equitable water resource allocation decisions, identify high water-risk catchments for prioritisation planning, quantitative analysis of impacts on natural resources, and provide a hydrological contextual understanding for water stakeholders that might not be available otherwise.

Dr Tanner and Prof Hughes were responsible for testing the new platform with water professionals in South Africa. The aim was to validate the platform outputs with local data, understand how useful the platform is from a user perspective, and see if the platform can be adapted to include local data in the future. The testing revealed that although the rainfall and evapotranspiration data seemed to be reliable and useable, the runoff data produced by the eight global hydrological model were highly uncertain with some outputs being totally unreliable. The web-based platform which will go live in December 2018 has been updated with the relevant information.

CONGO RIVER USER HYDRAULICS AND MORPHOLOGY (CRUHM)

Sponsor: Royal Society – Department for International Development (DFID) Africa Capacity Building Initiative
DA Hughes
Collaborators: (1)University of Bristol, School of Geographical Sciences, Bristol, United Kingdom, (2)University of Kinshasa, Dept. Natural Resources Management, Kinshasa, Congo, (3) University of Leeds, Leeds, United Kingdom, (4)University of Dar es Salaam, Dar es Salaam, Tanzania
Project dates: July 2016 - July 2021

There is a lack of knowledge about water resources of the Congo River Basin. These gaps hinder management strategies necessary for developing water resources services and also for addressing impacts of land use and climate change. The CRuHM project is an initiative for research and capacity building in water resources of the Congo River Basin. It is led by a consortium of partner institutions in

Sub-Saharan Africa and the United Kingdom (UK). The overall objective of the CRuHM initiative consists of carrying out large scale hydraulics and hydrological science research on the main channels of the Congo River in order to address the severe lack of basic knowledge and understanding, in support of socio economic benefits with regard to water resources services such as navigation and hydropower. Further information is provided in Mr Pierre Kabuya's student report.
This year the second field work campaign was postponed to 2019 due to the Ebola outbreak in the DRC. Instead the project team carried out field work training and workshopping, in addition to attending a number of conferences and meetings (see annual report and PhD candidate Pierre Kabuya's stdent report).

Field work training by the CRuHM team

IMPACTS OF CLIMATE CHANGE INTO THE DETERMINATION OF ECOLOGICAL RESERVE

Sponsor: Water Research Commission
JL Tanner, SK Mantel , AR Slaughter, NJ Griffin, and MG Wolff
Collaborators: Ms Pumza Dubula (PhD student), Dr Piotr Wolski (Environmental and Geographical Science, University of Cape Town), South African specialists on macroinvertebrates (TBD), fish (Dr Bruce Paxton, Freshwater Research Centre), riparian (Dr James MacKenzie) and geomorphology (Dr Benny van der Waal, Rhodes University)
Project dates: April 2018 – March 2019

This project (a solicited WRC proposal) aims to evaluate the impacts of climate change into the determination of ecological Reserve. Environmental water requirements (EWR), or 'ecological Reserve' flows are the only 'right' to water, in addition to the Basic Human Needs Reserve under South Africa's National Water Act (NWA, Act 36 of 1998). The vulnerability of freshwater resources to the impacts of climate change has been recognised by the Intergovernmental Panel on Climate Change (IPCC Fourth Assessment). The Water Research Commission has also placed emphasis on the need for research on climate change with potential consequences on water resources through increased temperatures and increased hydrological variability (surface and groundwater). These are anticipated to manifest as changes in seasonal rainfall patterns, potential flooding and drought, and sea levels changes in the coastal areas. Thus, the motivation behind the project is the knowledge gap of the impacts of climate change on the ecological Reserve that will be determined using the Habitat Flow Stressor Response defined in the Revised Desktop Reserve Model.

The specific aims of the project are:
1. Determine the impacts of climate change on ecological reserve.
2. Assess the resulting impacts of the increased variability.
3. Identify and evaluate the adaptive response options.

The project has two focal catchments: Doring River in the Western Cape and Crocodile River in Mpumalanga. Doring is a naturally seasonal river that lies to the east of the Olifants River in the Western and Northern Cape. Scenarios of climate change indicate that the region may receive up to 15% less rain in the next 50 to 100 years. The Clanwilliam Yellowfish (Labeobarbus capensis), a vulnerable endemic, can be found in the river as one of eight endemic fish in the system, making it a fish biodiversity hotspot. The Crocodile is a relatively large river basin and one of the most economically productive in the country. The River is characterized by a broad range of riverine habitats ranging from cold mountains streams of Drakensberg to the slow flow warm water where the river meanders the Lowveld. As a result of the diverse habitats the river is also one of the most biologically diverse systems in South Africa with at least 49 fish species occurring.

The project team has received climate projections (rainfall and evaporation) for the area from Dr Wolski for Representative Concentration Pathway (RCP) 2.6, 4.5, 6.0 and 8.5 (with 43-100 GCMs under these RCPs). Dr Tanner has setup the Doring hydrological model and is in the process of inputting these projections to obtain the future hydrology before comparing it with the ecological Reserve requirements. Dr Slaughter will be generating simulations of future water quality. Once completed, all these outputs will be sent to the four specialists to assess the impacts and suggest adaptive responses to these changes.

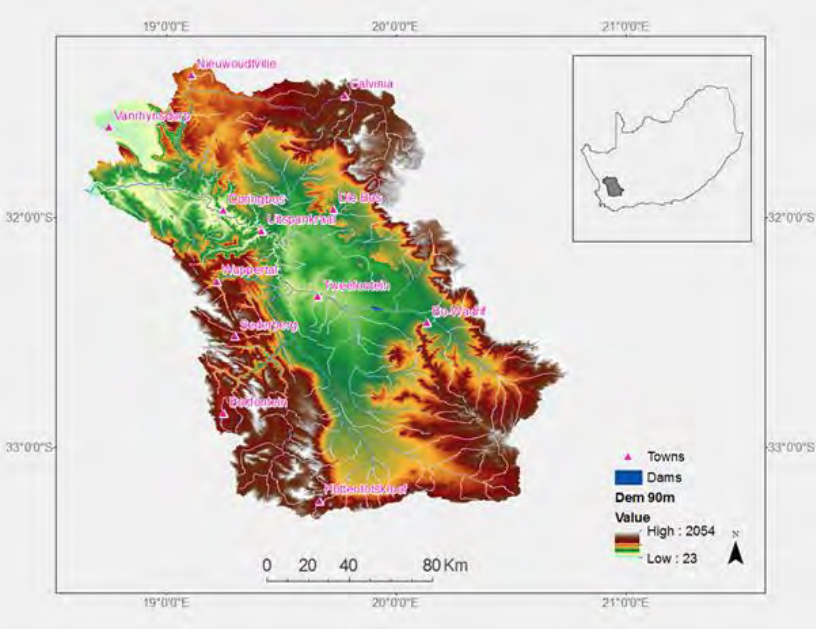


Figure 1 Map of Doring River catchment in the Western Cape.

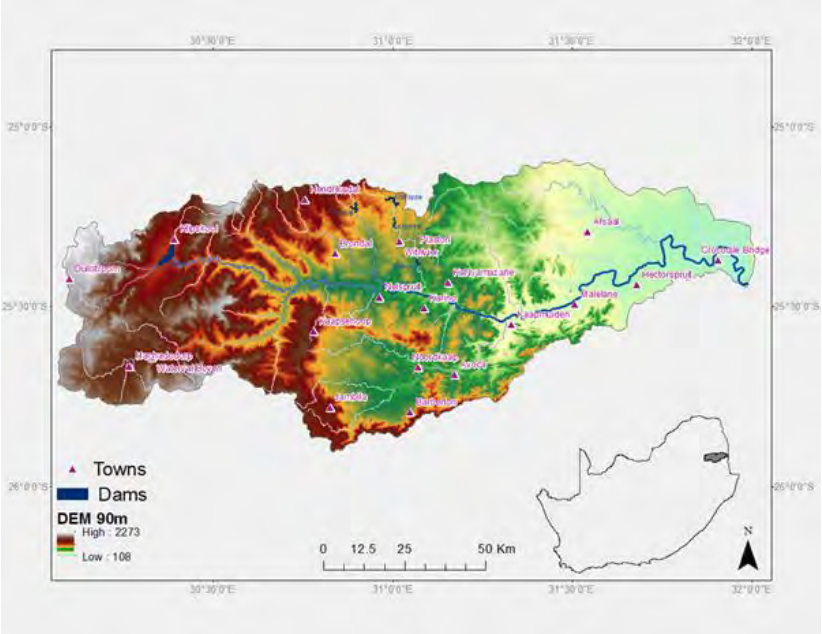


Figure 2: Map of Crocodile River catchment in Mpumalanga.

DEVELOPMENT AND BENCHMARKING OF A DECISION SUPPORT FOR AQUATIC TOXICITY TESTING: TECHNOLOGY TRANSFER AND IMPLEMENTATION OF THE TOXICITY TESTING GUIDELINE / TECHNOLOGY

Sponsor: Water Research Commission
NJ Griffin, ON Odume, PK Mensah and CG Palmer
Project dates: 1 April 2015-30 December 2018

In South African water management, water quality and ecological health are addressed using a combination of chemical testing, biomonitoring and toxicological testing. The application of chemical testing of surface water and effluent is well established. Routine biomonitoring has more recently been established in the River Health Programme (now the River Eco-status Monitoring Programme (REMP)) and in Water Use Licenses. Although toxicological testing has had a place in Water Use Licensing, its application has lagged, particularly in resource monitoring. Recent reviews have identified sufficient short-term capacity for testing at independent laboratories, most of which are not accredited and have varying levels of quality control. It is envisaged that an increase in accredited capacity will follow increased demand consequent on greater application of routine toxicological testing.

In 2014 – 2015, revisitation of the application of toxicology in Water Use Licensing led to the production of a tool, the Integrated Water Use Application Bioassay (IWUAB) Toolkit that enabled selection of appropriate toxicological tests for the licensing process. Test selection and test timing is guided by a number of parameters broadly related to the industry or user, the affected river condition, and historic data and experience with testing. The IWUAB aims to address identified capacity gaps in the application of routine toxicity testing in South Africa.

The current project has pilot-tested the IWUAB and provided training to and gather feedback from practitioners in order to refine the tool. Sampling and analysis in four identified sectors (municipal, mining, industry and agriculture) is complete. Analysis of data has revealed that despite some high effluent toxicities (particularly in municipal WWTW effluent), impact on instream toxicity was often limited. This seems to be a function of dilution in larger rivers, and interaction with upstream river toxicities. Another common red flag raised in the results was where downstream toxicities exceeded a fixed standard set by the IWUAB. In most of these cases, this seems to have been a result of high upstream toxicities prior to effluent discharge, rather than the toxicity of the effluent itself (in rarer examples, effluent discharge seemed to improve resource quality). This level of resource toxicity was not anticipated and is indicative of the serious challenges faced in sustainable management of South African water resources.

The varied results from the range of tests applied indicate the value of using multiple tests to assess river and effluent toxicity, as tests on different taxa often indicated different levels of toxicity.

Initial analysis has raised questions as to the cost of sampling at the intensities recommended by the IWUAB. Larger operations will find the cost trivial compared to overall operating costs, but smaller, and in particular small-scale and emergent agriculturalists or business may find the cost of testing to be more challenging.

The draft Final Report for this project has been assessed and the final report is currently being finalized. Output from the project will contribute to refining the IWUAB and contribute to its application in the use to toxicological testing in water management in South Africa.

DEVELOPMENT OF MACROINVERTEBRATE TRAIT-BASED APPROACH FOR ASSESSING AND MANAGING ECOSYSTEM HEALTH IN SOUTH AFRICAN RIVERS – INCORPORATING A CASE STUDY IN THE TSITSA RIVER AND ITS TRIBUTARIES, EASTERN CAPE

Sponsor: Water Research Commission
ON Odume
Collaborators H Dallas (Freshwater Research Centre)
Collaborating organisation: Department of Freshwater Invertebrates, Albany Museum, Grahamstown.
October 2015 - March 2018

South Africa has made considerable progress in the development of tools for managing aquatic ecosystem health. Biomonitoring is one of the approaches and tools used for assessing the health of freshwater ecosystems in South Africa. Current approaches as well as tools developed to date focus mainly on assessing aquatic ecosystem structure through taxonomic analysis of resident biota. Globally, there is a growing recognition that explicit incorporation of traits into existing tools and approaches, or the development of trait-based approaches (TBA) could enhance the diagnostic and predictive capacity of biomonitoring tools, and could provide a clear link between ecosystem structure and function.

The TBA, which is rooted in theoretical ecology, holds promise in that the inclusion of traits into existing biomonitoring approaches and tools, or the development of new tools based on the TBA, could enhance the science and practice of biomonitoring. Specifically, in the literature, the following have been identified as the potential advantages of explicit consideration of traits in riverine ecosystem biomonitoring:

- Prediction of biodiversity assemblage response to effects of aquatic stressors and other human-induced activities.
- Linking ecosystem structure and function.
- Providing insight into biota resource use, niche partitioning, and potential effects of biodiversity on ecosystem functioning.
- Providing insight into the consequences of potential loss of keystone species and ecosystem engineers within a given system.
- Predicting the biological impact of introducing non-native biota into an ecosystem.
- Providing impact diagnosis through the underlying trait-environment relational processes.

Despite the global recognition of the potential contribution of the TBA to freshwater biomonitoring, the approach is not well-established in South Africa. This project therefore provides a conceptual framework and makes a case for the TBA in the context of aquatic ecosystem health management in South Africa. The project deals only with macroinvertebrates in freshwater systems, with particular attention to riverine systems. While the concept of traits is relevant to all taxonomic groups and ecosystems, only riverine ecosystems and macroinvertebrates are dealt with in the current project.

Project Aims

The specific aims of the project are:

i) To develop a comprehensive framework for the application of traits that enable both structural and functional assessment of aquatic ecosystem health.
ii) To develop an updatable database of South African aquatic macroinvertebrate traits.
iii) To provide a clear case study of the utility of the trait approach in both functional and structural assessment of a selected South African riverine ecosystem.

Methodology and approach

The project combines desktop study, workshop and a case study to fulfil its objectives. An initial literature review of the subject matter was undertaken, which was then brought forward at a specialist workshop, were critical concepts and issues were interrogated more broadly in relation to developments in aquatic ecology and more specifically in the context of South Africa. Ideas generated from the workshop were then taken further into the conceptual framework, on the potential application of traits in freshwater biomonitoring in South Africa.

A systematic approach was followed in compiling the database. The Freshwater Invertebrate Database of Dr Jenny Day, and the Albany Museum freshwater invertebrate database, were used as the primary information sources for macroinvertebrate species occurring in South Africa, and trait information was compiled from the literature. Experts, particularly at the Albany Museum in Grahamstown, were consulted during the trait information compilation. The last objective was achieved through a case study in the Tsitsa River and its tributaries within the Mzimvubu catchment, Eastern Cape, South Africa. The purpose of the case study was to demonstrate the potential utility of the TBA in South Africa. To realise this objective, the Tsitsa River and its tributaries including the Pot, Little Pot, Qurana Rivers as well as the Millstream were selected for the study. These rivers are differentially impacted by sediments, offering an opportunity to use the TBA to evaluate the responses of macroinvertebrates to a specific stressor: sedimentation. Field work, which include the sampling of macroinvertebrates, and collecting and analysing water samples for physicochemical variables: dissolved oxygen, electrical conductivity, nutrients, temperature and turbidity as well as for sediment particle size characteristics, were undertaken seasonally from August 2016 – April 2017. All data collected were subjected to appropriate statistical analysis.

Results and Discussion

Aim 1

For the full potential of the TBA approach to be realised in South Africa, it was necessary to provide conceptual clarity and a framework for the application of traits in freshwater ecosystem management. We defined a trait as any feature or characteristics measurable at the individual level, from cell to the whole organism that defines and characterises the organism in terms of its biology (e.g. morphology, biochemistry, physiology etc.), and behaviour. This definition implies that i) a trait is measured at the level of the individual in terms of biological organisation; ii) a trait can be biological as well as ii) behavioural. The so called ecological traits are excluded from the definition because these are products of the interaction between the organism and its environment and not attributes inherent in the organism, though ecological preferences are included in the compiled trait database. We presented a framework for the potential use of traits for the assessment of ecosystem functioning, and which could also guide further thinking and developing of modelling tools for predicting assemblage response to aquatic stressors. The proposed framework assumed a step-wisely hierarchical approach in determining the potential occurrence of a taxon at each spatial scale below the level of the region. The framework assumes that at each spatial scale, the environmental characteristics (filters) interact with the taxon through its traits to determine the taxon's potential occurrence at the subsequent lower spatial scale. The subsequent potential occurrence of a taxon is determined by not a single trait but by a combination of traits interacting with each other and the external environment.

We propose ways in which trait information can be integrated into Resource Directed Measures such as Resource Quality Objectives (RQOs) and into river health monitoring tools such as the South African Scoring System version 5 (SASS5) and the river ecostatus model, Macroinvertebrate Response Assessment Index (MIRAI). In terms of the application of trait in water resource management within resource directed measures (RDM), we recommend the inclusion of traits in resource quality objectives (RQOs). The nature and type of traits information included in any RQO will be case specific, depending on the water resource, the management class and the surrounding impacts. The trait information included in RQOs should at least address one or more of the following:

i) provide diagnostic and predictive trends in terms of biological attributes as well as the main water quality stressors likely to influence the RQOs. See an example of a trait-based RQO statement:

> In an effluent-receiving water resource, where such effluent is impacting on and still likely to impact on the biological attributes in the future, a good example of a trait-based RQO statement would be "the percent of non- air-breathing, gill-bearing taxa may not decrease by more than a certain percent relative to the reference condition". The trait-based RQO statement provided here is diagnostic because the possession of gills and the capacity to breathe atmospheric oxygen are directly linked to oxygen depletion, which can be occasioned by wastewater effluent discharges". The statement is equally predictive because a continuous discharge of wastewater

effluent into a water resource is likely to cause physico-chemical conditions unfavourable to gill-bearing macroinvertebrate taxa, which are non-air breathers.

ii) Provide an indication of trait-linked ecosystem functioning that needs to be protected and maintained in the desired class. See example below:

"Ecosystem functioning such as nutrient cycling can be integrated into RQOs indirectly through traits that are directly related to nutrient cycling. An example of a trait-based RQO statement linked to ecosystem functioning such as nutrient cycling could read "the proportion of taxa with mouth-parts adapted for grazing and shredding may not decreased by more than a determined percent at the impacted sites relative to a reference condition". Adaptation for grazing and shredding is directly linked to breaking down of coarse organic materials vis-à-vis nutrient cycling in the aquatic ecosystem.

Aim 2

An updateable trait database for South Africa macroinvertebrate is compiled. The database contains information on 40 trait categories and 204 traits attribute/modalities. Of the 40 trait categories included in the database, 12 are biological, 12 behavioural and 16 ecological preferences. The database is designed to accommodate taxonomic flexibility and in this regard, trait information is entered at multiple taxonomic levels: family, genus and species, allowing researchers working at multiple taxonomic resolutions to retrieve relevant information. There are still many gaps in the database, but this effort is significant and represent an attempt to synthesised available trait information on South Africa macroinvertebrates, which is then make public.

Aim 3

Based on the sediment particle size distribution of the river systems studied, four distinct site groups emerged: Group 1 (Tsitsa upstream site and Qurana River), Group 2 (Tsitsa downstream site and Millstream upstream site), Group 3 (Pot River, up- and downstream sites, and Millstream downstream site) and Group 4 (Little Pot River). These site groups formed a clear gradient of sediment impact in this order: Group 1> Group 2> Groups 3 and 4. Sites in the Tsitsa, Qurana and Millstream Rivers were more impacted by sediments compared with those in the Pot and Little Pot Rivers. The Pot and Little Pot Rivers drain well-managed catchments that are largely own by private individuals, while the Tsitsa River catchment is largely subject to communal land practices.

Using a novel TBA, we classify South Africa macroinvertebrates into four vulnerability classes in relation to the potential sediment effects in riverine ecosystems. Twenty-five macroinvertebrate families were designated highly vulnerable and 22 designated as vulnerable. Twenty-seven families were designated as resilient to or tolerant of sediment impact, while only 18 families were described as being highly resilient to or tolerant of sediment influence in riverine ecosystems. We also attempted to predict the macroinvertebrate assemblage response to sedimentation using relative abundance and frequency of occurrence (FROC) data. High correspondence between predicted and observed data was recorded for the sediment-impacted sites groups compared with the least impacted control sites. For the least impacted sites, all taxa whether vulnerable or resilient occurred frequently and in some instances in high abundances. Further, the majority of the taxa that were significantly associated with the sediment-influenced sites through the Pearson point-biserial correlation analysis, were designated as either tolerant or highly tolerant of sediment effects, supporting our classification system.

A new sediment biomonitoring index (SBI) using the TBA was developed, which we recognised as version 1. The index proved responsive to sediment stress in the Tsitsa River and its tributaries where the case study was undertaken. Based on the results of the SBI, the rivers within the study catchments ranged between being minimally sedimented and moderately sedimented. The index has potential as a stressor-specific biomonitoring tool in South Africa. It was weakly correlated with SASS5 Scores and ASPT values, suggesting that the two indices are responsive to different stressors, with SASS5 being a more general water quality index, and the SBI designed specifically for sediment stress. However, although SBI holds potential as a stressor-specific biomonitoring tool in South Africa, it requires further testing across the country. Usual SASS5 data can be analysed in terms of the SBI using the SBI calculator spreadsheet that comes with this report. It is envisaged that such testing would elicit areas for further

refinement and improvement in a subsequent version. The SBI range from 0-100 and the benchmark values are as follows: >70 = unsedimented, >50 – 70 = minimally sedimented, >30 – 50 = moderately sedimented, >10 – 30 = seriously sedimented, and 0 – 10 critically sedimented. We developed an automated spreadsheet to allow for easy use, testing and application of the SBI as a sediment-specific tool in South Africa. The spreadsheet comes with this report.

Ms N Mti preparing documents for meeting

Conclusion

This study is one of the first in South Africa to investigate the potential for the adoption of a trait-based approach (TBA) that can add value to the science and practice of biomonitoring in South Africa. We have attempted to provide conceptual clarity regarding key concepts relating to the potential application of the TBA. A conceptual framework is provided, which could guide further development in specific areas that the TBA can add value, including improving the predictive and impact diagnostic capacity of biomonitoring tools or the development of new TBA-based tools as well as integrating trait information into RQOs. An important contribution, which the TBA can make to biomonitoring in South Africa is the potential for concurrent assessment of the structural and functional components of the aquatic ecosystems. In this regard, we have argued that the use of functional traits must be rationalised and justified in relation to specific ecosystem function, rather than indiscriminate use of all biological traits as functional traits. Further, because traits mediate the underlying relational processes between an organism and its external environment, explicit consideration of the TBA can improve our understanding of the resilience and vulnerability of organisms to specific environmental stressors. This principle was followed in the development of the SBI.

We have developed a new sediment specific index, which we then use to assess the degree of sedimentation in the river systems, where we undertook the case study. The index would need to be tested more widely for applicability across a range of sedimented-stress riverine systems in South Africa.

Recommendations for further research

Ms B Mahlaba sorting macroinvertebrates up to family level in the laboratory

This research has indicated that trait information can easily be integrated into the RQOs. To this end, we recommend the integration of traits into RQOs, to provide statements that are diagnostic and predictive, which explicitly link ecosystem structure with function.

Future research areas are suggested to take the TBA further, particularly in relation to the development of predictive modelling tools, assessment of vulnerability of biological assemblage to climate change and high priority water quality stressors e.g. acid mine drainage, salinisation. It is also important that future research considers field and experimental work linking functional traits and specific ecosystem function as well as further testing and possible refinement of the newly developed SBI. In terms of basic research, there is an urgent need for more life-history research on macroinvertebrates in South Africa as it was evident that trait information was scarce during the compilation of the database.

ADAPTIVE INTEGRATED WATER RESOURCE MANAGEMENT (IWRM) PROJECTS

THETSITA PROJECT: LAND AND WATER GOVERNANCE DEVELOPMENT

Sponsor: Department of Environmental Affairs: Natural Resource Management
MG Wolff, CG Palmer and N Mtati
Project dates: April 2018 - March 2021

The Tsitsa Project (formerly known as the Ntabelanga Laleni Ecological Infrastructure Project) has grown considerably since its inception in 2014 and aims at developing and managing both land and water in a sustainable way for Tsitsa River catchment in the Eastern Cape. The project vision is: "To support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services". The project approach is different to other similar projects as it deliberately seeks out the community's ideas and participations as a starting point; it recognises the inextricable links of complex social-ecological systems; and recognises the importance of collaboration and knowledge sharing in achieving successful natural resource management and sustainable land management.

Our key research questions are:

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

This project is a continuation of research undertaken from 2015-2017 by the Institute for Water Research within the Tsitsa Project (formerly known as the Ntabelanga Laleni Ecological Infrastructure Project) whose outcomes suggested:

1. There is a real basis from which to extend knowledge about "participatory governance", for pathways for local residents to communicate their knowledge of their catchment, and their related needs in terms of NRM-based livelihoods, to formal institutions such as Department of Environmental Affairs, the Catchment Management Agency within the Department of Water and Sanitation, and local government.
2. There is recognition that there is uncertainty about the Department of Water and Sanitation institutional arrangement for Catchment Management Agencies and Catchment Management Forums, and a lack of confidence in the Department of Environmental Affairs that building a Tsitsa River Catchment Management Forum is a sufficiently robust outcome to ensure participatory landscape and water resource governance in the Tsitsa River catchment.
3. The research process can act as a basis for a participatory governance process in the Tsitsa River catchment that is sufficiently flexible to feed into the formal governance structures of a wide range of natural resource management institutions at local, regional and national scales.

When projects such as the Tsitsa Project end – even if they have lasted for several years – there is a danger that as research initiatives end, outcomes crumble – nothing or little is left behind. We strongly suggest that empowering communities to engage in participatory natural resource governance – through a capacity to engage effectively with existing formal governance structures – is the best possible investment in sustainability of both livelihoods and the ecological infrastructure of the catchment. We recognise that participatory capacity must be broader and more flexible that just the participatory interface of Department of Water and Sanitation water governance – Catchment Management Forums interacting with the Catchment Management Agency. Other examples include Department of Environment Affairs, National and Regional; local government – local and district municipalities, other

connected government departments such as Agriculture and Health, and the Eastern Cape government.

To this end we have:

- Used the trust and capacity built over the last three years to identify to start building what will informally be called "land and water forums". We envisage a forum or representatives that will have the capacity to communicate with a variety of formal land and water governance institutions. These will include the Department of Environmental Affairs: Natural Resource Management and their "Working for" programmes, the Department of Water and Sanitation Catchment Management Agency, the municipalities and traditional leadership;
- Customise the Adaptive Planning Process that has been used to engage with local residents about catchment management, so that community workshops empower local people to interact with a wider range of existing institutions;
- Work with the to-be appointed Catchment co-ordinator – and the Community Liaison Officers (CLOs) in an intensive expansive learning process. They will then be able to work with residents at both at the broad scale of a catchment-wide, representative, "land and water forum" - and at the finer scale of the local villages. Then, knowledge and capacity for participatory governance will become real at the household, as well as the Tsitsa River catchment scale; and
- Monitor and evaluate expansive learning and participatory actions at selected village and catchment scales.

The underpinning methodology is transdisciplinary. The concept of complex social-ecological systems provides a lens to forefront the role of adaptation and feed-back. The tried and tested participatory governance methods of Cultural History Activity Theory and expansive learning, combines with participatory governance action- learning of strategic adaptive management, using the adaptive planning process.

Nosi Mtati and Ayabulela Madikana at the Science Management Meeting in Hogsback, May 2018

Research Processes in 2018

The IWR team, with colleagues in other Rhodes University departments, participated in the development on the overall integrated research design and the concept to track the balance of research across the whole system, so that research topics like governance, local resident (community) knowledge and aspirations, views about livelihoods and pathways to equity, do not get swamped by the imperative to understand sediment movement. To this end the IWR team welcomed Nosi Mtati, as community liaison officer, to the governance team. Her work focusses on continuing to maintain relationships with the traditional leaders within the Tsitsa Project and also building new relationships with local, provincial and national government departments.

During 2018 the IWR team, with colleagues in other Rhodes University departments, ran various workshops and meetings, bringing together scientists, managers, implementers (of the "Working for" rehabilitation work), local government, traditional leaders, students, farmers and community representatives. Two of the highlights for the team were: (1) a successful meeting of all implementers, scientists and managers to discuss clustered work areas in the catchment in March; and (ii) a Science Management Society meeting held in Maclear in October. The Science Management Society meeting was particularly important as it brought together, for the first time, all the traditional leaders, local municipality representatives, implementers and scientists in a meeting in which the Tsitsa Project was discussed. The outcome of working in a more integrated manner, while time consuming, is that the Tsitsa Project team (across the research and management levels) continues to grow. The Tsitsa Project, with its different approach, is attracting interest from government departments and national and international funders as an example of how to work in a complex social-ecological system.

Participants at the Science Management Society meeting in Maclear, October 2018

TSISTA PROJECT SYSTEMS PRAXIS COMMUNITY OF PRACTICE COORDINATION

Sponsor: Department of Environmental Affairs: Natural Resource Management
R Bester and J K Clifford Holmes
Project dates: August 2018 – March 2019

Project description

This is a praxis-oriented research project. It is concerned with coordinating the emergence of a group of researchers, hereafter referred to as a community of practice (CoP), who are interested in championing a Systems Thinking paradigm and the use of associated tools within the Tsitsa Project (TP). TP describes itself as a collection of CoPs collaborating in the Tsitsa River Catchment to mitigate household risk. The interdisciplinary interactions between delineated group entities (Figure 1) and the System Praxis 'CoP' have shaped the latter's purpose as well as its choice in members and tools since its formalization in August 2018. The environmental

context created by TP and the greater context in which TP must function are dynamic, evolving and vulnerable to stochastic shocks. The conditions and circumstances in which the System Praxis 'CoP' must operate are then such that there is a constant re-evaluation of CoP objectives and activities.

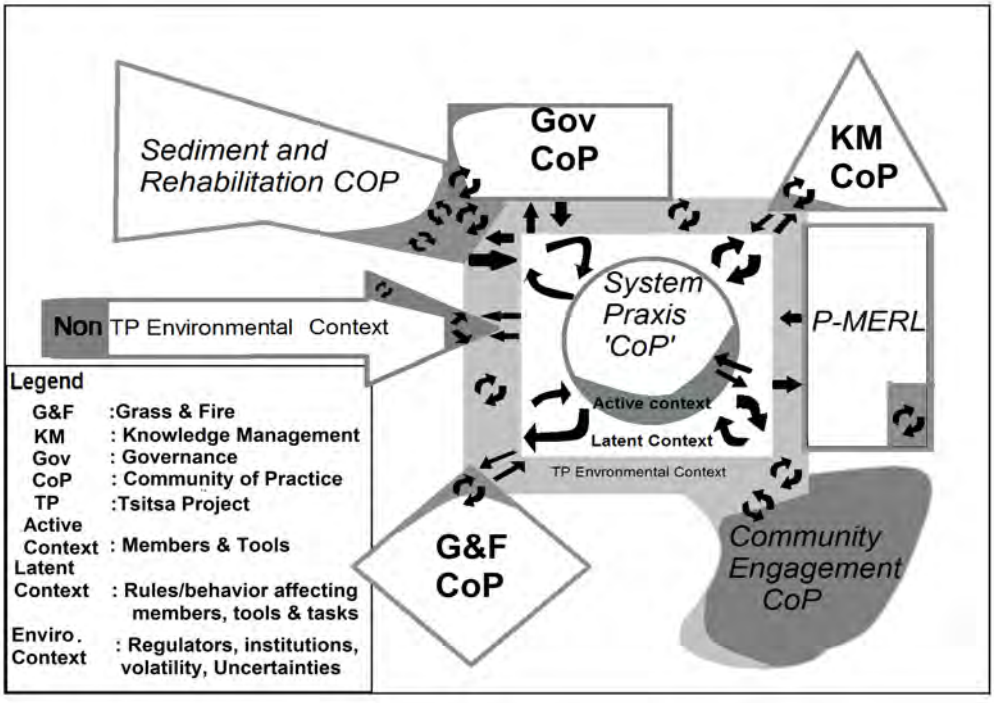


Figure 1 - overview of Tsitsa Project from the System Praxis 'CoP' perspective

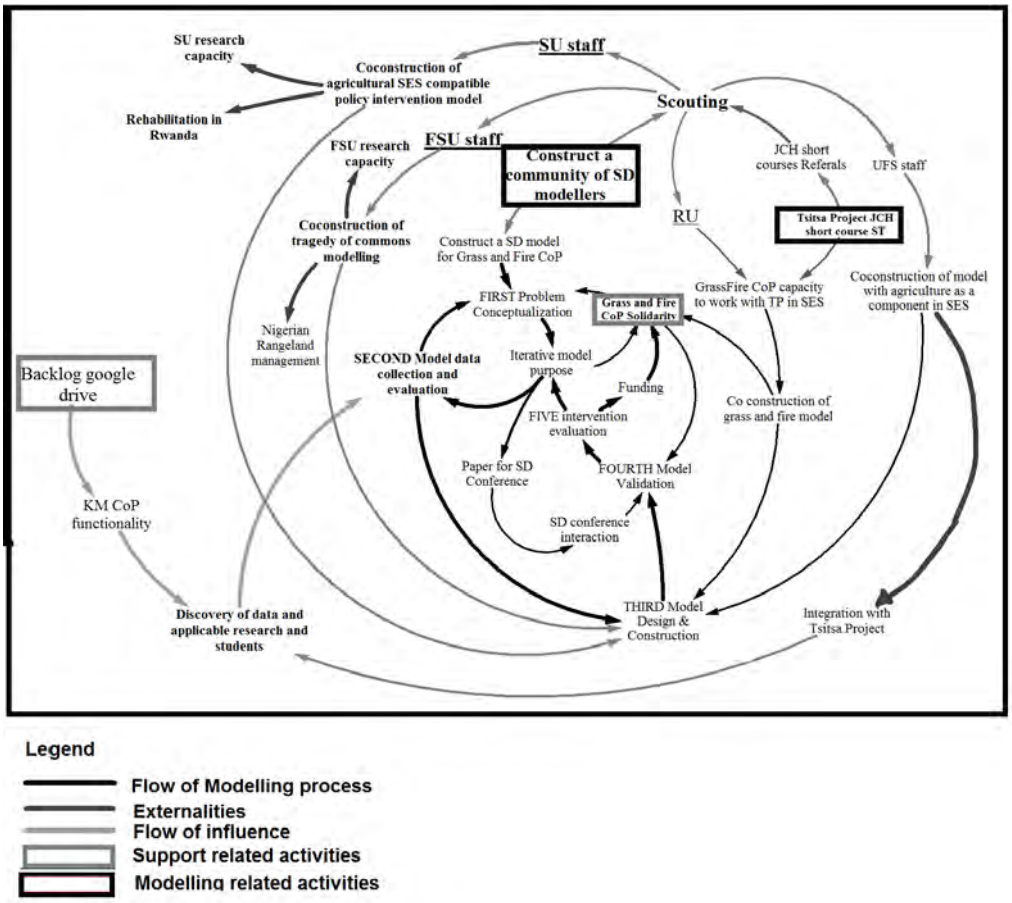


Figure 2 - Summary of TP research activities

Figure 2 is a diagrammatic representation of System Praxis 'CoP' activities at the time of writing. These activities feed into three current CoP objectives:

1. Providing system dynamics modelling support for the merging CoP around Grass, Fire and animal management
2. Providing Systems Thinking and associated methods support to TP CoPs
3. Increasing the stock of Systems Capabilities among TP stakeholders

IWR CITIZEN SCIENCE GROUP
NS Mgaba

Dr Paul Mensah was the leader of the IWR Citizen Science Group with other members being Ms Khaya Mgaba and Ms Ntombekhaya Mti. Doctoral students Matthew Weaver, Notiswa Libala and Phindiwe Ntloko helped during field trips. This year the group demonstrated and taught Kingswood College students how to use mini-SASS. The learners were taken to the Palmiet River and engaged in mini-SASS demonstration, showcasing the value of water resources and how resident biota are able to respond to changes in water quality. The learners were also taught important macroinvertebrate identification skills.

Kingswood College students sampling and identifying macroinvertebrate from the Palmiet River.

COMMUNITY ENGAGEMENT AT THE IWR 2018

Sci Fest Africa is South Africa's largest science festival. The theme for 2018 was Innovation 4.0, with reference to the Fourth Industrial Revolution. SciFest festival promotes the public awareness, understanding and appreciation of science, technology and innovation in South Africa. The Institute for Water Research (IWR) uses this opportunity to give back to the community and share the knowledge gained through scientific studies. IWR staff and students showcased the work conducted by the institute. Biomonitoring, water quality testing, and hydrological models where the key features of the IWR exhibition and the IWR students explained the use of aquatic insects as indicators of water quality to the visiting scholars.

Saint Mary's primary school students identifying macro invertebrates to understand the status of the water

BUILDING CAPACITY THROUGH INTERNSHIP TRAINING IN ENVIRONMENTAL WATER QUALITY

The Institute for Water Research runs an internship programme that develops young water research professionals in all aspects of the Institute's work over a one year period. The institute has been running this programme for more than 6 years. In 2018 more opportunities were open for interns with non-scientific background. Ntombekhaya Mti was recruited as a temporary intern while studying a Management Assistant course at East Cape Midland College. Ms Mti is responsible for assisting with administrative work such as handling incoming and outgoing calls, helping to organise meetings and also being in charge of stationery and equipment. These have helped her gain experiences and be familiarised herself with a working environment. She currently works on the Makana Water Forum project together with Ms M Wolff, Mr M Weaver and Ms M Ralekhetla.

Mr Sbongiseni Mazibuko engaging primary school students during the Scifest 2018.

NATIONAL RESEARCH FOUNDATION (NRF) INTERN

The National Research Foundation (NRF) internship programme offers opportunities to unemployed graduates and postgraduate candidates to acquire practical work experience through mentoring and exposure to a work environment. This year the IWR hosted Ms Bawinile Mahlaba, an NRF intern. During this period she has developed research skills through exposure to students and staff research project. She has been involved in field work, laboratory experiments, analysis and maintenance of aquatic culture (fish, snails and shrimp). At the same time, she was offer an opportunity to register for a part-time Environmental Water Management honours programme at Rhodes.

POST DOCTORAL FELLOW ACTIVITIES

IMPROVING UNDERSTANDING OF SUB-SURFACE PROCESSES OF THE FAIRVIEW SPRING CATCHMENT IN GRAHAMSTOWN, EASTERN CAPE OF SOUTH AFRICA

Postdoctoral Fellow: GI Ezenne
Supervisor: JL Tanner

Dr Ezenne began her post-doctoral fellowship at the IWR in April 2018. She has contributed to the writing of a number of proposals and is largely working towards increasing capacity in the use of high-level field equipment for determining actual evapotranspiration (Eddy Covariance and Large Aperture Scintillometer). Among the studies done so far, two review works have been completed namely: (i) Current and potential capabilities of unmanned aerial systems (UAS) for crop water productivity in precision agriculture (ii) Interactions between surface water and groundwater across major river basins in Africa. Among the proposals jointly worked on, the one on 'Critical catchment hydrological model inter-comparison and model use guidance development' was successful and Dr Ezenne will be in charge of Soil and Water Assessment Tool (SWAT) model for that work. Dr Ezenne is currently processing more than two years of Eddy Covariance data for comparison of differences in evapotranspiration responses over a catchment. Further research work includes: (i) The investigation of evapotranspiration responses using the Large Aperture Scintillometer and (ii) Improving understanding of sub-surface processes of the Fairview spring catchment in Grahamstown, Eastern Cape of South Africa.

OCCURRENCE AND FATE OF MICROBIAL PATHOGENS AND ORGANIC POLLUTANTS IN SOUTHAFRICAN FRESH WATER ENVIRONMENTS, AND THE IDENTIFICATION OF MICROORGANISMS IN CONJUNCTION WITH MACROINVERTEBRATES AMENABLE AS BIOLOGICAL INDICATORS OF THE POLLUTANTS

Postdoctoral Fellow: CF Nnadozie
Supervisor: Dr N Odume

Locally, South Africa is a water scarce country and therefore freshwater resources serve various industrial, agricultural and domestic sectors. However, anthropogenic activities, disposal of human and animal waste and even medical waste into freshwater sources give rise to pollution of freshwater resources. Worse still, some of these pollutants are uncertain. These various types of discharges add both microbial pollutants (pathogens) and chemicals into freshwater environment. The occurrence of pathogenic microorganisms in water sources always presents a potential risk to human, and constitute an impending sanitary risk because of increasing resistance against antibiotics. On the other hand, exposure to chemical pollutants, such as pesticides, personal-care products and pharmaceuticals threatens the heath of aquatic organisms and humans. To accurately assess and manage the risks from microbial and chemical waterborne pollutants, it is important to understand their fate and distribution in freshwater systems. In this regard, biological indicators present a valuable proxy, as suggestions can be made from the absence/presence, condition, comparative abundance and community structure of a subgroup of organisms to provide an index of overall ecosystem functioning and health. Macroinvertebrates are generally the most used biological indicators of stream health. However, bacterial diversity is also highly sensitive to pollutant perturbation, and selective enrichment of the pollutant users occurs if the pollutant is present in the environment.

The interaction of the pollutants with the freshwater microorganisms determine the fate of the contaminants with respect to their chemical nature and degradative capabilities of the microorganisms. The presence of important degrading microbes with the natural tendency to degrade the pollutant at a suitable rate can be used to assess the fate of these pollutants and indicate the full scope of potential hazards. With the advent of next generation sequencing (NGS) it is now possible to sequence all the microorganisms within an environment while bypassing cultivation. By applying metagenomics sequencing, it is possible to profile hundreds of microorganisms and their functions within a sample. A notable advantage of this approach is that old, newly emerging infectious agents as well as pollutant degraders can be discovered using the same metagenomic library. The biological data is usually correlated with the physicochemical parameters measured for the environment to clearly understand effects of pollution in an environment.

TEACHING AND TRAINING

WATER RESOURCE MANAGEMENT

The Water Resources module is a three week module taught at second year level in the Department of Environmental Science as part of the env202 "Global Environmental Problems and Policies" course. The course was developed by Dr Griffin of the IWR and first presented in 2006. The course aims to present interdisciplinary analyses of environmental problems and examine policy responses from global to local scales, and the Water Resources module is taught in that context.

As such, the course presents some basic background in freshwater physicochemistry and biota and ecology in standing and flowing water systems. General management practices with respect to freshwater lead on to an overview of aspects of international water law and South African water law. Finally, the course looks at the report of the World Commission on Dams as a lens to assess the ecological, social and economic changes associated with these common water management and storage practices.

TROPICAL BIOLOGY ASSOCIATION KENYA COURSE

Dr Griffin was invited to teach on the Tropical Biology Association's Kenya course held In July and August at the Mpala Research Centre near Nanyuki in Laikipia County, Kenya. The course is a four week long Master's level course that focusses on research on savannah ecology, and Dr Griffin's module looked at riverine ecology in this context. Twenty four students attended the course, with roughly equal representation from Europe and Africa. The course was structured such that the first part involved gaining an understanding of the area, and of appropriate methods, techniques and approaches for conducting field research. The second part of the course involved students devising a research project to undertake, and completing, analysing and presenting the results of their research.

Dr Griffin explains macroinvertebrate sampling on the Nanyuki River (photo by V.Scharnhorst)

COASTAL WATER QUALITY SAMPLING

Drs Odume, Griffin and Nnadozie compiled and presented a course on coastal water quality sampling for the Department of Environmental Affairs. The course was for staff who were responsible for collecting samples for water quality analysis, and had a particular focus on the recently updated Water Quality Guidelines for Recreational Use (DEA 2012). Training addressed issues related to basic coastal and estuarine ecosystem functioning, planning a sampling programme and sampling theory, physicochemical and microbiological sampling (including in situ data collection), and basic analysis of data. The course was presented at the Department of the Environment Oceans and Coasts division on East Pier in Cape Town harbour in September 2018. A guideline on sampling was submitted to the department.

ENVIRONMENTAL WATER MANAGEMENT HONOURS

The Institute for Water Research in 2018 for the first time presented an Honours course in Environmental Water Management. The degree is offered in collaboration with the Geography Department, who formally hosted the programme. The EWM Honours course builds on a module that had previously been offered by Geography at Honours level with one module taught by IWR. Eight

students registered for the course in 2018, and modules were also offered to interested students from other departments.

The Honours programme was made up of five components, with four taught model and a research project. Taught modules included Adaptive Integrated Water Resource Management (A-IWRM) taught by Prof Palmer, Environmental Water Quality (EWQ) taught by Dr Griffin and Dr Mensah, Freshwater Ecology taught by Dr Odume, and Hydrology taught by Dr Tanner and Dr Mantel. A-IWRM addresses how the international water resource management standard, IWRM, had not been fully successful in South Africa.

A-IWRM brings the theory and practice of complexity, thinking, strategic adaptive management and social, expansive learning into Integrated Water Management (IWRM). The EWQ module presents the three tools, used to manage environmental water quality: physicochemical monitoring, biomonitoring and ecotoxicology. The module presents each topic alone, and also addresses how these should be used together holistically in the management of water quality in the environment. The Freshwater Ecology module examines issues related to management of freshwater ecosystem health, and the links between freshwater ecosystem structure, functioning and services. The Hydrology module focusses on surface and groundwater hydrology with the majority of the course dealing with water quantity and a smaller part dealing with water quality. Students learned about human influences on hydrological systems, and are exposed to the tools and methods of the discipline.

Students presented their research projects at the Society of South Africa Geographers student conference held in Bloemfontein in early October 2018.

Honours students at the SSAG conference

APPLICATION OF MACROINVERTEBRATE TRAIT-BASED BIOMONITORING AND STABLE ISOTOPES FOR ASSESSING LAND USE IMPACTS ON RIVER ECOSYSTEM STRUCTURE AND FUNCTION IN THE KAT RIVER AND ITS TRIBUTARIES, EASTERN CAPE SOUTH AFRICA.

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

Brief introduction and summary

Land use activities have long been recognised as a major concern globally because they are associated with disturbances (e.g., agricultural, industrial and urban area) that lead to soil erosion, sedimentation, nutrient enrichment, and input of other pollutants to freshwater ecosystems (Fugère et al. 2016). These pollutants are among the most important stressors affecting the structural and functional integrity of freshwater ecosystems. For example, human populations, deforestation of riverine areas, cultivation of stream banks, and gold and sand mining are increasing exponentially in Africa, with direct consequences on water quality (Fugère et al. 2016). These activities lead to landscape modification, soil erosion and habitat fragmentation, and are among the major drivers of pollution inputs into water bodies. The delivery of pollutants such as sediments and nutrients have

been recognised to be among the major consequences of land use disturbances and these have direct effects on aquatic organisms, the rate of primary productivity, and the trophic structure of stream macroinvertebrates (Wagenhoff et al. 2012; de Carvalho et al. 2017).

Macroinvertebrates play a key role as primary consumers in streams and rivers, they are adversely affected by pollution and they respond in different ways to environmental gradients as a function of their morphological, physiological and biological traits (Sechi et al. 2017). Studies have shown a significant decrease in the diversity of macroinvertebrates in the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) in streams impacted by land use (Siegloch et al. 2017). Furthermore, declines in biodiversity due to anthropogenic activities and changes in the organic matter available for primary consumers in streams can also affect the greater and/or entire trophic structure, with profound implications for ecosystem structure and function (Voß & Schäfer 2017).

The aim of this study is therefore to evaluate the effects of land uses (agriculture, urbanisation and industrialisation) on macroinvertebrate assemblage distribution and trophic structure in a South African river system. The study hopes to explore the complementary use of taxonomic, trait based and stable isotope analysis to address the aim and objectives of this study.

THE EXAMINATION ON THE INFLUENCE OF SEDIMENT PARTICLE SIZES ON SPECIES OF LEPTOPHLEBIIDAE

Student: A Chili
Supervisors: JL Tanner and SK Mantel
Degree: BSc (Honours) Environmental Water Management

In South Africa, the decline in water quality of aquatic ecosystems, particularly rivers and streams have compromised the functionality of these systems. Sedimentation of riverine ecosystems has been recognised as a water quality stressor of concern. Sedimentation is a natural occurring process, but when exacerbated can lead to deleterious effects on the ecosystem, and importantly the biota that the system supports. The impact of sedimentation on aquatic biota ranges from burial, clogging, as well as abrasion. A critical factor that determines the effect of sediments on aquatic biota is the particle size. In

Student collecting sediments along the river bank.

this study, the effect of sediment particle sizes on burial was investigated. Mayflies species collected from a relatively pristine river were exposed to sediments of different particle size classes 2000µm, 125µm and 4µm, in a static experimental set up. Effect of sediment particle size on burial was assessed by measuring the time it takes the mayflies species to excavate themselves from the sediments. The results indicate that species exposed to finer sediments of particle size of 4 µm took longer time to escape burial compared to the remaining two particle sizes, and this time was significantly different between the particle size classes. The implication of the finding is that finer sediment particles (4 µm) may pose more threat to aquatic biota from burial. Careful management is required and could be useful when it comes to South African water guidelines.

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

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

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

MAINSTREAMING CLIMATE CHANGE INTO THE RESERVE DETERMINATION PROCESS

Student: PP Dubula
Supervisor: JL Tanner, SK Mantel and PA Scherman
Degree: PhD (Water Resource Science)

In the National Water Act (NWA, 1998) the protection of the resource base is formalised through the Reserve, classification and resource quality objective concepts. The ecological Reserve is the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource (NWA, 1998). Climate change however poses a significant threat to this allocation of water and hence the sustainability of aquatic ecosystems and ecosystem services to society.

In order for the Department of Water and Sanitation (DWS) to meet their mandate to protect aquatic ecosystems, given the constraints of climate change, it is necessary to take cognisance of the implications of climate change and to make the necessary adjustments and changes to the current ecological reserve determination methodology. This is to ensure that sufficient water, at the right time, distributed in the right flow pattern and of adequate quality is provided, so that key ecological processes are sustained, and

that biotic communities maintain their health and integrity. This study aims to investigate and recommend appropriate approaches of mainstreaming climate change considerations into the ecological Reserve Determination process through review of the conventional process as currently practiced, identifying gaps in knowledge regarding climatic impacts.

The PhD will be conducted through publishing five journal articles in peer reviewed journals. The study is still in its initial stages and presently the literature review and research is being done towards producing the first journal article. This first paper will focus on assessment of the successes and shortfalls of the ecological reserve determination process under a changing climate. The aim is to conduct a review of ecological Reserve determination process versus its operationalisation and implementation. The paper will evaluate the successes and shortfalls and the enablers for successful implementation and the stumbling blocks that hinder successful implementation. Reflections will be made on how successful implementation of the ecological Reserve is important as a climate change adaption measure towards enhancing resilience and reduction of vulnerability of the water sector to the impacts of climate change.

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

Student: OA Edegbene
Supervisor: ON Odume
Degree: PhD (Water Resource Science)

Bioassessment is the monitoring of the health condition of water bodies using biological indicators.

In Nigeria monitoring of aquatic health has received a great boost in recent years, though this monitoring process is still at the age long use of physicochemical parameters, and very crude biological methods (Adakole and Annune, 2003, Arimoro and Ikomi 2008c and Edgebene and Arimoro 2012).

Aquatic ecosystems in Nigeria are bedevilled by various degrees of anthropogenic activities which are occasioned by unenforced and or poorly enforced environmental laws (Arimoro and Ikomi, 2009). These activities as well as negligence of environmental issues have impacted greatly on the quality of the water and the resources inherent in the aquatic ecosystems and thus impacting greatly the functionality of the freshwater ecosystems in Nigeria (Edegbene et al. 2015). This project arises out of the need to develop a standarized protocal for monitoring ecosystem health in Nigeria.

The project objectives are:

(i) To develop and standardized a macroinvertebrates-based biomonitoring protocol for wadeable streams and rivers in Niger delta region of Nigeria.
(ii) To use the newly developed protocol to assess aquatic health of selected streams and rivers in the region.
(iii) To undertake and compare site-specific species-level assessments with family-level non-site-specific assessments in the selected rivers and streams.
(iv) To use the systemic-relational perspective to investigate institutional arrangements related to aquatic ecosystem health management in Nigeria.

EVALUATION OF ENDOCRINE DISRUPTING COMPOUNDS IN FRESHWATER OF EASTERN CAPE PROVINCE OF SOUTH AFRICA

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

Samplings

Sampling started this session on 28th March, 2018 with Bloukrans River and Grahamstown wastewater treatment plant. Samples were taken at the upper, middle and lower course of the river. Raw wastewater and treated effluents were also collected the same day from the wastewater treatment plant. All samples were taken to the laboratory for analyses.

Samples were collected regularly from three rivers (Bloukrans, Tyhume, and Swartikops) and at wastewater plant in Grahamstown and Alice until Buffalo River and King Williams Town wastewater were added to the sampling sites in May, 2018. All the sites were sampled according to seasons. Access to Uitenhage wastewater was denied. Samplings have spanned three seasons.

Sample Analyses

Physicochemical parameters such as pH, oxidation-reduction potential (ORP), dissolved Oxygen, conductivity, resistivity, total dissolved solids (TDS), salinity (PSU), temperature, pressure and geographical positioning system (GPS) were measured on site. Only those parameters that require secondary treatments before analysis were done in the laboratory. Samples for assay on spectrophotometer were pre-treated with the appropriate Merck Spectroquant(R) kits and analyzed on UV Mini 1240 UV-VIS Spectrophotometer (Shimadzu Corporation, Japan) in the Quality Control laboratory. Parameters measured include chemical oxygen demand (COD), ammonium, phosphate, sulphate, nitrite, nitrate and chloride ions.

Bacteriological assessment were conducted on all the samples collected using existing laboratory protocols. 1ml of each water sample is added to 9ml of Luria broth and incubated at 37 0C overnight, this is followed with serial dilution. 0.1ml of each sample is aseptically picked and spread on nutrient agar. Each sample is replicated on three plates. The plates are incubated for 24 hours at 37 0C. Colony-forming units (CFU) counted after 24 hours. Five colonies are selected from each sample for isolation on nutrient agar. Isolated colonies are allowed to grow for 24 hours at 37 0C. The isolates are stored in refrigerator for PCR and DNA analysis.

Bacteria isolation on EDCs: bacteria were isolated from wastewater sludge and grown on ten selected endocrine disrupting compounds (EDCs) (Bisphenol A, Triclosan, Dichlorophenol, Diethylstilbestrol, Estrone, Octylphenol, 17A-ethynylestradiol, B-estradiol, Nonylphenol, Atrazine); and a mixture of all the compounds with the view of isolating bacteria that can decompose EDCs. Culturing on these EDCs lasts for two months on a shaker regulated at 37 0C and 100 rpm.

This was followed by serial dilution and spread plate on R2A agar. Plates were incubated for 24 hours at 37 0C. CFU were counted and recorded. Some of the colonies were further isolated on R2A for 24 hours. Isolate were stored for analyses of PCR and DNA.

Water samples collected were processed in the laboratory with various organic solvents culminating in a liquid- liquid extraction of metabolites needed for spectroscopy.

Spectroscopic Analysis

Extraction of organic content of the water samples follow existing laboratory protocols of liquid-liquid extraction with organic solvents (chloroform and ethyl acetate). The extraction was done in duplicate to take care of all aspects of spectroscopy.

FT-IR Spectroscopic Analysis: All the extracted samples were analysed on Perkin Elmer Spectrum 400 Frontier/FT-IR spectrometer. The spectra obtained were subjected to baseline correction, smoothened

and peak picking. The spectra obtained were subjected to analyses on BioRad KnowItAll(R) to compare the spectra band of the water samples and generate the distinction of each sample from the functional group and fingerprint regions of the spectra. FT-IR spectra were saved as ASCII text files (*.txt), then imported to Microsoft Excel, saved as CSV comma (*.csv) files before importing to the MetaboloAnalyst 3.0 software for multivariate analysis.

NMR Spectroscopic Analysis: Water extracts were assayed on Bruker AvanceTM III HD 400 MHz spectrometer, TopSpin 3.5 pls (Bruker BioSpin, Rheinstetten, Germany). 1H-NMR, 13C-NMR, NOESY and TOCSY spectra were obtained for all the samples. Data obtained from NMR were analysed with Mnova (MestReNova Inc) and MetaboAnalyst packages. Data obtained from Mnova were separately superimposed and binned using, saved as ASCII text files (*.txt), then imported to Microsoft Excel and saved as CSV comma (*.csv) files for easy analyses. CSV was imported to the MetaboloAnalyst 3.0 software and multivariate analyses were subsequently carried out.

Chemometrics: Both FT-IR and NMR transformed data were subjected to chemometrics on MetaboloAnalyst 3.0 software (Parasitology Building, 21111 Lakeshore Road Ste. McGill University, Anne de Bellevue, QC, Canada; http://www.metaboanalyst.ca). This is to generate the association and distinction between the water samples. The following general procedures were carried out on the data; checking for missing values, filtering using median intensity value, quantile normalisation with Log 2 transformation, Pareto scaling and cross-validation of the normalised dataset by permutation tests using LOOCV method with the performance measure set at Q2.

LC-MS: 29 prepared samples were sent to the Department of Chemistry, University of Witwatersrand for LC-MS analysis of the targeted 14 endocrine disrupting compounds (Bisphenol A, Perchlorate, Phthalate, Triclosan, Dichlorophenol, Triazole, Diethylstilbestrol, Estrone, Octylphenol, 17 A-ethynylestradiol, B-estradiol, Imidazole, Nonylphenol and Atrazine). Unfortunately the laboratory does not have the expertise in handling EDCs, contrary to the assurance given by the staffers.

Work in Progress

LC-MS analysis of the samples: The HOD Chemistry is facilitating this. Hopefully it will be concluded before 2018 runs out.

Metal content analysis with either atomic absorption spectrometry (AAS) or inductively coupled plasma - optical emission spectrometry (ICP-OES) is awaiting attention. AAS is available in Pharmaceutical chemistry department but not installed and Chemistry department has ICP-OES but out of order. Work will continue as soon as any of these instruments is functioning.

Isolated bacteria are awaiting polymerase chain reaction (PCR) and DNA analyses.

Challenges

Uitenhage wastewater cannot be sampled because the authority failed to grant access to the treatment plant.

Digital analyses of physico-chemical parameter needs to be embraced because the current method of photometer analysis is cumbersome and unreliable. Pysico-chemical parameters are best measured on-site.

Statistical packages for some specialized analyses (e.g: Mestrenova, ChemDraw, Easy Analytics etc.) are required. Presently I rely on trial versions of these software and before they are mastered, the trial period will be over.

Expertise acquired

Usage of Perkin Elmer Spectrum 400 Frontier/FT-IR spectrometer; trained by Dr Olawode. Trained on Bruker AvanceTM III HD 400 MHz spectrometer, TopSpin 3.5 pls (Bruker BioSpin, Rheinstetten, Germany) by Prof Krause (HOD Chemistry). Usage of different Photometers.

Chemometrics on MetaboloAnalyst 3.0 software, by Dr Olawode. Using Mnova (MestReNova Inc) statistical package by Dr Olawode I attended isiXhosa class.

Request
Facilitation of the outstanding analyses.Assistance with bursary for 2019.

Article Submitted to Supervisor:
FT-IR Spectroscopy and Chemometric Analyses of Wastewater, Sludge and Treated Effluent in Eastern Cape Province of South Africa

INVESTIGATING EVAPOTRANSPIRATION OVER VARIOUS CROP TYPES WITHIN THE WESTERN CAPES SWARTLAND MUNICIPALITY USING MODIS SATELLITE IMAGERY FOR MORE EFFECTIVE CROP MANAGEMENT

Student: EB Greyling
Supervisors: SK Mantel and JL Tanner
Degree: BSc (Hons) Environmental Water Management

Within the South African context, up to 50% of surface water is allocated to agricultural purposes. Since it is such a large percentage, effective management must be consistently explored. The Western Cape, a winter rainfall area, has experienced severe water shortages and drought in recent years, leading to greatly decreased agricultural harvests and generally slowed agricultural practice. Due to the near constant threat of drought, South African farming has adopted practices and methods aimed at maximising precipitation utilization.

The purpose of this study was to evaluate satellite evapotranspiration measurements over dryland and irrigated crops to gain a comprehensive understanding of how water is lost through evapotranspiration within the agricultural sector. This was achieved through a desktop-based evaluation of satellite imagery in conjunction with current crop irrigation methods. This included evaluating MODIS evapotranspiration satellite data in conjunction with CHIRPS rainfall data from 2011-2017. Normalised Difference Vegetation Index (NDVI) data were also incorporated to evaluate past crop growth cycles for improved future management. FruitLook (http://www.fruitlook.co.za) and Cape Farm Mapper (CFM) (https://gis.elsenburg.com/apps/cfm/) are online farm management applications that were utilised throughout the study.

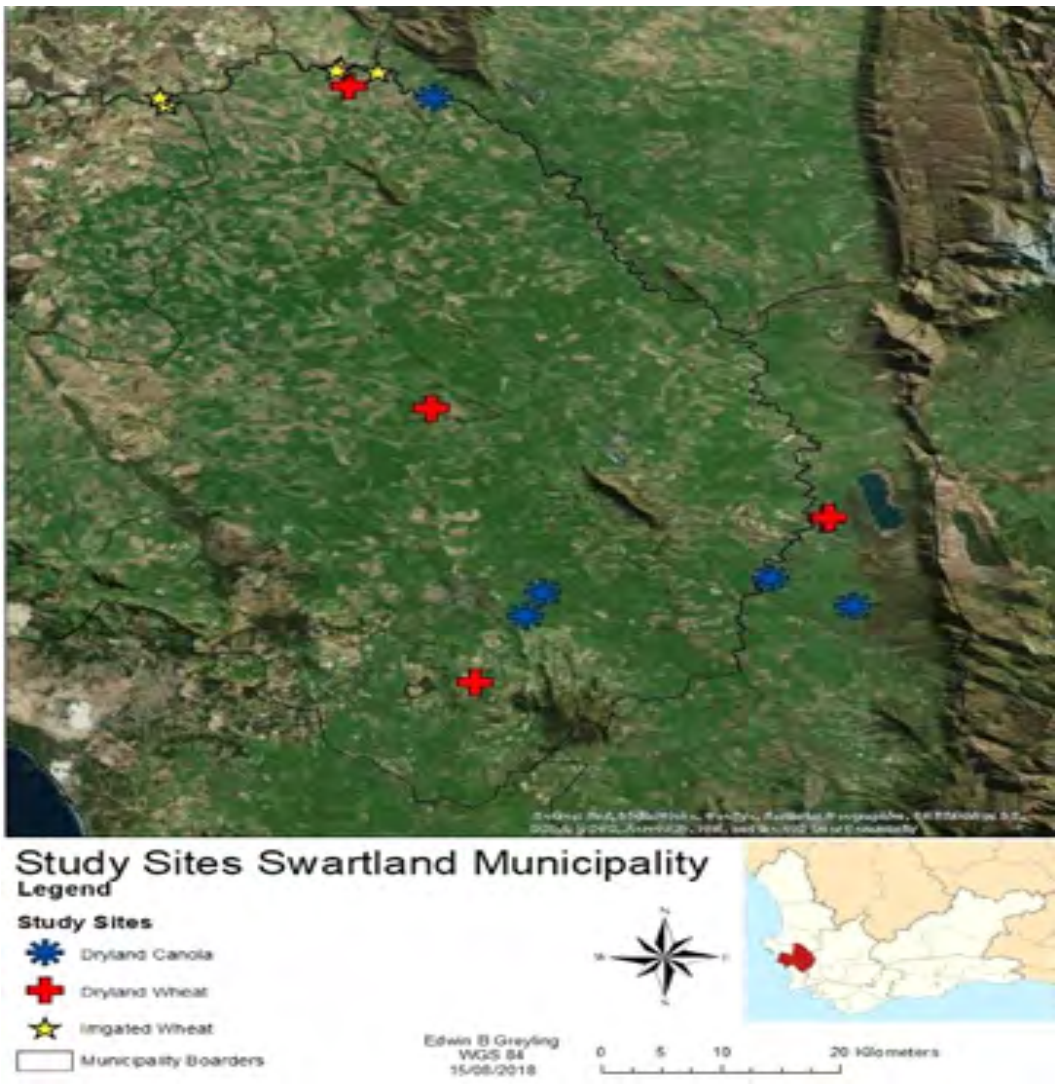
There were three objectives of the study:

1- To assess if MOD16 can be used to achieve more effective crop management via improved understanding of evapotranspiration dynamics relative to rainfall in the Western Cape during drought periods;
2- Given typical agricultural characteristics (crop type and irrigation scheme) in the Swartland Municipality, evaluate if MOD16 can differentiate different crop type signals, and identify irrigated and dryland agriculture;
3- Assess how valuable the outputs from FruitLook are to farmers in the Western Cape for managing their crops in a varying climate.

Studies such as this are necessary for continued water conservations efforts, particularly those surrounding the agricultural sector. Greater water availability will allow for expansion of the agricultural sector as well as reduce water stress in all other areas. Results found that a larger amount of water was evapotranspired over irrigated rather than dryland crop structures. Rainfall data showed that the Western Cape has been experiencing drought conditions since 2014. This coincides with crop failure which was observed in 2014 over all crop landscapes.

Similarly, a large decrease in rainfall was also observed over the entire Western Cape in 2017 where higher ratios of evapotranspiration to rainfall were observed over all crop structures. With the information gathered from this study the most appropriate planting and harvesting times for future seasons can be determined from past data. It was also found that exploring past crop failure patterns can

provide useful insights into potential future crop failure mitigation strategies. Future improvements to the study were explored, and it was found that although this study was helpful, further use of this methodology may be more applicable to larger crop landscapes than those evaluated in current study. More studies of a similar nature need to be conducted to better understand evapotranspiration dynamics over crop landscapes in to the future.



Swartland Municipality and the 15 study sites where the research was conducted.

FURTHER DEVELOPMENT OF A SIMPLE EROSION AND SEDIMENT TRANSPORT MODEL FOR CATCHMENT MANAGEMENT IN AFRICAN CATCHMENTS.

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

Erosion and sediment yield research provides important information on the mass of sediment leaving catchments, denudation and the impact of human activities on sediment production and movement. This is very important given that erosion and sediment yield is a global problem that has led to loss of fertile agricultural land, loss of reservoir storage and affected riverine ecosystems. Information on erosion and sediment is currently scarce, sparse and available at poor spatial and temporal resolution. The African continent lacks sufficient research on sedimentation trends and reporting on the erosion research is low as it is contained in internal project reports (Vanmaercke et al., 2013). The provision of sedimentation information is crucial for catchment management as catchment managers are empowered to make relevant decisions and design management policies informed by scientific research outputs.

Vanmaercke et al. (2013) highlights that numerous constructed and planned water reservoirs in Africa are faced with storage losses because of high sedimentation rates. Reservoir storage loss is a growing problem in countries such as South Africa where a quarter of the country's dams are affected by varying intensities of sedimentation (Msadala et al., 2010). Reservoir storage loss causes acute hydrological problems as competing water demands will not be met, thus leading to over exploitation of surface and groundwater resources at the expense of the wider environment. Sedimentation problems have evolved from being a scientific issue to a socio-political issue.

The African continent is experiencing a rapid growth in population (UN ESA, 2011) and resource demand is expected to increase in response to population growth. Population growth increases competition for water resources leading to conflicts on water resources allocation. Other secondary problems associated with lack of water such as disease and famine are already common on the continent. There is need to ensure that growing population are provided with water in sufficient quantities and adequate quality. This may be achieved by properly managing current reservoirs to ensure that they maintain a reasonable lifespan. New reservoirs can also be constructed to cater for the water and even energy needs of growing populations. However, the sustainability of water provision initiatives is dependent on the ability to manage these systems sustainably.

Therefore, erosion and sediment yield studies can contribute positively to a water secure African future by providing information for use in catchment management.

The current research seeks to extend the Water Quality and Sediment model (WQSED) (Bryson, 2015; Gwapedza et al., 2018) to catchments in selected African countries. The WQSED was developed in South Africa and has been previously applied in the country by Gwapedza et al. (2018). The overall aim of the PhD research is to simplify, improve, further test and validate the WQSED. Specific objectives include 1. Examine the use of readily available spatial datasets to estimate and regionalize model parameters. 2. Investigate and account for the temporal and spatial scale issues associated with the application of the WQSED. 3. Further test and validate the applicability of the WQSED in environments beyond South Africa; if possible also apply the model in areas where already established models such SWAT and HBV-SED have been applied and compare model performance. Given the relative simplicity of the WQSED its successful application in the African region will provide researchers and catchment managers with a simple, efficient tool/model that has low data requirements. The WQSED is envisioned to be more applicable to data scarce African catchments, and thus is expected to expand erosion and sediment yield research and produce valuable information for sustainable catchment management.

IMPROVING UNDERSTANDING OF THE SURFACE AND GROUNDWATER DYNAMICS OF THE GRAHAMSTOWN FAIRVIEW SPRING AND SURROUNDING RIVERS

Student: C Hale
Supervisors: JL Tanner, SK Mantel and DA Hughes
Degree: BSc (Hons) Environmental Water Management

Surface water-groundwater interactions are crucial in understanding the dynamics behind subsurface re- emergence as springs. Surface water-groundwater (SW – GW) interactions are poorly understood as there are hydrologic parameters which are difficult to quantify since they are unable to be easily measured or viewed (groundwater). South Africa has a complex geological history and the Cape Supergroup (Cape Fold Belt) is a particularly complex group geology. Grahamstown is found on the north-east extent of the Cape Fold Belt/Cape Supergroup. The Cape Fold Belt consists of fractured rock aquifers made up of quartzites, sandstones and shales. This aquifer system in particular is complex and heterogeneous in nature.

The nature of the fracture alignment frequently leads to the re-emergence of subsurface water as springs and seepages. Springs in the Cape Fold Belt are important to communities as they deliver a source of potable water. Further, the numerous springs and seeps have developed groundwater dependent ecosystems with many endemic species. Understanding the sub- surface dynamics of the

springs is vital in managing this resource, in the context of a country faced with multiple water shortages. The Grahamstown Fairview Spring is used extensively by the community of Grahamstown. The re-emergence of groundwater via the spring orifice (mouth) is made accessible by a pipe that directs the flow under the R67. Recent research on the Grahamstown Fairview Spring (Smetherham et al. 2018) produced a spreadsheet model to represent the discharge of the spring. Recent high rainfalls in December 2017 resulted in an increased spring discharge that the model was unable to reproduce, and therefore there are unknown processes or mechanisms within the system that are not being accounted for in the model. This project worked towards improving understanding of these unknown processes, thereby contributing to a better understanding of and representation of the system by the spring model. The work identified the possibility of a changing sub- surface catchment area (the surface water and groundwater catchment areas are likely different sizes). Once the model structure was updated to account for this increase in catchment size during wetter weather, it was better able to represent the observed spring discharge indicating that this process is a distinct possibility.

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

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

This research started in February 2017 and is funded through the Congo River Users Hydraulics and Morphology (CRuHM) project, which is a joint programme between UK institutions (Universities of Bristol and Leeds) and sub Saharan African institutions (University of Kinshasa, University of Dar Es salaam and Rhodes University). In 2017, the main research work focused on the development of an integrated framework for the classification of the Congo Basin into understandable hydrological modelling units, generated on the basis of the natural geomorphology and anthropogenic activities. The other pieces of the work dealt with the morphological analysis of the wetlands and the estimation of the disaggregation parameters for transforming the monthly flows into daily. However, in 2018 the work done so far is a complement of what has been undertaken in 2017. It focuses on the development of the regional hydrological indices for the Congo Basin and the parameterization of the hydrodynamic processes of the massive wetland systems in the upper Congo Basin (Lualaba). A part from the work done, there was a number of capacity building activities such as workshop, international conferences and fieldwork training, that were conducted during 2018.

Progress so far

Recently, approaches have emerged to constrain hydrological models in ungauged sub-basins in order to produce behavioural parameter ensembles that match regionalised hydrological response indices (Yadav et al., 2007; Zhang et al., 2008; Tumbo and Hughes, 2015; Hughes, 2016; Ndzabandzaba and Hughes, 2017). The approach used for the Congo Basin consists first in a similarity analysis of the sub-basins on the basis of basin's physical properties that account for a large variability. These are: soil texture, average slope, curve number, topographic wetness index and aridity index. The results of this analysis showed that the whole Basin could be divided into six homogenous regions and each of them having its physical major controller of its variability. Concomitantly to this analysis, a regional quantification of the hydrological indices was carried out through an iterative approach on the basis of the existing information for each identified region. These are the mean monthly runoff volume (MMQ in Mm3), the mean monthly groundwater recharge depth (MMR in mm), the 10th, 50th and 90th percentiles of the flow duration curve (FDC) expressed as a fraction of MMQ and the percentage of zero flow. Through the application of the uncertainty version of the Pitman model, the preliminary results for the upper part of the Congo Basin have shown that the approach could be applied with a high degree of confidence for prediction in ungauged catchments. This work was presented at the 3rd International Conference on African Large River Basin Hydrology (ICALRBH) held in Algiers, Algeria, from 6th to 9th May 2018.

Among the known challenges in modelling the upper part of the Congo Basin are the existence of massive wetland systems, of which the filling and emptying mechanisms are not well understood. These wetland systems considerably alter the downstream flow regimes by storage, slow release and peak flow attenuation. It was therefore appropriate to account for their effect in the basin scale hydrological modelling framework. The approach developed in this study consisted in (i) Disaggregating the simulated monthly flows into daily in order to obtain the plausible wetland inflows, (ii) setting up and running different LISFLOOD-FP hydrodynamic models for each wetland system, (iii) estimating the parameters of the Pitman wetland sub-model by corresponding the LISFLOOD-FP with the Pitman wetland sub-model outputs, and (iv) informing the basin scale hydrological model with the hydrodynamic understanding of the wetland system. The results obtained through the application of this approach in the Upper Congo Basin have been presented at the AGU/Chapman Conference on the Hydrological Research in the Congo Basin held in Washington DC, USA, from 25th to 27th September 2018.

Future work

The future work will be the continuity of what is done in this year 2018 and will mainly focus on the extension of the developed approaches to the other parts of the Congo Basin. In addition to that, the work will develop a wetland morphological analysis based approach to derive wetland hydrodynamic parameters. Issues related to Wetland bathymetry effects and the hydrodynamic model spatial resolution will be considered as well.

USING A SOCIAL-ECOLOGICAL SYSTESMS APPROACH TO INVESTIGATE THE IMPORTANCE OF SEEP WETLANDS ECOSYSTEM STRUCTURE AND FUNCTIONALITY IN THE TSITSA RIVER CATCHMENT, EASTERN CAPE, SOUTH AFRICA.

Student: N Libala
Supervisors: ON Odume and CG Palmer
Degree: PhD (Water Resource Science)

Many rural farmers in South Africa rely greatly on aquatic resources such as wetlands for their livelihood. Wetland ecosystems are among the most valuable and productive ecosystem in terms of both ecological and social components (Jiang et al., 2015). They provide services which are important for supporting the livelihoods of most people in rural areas.

Despite their importance in sustaining livelihood, wetlands loss and degradation throughout the world has been considerable. In South Africa, it has been estimated that between 35 – 50% of wetlands have been lost or degraded (Kotze et al., 1999; DWAF, 2005; SANBI, 2006). The main direct threats are agriculture; mining; poor land management such as overgrazing and inappropriate burning practices resulting in degradation of the catchment and wetlands; alien species expansion; urban development; and pollution. Indirect threats include: increased population growth; poverty; and unawareness (Swanepoel and Barnard, 2007). The rural poor are the most vulnerable to the impacts of wetland degradation (Pollard et al., 2010), because they directly use wetlands for their livelihoods. It has also been indicated that wetland importance or functioning is often ignored in policy making and local communities are excluded in decision making and this contributes to ecological and social damage. Therefore, to ensure the conservation, management and sustainable use of wetlands, an understanding of integrated social-ecological system is required (Virapongse et al., 2016).

The Umzimvubu River catchment is subject to high degradation as a result of overgrazing, over-cultivation and social and political issues (Pretorius, 2016). The present study focuses on hill slope seep wetlands which are known to be critical and fragile ecosystems, capable of supplying ecosystem services such as biomass production for livestock grazing (ERS, 2011). They are about the only ecosystems that supply grass for grazing throughout the year, serving as an important ecological infrastructure that supports the local livelihoods. In the absence of appropriate management strategies and lack of scientific understanding of these ecosystems, they are disappearing at an increasing rate within the catchment.

Methods drawn from both natural and social sciences were combined in this study as this is an approach

that allows the advantages of both the quantitative and qualitative research methods to be utilized in a complementary manner, thus allowing a more comprehensive, in-depth appreciation of the research problem, as well as merging the results from both sides so that the comparison could be made. Eleven Wetland seeps have been selected in the study area. At each seep, basic soil physical and chemical properties were measured. Patterns of vegetation composition distribution were evaluated. Wetland Seep ecosystem functioning linked to grazing indices such as productivity, was investigated. Relevant vegetation functional traits linked to seep functioning were used to evaluate wetland seep resilience and vulnerability to grazing. In order to investigate community understanding about seep wetlands benefits in relation to livestock grazing, social science methodologies, including, interviews were used.

The project objectives are:

- To assess the ecological health of hillslope wetlands using bioassessement tools
- To assess the vulnerability and resilience of hillslope seep wetland plant species to disturbances (grazing) using the functional trait approach.
- To provide basic soil characteristics of the selected seep ecosystems as well as their pattern of vegetation community structure
- To understand farmers value systems and grazing practices in relation to hill slope seeps in order to facilitate their protection.

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.

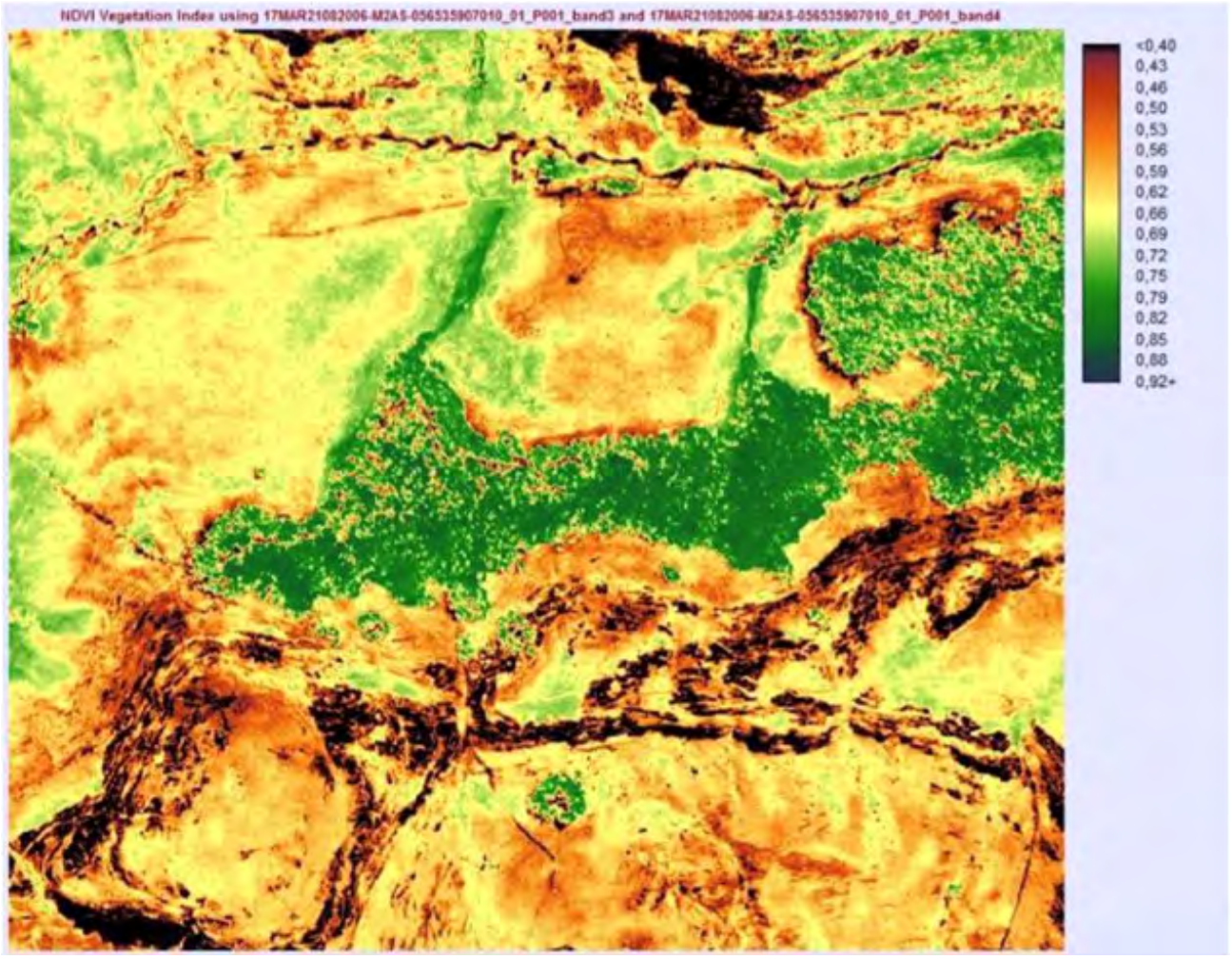
Primary areas of vegetation production have been shown to supply essential Ecosystem Services that support substantial livestock herds. Particular vegetation types are favoured over others, and so grazing habits are not uniform throughout the catchment. Hill slope seep wetlands, riparian meadows, contour banks and natural grasslands are examples of productive vegetation resources that have been recognised as common feeding

Example of gully in Tsitsa Catchment

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.

In this research, vegetation types will be identified in a pilot area of 5x5 km2 using high-resolution satellite imagery in order to determine and distinguish their spectral signatures. These signatures will then be used to distinguish these vegetation types in a larger spatial area with a lower resolution (25x25 km2). MODIS indices

including the Normalised Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and the Photosynthesis Net time series (PSNnet ts) will be used to determine the average condition and annual production of these vegetation types.



Example of seep wetland identified using MODIS NDVI.

USING STABLE ISOTOPE AND WATER QUALITY INFORMATION TO TRACE SOURCES OF WATER SUPPORTING A PALMIET WETLAND IN THE HEAD WATERS OF THE KROM RIVER IN THE EASTERN CAPE

Student: B Mahlaba
Supervisors: JL Tanner and SK Mantel
Degree: BSc (Honours) Environmental Water Management

Palmiet wetlands form part of the 50% of degraded wetlands in South Africa. They are unique ecosystems, with endemic plants that trap large quantities of eroded sediment and are mainly found in the Eastern and Western Cape. Palmiet wetland restoration programmes are taking place in South Africa but knowledge of the hydrological functioning of these systems is lacking, leading to reduced ability to effectively protect the remaining wetlands. Therefore, this study focuses on identifying sources of water which support a Palmiet wetland in the headwaters of Krom River. The project objectives are; determining if there is a groundwater contribution to the wetlands; and to assess whether physico-chemical variables and isotope data can be used to trace sources of water supporting the wetland. To achieve these objectives experimental methods and desktop methods will be employed. This includes field and laboratory experiments (sample collection, and isotope and water quality analysis) together with desktop methods such statistical analysis and simple water balance model. Water samples have been collected from surface water bodies, groundwater and rain. In the laboratory physicochemical variables and isotopes have been measured using specific probe and Isotopic Ratio Mass, respectively. The study demonstrated a strong groundwater contribution to the wetland and the water quality data was able to differentiate groundwater from different aquifers within the study site.

MAPPING AND PREDICTING LIVESTOCK DISTRIBUTION PATTERNS IN THE RURAL COMMUNAL RANGELANDS OF MGWALANA, EASTERN CAPE, SOUTH AFRICA

Student: Q Mkabile
Supervisor: CG Palmer, AR Palmer and SK Mantel
Degree: MSc (Water Resource Science)

Mgwalana is one of the rural areas in the Eastern Cape Province in South Africa, where communal lands have been utilised by livestock for many years. The surrounding rangelands within the area are perceived as unproductive and degraded; due to extensive agriculture and livestock farming (Perret et al., 2000; Palmer and Ainslie, 2006). The rangelands support cattle grazing and this dependence on natural resources, even though the areas are subject to rangeland degradation, at least provides basic living requirements for the communities (Rasch et al., 2017; Shackleton et al., 2001). The livestock move around in the communal rangelands in search of resources, such as food, water and shelter as a wind barrier (Rutter, 2007). Their grazing distributions is influenced by social and external factors including water availability & forage material and interior factors such as spatial memory which guides them to grazing material (Ganskopp et al., 2009; Saizen et al., 2010). On a daily basis, livestock decide where to graze, ruminate, rest and drink (Ganskopp et al. 2009). Even though livestock farming has been practised for a long time, there have not been many studies addressing the distribution patterns of livestock in these rural areas.

Ms Caitlin Smith and Ms Bwanile Mahlaba sampling water in a borehole in the Krom River

This study aims to link monitored livestock distribution to landscape variables in Mgwalana, and to use the modelled relationship to predict livestock distribution in quaternary catchment T12A and T35A-E.

Objectives:

I. To identify and map livestock distribution in the rangelands of Mgwalana
II. To relate landscape variables to livestock distribution
III. To use a desktop method that consists the measured landscape variables to predict potential livestock distribution in quaternary T12A and T35A-E

Geographic Information Systems (GIS) is a tool that has been used to map land use and monitor animal movement. In the South African context, the use of GIS combined with Global Positioning Systems (GPS) in domestic livestock needs to be given more attention. GPS collars were used to track livestock in summer (November-January 2016) and in winter (July-September 2017). The distribution data was combined with GIS derived surface layers to predict potential livestock distribution in quaternary catchment T12A and T35A- using the ArcGIS Predictive Analysis Tool The selected GIS surface layers were (1) elevation (height above sea level), (2) slope (steepness) and (3) aspect (solar radiation intercepted by that surface), which were all generated from a Digital Elevation Model (DEM), (4) Normalized Difference Vegetation Index (NDVI) which is used to represent the presence of vegetation and lastly, (5) Topographical Wetness Index (TWI) which were a representation of surface wetness.

Preliminary results show that core livestock distribution is located on grazing resources near homesteads and water sources, suggesting these areas on the landscape are important in predictive modelling. The results also demonstrate that without adequate fencing and livestock management, livestock utilize local grazing resources. With the decline in the use of herders within these communities, livestock are further concentrated around human settlement. The research will benefit the local community members by emphasising the need of strategic herding and labour through the identifying and highlighting areas that are potentially underused and overused. The research could also provide baseline information needed for rangeland strategies such rotational grazing.

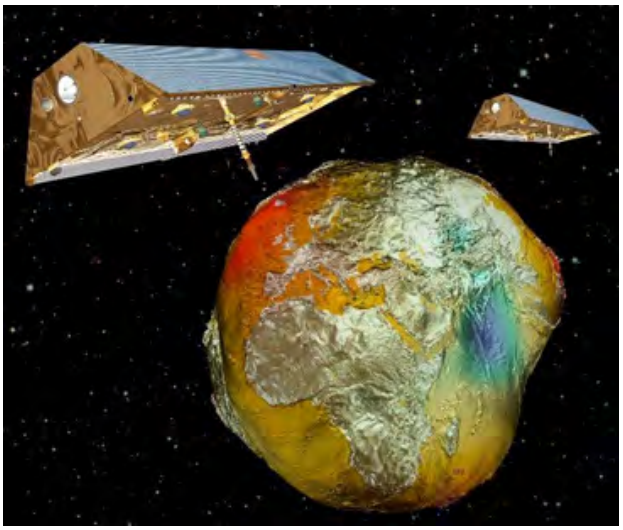
The distribution of livestock in summer 2016 (left) and in winter 2017 (right)

A local herder Ndade, assisting with handling the cattle and placing the GPS collars on the necks of the animals

VALUE OF GRACE PRODUCTS FOR HYDROLOGICAL MODELLING IN SOUTH AFRICA

Student: KN Mokoena
Supervisors: SK Mantel and JL Tanner
Degree: BSc (Honours) Environmental Water Management

Globally, water has been recognised as a fundamental natural resource that sustains social and economic development as well as environmental diversity. With increasing populations, shifts in climate, global warming and limited monitoring networks for both ground and surface water, freshwater resource quantities are becoming
difficult to assess because of the rapid changes in water supply and uses. Hence, there has been a growing need to monitor, sustainably manage current resources, and discover new freshwater sources. The Gravity Recovery and Climate Experiment (GRACE) was designed to quantify both ground and surface water potential. My honours project was to assess the value of using GRACE data products for hydrological modelling in South Africa.



Global gravity image by the GRACE sattelite

The study compared GRACE data products from three research groups namely: Centre for Space Research at University of Texas, Austin (CSR), Jet Propulsion Laboratory (JPL), and Geoforschungs Zentrum Potsdam (GFZ), with the Pitman hydrological model outputs for Doring River, Western Cape. The study compared evapotranspiration estimated from the GRACE- generated total water storage, since evapotranspiration is the most uncertain variable in hydrological modelling. The results showed that the three GRACE data products had similar outputs. The Pitman model evapotranspiration estimation was comparable to the GRACE estimation but had a lag period. The study highlighted the limitations of the application of GRACE to small catchments.

Through revealing the applicability, use and value of the GRACE model, this study contributes to the feasibility of using new and uncommon methods of validating and calibrating hydrological models using gravity derived-total water storage, and the potential of GRACE to obtain data particularly in areas where there are limited stream gauges for validation of hydrological models. This can benefit the updating of hydrological models and promote research and sustainable management of in freshwaters in South Africa.

TRADITIONAL ECOLOGICAL KNOWLEDGE AND ECOSYSTEM SERVICE DEBATES: CASES OF BHACA AND XESIBE COMMUNITIES IN RURAL EASTERN CAPE, SOUTH AFRICA

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

Project Summary
This study aims to contribute to the on-going search for sources of wisdom to address uncertainties resulting from the phenomenon of rapid ecological change globally and in traditional areas of South Africa specifically. In the decade of the 1980s, this search yielded two results: the recognition that there are alternative sources of wisdom outside of the architectures of western scientific traditions of knowing, especially traditional ecological knowledge, and a reframing of the concept of human-nature relations in the rubric of ecosystem service discourse. There exists a strong relation of complementarity between the two in that they both emphasise an interconnected systems-view of nature. In spite of this,

debates that are dominating the ecosystem service research agenda including management, valuation, conceptualisation of ecosystem services, as well as interpretation of ecological change feedbacks have done little to reflect the contributions of traditional ecological knowledge. This study will be conducted in two traditional villages of Gogela occupied by Xesibe tribe and Colana occupied by Bhaca tribe, who have over historical times substantially depended on ecosystem services, but on the other side, have endured multiple effects of ecological change including degradation of wetlands and rangelands, and have, over these years devised their own ways of dealing with these problems. The study employs tools of critical realism to respond to the question: what can traditional ecological knowledge, in virtue of its necessary properties, contribute in our search for a better understanding of the ontology of nature, and therefore develop more responsive epistemic tools to interpret and respond to complex manifestations of ecological change of our times?

Research objectives

1. To describe the contribution of ecosystem services to the well-being of local people
2. To describe the elements that constitute TEK such as beliefs, customs, taboos, myths, morality and spirituality and discuss how they are used in managing, interpreting changes, valuating and understanding of ecosystem services
3. To describe how TEK is used to interpret, and respond to ecological changes in the study villages
4. To capture and describe knowledge and practices around management of rangelands and wetlands
5. To explore how these findings can contribute to improved management or restoration of wetlands and rangelands in the former Transkei area.

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

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

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

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)

Increasing sediment loads in freshwater ecosystems is of great ecological concern. Elevated fine sediments (organic and inorganic particles of less than 2000 μm) are widely recognised as one of the major causes of aquatic ecosystem health impairment (Murphy et al., 2017). Elevated levels of sediment loads can impact on aquatic organisms and their microhabitat e.g. through damages to respiratory and feeding organs, abrasion of soft- sensitive tissues, alteration of habitat quality and modification of food availability and quality(Jones et al., 2012; Turley et al, 2016; Mathers & Wood, 2017). These effects can

manifest themselves in the form of biodiversity loss and general impairment of the overall ecosystem health, which may impact negatively on ecosystem structure and function (Naden et al., 2016; White, Hill, Bickerton, & Wood, 2017). Effects of elevated fine sediment loads on freshwater ecosystems have been monitored using aquatic macroinvertebrates as bioindicators (Mathers & Wood, 2016; Turley et al., 2016; Doretto et al., 2018).

In South Africa, macroinvertebrate responses to stressors are evaluated using the taxonomic structural analysis approach. However, there is a growing recognition of the predictive power of traits and that including traits in biomonitoring approaches could improve the diagnostic and predictive potential of biomonitoring tools. A trait-based approach focuses on traits attributes possessed by macroinvertebrates which allow species to deal with environmental problems and opportunities (Webb et al., 2010). Therefore, assessing impact of sediment loads require careful considerations of how macroinvertebrates traits may change in a potentially impacted ecosystem, which can influence the ecosystem function. The uses of species traits have potential to add the following to the practice of biomonitoring: i) diagnosis of impacts, ii) biodiversity assemblage prediction, iii) traits-linked to ecological function assessment.

Miss B Mdludla, Honours student assisting in the field filtering water samples for chlorophyll a analysis in the Tsitsa River

The Tsitsa River and its tributaries is subject to excessive sediment delivery particularly during wet seasons. Therefore the aim of this project was to develop a trait-based approach at the family and species level to evaluate and investigate the responses and vulnerability of macroinvertebrate to sediment stress in the Tsitsa River and its tributaries.

Specific objectives:

- Characterise sediment particle size distributions in the Tsitsa River and its tributaries
- Investigate the potential vulnerability and resilience of macroinvertebrates to sediments stress
- Develop a trait-based approach for assessing macroinvertebrate responses to sediment stress in the Tsitsa River and its tribuataries
- Compare family-and species-level macroinvertebrate-based approaches for assessing sediment impacts in the Tsitsa River and its tributar

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

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

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


Coal mining pollutes neighbouring river systems and groundwater systems in the grasslands

valuation often being limited to monetary values. Moreover, this valuation approach incorporates mainly environmental attributes leaving out the social and political aspects.

New developments have arose that view economic activities such as mining as part of a greater complex ecological system (CSES) involving both social and environmental attributes. We intend to explore mining activities and the aligning valuation methods used as part of a complex social ecological system. These approaches acknowledge that coal mining takes place in a space that includes both the environment and various stakeholder groups or institutional arrangements. Analysing coal mining as part of a CSES allows for the incorporation of social, political and environmental aspects into economic natural resource valuation.

Mining often takes place in a mixed land use area which consist of various stakeholders who may value the same resource differently. We aim to develop a framework that incorporates key concepts such as CSESs into resource valuation allowing for a more holistic approach in valuing the costs of economic activities such as mining. Our study area is the mining town of Carolina. There have been a number of contestations over the impact of mining on other land uses like agriculture. Water quality depletion has also been linked to coal mining as the source due to the pollution released. A resource valuation study has been done in Carolina which produced numerical values which were not representative of the various stakeholders in the area. In developing our framework we intend to analyse the extent of mining impacts in the area, the stakeholders involved, the valuation method used and whether the values presented were representative of the various stakeholders.

Overall, the aim of the research is to provide critiques and alternatives to the economic natural resource valuation approaches in a political ecological economic context that realises the interplay of the environment and the political, economic and social factors.

EVALUATING THE LEVEL OF EPISTEMIC JUSTICE IN THE APPLICATION OF ADAPTIVE PLANNING PROCESS FOR INTEGRATED WATER RESOURCE MANAGEMENT

Student: M Ralekhetla
Supervisor: SA Paphitis and CG Palmer
Degree: MSc (Water Resource Science)

In South Africa, the practice of IWRM is done through institutional arrangements, where Catchment Management Agencies (CMAs) are meant to undertake water resource management at a regional level. One of the CMA's duties is to develop a Sub-Catchment Management Strategy (CMS), with participation from other stakeholders in the region, whose participation is made possible through Catchment Management Forums (CMFs). A CMF is a voluntary and non-statutory body that anyone who is interested in water resource management can join.

An Adaptive Planning Process (APP) was used to develop a local CMS for the Upper Kowie catchment. The APP, is a planning component of Strategic Adaptive Management (SAM), a stakeholder-centred approach that facilitates the repetitive development of future rationalities and future-focused objectives as the basis for adaptive cycles of consensual decision-making (Rogers and Luton, 2011). There is bound to be power struggles among all these parties where some knowledge types are given more credibility over others. This is what Fricker (2007) terms epistemic injustice: "a wrong done to someone in their capacity as a knower". Such struggles become barriers to participation in community development projects, as people end up feeling discouraged to attend or even speak in a space where their opinion means little.

The approach used in engaged projects have an impact on the level to which injustices are either prevented or perpetuated. An evaluation framework was developed in consultation with literature, and relevant criteria was selected from different frameworks participants' experience of epistemic justice during the application of an APP to develop their local CMS. The framework wanted to find out participants' understanding of concepts, their satisfaction, their experience of learning and co-learning,

their views on equality of voice, process flexibility and adaptability, and inclusive facilitation. Guiding questions to fit the criteria of the evaluation framework were formulated and participants were asked to reflect on the APP as it was facilitated during two integrated adaptive planning workshops in the Upper Kowie catchment.

In their reflections, participants acknowledged the APP for being inclusive and giving a platform to share ideas and learn. However, their concern was that the workshops failed to achieve good stakeholder representation, and that the focus of discussion was not clear enough. Participants further emphasised that their local municipality needed to be capacitated to do their work better, which highlighted the need for a CMF that deals with both water resource management and water service delivery. The results show that APP has potential to guide an effective implementation of IWRM in South Africa, but personal reflections helped to uncover some epistemic injustices that might need to be incorporated in future applications.

Makana water stakeholders in groups to describe the social, technological, environmental, economic and political characteristics of their catchment.

Stakeholders building an objectives hierarchy to guide them to the vision.

QUANTIFYING AND COMPARING ACTUAL EVAPOTRANSPIRATION ON PALMIET WETLANDS USING THE MODIS ET PRODUCT, FRUITLOOK, PITMAN MODEL AND SCINTILLOMETER DATA: A CASE STUDY OF THE KROM WETLAND.

Student: PP Ramatsabana
Supervisors: JL Tanner and SK Mantel
Degree: BSc (Hons) Environmental Water Management

Wetlands have been highlighted as the most extensively compromised ecosystem in South Africa (National Biodiversity Assessment, 2011). Palmiet wetlands in particular are becoming increasingly degraded across their distributional range (Rebelo, 2012). Degraded wetlands have reduced capacity to perform valuable ecosystem functions and this has disadvantageous consequences (Collins, 2005), particularly on the water security of South Africa (Gull, 2012). There is indication that restoration and protection of wetlands can be enhanced if their hydrology is properly understood. Of the various components of the hydrological cycle, evapotranspiration is key since it significantly contributes to the depletion of water and therefore affects catchment water balance (Labedzki, 2011: 3). Quantification of evapotranspiration is challenging and much uncertainty still exists about the most useful and appropriate method that can be used to accurately quantify this phenomenon (Labedzki, 2011: 209).

Currently, there is limited knowledge about the hydrological functioning and processes of South African wetlands. Palmiet wetlands in particular are understudied and there is limited scientific knowledge about their evaporative demands (Rebelo, 2012). In a semi-arid setting like South Africa, actual evapotranspiration significantly affects catchment water balance (Kongo et al., 2011). Therefore, it is important to consider how evapotranspiration can be quantified with reliable accuracy in order to improve monitoring and management of these wetlands. In this study, four approaches were compared to assess their effectiveness in determining actual evapotranspiration on Palmiet wetlands. These

approaches, selected based on availability of data requirements are: three estimation techniques (remote sensing- based MOD16 data product, FruitLook and the modified Pitman Model) as well as a measurement technique (scintillometer measurements). Overall, comparisons between all the different data sets did not yield consistent outcomes. There is a lot of uncertainty in all of the estimates but generally it seems the higher Pitman estimates over the Krom wetland were reliable while the lower MOD16 estimates off the wetland seem to be more reliable.

The Krom Palmiet wetland is an attractive case study because it is one of few Palmiet wetlands in South Africa which remain relatively untransformed (Pulley et al., 2018) and therefore provides an important opportunity to study the hydrology of this type of wetland. Secondly, very little work has been done to study the ETa of this particular wetland as well as the majority of South African Palmiet wetlands thus, scientific understanding concerning their hydrology is limited. This study will go some way towards bridging the current research gap. By applying different approaches to quantify ETa, the study will also contribute to knowledge about the effectiveness of these approaches. Lastly, the wetland is located in the Krom River catchment which, has been indicated as a priority area because of its role as a key water source for the Nelson Mandela Bay Metropolitan Municipality (Department of Water Affairs, 2010). The Krom River catchment is also the focus of ongoing work in terms of research into Palmiet wetlands (Pulley et al., 2018) and national restoration by the Working for Wetlands programme.

DETERMINING THE HYDROLOGICAL FUNCTIONING OF PALMIET WETLANDS IN THE EASTERN AND WESTERN CAPE OF SOUTH AFRICA.

Student: CJ Smith
Supervisor: JL Tanner
Degree: MSc (Hydrology)

Wetlands are one of the most vulnerable ecosystems in South Africa, with 65% of wetland ecosystems regarded as threatened (Nel et al., 2011). Palmiet wetlands in the Eastern and Western Cape are particularly threatened, with serious consequences for water security in many towns in their catchments. There are serious knowledge gaps in our understanding of palmiet wetland structure and function, particularly in the hydrological functioning of these systems. Palmiet (Prionium serratum) is a robust perennial plant that is endemic to wetlands and rivers located in sandstones and quartzites of the Table Mountain Group (TMG) geology, in the Eastern and Western Cape.

The aims of the study include:

1. Determine the surface and groundwater dynamics of the Krom River upper catchment (K90A).
2. Identify the relationship between the Palmiet wetlands and hydrological functioning of the catchment.

The study area is located within a sub-catchment of the K90A upper Krom River catchment in the Eastern Cape Province of South Africa. Water level data was collected from the river, the wetlands, a number of piezometers, and boreholes; an Electrical Resistivity Tomography Survey was undertaken; the area was extensively surveyed and water quality and isotope analysis was carried out.
The proposed conceptual model is that the Palmiet wetlands are sustained by sub-surface water (both groundwater and interflow) moving through preferential flow paths in the alluvial fans which are in turn sustained by groundwater discharge from the surrounding sandstone and quartzites of the Nardouw Subgroup and Peninsula Formation (TMG). A mixing cell model (which makes use of water quality data), the modified Pitman hydrological model and the Groundwater Yield Model for the Reserve (GYMR) were set up for the study catchment.

The results of the field data collection and modelling results indicate that groundwater accounts for a large percentage of the wetland water balance. The mixing cell model indicates that groundwater accounts for 33% of the inflow into the Kompanjiesdrift (downstream) wetland for May 2018. The project has identified that a consistent water supply in the form of low flows in rivers is important for Palmiet's establishment and survival.

Groundwater plays an important role in sustaining the wetlands (particularly during dry periods). It is evident that a consistent water supply is a Palmiet system driver and a key component of Palmiet wetland formation. Sustained discharges from the TMG geology ensure this consistent water supply to the Palmiet.

Ms C Smith surveying the Krom River channel with a DGPS.

Palmiet growing in the Krom River.

Conference presentation: Attended the National Wetland Indaba in Kimberley, Northern Cape in October 2018 and presented a poster detailing the results of the project.

CIVIL SOCIETY ENGAGEMENT WITH WATER GOVERNANCE AT A LOCAL GOVERNMENT SCALE IN SOUTH AFRICA

Student: MJT Weaver
Supervisor: CG Palmer and J O'Keeffe
Degree: PhD (Water Resource Science)

Many of the world's water basins and the complex social and ecological systems they support are under threat. Problems associated with the management of water are complex and well suited to adaptive and integrated management approaches. South Africa has adopted the ideology of decentralised, participatory water governance. Water resource management and water service delivery is the responsibility of regional and local government officials and policy makers who also have been mandated to enable stakeholder participation in water governance processes. Grass-roots multi-stakeholder engagement platforms, catchment management forums (CMFs), have been established as key participation conduits. CMFs have the potential to foster learning and adaptive capacity development of water management actors and stakeholders and in doing so, play a valuable role in improving the sustainability of catchments and embedded water management systems.

From 2014 to 2016 I conducted my masters research on the emergence, practice and social learning of a civil society organisation, Water for Dignity (WFD), in response to household water service delivery issues in Grahamstown East (the township of Grahamstown) (Weaver et al. 2017; Weaver et al. (two manuscripts under revision). In 2016, took the opportunity to upgrade my degree to a doctoral level. The upgrade provided me with the opportunity to expand the transdisciplinary aspects of my research to explore and improve participatory water governance in the Makana Municipality from 2016 to 2018. The emergence of a CMF, the Makana Water Forum (MWF) in 2016 provided a space to explore the effectiveness and sustainability of real participation of civil society with water governance. The MWF was South Africa's first CMF with an integrated water services and water resource management agenda.

Together with the MWF management committee, I facilitated a series of Change Laboratory workshops (Virkkunen & Newnham, 2013) (an interventionist method informed by Cultural Historical Activity Theory (Engeström, 2011)). The purpose of these workshops was twofold: firstly to further the scientific goal of understanding the empirical nature of civil society participation with water governance; and secondly to further the societal goal of improved civil society participation in, and function and sustainability of, the MWF, and in turn better management of the Makana Municipality water

management system. In these workshops, I guided participants through seven learning actions (expansive learning cycle) to identify, analyse and model remedial actions to problematic aspects (contradictions) of the MWF practice.

I explored the development of individual and collective transformative agency (purposeful actions towards changing a situation), a key outcome of a Change Laboratory process. Seven different forms of agentive expressions were identified. Constraining socio-economic and political conditions hindered the conversion of transformative agency to concrete actions.

The intervention with the MWF was too short a process to clearly observe the effects of transformative actions on the sustainability of the MLM water system. However, long chain transformative agency through the development one-on-one engagements, learning journeys and a reflexive component to the MWF engagements could support transformative pathways to sustainability in the municipality and water management system.

Figure 1: An example how MWF participants navigated the expansive learning cycle to address one of the problems the MWF faced. A problem (contradiction) related to lack of water knowledge capacity of MWF committee members led to the modelling of a new form of activity which included a new tool, the Water Tour. This was an interactive learning tour of the Grahamstown's water system. The outcomes were, inter alia, MWF committee member and community capacity development, increased MWF awareness and legitimacy, and relationship and trust building between municipal and government actors and civil society. The intervention has catalyzed the process modeling and implementation of remedial actions to other contradictions.

RESEARCH OUTPUT

PEER REVIEW JOURNALSAND CONFERENCE PROCEEDINGS

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"Water is the driving force of all nature"
Leonardo Da Vinci