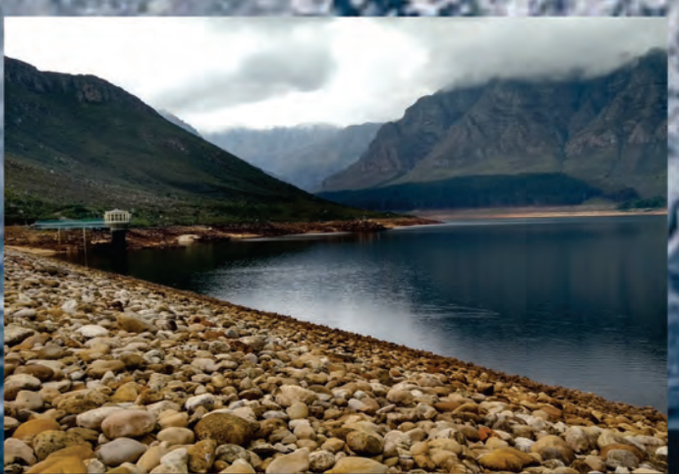
# Institute for Water Research

## Annual Report 2017

IWR



RHODES UNIVERSITY
*Where leaders learn*

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Rhodes University
Institute for Water Research
2017

***Left to Right***
***Back Row: Ms K Mgaba; Mr S Ndlovu; Prof D Hughes; Dr A Slaughter; Mr M Weaver; Mr D Rugai; Mr E Vellemu; Dr N Griffin***
***Third Row: Ms B Gusha; Ms J McLean; Ms D Louw; Dr J Tanner; Dr T Palmer; Dr N Odume; Mr K Smetherham; Mr D Choruma***
***Second Row: Ms M Ralekhetla; Dr S Mantel; Ms P Kabuya; Dr P Mensah; Mr S Mazibuko; Ms M Wolff; Mr C Murata; Mr D Forsyth***
***Front Row: Mr D Gwapedza; Ms P Ntloko; Mr N Mti; Prof T Palmer; Mr F Akamagwuna; Mr M Mkatali***

***Cover Photograph Acknowledgements***
***Top: Theewaterskloof Dam in Western Cape by Jane Tanner, Bottom: Baetid sub-imago in flight by Ferdinand de Moor***

# Staff and Members of the Institute

## STAFF

| | |
|---|---|
| Mr David Forsyth | Principal Technical Officer |
| Dr Neil Griffin | Research Officer UCEWQ-IWR |
| Mr Nick Hamer | Research Associate |
| Ms Bawinile Mahlaba | Intern |
| Dr Sukhmani Mantel | Senior Research Officer IWR |
| Ms Juanita McLean | Administration Manager |
| Dr Paul Mensah | Research Officer IWR |
| Mr Sbongiseni Mazibuko | Research Assistant |
| Ms Ntombekhaya Mgaba | Senior Technical Officer |
| Mr Mzwanele Mkatali | Technical Assistant |
| Ms Ntombekhaya Mti | Intern |
| Dr Nelson Odume | Director of UCEWQ |
| Prof Tally Palmer | Professor / Director of IWR |
| Dr Andrew Slaughter | Research Officer IWR |
| Dr Jane Tanner | Research Officer IWR |
| Ms Siphokazi Tantsi | Intern |
| Ms Margaret Wolff | Part time Project Manager UCEWQ-IWR |

## ASSOCIATES

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

## 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 Caleena de Carvalho | BSc (Hons) |
| Mr Augustine Edegbene | PhD (Water Resource Science) |
| Mr Adebayo Farounbi | PhD (Water Resource Science) |
| Mr David Gwapedza | MSc (Hydrology) |
| Mr Onalenna Gwate | PhD (Water Resource Science) |
| Mr Pierre Kabuya | PhD (Hydrology) |
| Ms Tia Keighley | MSc (Water Resource Science) |
| Ms Notiswa Libala | PhD (Water Resource Science) |
| Mr Zwidofhelangani Lidzhegu | PhD (Water Resource Science) |

| | |
|---|---|
| Ms Eunice Makungu | PhD (Hydrology) |
| Ms Ntombekhaya Mgaba | MSc (Water Resource Science) |
| Ms Qawekazi Mkabile | MSc (Water Resource Science) |
| Ms Sinako Mtakati | BSc (Hons) |
| Ms Vuyelwa Mvandaba | MSc (Hydrology); Based at CSIR |
| Mr Siyabongu Ndlovu | MSc (Water Resource Science) |
| Mr Coli Ndzabandzaba | PhD (Hydrology) |
| Ms Pindiwe Ntloko | PhD (Water Resource Science) |
| Ms Nadia Oosthuizen | MSc (Hydrology); Based at CSIR |
| Ms Mateboho Ralekhetla | MSc (Water Resource Science) |
| Mr Dionis Rugai | PhD (Hydrology) |
| Mr Kyle Smetherham | MSc (Hydrology) |
| Ms Caitlin Smith | MSc (Hydrology) |
| Mr Gareth Thomson | MSc (Water Resource Science) |
| Mr Emmanuel Vellemu | PhD (Water Resource Science) |
| Mr Matthew Weaver | PhD (Water Resource Science) |
| Ms Margaret Wolff | MEd |

**2017 GRADUATED STUDENTS**

| | |
|---|---|
| Ms Athina Copteros | PhD (Geography) |
| Ms Yvonne Chiliboyi | MSc (Water Resource Science) |
| Mr Sbongiseni Mazibuko | MSc (Hydrology) |

**MEMBERS OF THE BOARD OF CONTROL**

| | |
|---|---|
| Prof Janine Adams | NMMU, Botany Department |
| Mr Heteesh Bhoola | Unilever SA |
| Prof Peter Clayton | Chairman, Rhodes University; Deputy Vice Chancellor: Research & Development |
| Prof Fred Ellery | Rhodes University, Department of Geography |
| Prof Heila Lotz-Sisitka | Rhodes University, Environmental Learning Research Centre |
| Ms Juanita McLean | Secretary to BOC and Administration Manager |
| Mr Fikile Guma | Department of Water Affairs |
| Dr Jennifer Molwanta | WRC (Water Research Commission) |
| Prof Carolyn (Tally) Palmer | Rhodes University, Director of Institute for Water Research |
| Dr Nelson Odume | Rhodes University, Institute for Water Research, Director UCEWQ |
| Dr Angus Paterson | SAIAB (South African Institute for Aquatic Biodiversity) |
| Prof Sheona Shackleton | Rhodes University, Environmental Science |
| Dr Dirk Roux | SANParks |

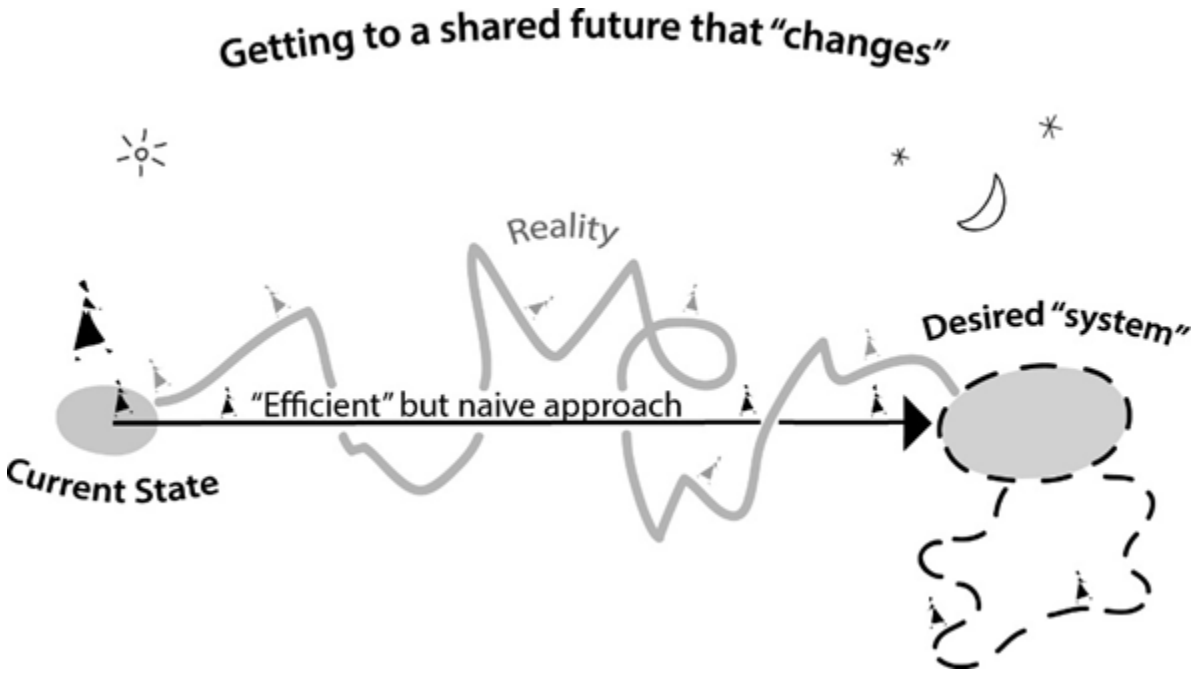
# IWR Director's Report

This year, 2017, has been one of change, challenge and confident progress.

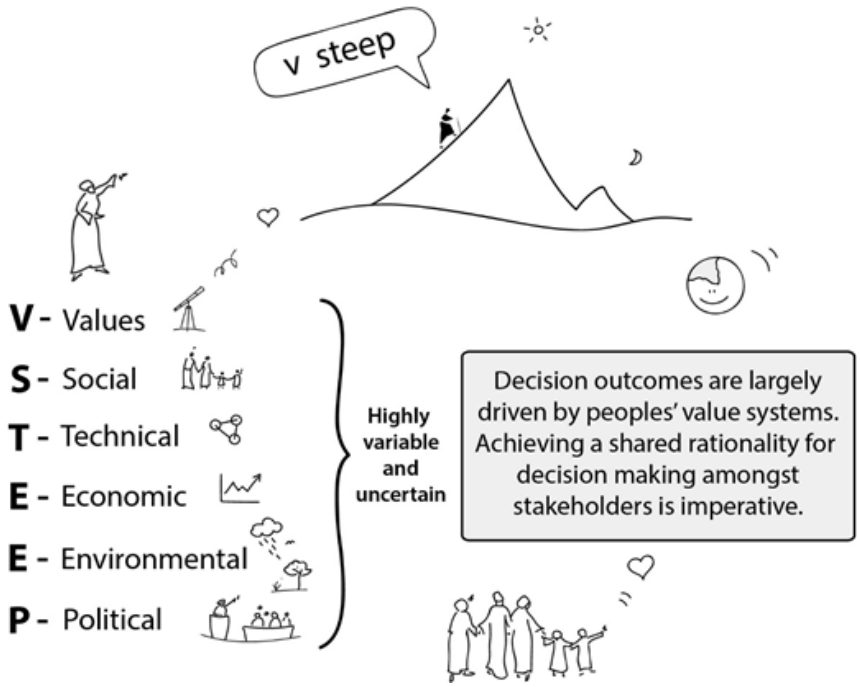
In November 2016 Professor Carolyn (Tally) Palmer was appointed as the Director of the Institute for Water Research (IWR) on a three year contract. This is the first year that the IWR has not had a full time, permanent, senior University staff member, this is a strong signal from the University of i) commitment to transformation, and ii) financial constraint. One of the Director's contractual requirements is to work actively to ensure rapid succession into this leadership role. It is imperative that we respond positively and actively to this context.

In January 2017 all the staff and students of the IWR participated in a two-day strategic Adaptive Planning Process in order to start using Strategic Adaptive Management (SAM) in the IWR. The workshop, was facilitated by Professor Kevin Rogers (Emeritus Professor, University of the Witwatersrand), who developed SAM as an approach to managing complex adaptive systems. Researchers in the IWR have used SAM in their Integrated Water Resource Management research, and it seemed sensible to apply it in our own management.

Strategic Adaptive Management draws on an understanding of the way complex systems work. Attention is paid to each of the elements in the system and the relationships between them; the influencing feedbacks, taking notice of non-linearity and unexpected outcomes; and especially, the many dimensions of context. Adaptive planning is a participatory process in the early stages of SAM. It allows a group of people with a shared future, to plan together for that future. An early shared understanding is the acceptance that pathways are circuitous and must be navigated:




At the start of the workshop participants shared their current concerns, and accepted they could not be solved over the two days. The concerns were listed so as to check whether the outcome of the process would address them, and at the end of the process we agreed the concerns would be addressed by the action plan. We co-operatively developed a vision, and then explored our context in terms of our values as well as the social, technical, environmental, economic, and political constraints and opportunities. Out of those we developed a hierarchy of objectives to guide us steadily and flexibly toward our desired future.




The staff and students of the IWR envisage our shared future as:

- offering a warm, welcoming place, where humanity and equal opportunity thrive; and where there is respect for the gender, race, nationality, and any other differentiating factor, of each person;
- producing cutting edge, socially, and ecologically responsible research outcomes which feed into a vibrant teaching, supervisory, and community-engaged programme;
- producing collaborative (local and international) research that is highly valued and used in a wide range of decision making;
- contributing effectively to the development of professionals in sustainable Adaptive Integrated Water Resource Management across Africa;
- offering a vibrant, internationally acknowledged, and well-resourced space to work; and
- being resilient and adaptive because change is accepted as both reality and opportunity.

The objectives hierarchy led to goals for different time periods. Four main behavioural changes and associated goals were identified for 2017–2020:

- Act to diversify income streams and increase income and savings so that: i) Rhodes University is assured that contracts to IWR staff can be offered beyond immediate project time-frames, and ii) 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.

After adaptive planning comes adaptive management. IWR staff and students formed groups to take responsibility for progressing the four objectives, and feedback on progress was discussed and evaluated at weekly meetings. Adaptations to "business as usual" included the initiation of new funding proposals and offering in-house courses for skills development. This feedback and discussion process is required by SAM.

Progress in 2017, in the four primary strategic areas, is evident.

*Diversified income*: The proposal submission rate to the Water Research Commission was maintained. Three international grant proposals were submitted with partners, but none of these was funded. It is clear that effort must be sustained and international research collaborations fostered. Professor Denis Hughes remains our best internationally connected researcher. An MOU has been developed with Dr Eric Igbinigie, the CEO of a BEEE-accredited natural resource consulting company. This enterprise is well placed to benefit from the new radical economic transformation legislation and IWR researchers will become preferred partners in appropriate consulting projects.

At present, the IWR runs one Rhodes University-accredited certificate of participation (Environmental Water Quality). Paying participant numbers increased from 4 in 2016 to 16 in 2017. Congratulations to co-ordinator Dr Paul Mensah. During 2017 course outlines for seven new courses have been developed and these will be accredited. This course material has been used as the basis for additional modules in the Environmental Water Management Honours degree, currently offered by the Geography Department. From 2018 the course will be co-offered by the IWR. This initiative will: bring between 8 and 12 new honours students into the University; enable IWR staff to deepen teaching and learning skills; augment the post-graduate candidate stream into the IWR, and, in time, will become an additional income stream.

*Skills Development*: The IWR provided 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 Post-Graduate Studies.

*Research output*: There is a focussed writing morning every second Friday, which has encouraged a writing commitment and habit. The publication output of the IWR has improved in 2017 from 20 reports and 13 papers in 2016 to 24 reports and 33 papers in 2017.

*IWR reputation and profile*: In addition to the academic reputation and profile accrued from academic output, efforts by the IWR to increase its profile within the University have included active participation in University activities, for example: Dr Nelson Odume was the guest speaker at the Environmental Awards and Matthew Weaver won the individual contribution award, the IWR is part of "Water World" at SciFest Africa, and the IWR responded exceptionally quickly to the call to increase the honours student intake. Provincially, the IWR has interacted positively with the Eastern Cape Departments of Water and Sanitation, and Environmental Affairs, with the Premier's office, and with a variety of local and district municipalities. Nationaly, the IWR has been acknowledged for contributions to the National Water Quality Management Policy and Strategy. Feedback from IWR students indicated that they did not feel sufficiently aware of all the initiatives and that in 2018 they would like to increase their participation. Professor Palmer has been identified as the Director of the newly founded Water Conservation Centre of Excellence in the African Research Universities Alliance (ARUA). The IWR will be the Centre's hub. The IWR is now also part of the African Transdisciplinary Research Network. In 2018 the IWR will host the Environmental Water Management honours, with 6 – 12 new honours students attracted into Rhodes University. International profile will be a 2018 focus.

The SAM process is designed to be: i) inclusive, acknowledging the value of the knowledge held by each individual participant and; ii) deliberative, with the aim of achieving consensus rather than consulting for compromise. Important in SAM is the following philosophy: 'the best way to achieve what you want is to help others with a shared future to achieve what they want'.

The IWR is now working as a cohesive whole across all areas of academic expertise and with the actively involved participation of support staff. Leadership is shared. Further details are reported by the Director of the Unilever Centre for Environmental Water Quality, Dr Nelson Odume, and the Hydrology Research Leader, Dr Jane Tanner.

I take this opportunity to thank everyone in the IWR for their hard work, enthusiasm, commitment, and support. Congratulations to Dr Paul Mensah for his promotion to Senior Researcher. Thanks to Emeritus Professor Denis Hughes for his continued, and substantive contributions. The Departments of Geography and Environmental Science, and the Environmental Learning Research Centre, are much appreciated as key partners. The IWR Board members offered good guidance, and we continued to receive excellent strategic and financial support from the University. Particular thanks go to the Dean of Science, Professor Tony Booth and the Deputy Vice Chancellor Research and Chairperson of the IWR Board, Dr Peter Clayton.

**Professor Tally Palmer,**
**Director IWR**

***Illustrations by Tammy Griffin from the accessible handbook "How to…." series;***
***Reference: Rogers, K.H. and Luton, R. (2011). Strategic adaptive management as a framework for implementing integrated water resource management in South Africa. WRC Report No. KV 245/10. Water Research Commission, Pretoria, South Africa.***

# Unilever Centre for Environmental Water Quality (UCEWQ)
# UCEWQ Director's Report

## INTRODUCTION

The Centre is committed to growing a people-centred scholarship in the water sector, and contributing to capacity building on the African continent. As always, staff and students of the Centre continue to receive accolades in recognition of their exceptional contributions to democratic water governance and sustainability research. Two of these awards are significant and noteworthy. First, the Rhodes University Environmental Award in the individual category was awarded to Mr Matthew Weaver, a PhD student in the Centre. The award recognises individuals with exceptional and distinguished contributions to environmental sustainability. Mr Weaver was recognised for his engaged and participatory research processes, harnessing people's voices to improve democratic water governance processes in the Makana Local Municipality. Mr Weaver's research and active involvement in the local water governance arena has contributed to the establishment of the local water and sanitation forum. The award was formally presented to him on 26 September 2017, where Dr Odume gave the key note address.

***Mr Matthew Weaver and other winners at the Rhodes University Environmental Award (left photo) and Mr Weaver receiving the award from DVC Research and Development Dr Peter Clayton (right photo).***

***Ms Mgaba receiving a certificate of attendance of SPAS in São Paulo, Brazil.***

Second, Ms Ntombekhaya Mgaba was awarded a prestigious IWRM grant to attend the first São Paulo Advanced School (SPAS) on Integrated Water Resource Management, hosted by the International Institute of Ecology, Management and Water Resources. This competitive training opportunity, which was held from 2 – 15 September 2017, attracted 100 participants from 34 countries across all continents. Ms Mgaba presented aspects of her MSc research. We are indeed proud of these notable awards and strides. Ms Qawekazi Mkabile, Mr Matthew Weaver, Mr Dennis Choruma, Ms Pindiwe Ntloko, and Ms Notiswa Libala all received NRF scholarship for their studies.

This year, we took a strategic decision to actively contribute to the training of professionals who are already working in the water sector. To this end, the Centre ran a Rhodes University 10-credit accredited short course on Environmental Water Quality (EWQ) in Integrated Water Resource Management. The first stream of the one-week course took place in February 2017, with four delegates and the second in October with 16 delegates, who were mostly from the Department of Water and Sanitation. The course covers various aspects of EWQ including catchment systems and water governance, water physicochemistry, biomonitoring, ecotoxicology and tools used for the achievement of resource directed measures and source directed controls. It is important to note that upon completion of the course and successful submission of an assignment, delegates are awarded a Rhodes University short course certificate of competency. Those who elect not to submit an assignment are given a certificate of attendance. Feedback from the delegates were affirmative and we hope to run the course again in 2018. I appreciate the effort of all the course facilitators and in particular the course coordinator, Dr Mensah.

## NATIONAL, REGIONAL, AND INTERNATIONAL INFLUENCE

UCEWQ continues to make policy influence in the water sector. This year, the flagship project '*Practicing Adaptive IWRM: Integrated Water Resources Management (IWRM) in South Africa: Towards Practising a New Paradigm*' came to an end. The project has made tangible contributions to the water sector. Most noteworthy of these is the uptake of the systemic, adaptive, and complexity-based thinking. This is already evident in the new National Water Quality Management Policies and Strategies for South Africa. From this project nine accessible handbooks on Adaptive IWRM practice will be made available nationally to local government, land, and water resource management institutions, NGOs and civil society. Knowledge co-development workshops in these concepts and practice have been conducted in the Olifants River Catchment, through the Association of Water and Rural Development, and in the Eastern Cape for the Department of Environment Affairs Natural Resource Management Chief Directorate. This is a strategic influence that we are proud of.

***EWQ Course delegates during the October stream.***

The Centre is deeply committed to making policy influence. In this regard, its staff and students have actively participated in and contributed to the WRC Dialogues (Water Current Policy Series), which are platforms for exchanging ideas on topical water issues affecting South Africa. Dr Odume was invited as a guest speaker by the WRC on Water Ethics and Governance at the WRC Dialogue on water stress, religion and culture, to mark the 2017 heritage celebration. He was also invited as a guest speaker by the National Department of Health to make input into the national hygiene programme currently being formulated by the Department. Prof Tally Palmer and her students are pioneering the governance research in the Tsitsa River catchment, within the framework of the Ntabelanga and Laleni Ecological Infrastructure Project (NLEIP).

On the International front, UCEWQ is actively collaborating with international partners. The AfriAlliance project led by Dr Odume organised a four-day workshop on integrated water resource management and ethics. The objective of the workshop was to co-produce knowledge, share insights and perspectives on ethically grounded water resource management in Africa and Europe. Workshop participants included government delegates, academics and delegates from AfriAlliance partners in Botswana, Morocco and Spain. The ideas generated at the workshop are already being taken further in practice and policy. Our international link with Professor Jill Slinger, who is our IWR Visiting Professor, remains solid. She has been actively involved in developing systemic concepts in our research projects. Dr Stephan Pietch from the International Institute of Applied System Analysis, visited the Centre and gave a talk on system modelling. He is already co-supervising with Dr Odume. In 2017, the Centre was also invited to participate in a transformational learning workshop by the Institute of Environmental Systems Research at the University of Osnabruck, Germany. This invitation stems from the recognition of the work being done at the Centre, particularly its transdisciplinary, engaged research. The transformational learning workshop attracted participants from universities in Germany and South Africa. The Environmental Learning Research Centre (ELRC) and Institute for Water Research will host delegates from this workshop in 2018. We look forward to this workshop!

UCEWQ staff and students are committed to active participation in community engagement initiatives. Dr Paul Mensah and Ms Khaya Mgaba have taken on the leadership of our community engagement initiatives. As part of the Centre's

contribution to career guidance in the water sector, Dr Mensah, Ms Mgaba, Ms Mti and Ms Tantsi organised career guidance in the water sector for learners from three high schools: Nombulelo High School, Mretyana High and Nathaniel Nyaluza, within Grahamstown. Students were also taken to the nearby Bloukrans River to see first-hand how pollution from the catchment affect the health, water quality, and overall functioning of the river. Learners engaged in mini-SASS as a way of better understanding and evaluating aquatic health. Already, in 2018, the group is planning to organise an interschool water centred quiz competition.

UCEWQ staff and students also participated in Scifest Africa 2017. This year, learners from high schools were made to identify macroinvertebrates in three samples collected from river sites that were differentially impacted. The idea was to allow learners to discern the difference between the kinds of macroinvertebrates in these samples as indicators of the health of the sites from which the samples were collected. UCEWQ students have also taken the campaign on saving and conserving water to schools. Mr Weaver and Ms Mkabile gave a presentation on the status of water in Grahamstown and provided tips on how best to save and conserve our most precious resource: water. We are fully committed to working with communities to find lasting solutions to the water crises in our community. UCEWQ students were also not left out in the faculty of science open day and in the ESKOM expo. Ms Libala, Mr Akamagwuna and Mr Weaver took on mentoring of learners, helping them to prepare for the annual ESKOM expo.

## PARTNERSHIPS, LINKAGES, AND PERFORMANCE

Unilever South Africa remains the core founding partner of the Centre. I indicated in my 2016 report that the Centre and Unilever SA signed a three-year Memorandum of Agreement (MOA). We enter into the third year of the agreement in 2018 and we will continue to work closely with our Unilever SA champion, Ms Preola Adams, who has been an anchor for us and we are grateful to her. Unilever SA has identified household water security and catchment water security, in terms of quantity and quality, as key priority areas to which they would like to make contributions. During this year's World Water Day, Unilever SA working with UCEWQ, sponsored a water event at Vukani where household water tanks and sunlight washing powder were donated to lucky winners. The idea of household water tanks came out of the research conducted by UCEWQ staff and students in which residents indicated their preference for a small indoor water tank compared with a large communal outdoor water tank. Unilever SA and UCEWQ also sponsored a series of water conservation campaign across the Eastern Cape. In 2018, we are looking forward to mapping out a strategy for catchment water security in two catchments where Unilever's plants are situated, one in Gauteng and the other in Kwazulu-Natal.

This year, we led the Rhodes University bid to host an ARUA (African Research Universities Alliance) Centre of Excellence in Water Conservation. This is a strategic and important move as a successful bid would open up opportunity for continent-wide partnership and collaboration.

Our developing partnership with Assured Turnkey Solutions (PTY) LTD – a BBEEE company that offers environmental and social advisory services, is another strategic alliance. We are looking forward to this partnership yielding consulting income opportunities. We also now have a formal agreement with Scherman Colloty & Associates CC on developing and teaching of short courses. Prof Jill Slinger's appointment as Visiting Professor was renewed by the University and Drs Eric Igbinigie and Victor Munnik were appointed as Senior Research Associates. Both have already contributed substantially to the Centre.

***UCEWQ students with learners during the Faculty of Science Open Day.***

Our partnership with the South Africa Young Water Professional (YWP) remains solid. Two of our PhD students: Mr Matthew Weaver and Ms Notiswa Libala are part of the Eastern Cape provincial executive committee. This year, our students will also be attending the International Young Water Professional Conference in Cape Town. This is the first time Africa is hosting this international conference and we are excited that our students are able to fully participate.

Our staff and students continue to attend and present papers at both local and international conferences and workshops. Ms Pindiwe Ntloko presented a paper at the 2017 Society for Freshwater Science (SFS) International Conference in Raleigh, North Carolina, USA. Ms Libala presented a paper at the prestigious International Congress for Conservation Biology in Cartagena, Colombia. Ms Qawekazi Mkabile, Ms Notiswa Libala, Ms Mateboho Ralekahla, Mr Siyabonga Ndlovu, and Mr Frank Akamagwuna all attended and presented papers at the Rhodes University interdisciplinary postgraduate conference. Mr Frank Akamagwuna attended and presented a paper at the 2017 SASAQ conference in Johannesburg. Prof Tally Palmer presented at the Savannah Network Conference and Dr Neil Griffin and Dr Paul Mensah facilitated a workshop on the use of toxicity testing in water use licensing.

Our student enrolment and graduation rate remain admirable. In 2017, Dr Athina Copteros, and Ms Yvonne Chiliboyi obtained their degrees. Mr Matthew Weaver successfully upgraded to a PhD. Mr Emmanuel Vellemu, Ms Tia Keighley and Mr Gareth Thompson have submitted their theses for external examinations. Mr Frank Akamagwuna, Ms Khaya Mgaba, and Ms Margaret Wolff are near completion. 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 2017, we welcomed an NRF-funded intern Ms Siphokazi Tantsi who, under the mentorship of Dr Odume, has taken on a leadership role in a number of projects including organising the international AfriAlliance workshop. Ms Bawinile Mahlaba who joined us in 2016 has now taken on a postgraduate study at Cape Peninsula University of Technology (CPUT). Ms Ntombekhaya Mti joined the Centre in 2016 and remains with us. She has acquired new skills in shrimp culture, water quality testing and Microsoft Excel. Ms Mkabile who joined the Centre as an intern last year has commenced her MSc study with us this year. Mr Mzwanele Mkatali who has been an intern with the Centre for the past four years, registered for an Honours programme in Chemistry last year and is on his way to completing it this year. We are indeed delighted that the Centre is able to provide an opportunity for people to develop and acquire new skills.
Our laboratories and cultures are in excellent condition and we continue to participate in the National Laboratory Proficiency Testing Scheme.

Our Environmental Water Quality (EWQ) Honours module, which is offered to Departments of Environmental Science and Geography students, was successful. An important highlight, is that beginning in 2018, we will be offering a joint Honours programme with Geography in Environmental Water Management.

Lastly, I would like to express my deepest appreciation and gratitude to all staff and students of the Centre who have worked tirelessly to make 2017 a huge success. I have every reason to believe that the year ahead will be even better and more rewarding.

**Dr Nelson Odume,**
**Director UCEWQ**

# Hydrology Report

This year has been a full and busy one for the Hydrology Group of the Institute, as well as one of transition with the retirement of Prof Denis Hughes as Director. Prof Hughes has lead and guided the Hydrology Centre for many years and has been a mentor to many of us throughout our early career development. Prof Hughes will remain in the Institute as an Emeritus Professor and we are grateful to have his continued guidance and input. With the directorship moving over to the Water Quality section of the Institute, we are also grateful that Rhodes University is supporting an additional Hydrology post, with Dr Jane Tanner being employed to lead hydrology within the Institute. Further change for the Hydrology Group is in the form of Dr Andrew Slaughter leaving on a two-year visiting professorship at the University of Saskatchewan in Canada. We are pleased that he will retain involvement at Rhodes over the next two years through current projects, and wish him well on his exciting journey. Dr Slaughter developed a novel water quality model at the Institute which links specifically with the routinely used system models in South Africa, and the Institute remains committed to promoting the use of the model for the management of water quality within South Africa.

***Denis Hughes, Geoff Pegram and international colleagues at the IAHS Scientific Assembly, Port Elizabeth.***

## 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, as well as promoting the research and contributions from developing nations on the international stage. Prof Denis Hughes remains very much involved in the hydrology arena and contributes to the Bureau of the International Association of Hydrological Sciences (IAHS) as a member of the new IAHS Working Group for Representation of Developing Countries and part of the working group for Hydrological Education. As part of this work, the Hydrology Group played a key role in the organization of the IAHS Scientific Assembly, which was held in Port Elizabeth in July this year. This was the first time an IAHS Scientific Assembly meeting has been held in sub-Saharan Africa, and the theme was appropriately titled, "Water and Development: scientific challenges in addressing societal issues". Papers were presented by Dr Jane Tanner, Dr Andrew Slaughter and PhD candidate David Gwapedza.


***The 2017 International Association of Hydrological Sciences (IAHS) Scientific Assembly held in July 2017, Port Elizabeth, South Africa.***

A new African research group was launched by Dr Jane Tanner in Entebbe, Uganda in August 2017. The research group was launched in conjunction with the Hydrology Group at the IWR and the Africa Groundwater Network and is titled "One Resource". The research group consists of a small group of committed scientists and practitioners who will focus on scientific research in the field of surface water/vadose zone/groundwater interactions. The group members are located throughout Africa with representation from all of the major river basin and aquifer systems. The group will also work towards increasing awareness of the importance of surface water and groundwater interactions in Africa and aims to foster stronger links between surface water and groundwater hydrologists

and to contribute towards education and capacity building in the field of surface and groundwater interactions. The group was launched with funding from the Carnegie RISE program, which looks to enable 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.

*One resource at source of the Nile, Uganda*

Further exciting work being undertaken in Africa is the Royal Society-DFID Africa Capacity Building Initiative CRuHM (Congo River User Hydraulic and Morphology) project. The project is a collaboration between the IWR, the University of Kinshasa in DRC; the University of Dar es Salaam in Tanzania; the University of Bristol and the University of Leeds in the UK. The aim is to carry out large scale hydraulic and geomorphological science research on the main navigable channels of the Congo River to address the severe lack of basic scientific knowledge and understanding in these water engineering fields for the world's second largest river. The project highlights the continuing success of the RISE program as Prof Raphael Tshimanga, who was a previous RISE Hydrology student based at the IWR, who went on to become the HOD of Natural Resources Management at the University of Kinshasa is a key partner in this research project. PhD candidate Pierre Kabuya is currently based at the IWR and jointly supervised by Dr Raphael Tshimanga and Prof Denis Hughes. Pierre has just returned from a successful field trip in the Congo River Basin.

***Pierre Kabuya and fellow project members on their field trip in the Congo River Basin.***

As part of this CRuHM project, Hydro has hosted two successful workshops for the entire project team at Rhodes University. In addition, Dr Jane Tanner, Dr Sukhmani Mantel, Dr Andrew Slaughter and Mr Pierre Kabuya, attended a week-long LISFLOOD training workshop at the University of Bristol, in the United Kingdom during June 2017. LISFLOOD is a hydrodynamic model specifically designed to simulate floodplain inundation, and was developed within the University of Bristol. This model, together with Prof Denis Hughes' modified Pitman Model will be used to represent the Congo River Basin as part of the CRuHM project.

Dr Andrew Slaughter attended a workshop in Kampala, Uganda after leading a pre-proposal submission for an International Council for Science-funded call for projects relating to advancing Sustainable Development Goal 11 (SDG11): 'making cities and human settlements inclusive, safe, resilient and sustainable'. As a pre-requisite for submitting a full proposal, Dr Slaughter, as the principal investigator, was invited to attend a workshop on transdisciplinary research at Makerere University, Kampala, Uganda during August/September. The project team includes a team from Rhodes University (Dr Andrew Slaughter, Dr Sukhmani Mantel, Dr Nelson Odume and Dr Roman Tandlich), a collaborator from Zambia (Dr Emma Sitambuli) as well as student outreach and civil society groups and local government. The proposal relates to optimising domestic rainwater harvesting through the use of a novel water quantity model and water quality testing. Of the almost 300 pre-proposals received, their pre-proposal was selected as one of 30 invited to submit a full proposal.

The Carnegie RISE programme for the Sub-Saharan Africa Water Resources Network (SSAWRN) came to an end in December 2016 after nine years of funding. The project was Prof. Denis Hughes' brainchild and has been a big success for IWR and Rhodes University with three MSc graduates and eight PhD graduates, some of whom have joined IWR as staff members including Dr Nelson Odume, Dr Jane Tanner and Dr Paul Mensah. Due to Prof. Denis Hughes' prudently frugal spending and with the advantageous Rand-Dollar exchange rate, there were funds left over to support postgraduate students who still needed to submit including Mr Sbongiseni Mazibuko who received his MSc degree this year and Mr Emmanuel Vellemu who has submitted his thesis for review. Funds were also transferred to the other three SSAWRN nodes for their students to complete. From the IWR budget, there were sufficient funds to bring in two new postgraduate students including Mr David Gwapedza who has upgraded his MSc to a PhD and Ms Phatsimo Pearl Ramatsabana who will begin her MSc next year after completing her Honours in Geography Department.

## NOTABLE CONTRIBUTIONS AND ACHEIVEMENTS

Prof Hughes continues to serve as chair of the Professional Advisory Committee for the Water Resources Science Field of Practice of SACNASP (South Africa Council for Natural Scientific Professions) and also remains as a co-editor (Journal of Hydrology – Regional Studies), and associate editor for several international journals (Hydrological Sciences Journal, Hydrological Processes, Hydrology Research).

***Helen Barber James (Albany Museum) and Sukhmani Mantel reviewing a student's CV.***

***Dr Mantel and Dr Januchowski-Hartley at Rhodes University.***

Dr Mantel serves as an Associate Editor of the African Journal of Aquatic Sciences, is serving on the Rhodes University Environment Committee and remains the Vice President of the Freshwater Working Group (FWWG) of the Society for Conservation Biology (SCB). For the biannual International Congress for Conservation Biology (ICCB) 2017 meeting, held in Cartagena Colombia, she worked with other FWWG board members and the SCB to organize various events. Dr Mantel served as the co-chair of the ICCB Equity, Inclusion and Diversity (EID) Committee which organised a Knowledge Cafe and 3 lunch plenaries focusing on EID issues. She also collaborated with Dr Helen Barber-James of Albany Museum (a FWWG board member) to develop CV guidelines for students and early career researchers and hosted a CV clinic at the International Congress.

Dr Mantel and Dr Barber-James presented a poster at the International Congress which highlighted their research into the importance of geological history in riverine biomonitoring in the Southern Cape, in collaboration with Dr Ferdy de Moor and Mr Terrence Bellingan. The travel to the Congress was funded by an RU Grant and supplemented by a Pozible campaign on Connecting Conservation Colleagues that was organised by FWWG's President Dr Stephanie Januchowski-Hartley. Incidentally, Dr Januchowski-Hartley visited the Institute in November 2017 on an NRF KIC grant to further collaboration with Dr Mantel and Dr Barber-James.

Dr Andrew Slaughter and PhD candidate David Gwapedza and were invited to attend a workshop on using the HYdrological Predictions for the Environment (HYPE) model at the Swedish Meteorological and Hydrological Institute (SMHI) in Norrköping, Sweden during early September. The HYPE model is an open source hydrological and water quality model used for large-scale water resource modelling, typically on regional or global scales. The HYPE water


***HYPE workshop participants in Norrköping, Sweden.***

quality component is currently under development and Dr Slaughter, who has developed a water quality model within the IWR, and the HYPE developers are looking at potential collaborative opportunities in terms of model development going forward. The SMHI runs the workshop yearly in an effort to increase global capacity in using the HYPE model and to facilitate local expertise within water resource modelling studies using HYPE on regional and global scales.

Dr Jane Tanner and Dr Mantel attended the EGSIEM Autumn School for Satellite Gravimetry Applications in Potsdam (Germany) to expand their knowledge of GRACE satellite data for application in hydrological modelling. The travel was supported by the Helmholtz Centre Potsdam GFZ Research Centre for Geosciences. Further collaboration in terms of using GRACE data to support drought prediction in South Africa is being pursued in conjunction with the Water Research Commission in South Africa.


***Dr Sukhmani Mantel beneath a model of the GRACE satellite (L) and with Dr Jane Tanner with a model of the earth's gravity field (R).***

The biennial conference of the Groundwater Division of the Geological Society of South Africa (GWD of the GSSA) was held in Cape Town in October this year. Dr Jane Tanner and MSc students Kyle Smetherham and Caitlin Smith presented their research on groundwater. Mr Smetherham presented his research on improving understanding of the groundwater dynamics in Grahamstown, while Ms Smith presented on her work on surface water and groundwater interactions in the Palmiet wetlands of the Krom River. Dr Jane Tanner presented research carried out in conjunction with Groundwater Consulting Services (GCS) on stream flow reduction activities impacting the water resources supporting the lakes and wetlands of the iSimangaliso Wetland Park. As always, the Institute is very grateful for the travel support that some of these individuals received from Rhodes University.

As part of our continuing model revision and development, Mr. David Forsyth has replaced the database engine used in SPATSIM (Spatial and Time Series Information Modelling) to increase the speed, portability and ease of installation of the programme. Over the last few years the Windows landscape has changed markedly. This has caused increasing problems with the old database engine used in SPATSIM. To modernize the software, SPATSIM Version 3 was created over 2 months by removing the old engine and re-implementing all database access using the SQLite3 engine. This change has also allowed for some long planned upgrades to the software suite which will make it easier to use. In addition to the SPATSIM upgrade, Prof Denis Hughes has further modified the Pitman Model to improve the runoff generating processes in Dambo areas occurring in the large river basins of southern Africa. Mr Sbongiseni Mazibuko, who achieved his MSc in Hydrology through the Institute this year has been employed as a research assistant to test these new model routines in different African environments.

The Hydrology group will be offering a Hydrology Honours Module to the Environmental Water Management and Geography Honours groups in 2018. This module will be run by Dr Jane Tanner and Dr Sukhmani Mantel.
Lastly 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 Jane Tanner,**
**Hydrology Research Leader**

# Hydrology Projects

## Extending Functionality and Knowledge transfer of the Water Quality Systems Assesment Model

**Sponsor:** Water Research Commission
AR Slaughter, NJ Griffin, SK Mantel, DA Hughes and D Gwapedza
Project dates: April 2015–March 2018

South Africa is a semi-arid country where water is a limiting resource. As evident with the recent drought within the country and the continuation of the drought in the Western Cape, it is likely that water scarcity will become worse in the future due to development and climate change. Adding to the problem of water scarcity is the increasing threat of water pollution, which further limits the amount of water available for use. Given these multiple threats to water security in South Africa, it is imperative that tools be developed to facilitate efficient management of water resources. Although several hydrological and systems models that allow management of water quantity have become established within South Africa, no water quality model is as yet routinely used.

Development on the Water Quality System Assessment Model (WQSAM) was initiated with the Water Research Commission (WRC) project K5/2237, and aimed to develop a water quality model that links specifically with the routinely-used systems models and to overcome two major problems hindering the use of internationally-developed water quality models: 1) the lack of observed data and; 2) the relative complexity of internationally developed models. WQSAM focusses on a limited number of water quality variables that are important to water quality management, and includes only the processes that explain the majority of variation of these variables (requisite simplicity), thereby allowing the model to use the limited available observed data.

Further development of WQSAM was allowed by additional funding by the WRC for the current project (K5/2248). This project is drawing to an end, with all deliverables produced except for the final report, and a final reference group meeting is scheduled for the end of 2017. Through this project, WQSAM has been further developed and improved to: 1) include additional important water quality variables such as microbial indicators and sulphate; 2) further develop the estimation of non-point sources by a quantitative link to land cover; 3) validate the primary production processes represented in the model through remote sensing data and; 4) include a soil erosion and sediment transport model.

Mr David Gwapedza is the Masters student on the project, and is further developing the soil erosion and sediment transport model originally developed by Mrs Louise Lodenkemper by regionalising the parameters of the model and further testing and improving the model. David's project has recently been upgraded to a PhD, which is a testimony to both his excellent work on the project and also the wide scope for research into sediment transport in South African catchments.

The two projects (K5/2237 and K5/2448) have already produced in excess of 12 scientific publications. It is hoped that in the future, the traction that WQSAM will receive within water resources management in South Africa will increase, and arrangements are already in place to introduce the model to one of the Catchment Management Agencies. The use of the model has also been included in several project proposals.

## Rehabilitation of Grasslands after Eradication of Alien Invasive Trees

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

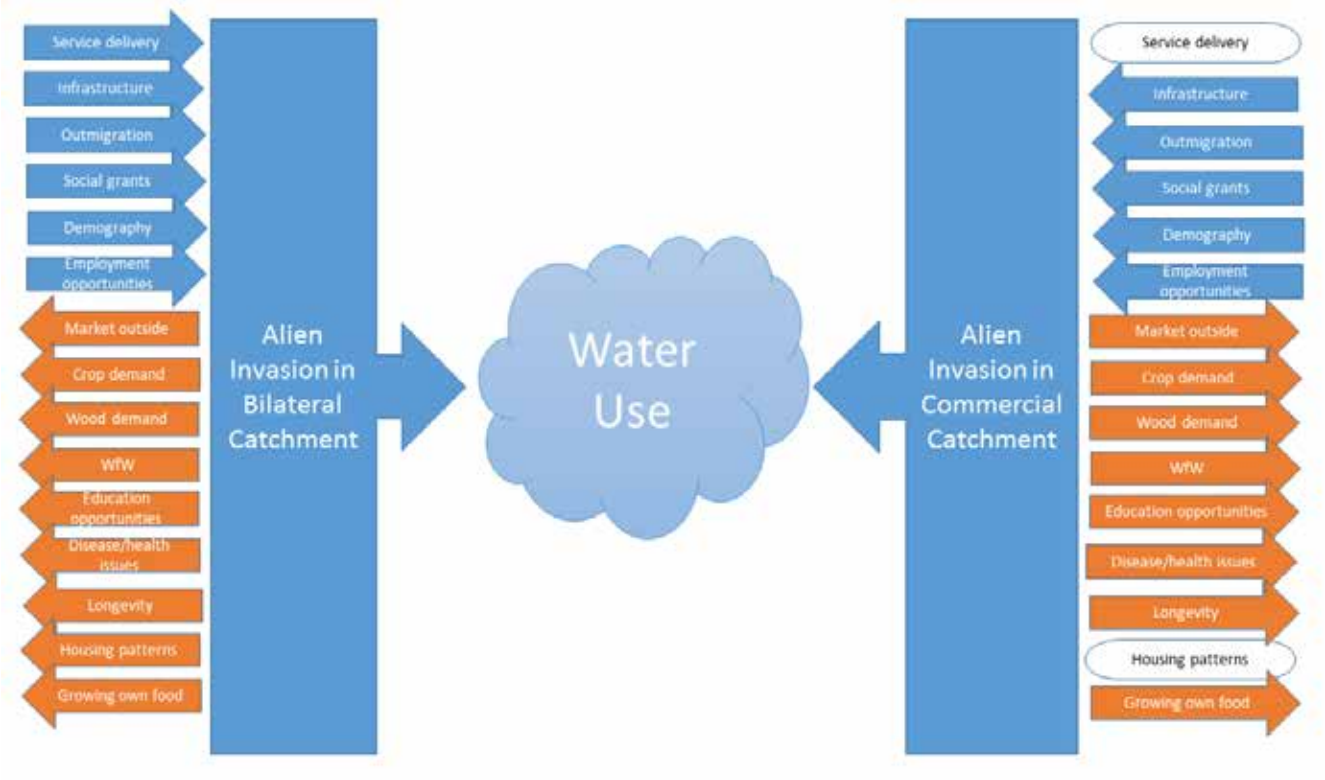
Clearing of the Invasive Alien Plants (IAPs) on their own is not sufficient motivation to proceed with the national Working for Water (WfW) programme, and there needs to be consideration of the sustainability of the landscape when the activities of WfW are completed. In order to ensure sustainability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

Thus, the aims of this project are:

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

The project has three focal catchments in the Eastern Cape and the project has funded three postgraduate students at Rhodes University – Onalenna Gwate (PhD, Rhodes University; Thesis submitted 2017), Perpetua Okoye (MSc, Stellenbosch University, graduated 2016) and Bukho Gusha (PhD candidate, Rhodes University) – and one Honors student, Mr Chris Scorer (BSc, Rhodes University, graduated 2017).
The project is progressing on track and nine deliverables have been submitted to the Water Research Commission. The past year we organised two workshops. The first workshop involved various project team contributors and collaborators who have worked in the study catchments to develop a narrative of likely scenarios for land use change over the next 10 years based on the project team's experience and research about the catchments. From the input we developed scenarios on the influence of for factors (such as alien invasion activities) in two types of catchments in the Eastern Cape – bilateral catchments (a term which describes the status of the so-called 'communal land tenure' system, due to the interaction of the components of traditional leadership and the municipal system in land allocation) and commercial catchments, as shown in the figure below.

The second project workshop was organised by Mr Chenai Murata to present these projected scenarios on land use change to the community of Mgwalana and to additionally present the possibility of improving livestock marketing opportunities in communal villages. For the latter, Mr Murata accompanied four village leaders to a Meat Naturally




***Comparison of factors influencing alien invasion activities in bilateral and commercial systems over the next decade and the effect on water use. The arrow direction is related to whether the impact is expected to be positive or negative.***

livestock sale event in Matatiele. On return, the villagers presented their impressions of how Mgwalana villagers could follow a similar model to organise a livestock sale. The process requires quite a bit of planning and organisation that the villagers are in the process of following with the assistance of Mr Murata, Ms Bukho Gusha (PhD student) and Ms Thantaswa Zondani (Agricultural Research Council, Animal Production Institute).

***Mr Nani explaining what he learned and observed at the Matatiele Meat Naturally auction during a workshop in Mgwalana.***

## Determining the Hydrological Functioning of the Palmiet Wetlands in the Eastern and Western Cape of South Africa

**Sponsor:** Water Research Commission
JL Tanner
Project dates: April 2016 – March 2018

The investigation is introduced in Caitlin Smith's student project outline with further detail being provided below. Palmiet ecosystems are endangered and restoration initiatives suffer from a general poor understanding of these complex systems. This project aims to contribute to a multidisciplinary approach which looks at the geomorphological, hydrological, and ecological factors that underpin and sustain these wetland ecosystems. This project is focused on the hydrological component and builds upon an existing project led by Prof Fred Ellery, which is looking at the erosion dynamics of the system.

A key feature of Palmiet wetlands is that they generally have high slopes for their discharges, and therefore are vulnerable to collapse. Demonstration that collapse may be a result of natural processes (early results of geomorphological investigation) departs radically from the widely held perception that wetland degradation is due to anthropogenic influences alone. This requires an understanding of catchment hydrological response and the way wetlands are impacted by this response, particularly during extreme events.

In addition to the aims outlined in Caitlin's student project overview, a third aim is included which will be closely linked to the modelling outcomes of this project. The third aim includes:

> *Determine whether wetland degradation is impacting the hydrological integrity of the river, thereby compromising water security and human wellbeing*

***Dr Jane Tanner and Ms Caitlin Smith in the Krom River Headwaters.***

An instrumented study site within a relatively pristine Palmiet wetland located on the upper Krom River catchment within the Eastern Cape has been set up. While the project is still underway, indications are that these endemic wetlands are closely linked with the typical alluvial fan geomorphology/geology associated with the Table Mountain Group (TMG) sediments of the Cape Fold Belt. The wetlands seem to be sustained by subsurface (both groundwater and interflow)

water moving through preferential flow paths in the alluvial fans which are in turn sustained by groundwater discharge from the surrounding sandstone and quartzite geology of the TMG sediments.

Key linkages between this geomorphological hypothesis and the understanding of catchment hydrological processes have been explored using the HECRAS and Caesar-Lisflood hydrodynamic models (set up by Ms Pippa Schlegel in the Geography Department). Currently the project is setting up four models, the groundwater balance model GYRM, the integrated modified Pitman model, a mixing cell model and the more detailed numerical MIKE-SHE model. It is hoped the modelling will contribute to the understanding of the system by testing the validity of various hypotheses of system functioning and determine how the hydrology links with the erosion dynamics of the system.

## The Development of an Intergrated (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 will use the modified Pitman Model together with forecasted climate data to predict hydrological drought for both surface water and groundwater resources. Currently the project is in the early stages of development and planning.

## Establishing a 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 workshop was help in conjunction with the Africa Groundwater Network's annual meeting and brought together hydrologists and hydrogeologists to discuss key issues around the understanding of and modelling of SW/GW interactions. 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.


***One resource at source of the Nile, Uganda***

**IKS to enhance rewards for Ecosystem Services in Rangelands Infested with Invasive Alien Plants**

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

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

of indigenous knowledge systems and practices used by local communities to manage rangeland resources in both communal and private lands and develop community-based Reward for Ecosystem practices using a bottom up approach.

Mr Chenai Murata, who has supported us by running workshops on the WRC project 'Rehabilitation of Grasslands After Eradication of Alien Invasive Trees', is registered as a PhD student under the project. The title of his research is 'A realist exploration of the role of indigenous ecological knowledge in people's understanding of and dealing in ecosystem services in Eastern Cape, South Africa'. He is being supervised by Dr Anthony Palmer and Dr Gladman Thondhlana (Department of Environmental Science, Rhodes University). The aim of the PhD project is to establish the relevant indigenous knowledge and practices that people in communal villages have historically been using in understanding and management of ecosystem services, and how such knowledges and practices have adapted and evolved over time.

## Infrastructure Funding Instrument Grant for Evaportranspiration Flux

**Sponsor:** National Research Foundation
SK Mantel
Collaborator: AR Palmer (Agricultural Research Council)
Project dates: Ongoing

Dr Anthony Palmer (Agricultural Research Council) and Dr Mantel motivated for a National Research Foundation (NRF) 2014 call for National Equipment Programme grant for equipment for measuring the carbon and water fluxes using the Eddy Covariance and Scintillometer systems. The funding proposal for R1.8 million (of which R1.249 million is provided by the NRF) was approved and we received all three systems last year. Dr Palmer, Dr Mantel and Mr Gwate have installed one Eddy Covariance system on a secure thicket site outside Grahamstown. The data gathered by the equipment has been used by Mr Gwate on the WRC project K5/2400/4 and these data will be fed into an international network (Fluxnet) that collaborates in using these data to parameterise and validate global circulation models for climate projections. Mr Gwate has submitted his PhD thesis and will graduate next April from Rhodes University.

Starting in 2019, a Botswanan hydrology student funded by the Carnegie RISE SSAWRN funds will be registered for an MSc under Dr Jane Tanner. The student (who is currently doing her Honors at Rhodes University) will use the Scintillometer over a farm outside Grahamstown. The project will assess the evapotranspiration from cultivation activities for conducting a water balance of the catchment.

## Improving the Representation of the Runoff Generating Process of the Dambo Areas in the Pitman Model

DA Hughes and SC Mazibuko
Project dates: May 2017 – Present

The investigation involves the improvement of the understanding of runoff-generating processes in the dambo areas occurring in large river basins of southern Africa. Dambos provide important natural resources and serve socio-economical and environmental functions which are vital for a diverse nature of biodiversity. Given the pressure exerted by human needs and the change in climatic regimes, there is therefore a great need to understand and make well-informed decisions which maintain their sustainability.

Hydrological models are playing an important role in generating information used to make informed decisions with regards to the planning and management of water resources. From this perspective, the Pitman model – which has been widely and successfully used in southern Africa – is applied as means of improving the understanding of hydrological processes in the dambo areas. Modelling results using the old version of the model did not adequately represent the seasonal distribution of stream flows due to the assumptions used to represent runoff generating processes in the model. Therefore, the main activities of this project involved; (i) re-conceptualising the main runoff generating processes, (ii) restructure the Pitman model algorithms, and (iii) applying them in a variety of river basins in the Central African Republic, Zambia, Zimbabwe, Swaziland and South Africa. To date, a number of improvements in the modelling results have been observed in some river basins while others are still under investigation. This project has also provided a room for improving other components of the runoff generating processes in the model.

# Environmental Water Quality Projects

## IWR Citizen Science Group

NS Mgaba and PK Mensah

Dr Paul Mensah is the leader of the IWR Citizen Science Group with other members Ms Khaya Mgaba, Mr Mzwanele Mkatali, Ms Siphokazi Tantsi and Ms Ntombekhaya Mti. The group this year was able to visit three Grahamstown schools, including Nombulelo High school, Mretyana High and Nathaniel Nyaluza. Each school was visited for two days. Day one saw the organisation of a career guidance session on water and related fields. On day two, the learners were taken to the Bloukrans River and engaged in mini-SASS. The purpose of this activity was to teach the learners to understand how water quality of freshwater get impacted by pollution and the role they can play to prevent water stress and water scarcity in their communities. The Group intend to carry on with this initiative next year and include other interesting activities like organising a quiz competition on World Water Day among the schools.

***Dr Paul Mensah, Ms Ntombekhaya Mti and Nombulelo High School students during the field trip***

## Community Engagement at the IWR 2017

It was a busy year for the IWR in 2017 as many of the staff and students got involved with a variety of community engagement activities.

The year started off with a team of students putting together an exhibition during Scifest Africa (South Africa's largest science festival). The IWR formed part of a group of departments and institutes under the SAIAB Water World banner and interacted with over 7400 pupils over the week-long festival. Part of the exhibit included mini-SASS and the pupils learnt a great deal about water quality and bugs in rivers from the students.

Although not all of the post-graduate students in the IWR work directly with community members in their own research work, the chance to engage with younger, keen pupils from the Grahamstown schools is always taken up enthusiastically. The students show a great willingness to share local knowledge and to help students with their work and questions.

Every year the Rhodes University Science Faculty hosts an Open Day and once again, the IWR was present to showcase the work conducted by the institute. Biomonitoring, water quality testing, and hydrology where the key features of the IWR exhibit. Students also spoke to pupils about possible involvement with the Young Water Professionals and discussed career options in the water sector.

Many school pupils in Grahamstown take part in the annual Eskom Science Expo. Two of the IWR PhD students volunteered to mentor pupils taking part in the Expo and helped create ideas and guidance for projects.
Staff and students were involved in a variety of water awareness activities in and around Grahamstown which included biomonitoring, discussing career choices, and the state of water in the Makana Municipality.

Mandela Trading Live 2017 saw a small group of youngsters down in the Botanical Gardens learning the techniques for collecting bugs from streams and rivers. Unfortunately, due to the low level of the river in the Botanical Gardens few

bug samples were found on site. Fortunately, one of the IWR technical officers had collected samples earlier in the day from a faster flowing river so the youngsters were able to sit on the grass and look at bugs with magnifying glasses.

The IWR is leading the way in South Africa with the formation of a Water, Sanitation and Catchment Management Forum. The Forum has emerged out of the work being conducted by two postgraduate students, but also falls in line with the requirements of the National Water Act in terms of engagement with communities in water management. As the Makana Municipality continues to face water and sanitation challenges, and the rain stays away, the IWR lends its support in any way that it can to create community awareness around water issues, but also to build relationships between the municipality and community members.

## Towards Ecosystem Functional and Structural Assessment for Better Decision Making to Enhance the Delivery of Ecosystem Goods and Services

**Sponsor:** Water Research Commission
ON Odume
Collaborators: H Dallas (Freshwater Research Centre)
Collaborating organisations: Department of Freshwater Invertebrates, Albany Museum, Grahamstown.
Project dates: 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 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 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, the following have been identified as the potential advantages of explicit consideration of traits in freshwater 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.

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 make a case for the TBA in the context of aquatic ecosystem health management in South Africa.

### Project Aims

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

To date, the project has progressed steadily and the final draft report is being submitted for consideration.

## Literature Review and Terms of Reference for Case Study Linking the setting of Water Use License Conditions with Resource Quality Objectives (RQOs) and/or Site-Specific Conditions in the Vaal Barrage Area and within the lower sections of the Upper Vaal River Catchment

**Sponsor:** Water Research Commission
ON Odume, NJ Griffin, PK Mensah and CG Palmer
Project dates: April – September 2017

The main aim of the current study was to engage through a consultative process with key stakeholders with an interest in the lower section of the Upper Vaal catchment (Vaal Barrage area) to develop an agreed Terms of Reference (TOR) for a comprehensive joint catchment study to improve the understanding of the linkages between SDCs and RQOs in order to inform better water resource management practices through the better application of applicable regulatory tools and guidelines. To achieve this aim, the following specific objectives were set out:

- To consult with all relevant stakeholders as identified in the preliminary meetings held between Sasol, WRC and DWS to ensure the study ToR addresses the relevant needs of all stakeholders; including DWS (all relevant units), proto-CMA, Catchment Management Forums, Local Municipalities, small industries, Sasol, Eskom and Rand Water.
- To frame the scope of the case study that will investigate how RQOs are set and in turn how effluent discharge standards are informed by the RQOs and applicable water quality guidelines. The scope should also consider parameters for which no RQOs have been published, but which have been included in water use licence conditions, and should inform future discharge standards for water quality parameters identified to be of relevance to the catchment.
- To ensure buy-in from the sub-units and stakeholders in terms of the localisation of the case study in the proposed study area.
- To agree and set the objectives, timeframes, budgets, and deliverables of the catchment case study

The project arises out of the realisation by stakeholders in the catchment that there are challenges in the approaches used for setting applicable water use license conditions, including discharge standards, which do not sufficiently take into account stakeholder and ecological concerns. For example, there are challenges on how license conditions are set and used to achieve the set RQOs as reported in DWS (2014) and gazetted in DWS (2015) for the Upper Vaal Catchment. Notwithstanding these challenges, stakeholders in the catchment agreed to work together to jointly developed a case study to address these issues. This project was therefore the first of such studies, and it therefore develops an agreed Terms of Reference for the catchment case study.

## 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: April 2015 – April 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 aims to pilot-test the IWUAB and to provide training to and gather feedback from practitioners in order to refine the tool. Sampling and analysis in three identified sectors (municipal, mining and agricultural) is complete and sampling in the industrial sector will terminate at year-end. 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.

***Instream toxicity sample site (agricultural sector)***

The project is now entering the training and final analysis stage and will terminate in early 2018. 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.

## Developing a Multi-Sectoral Integrative Licensing and Monitoring Framework, to align and Integrate Biodiversity and Environmental Water Quality, in the Coal Mining Development Life-Cycle

**Sponsor:** Water Research Commission
CG Palmer and AV Munnik
Project dates: April 2015 – March 2017

This extensive transdisciplinary project aimed to: 1) to review legislation governing mining in relation to the mining life cycle "cradle to grave" and to compare the requirements to actual mining practice; 2) provide an academic review of the legislation in relation to holding mining environmentally relevant to holding mining accountable for ecological impact; 3) assess the value of ecological infrastructure in the widest framining of value; 4) to explore the impact of coal mining on wetlands as key ecological infrastructure; and 5) to empower a multi-stakeholder group to engage with participatory governance of mining and ecological infrastructure. Some of this work was undertaken by sub-contracted researchers and the project as a whole was synthesised by Professor Tally Palmer and Dr Victor Munnik. Two MSc students were supported and have submitted theses: Gareth Thompson addressing Aim 1 and Tia Keighley addressing Aim 4.

The project is reported as an overview narrative written for the general public:
If you drive through South Africa's Highveld grassland landscapes, you will encounter a network of small streams and slightly larger rivers, and you will see the reeds and rushes and sometimes a gleam of water, characteristic of wetlands. The grasslands will be dotted with livestock; there will be mealie fields and a little irrigation. These grasslands form a hub of agricultural production. You will also see evidence of coal mining. Great piles of earth and coal, and a skyline with the silhouettes of coal-fired power stations represent the "engine room" of South African industry.

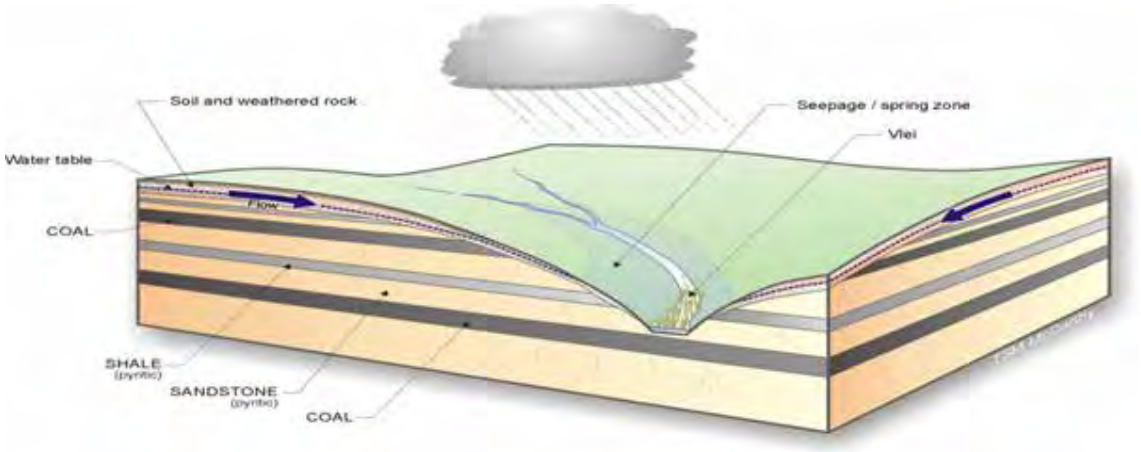
In this kind of landscape, this project was born, out of a new event. A court fined a mine for destroying a wetland, and made provisions that the fine must be spent on research into the interconnections between coal, cows, people and the natural environment.

*A siding with a coal pile and a weir with orange coal effluent residue called "yellow boy"*

This is the research we have done - also in a new way. "We" are a research team comprising academic specialists, students, and people knowledgeable of the case study place. We have woven a story of the interconnected threads of story. As we began, we found ourselves mired in a knot of laws. It was very difficult to find a coherent thread – so we took on two approaches: 1) understanding the purpose and direction of the laws that govern mining and the protection of landscapes; and 2) unravelling the legal requirements of mining, from prospecting to mine closure.

*Ms Tia Keighley sampling a wetland for macroinvertebrates.*

At the time, other team members investigated the wetlands that are so much part of the water network running and seeping through the grasslands. Ever since Noel Hynes wrote "The stream and its valley" in 1975, people have realised that water bodies in a landscape reflect the activities of the landscape – so water ecosystems are often the basis of ecological "health" monitoring. Traditionally two kinds of living organism are used to indicate the heath of watery ecosystem: plants and 'bugs' (mainly the insects and their larvae that live in water). So, we braved bumpy fields and farm tracks (with kind permissions) and slooshed about in water and mud, collecting plants and bugs in wetlands. We also sat on rocky sandstone sills and hill-slopes, looking out across the veld to see road and weirs, gullies and bare ground, and the places where wetlands connected with streams.



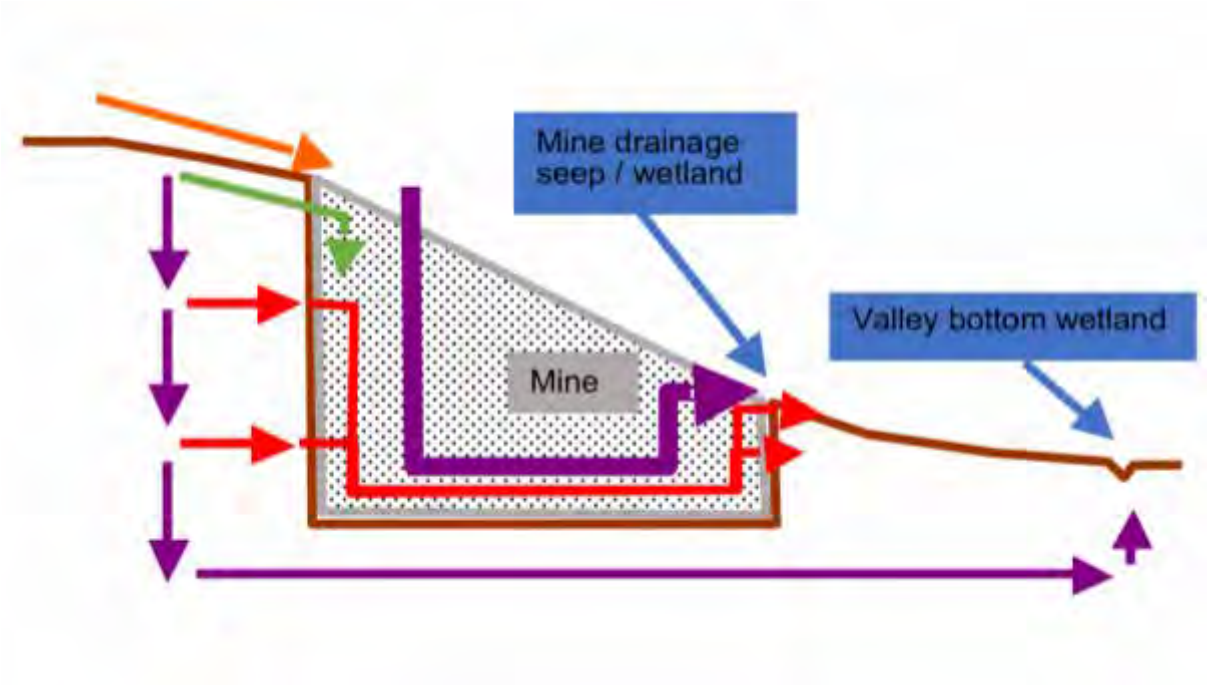

***Relationship between surface water sources, soil water, and coal seams (Diagram by Prof T. McCarthy, pers comm).***

Why wetlands? They are places where coals seams come close to the surface, and they are also actively used by livestock – agriculture and mining are local (competing) economic drivers.

As we talked to people in Carolina – the town in the case study area - where the town water supply turned acid in 2012 - we found people who were angry, anxious, and sometimes confused. We met miners who were defensive of their best efforts to be "clean and responsible", farmers with a threatened future, residents with memories of acid water streaming out their taps, and government officials who were being questioned about their effectiveness. The blame game thrived.

We also found a group of people committed to understanding their local place, and committed to working towards a more harmonious future. They belonged to all kinds of groups of people, and included civil society activists, farmers, miners, mining consultants, residents, and government officials. Their mechanism of influence was the Upper Komati Catchment Management Forum (UKCMF). They formed an acid mine drainage working group, and agreed to work with the research team in unravelling the coal and natural ecosystem story.

After a while it became clear that the "bugs and plants" could only tell us part of the coal mining impact story – with a small indication of such impacts. We then encountered a passionate hydropedologist who provided a "missing link". The geology and sub-surface soils are layered – with water seeping horizontally over impermeable layers, into the wetlands and streams. Mining punctures the layers and water seeps vertically downwards, with much less feeding the wetland. Mining causes the landscape to leak.




***Underground impact of open pit mining: surface runoff (orange arrow), sub-surface shallow lateral drainage (green arrow) and recharge to a groundwater-fed wetland (red arrows) are interrupted by open pit mining, with only sub-surface deep lateral drainage/seepage (purple arrows) feeding the wetlands. (Tia Keighley)***

In the meantime, the legal researchers could tell us that the law is complex and fragmented, but that there is evidence of progress towards more integrated legislation with better legal protection for wetlands – one hope being SPLUMA (the spatial planning and land-use act). The mining lifecycle laws were organised into a flow diagram of actions required by mines, and points where the process could be checked on, and where local people and other stakeholders could be involved.

By then the forum members had jointly learned from each other and from visiting specialists more about their place, and the legislated steps. This meant that together we could build a resource to empower them to interact proactively with mining processes. We also looked at the reality of how mines followed the step-wise process, and identified gaps in mining practice.

Throughout the three-year dialogue with the forum working group, we exposed power struggles between various groups – including between national government departments. These struggles meant, among other things, gaps in rep-

*Upper Komati Forum members*

resentation at forum working group meetings, and mismatches of regulatory activities.

At the start of this story we wrote of the economic interests of farming and mining. The "economics" of the natural world are more complex. It is a great trap to put a monetary value of the functions of ecosystems – so we looked at the multi-faceted value of wetlands.

Finally, at the end of three years, the forum working group had knowledge about the law, about the health of their ecosystem (including some evidence of ecological impact; the water flow being interrupted by mining; and the limitations of conventional rehabilitation - the sub-surface layers are not reconstructed). The UKCMF had collectively developed a 10-step process for oversight of mining operations based on a clear understanding of regulations. The government institutions understood their roles and responsibilities. The absence of some players indicated the limitations of formal regulation and the overall contribution is an alternative, parallel regulatory process.

This kind of multi-stranded research, embedded in local knowledge and empowerment is uncommon, and not well understood. This narrative hopes you find the details to follow written in research language, easier to understand. We also hope the outcomes takes everyone closer to sustainable and equitable natural resource protection and use.

## The Application of Ecotoxicity and Activity System Analysis of Salt Management to Water Resource Protection and Use (Domestic, Agriculture and Mining)

**Sponsor:** Water Research Commission
PK Mensah, CG Palmer and NS Mgaba
Project dates: April 2015 – March 2018

Freshwater salinisation in South Africa is on an increasing trajectory with elevated levels of sulphate, sodium and chloride ions in many of the country's rivers. A recent country-wide study reported 30 % sample to have unacceptable EC levels (i.e., >85 mS/m), while 25% sample have EC levels within tolerable range (i.e., 50-85 mS/m). This general review currently puts freshwater salinisation as one of the country's major water quality problems, and therefore appropriate guidelines for, and better ways of managing salts are required. The aim of this project is to develop salt guidelines for resource quality objectives (RQOs) and integrating these into salt management using Cultural Historical Activity Theory (CHAT). In order to achieve this aim, the following specific objectives have been set for the project:

- To conduct short-term and long-term lethal ecotoxicological tests using selected representative salts and organisms.
- To develop risk-based salinity guidelines using species sensitivity distribution.
- To use the resultant risk-based salinity guidelines as basis for setting resource objectives.
- To assess the current risk posed by freshwater salinisation in South Africa.
- To analyse salt management activities in agriculture facility and proposed a new management practice using CHAT.

The following deliverables have been submitted to the WRC since the inception of this project:

- Project inaugural meeting
- Inception report
- Progress report
- Report on the results of the acute and chronic toxicity experiments
- Report on CHAT analysis of saline water management practices

- Draft SSD risk-based salinity guidelines
- Draft CHAT-based salinity management practices
- Report on training and awareness creation for identified stakeholders
- Draft final report

The project's last reference group meeting is on 30 November 2017 and would submit the final report after that.

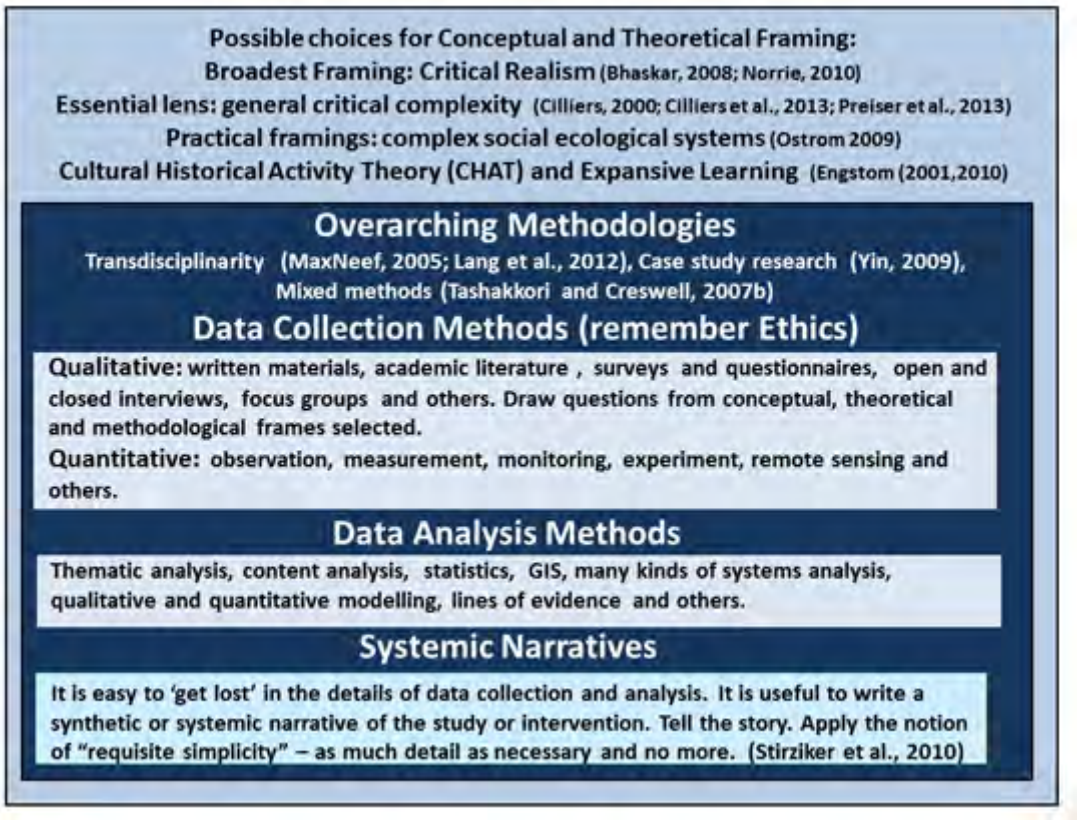
## Practising Adaptive IWRM: Integrated Water Resources Management (IWRM) in South Africa: Towards Practising a New Paradigm (TPNP)

**Sponsor:** Water Research Commission
CG Palmer and AV Munnik
Project dates: April 2014 – March 2017

This is some of the most exciting framing and foundational work undertaken in the IWR. In 2013 the Water Research Commission called for a solicited proposal to review and apply complex social-ecological systems thinking for a practical approach to on-the-ground Integrated Water Resource Management in South Africa. The project proved to be long, hard, complicated and complex. Every effort was made to embed to ideas and practice into government agencies and policy during the life of the project and those efforts must continue.

Integrated Water Resource Management (IWRM) has largely failed in South Africa since it was first embedded in law (National Water Act (NWA), No 36 of 1998) and policy (the first democratic National Water Policy, 1997). It is most specifically the practice of integration that is so difficult. We still work persistently in silos. The core goals for IWRM in South Africa, stated in the NWA, of equity, sustainability and efficient use, have therefore frequently not been met.

However, since the 1990's, a literature emerged, that indicated practical integration, and progress towards the core goals could be achieved using a set of "new" concepts. This set of concepts was sufficiently different from the traditional linear and top-down approach to IWRM, to be called "a new paradigm" for IWRM by the WRC. Early WRC research and practice in the South African National Parks and the Inkomati-Usuthu Catchment Management Agency was promising and guided this project.



The challenge was to demonstrate that the practice of new concepts will result in effective IWRM. Integrated Water Resource Management (IWRM) has largely failed in South Africa since it was first embedded in law (National Water Act (NWA), No 36 of 1998) and policy (the first democratic National Water Policy, 1997). It is most specifically the practice of integration that is so difficult. We still work persistently in silos. The core goals for IWRM in South Africa, stated in the NWA, of equity, sustainability and efficient use, have therefore frequently not been met.

However, since the 1990's, a literature emerged, that indicated practical integration, and progress towards the core goals could be achieved using a set of "new" concepts. This set of concepts was sufficiently different from the traditional linear and top-down approach to IWRM, to be called "a new paradigm" for IWRM by the WRC. Early WRC research and practice in the South African National Parks and the Inkomati-Usuthu Catchment Management Agency was promising and guided this project.

The overall recommendation is that the Department of Water and Sanitation adopt Adaptive IWRM practice, based on Adaptive IWRM principles. Failure of strong uptake will mean retention of old practices that have resulted in over-allocation and over-use of water; deterioration of water resource health, instream flows and water quality; human health issues related to microbial and other pollution; eutrophication; and water insecurity.

This project therefore recommends the use of the term Adaptive IWRM to signify the new approach and practice. The results provide clear, positive evidence that investment in further research into, and related practice of, Adaptive IWRM is essential.

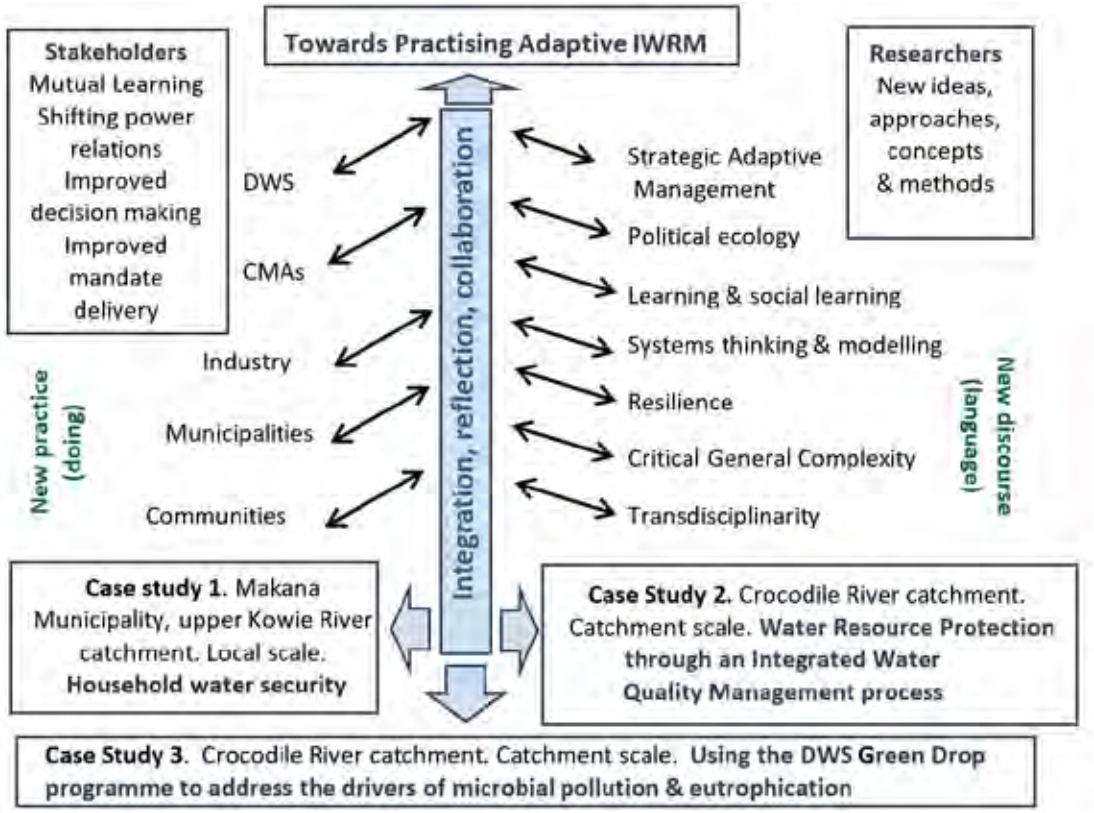
In addition to demonstrating pragmatic practice the project provides a scholarly application of philosophy and theory. Engaged, participatory action research was used in all the case studies. The project process envisaged case study research providing practical spaces to explore knowledge sharing between: (i) the new academic discourses in strategic adaptive management (SAM), political ecology, learning and social learning, systems thinking and modelling, resilience, general, critical complexity, and transdisciplinarity, and (ii) the practical knowledge in communities, industry, and local, provincial and national levels of government. The conscious development of integrating skills, reflection and collaborative initiatives were planned to mediate co-learning and knowledge sharing. The intention was to increase mutual learning, shifting power relations, improved decision making and improved mandate delivery in the practical Adaptive IWRM domains.

Social and other learning processes require attention to including reflexive opportunities, and explicit interrogation of, for example, the questions (i) was there a change in understanding of participants, (ii) was this change shared and understood within a broad social context or community of practice, and (iii) did the learning take place through social interaction?

Several integrating systemic approaches were practised in the case studies, including systems thinking, soft system modelling, and system dynamics modelling. studies. Strategic Adaptive Management (SAM) is a systemic, inclusive process that is particularly attentive to developing a rich understanding of context (social, technical, economic, environmental and political); a shared articulation of values and the co-development of a vision of a shared future. The use of SAM was taken further by paying specific attention to ensuring stakeholders participating in any of the research processes (planning, data collection and analysis, and knowledge sharing) were able to participate fairly. This required attention to the context of knowledge sharing, making use of translation where appropriate, as well as demonstrating an inclusive and invitational attitude in explicitly inclusive processes. All of these were part of paying attention to epistemic justice - the fairness and equity of participation. An awareness of the political ecology of the case studies supported SAM practice, because the role of politics is increasingly clear in any drive towards equity and sustainability.

Project Conceptual Framing: Engaged, action research, undertaken with an understanding that people in catchments comprise complex social-ecological systems (CSES), using appropriate complexity- and systems-based approaches and methods, in case studies, resulting in examples of practical Adaptive Integrated Water Resource Management (Adaptive IWRM). New practice emerged from new ideas, affecting both stakeholders and researchers, and was driven by reflection, integration and collaboration. (DWS – Department of Water and Sanitation, CMAs – Catchment management agencies)

A case study methodology and methods were followed as presented. Since scale has such a strong role influencing social-ecological systems, three aspects of scale were consciously included: i) bio-physical, ii) governance and ii) relational scales.




***The "fishbone" model proved to be valuable and effective in guiding the research***

Case study 1: Makana Municipality: The case study was engaged at the local government (Makana), sub-catchment scale (Upper Kowie River catchment), in the Eastern Cape. This case study was built on and extended previous work in the Lower Sundays River Valley Municipality, to the Makana Municipality – another local municipality in the Sarah Baartman District Municipality. Students supported by the project have extended the water governance work across the Eastern Cape and their data and insights fed back into the case study. The focus was on water governance in the local government and the local sub-catchment overlapping area. The work was linked strongly to community and citizen science. We coined the term "water for dignity", and facilitated the emergence of a civil society organisation that took on that name. Research started with a system description, using historical contextual analyses and household surveys by Water for Dignity citizen-researchers. Although the case study was initiated with the idea of investigating microbial pollution (identified initially as a research focus), household water security emerged as the main issue for citizens. By then, case study 2 was evidently addressing water quality and water resource protection research foci, so the household water security focus was retained.

**The Makana case study has accelerated local water institutional development with the establishment of the first South African Water, Sanitation and Catchment Management Forum. The combined forum is actively co-hosted by the local Municipality and the DWS. The forum, called the "Makana Water Forum" by participants, is actively developing a local catchment management strategy (CMS) for the Upper Kowie River Catchment, to contribute to the overall CMS of the Mzimvubu-Tsitsikamma proto-CMA (MT-CMA). To date more than 85 stakeholders, widely and deeply representative of local interests have actively participated in the Makana Water Forum. This ground-breaking and exemplary research proves is already extending to the Tsitsa River Catchment with the support of the DWS (MT-CMA) and the DEA.**

Case studies 2 and 3: Crocodile River sub-catchment in the Inkomati River catchment: The Crocodile River catchment proved to be the most fruitful case study site and serviced two TPNP research foci: (i) water quality issues that lead to, among other things, microbial pollution and eutrophication and (ii) water resource protection. The research was undertaken at the Catchment Management Agency (CMA) governance scale, at the biophysical catchment scale and included explicit attention to relational scales. A dti-NRF-THRIP project, provided additional resources for case study 2, and additional WRC funding for an associated project enabled greater depth of study in the Green Drop Campaign. The case studies are reported as (i) case study 2: water quality issues and resource protection; and (ii) case study 3: using the Green Drop Campaign to address microbial pollution and eutrophication. These case studies identified, but did not address directly the role of non-point sources of nutrients – which would also require both social and technical interventions.

**The Crocodile River case studies addressed the Adaptive IWRM challenge of building a co-operative integrated water quality monitoring process for the Crocodile River catchment, to progress solutions to deteriorating water quality as a threat to water resource protection. The research used Adaptive IWRM processes to build stakeholder capacity to co-operatively change behaviour and collectively improve water quality. This resulted in improvements in IUCMA monitoring of ecological Reserve indicators – indicating resource protection in action. The case study brought many large industries together (including sugar, pulp and paper, and mining industries), with local government, water service providers, water managers, and regulators. Stakeholders met three times a year for two years, and then handed stakeholder engagement to the Crocodile Forum.**

The Inkomati-Usuthu Catchment Management Agency (IUCMA) made case study 2 part of their business plan for Water Quality, in the process of operationalising their Catchment Management Strategy. The IUCMA practices Strategic Adaptive Management (SAM), and is arguably the best-functioning CMA in South Africa. The water quality-quantity model WQSAM, applied during the TPNP project for the first time, has been installed at the IUCMA, personnel were trained, and implementation is expected in 2018. The application of WQSAM is being further developed and applied in the Olifants River catchment.

Case study 3: grew out of the recognition that conventional research into microbial pollution and eutrophication was not going to result in sufficient in-stream change. Three Crocodile River Catchment local municipalities engaged actively in seven workshops. Municipal staff shared their experience that waste water treatment works (WWTW) are not a municipal priority. Funds were redirected away from WWTW, maintenance was neglected, works operated beyond their design capabilities, there were procurement difficulties, debt interrupted supplies of treatment chemicals, and Green Drop training was inadequate. The many inter-related problems, with feedbacks – like lack of funds and training demotivating operators – indicate that the effective operation of WWTW is "wicked problem". It is not likely be resolved by additional scientific understanding but rather by concerted engagement within DWS, and between national and local government. Politically-based changes are required, the research using political ecology approaches need to be further developed and applied.

Case study 3 achieved part of the goal of the TPNP "to work with stakeholders to enable mutual learning, shift power relations, improve decision making and improve mandate delivery". Stake holders were actively engaged, the dysfunctional power relations were identified, but an improvement in mandate delivery will need a shift in the power relations. That will require focused research and practice effort.

The Crocodile River Catchment can be used as a model Adaptive IWRM catchment; lessons learned can guide a National Water Resource Strategy. This was exemplary Adaptive IWRM practice: (i) There was sustained high-level stakeholder engagement and collaboration with active industry input; (ii) the Green Drop Programme was identified as a key intervention point for eutrophication and microbial pollution, and the deep intractability of the problem was made explicit. Multiple problems and their exacerbating feedbacks mean progress absolutely requires politically-based interventions; (iii) application of the WQSAM model was trialed and the model was installed at the IUCMA; and (iv) this case study research made strategic input into the 2017 DWS Water Quality Policy and Strategy, finding traction at the highest levels of the Department and can make serious input into the next National Water Resource Strategy.

The central arrow in the diagram of the "fishbone" model indicates a process of reflection, integration and collaboration that leads to the implementation of Adaptive IWRM. Concurrently with the case study work, the TPNP project team worked actively with IWRM practitioners, especially within government (primarily DWS but also DEA), so that the new paradigm practice happened during the TPNP project rather than being simply reported for the first time in this report. The many consultations with the DWS and other stakeholders are listed in the Impact Table. This core engagement process drew in a wide range of stakeholders and was fuelled by the discourse or conversation about new ideas and methods interacting with the practical case study experience.

The two core principles for practical integration are iteration and the use of the TD practice principles (text box below). A central TPNP finding, based on an understanding of complex systems, is that principles are more useful that rules or prescriptive guides. Principles can be applied flexibly in context specific circumstances and are both strong and flexible.

The Strategic Adaptive Management (SAM) process guides iterative participatory processes and the conscious reflexive use of TD practice principles. Practising SAM reduces tension as people discover non-linear processes are usual and expected. Expecting the unexpected increases social and practical resilience and encourages adaptation. Of the practice

principles in the text box below, the one that recurs most often is dealing with discontinuities. Most IWRM processes in South Africa are characterised by: changes of plan; changes of attendance, challenges with permission to travel, challenges with transport and other logistical issues and sequentially different attendees staff members, or representatives during a set of engagements that are designed to achieve a purpose. Accepting discontinuities as an inevitable reality is the first stage of adaptation; followed by making time allowances for reiteration of progress at the start of each meeting. If practising TD principles becomes a routine practice, discontinuity loses its acute frustration factor and becomes an opportunity for deepening learning. If this is explained up-front, group frustration levels also drop. The Adaptive Planning Process, which is the first step of SAM has proved to be a most valuable step for learning integration practice through planning among differing people with a shared future, for example in a catchment. SAM is particularly useful in integrating impacts and opportunities offered by the social, technical, environmental, economic and political characteristics, guide by agreed values.

**Principles of transdisciplinary (TD) practice from Palmer et al. (2013):**

- **Tolerate and even welcome discomfort and unresolved tensions, they are often gateways to knowledge and trust.**
- **Be sensitive to "aha" moments or insights, and note that irritation and conflict often signal moments of insight and a learning opportunity.**
- **Engage with balanced generosity; listen and share.**
- **Practice tolerance, build integrity and mutual trust.**
- **Be sensitive to "arrivals" of both people and ideas.**
- **Create and use reflective opportunities.**
- **Manage discontinuities (people come and go, and arrangements change suddenly).**
- **Sustain enquiry (keep going when it is tough).**
- **Be conscious that everyone involved in the process is a whole, multi-dimensional peron, with the potential to engage with their whole self and many ways of knowing.**

A set of guiding principles for the practice of Adaptive IWRM co-developed by participants at the 2014 TPNP "mirroring" workshop:

| Principles for practising Adaptive IWRM in South Africa: to transcend current practices, to transform, and to shape the future | |
|---|---|
| PRINCIPLE: | ADDRESSES: |
| From the National Water Act: equity, sustainability and efficiency | Discrimination, unfairness, and wastefulness |
| Courage - transformation is revolutionary and radical | Current paralysis in the status quo |
| Consciously accept, understand and act in terms of the implications of complex social-ecological systems:<br>- trust longer, winding journeys<br>- watch out for and accept emergence<br>- we can't know everything – all our knowledge is provisional so humility is essential<br>- requisite simplicity<br>- relationality and relationships are key drivers | Pitfalls of mistaken "efficiency" and arrogant knowledge |
| Foreground practice and learning by doing, changed behaviour arises from awareness and knowledge transfer | "Listen to me and do what I tell you" |
| Foreground the social | Habits of science only, and science superiority |
| Pay attention to context | Habits of stereotyping and seeking recipes that can be broadly applied |
| Use values and principles to guide contextual decision-making | Beliefs that stereotyped roles and recipes can be broadly applied |
| Pay vigilant attention to emancipatory and transformative potential | Convictions that: "the rules work and can be revised" |
| Pay attention to power relations | The powerful are happy with the status quo they created it and benefit from it. |

| Principles for practising Adaptive IWRM in South Africa: to transcend current practices, to transform, and to shape the future | |
|---|---|
| PRINCIPLE: | ADDRESSES: |
| Build on existing strengths and opportunities | Paralysis by enormity and tangledness* of problems |
| Cultivate consciousness and recognise "traps" of old practice - good facilitation can be helpful | That it is easier to ignore the implications of complexity and change |
| Work towards shared understanding | Starting with conflict |
| Work on challenges that bring people together | Paralysis by enormity and tangledness of problems |
| Create a vision of a shared future (learn to be adept at moving between the challenges of the present and what will embody that future) | Paralysis by enormity and tangledness of current problems |
| Recognise the power of citizen science and participatory governance | Acceptance that real participation is too hard and too expensive |
| Pay attention to learning opportunities: work-based learning for change; social learning where tensions create learning chances, and learning for capability (doing the task), rather than competency (understanding the task) | Changed behaviour arises from awareness and knowledge transfer |
| Engage and co-learn | Avoid engagement where you announce, and impart what is always only partial knowledge. Avoid just ticking "stakeholder engagement" box. |

*The metaphor we have come to use is that of the "knot": When one tries to untangle a piece of fishing line picked up on the beach, tugging in one place often tightens another, and then there is the seaweed, or fishing hooks that have become entangled. At first a lot of energy goes into loosening. In Adaptive IWRM the best we can often aspire to, is the conscious recognition of new options that arise as "knotty" problem areas are loosened, mindful of the future knots that will necessarily emerge. However, the team work, confidence and ability to take action, to monitor consequences and adjust direction become empowering ways of operating.*

The nine accessible Adaptive IWRM: "How to…." handbooks have been produced.
They have been tested with potential users and will be used extensively by civil society, staff and stakeholders in catchment management forums and agencies (CMFs and CMAs) and by local municipalities.

1. How to think and act in ways that make Adaptive IWRM practically possible
2. How to think about water for people and people for water: Some, for all, forever
3. How to establish and run a Catchment Management Forum (CMF)
4. How to manage Water Quality and Water Quantity together
5. How to engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities.
6. How to run a Green Drop campaign in a Catchment Management Forum
7. How to engage with coal mines through a Catchment Management Forum
8. How to use Strategic Adaptive Management (SAM) and the Adaptive Planning Process (APP) to build a shared catchment future
9. How to understand Environmental Water Quality in Water Resource Management

Adaptive IWRM been actively taken up and used by the DEA, Chief Directorate for NRM, in the Mzimvubu (specifically the Tsitsa) River catchment in the Ntabelanga Laleni Ecological Infrastructure Project (NLEIP).

The frontiers of scholarship are most often to be found in the best doctoral thesis of the day. In the course of the TPNP three doctoral students graduated with exceptional international referees' reports, one with no corrections, and one with the comment "exemplary transdisciplinary research". These are three of the 22 post graduate students who received full or partial support from TPNP. The master's theses are also innovative and contribute to the practice of Adaptive IWRM. The graduation of eight students is a strong contribution to "the linked development of concept, theory and method" in transdisciplinary research. We also developed a post-graduate "transdisciplinary research" short course

for Rhodes University Centre for Post Graduate Support, using Adaptive IWRM as one of the fields of study. Other scholarly outcomes are: 7 refereed publications, 4 poular articales, 18 conference presentation, and 18 workshops.

The conclusions and recommendations to the WRC and the DWS are:

Conclusion: Adaptive IWRM IS ground breaking: hard, slow, and EFFECTIVE and IS the way to achieve the balanced protection and use of water resources for the equitable and sustainable benefit those who live in South Africa.

Recommendations:
Immediate uptake by DWS: The DWS accepted Adaptive IWRM concepts in the 2017 Water Quality Management Policy and Strategy (WQMP&S); other immediate actions and applications are:

- formally adopt and promote the term ADAPTIVE IWRM,
- actively ensure the revised single water law is consistent with Adaptive IWRM,
- actively promote the "How to…" series
- use Adaptive IWRM in the Olifants River IWQMP,
- use Adaptive IWRM in the Master Plan for Water and Sanitation,
- check for consistency between the WQMP&S and the monitoring and evaluation framework,
- actively support SAM-based stakeholder engagement in catchments, while governance and institutional arrangements are evolving.

Longer term uptake by DWS:

- invest in embedding SAM in DWS water resource management and water service delivery (this will need purposeful, systematic and systemic action).

Uptake by the WRC:

- formally adopt the term ADAPTIVE IWRM
- actively promote the "How to…" series
- actively support building an Adaptive IWRM community of practice,
- actively promote the practice of engaged, transdisciplinary, action research where it is needed,
- address the research questions
    - How do we use SAM to catalyse effective IWQM at the catchment level while governance and institutional arrangements are evolving?
    - What is the political ecology of the Green Drop incentive programme and how to identify windows of opportunity in a fractured governance landscape"?
    - Household water security is key to reduced public protect. Use TPNP evidence of the importance of social networks to address the question: How can household water storage be supported to complement piped water delivery is urban and rural areas?
- recognise the WRC's global reputation is founded on the practical application of research to the benefit of people,
- recognise the power and necessity of integration to address water issues in both service delivery and resource management,
- recognise and reaffirm that water services (and the national economy) are dependent on the hydrological cycle and water resource protection,
- foster transdisciplinary research – which includes strong, well developed disciplinary research and judicious inter- and multi-disciplinary research,
- plan systemic adaptive research programmes (for example, explicitly LINK the "light houses") and manage peer review systemically (for example, make greater use of the global standards of peer-reviewed literature for scholarly merit, and mechanisms like programmatic colloquia for peer reviewed impacts on policy and practice;
- recognise key "windows of opportunity":
    - the new legislation, combining Water Resources and Water Services, is being drafted. Liaise with Department of Water and Sanitation (DWS) to ensure a systemic approach where integration and synthesis are used. (There are specialist practitioners in these skills who have been associated with the WRC.)
    - recognise student and young water professionals are hungry for the Adaptive IWRM approach.
    - identify linked WRC projects, add "adaptive catalyst" funds, and assign a small Adaptive IWRM specialist team to work with project leaders to increase the likelihood of added values from interactions and feedbacks.
    - Promote and invest in 'meta-research' that works across projects.

**FINAL NOTE: Adaptive IWRM research and practice is "tortoise work"**

**The literature on engaged action research as a catalyst in adaptive complex social-ecological systems is clear that:**

- **this research praxis requires "a certain slowness"**
- **outcomes and responses also emerge slowly and through time**
- **pathways of uptake and change are unpredictable.**

**HOWEVER:**
**This approach offers the most promising pathway of substantive progress in engaging with the most difficult social-ecological problems facing humanity.**

**From the TPNP we suggest: long term, substantive research investment in at least two catchment management governance entities, like CMAs, to support ongoing and developmental praxis IN Adaptive IWRM. It would be worthwhile to invest in at least a decade-long programme.**

**POST SCRIPT** Reference Group member, Dr Chris Dickens, Head Regional Office (South Africa), IMWI:
"*Agreed. Maybe it is worth addressing some deeper issues like how do you sustain progress and momentum in the face of such required slow pace? I see this a lot with transboundary River Basin Organisation creation. It takes forever and there is often some randomness involved in a first champion pushing things for a few years, then nothing for a few years, then a new champion coming in to drive the process trying to pick up pre-gap-period. I can't help but wonder if there may be ways to orient this toward a more cohesive process.*"

The acknowledgements in this project are heartfelt:
The authors thank the large group of people who have served on the Reference Group over the four years of the WRC Project K5/2248, and the WRC research managers who have had oversight in four periods of the project: Kevin Murray for vision, inception and for backing our team; Jennifer Molwantwa for deep enthusiasm and belief in the project; and Bonani Madikizela who participated in the conceptualisation and managed the project for two periods, one of transition, and the second for the concluding phase of the work and the final reporting.

Charles Breen, Kevin Rogers, Sharon Pollard, Derrick du Toit, Harry Biggs and Dirk Roux are foremost among those responsible for the intellectual and practical foundations of this work. Kevin Rogers was an early project member and powerfully influenced the work.

The collaborating authors include industrious, intelligent and committed students; imaginative, innovative academic leaders; and deeply engaged practitioners. Some students supported by the project are not listed as collaborating authors, but contributed to the "whole" of the work.

The IUCMA was a fantastically supportive practitioner-partner. We hope your future use of the project products is fruitful.

The "Water for Dignity" team were tireless civil society researchers. They substantively shaped the content of this report, and raise serious questions about how we value citizen science contributions. We thank Mr M Lipile, Mrs N Lipile, Mrs X Nzwana, and Mr S Saki. We thank the Khulumani Support Group and particularly Dr Marjorie Jobson, for their human rights and social justice leadership and example, and for their active participation in the Makana case study.

We thank participants in the Crocodile River Catchment Forum, who contributed with enthusiasm in the Green Drop Support Campaign as well as participants in the Upper Komati Forum who dealt with coal mining issues wisely but frankly. Both groups were responsible for many insights in this project.

Thanks to Tammy Griffin for her illustrations of the "How to…." handbooks.

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## AfriAlliance Action Group: Integrated Water Resource Management and Ethics

**Sponsor:** AfriAlliance Consortium with funding support from the European Union's Horizone 2020 Programme
**Action Group members:** ON Odume (Leader), C De Wet (Rhodes University, South Africa), NP Ngqwala (Rhodes University South Africa), P.Hebinck (Wageningen University, Netherlands), L El Youssfi (Université Moulay-Ismaïl, Morocco), E López-Gunn (ICATALIST, Spain), M Motsholapheko (University of Botswana, Botswana), P Ntloko (Rhodes University, South Africa), N Libala (Rhodes University, South Africa), F Akamagwuna (Rhodes University, South Africa)
Project dates: November 2016 – December 2018

The objective of the AfriAlliance project is for African and European stakeholders to work together in the areas of water innovation, research, policy, and capacity development to prepare Africa for future Climate Change challenges. The project drives Africa-EU cooperation by sharing (non) technological innovation for local challenges and identifying and boosting sustainable market and investment opportunities.

The AfriAlliance project focuses on Water and Climate Change research and (social) innovation (R&I) cooperation between Africa and Europe through a mix of forward-looking and bottom-up innovation and road mapping techniques. It identifies demands, opportunities, and constraints at different levels and develop strategic advice for improving Africa-EU collaboration.

Within the AfriAlliance Project, the IWR is leading an Action Group on Integrated Water Resource Management and Ethics. The Action Group on integrated water resource management (IWRM) and ethics arises out of the realisation that despite the adoption of the IWRM and developments in water resource policy, law, monitoring, regulation, management and research, the health and functionality of water resources in South Africa and indeed the rest of Africa, continue to deteriorate (CSIR 2010).

The Action Group proposes a Systemic-Relational (SR) environmental ethical perspective as an ethically grounded approach to water resource management. In seeking to develop criteria for managing and allocating water, the ultimate good/value that should be upheld is the well-being and health of the entire ecosystem, including humans and the non-human elements that provide the necessary support base upon which humans depend – without according ethical priority to any of these components. We conceptualise the ecosystem as a complex social-ecological system (SES), with humans as an integral part of ecosystems. In taking the SR perspective, the Action Group seeks to develop processes and a methodology that can be used to operationalise the SR perspective in relation to water resource management and practice, using case studies within the context of IWRM in order to do so.

Central to the SR perspective is the realisation that values exercise an important influence on the allocation of water for multiple uses and on the prioritization of what is considered important or not, in decision-making processes. In the practice of IWRM, specifically with regard to water allocation and decision-making, the SR approach and methodology explicitly bring forward the interconnectedness, interdependence, and on-going dynamic interactions of the various components of the SES, in which such components are accorded equal analytical and moral weightings.

The Action Group accordingly held a four-day workshop, from 10 to 13 July 2017, at Rhodes University, in Grahamstown, South Africa. Present at the workshop were members of the Action Group, from Botswana, Morocco, Netherlands, South Africa and Spain - as well as members of academe, government, and civil society from South Africa, mainly from the Eastern Cape Province.

After an introduction to AfriAlliance and the scope of the Action Group (as outlined above), the Workshop consisted of

i) an examination of systemic thinking and values in relation to complex social-ecological systems, and the corresponding application of the systemic-relational (SR) environmental ethical approach to water resource management
ii) Methodological issues relating to the application the SR approach in Water Resource Management. Key problems which arise in this regard concern how to include environmental ethics and values in research design, and how to incorporate local, national and international geographical levels, as well as time scale, in terms of the unit of study and unit of analysis.
iii) Case studies on Water Resource Management which raise environmental ethical issues. Case studies were presented which dealt with issues in selected areas in Botswana, India, Morocco, Spain, South Africa, and the United States of America.

iv) Interaction with an ecosystem management project in the context of planned infrastructure development in rural eastern South Africa. (Ntabelanga and Laleni Ecological Infrastructure Project -NLEIP). AfriAlliance and NLEIP members attended and addressed each other's workshops (which were occurring at the same time in the same town, and which were both utilising a complex systems and social-ecological systems approach) thereby taking issues of integration and of transdisciplinarity seriously.
v) Discussion of Future Research and Publication Plans for the AfriAlliance group.

Possible publications included a number of a relevant journal to incorporate the main contributions, by way of formal presentations as well as a synthesis of ideas and recommendations emerging from the discussion; a policy focused discussion paper, as well as a series of fact sheets which many be written to be relevant at specifically local or national government levels in specific countries; an environmental ethically related contribution to a climate change summit in South Africa in November 2017. Research wise, the future of the AfriAlliance programme is fully dependent upon whether its members are able to obtain additional external funding, which is sufficient to enable its members to take on the necessary post-graduate research students to enable the Action Group to take further the intellectual and [policy issues and linkages that are developing during its initial year of research.

Some fundamental issues which came out of the presentations and discussions, and which the workshop has given our AfriAlliance Action Group to take forward, include:

i)The central role that values perform in complex systems. Issues arise around how we are to understand and to work with that role. Given the heterogeneity and dynamic nature of complex systems, questions arise as to how specifically we need to define the research question that we are starting off with, or hence the way that we understand the complex system involved, upfront? Does this have implications for the moral/value issues that we see as involved in the research project, and whether these may change over time?

ii) Such dynamism in a complex system can also have significant political implications, particularly in the context of a 'development cum change' related undertaking/project that involves different constituencies with differing degrees of political and economic leverage, and differing values. Who decides/defines what acceptable value trade-offs are, and when they may be regarded as having been settled? I.e. whose politics actually counts in re/solving issues/disputes, and how is the natural environment to be represented in this regard? Participation is thus an issue to be addressed in terms of historically marginalised human groups as well as the natural environment. However, can the natural environment effectively be treated participatory, until all humans are?

***Evidence of knowledge co-creation during the AfriAlliance workshop.***

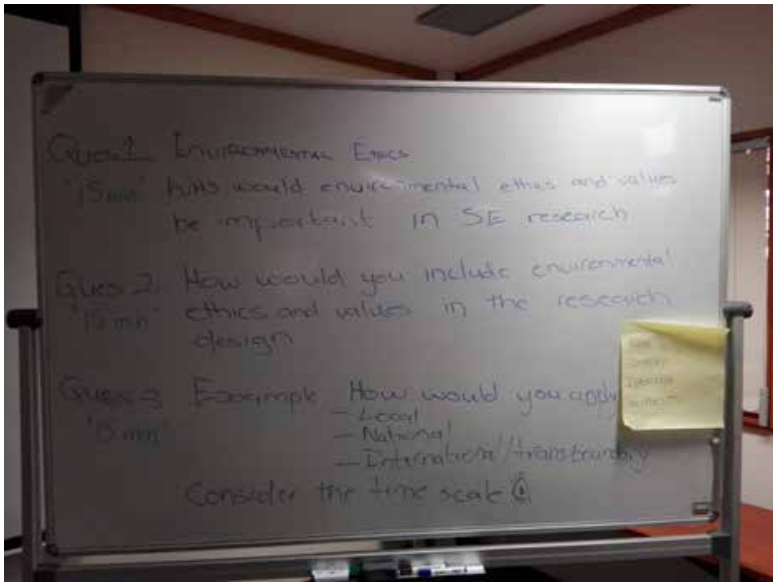
iii) The above issues take us directly to the management of water resources, which has to bring together potentially diverse tendencies such as the efficiency and affordability required for service delivery on the one hand, and the heterogeneity and unpredictability inherent in a complex social-ecological system on the other.

vi) In this regard, it is necessary to take account of the full range of institutions relevant to water preservation, management and supply, for ethical water governance. At what geographical level such institutions are to operate is a potential trade-off between managerial, economic and ecological dynamics, as people's livelihood dynamics may well extend beyond the water catchment in which they are based. How is the idea of a "social-ecological system: thus to be understood?

v) It is therefore necessary to be aware of, and consciously to incorporate, the ethical complexities involved in WRM. It is with this in mind, that the SR environmental ethical approach has been developed, to guide WRM, as Afri-Alliance argues that these SR ethical principles provide a framework in which value pluralism can be accommodated in WRM. It may however be the case that there is no homogeneous understanding of ethics (as e.g. in the

AfriAlliance perspective, where ethics provides a set of principles in terms of which differing values may be brought together - rather like a national level constitution provides a framework in terms of which different legal disputes may be resolved). There may well be differing views as to how ethics is to be conceptualised and applied - also in relation to values. We therefore need to be open and honest about our assumptions and about our intellectual, value and implementational trade-offs.

vi) The workshop reflected on ways in which environmental ethics and values (EEV) would be important to social-ecologically oriented research, and how one could incorporate EEV into research design aimed at making a policy contribution. This included internalising an SR perspective at case study level in future research. This would involve taking the research from this first year of the AfriAlliance project further - which would require more focused and detailed research projects undertaken by e.g. doctoral level students - for whom significant funding would have to be raised via a range of international level funders. A number of funders were considered.



*Evidence of knowledge co-creation during the AfriAlliance workshop.*

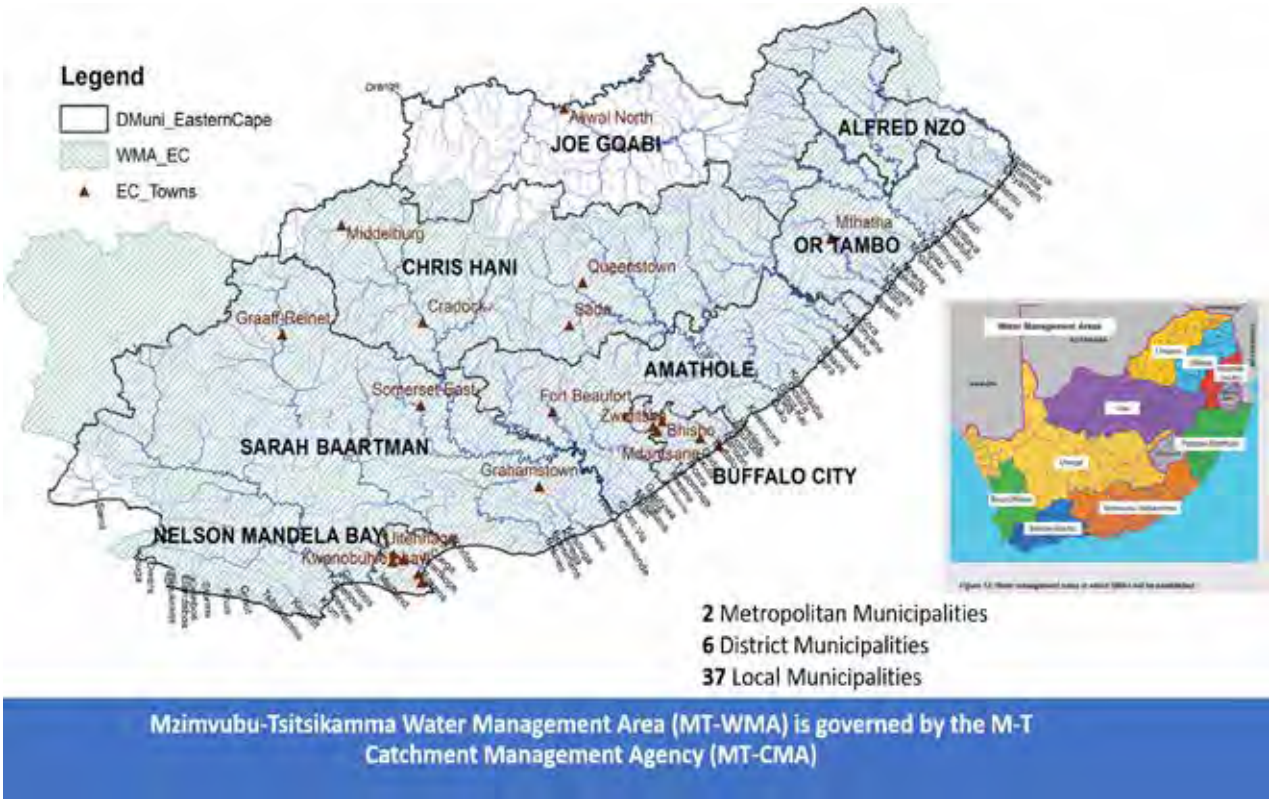
vii) Possible publications by the members of the workshop were discussed, with various team style contributions for a special edition of a journal being favourably considered. Also agreed upon, are that i) a Policy Issues type document, needs to be formulated, which raises the WRM/SES policy implications coming out of the various case studies and the discussion coming out of the workshop, as well as ii) a range of short Fact Sheets, which should be rather more country/issue specific. These can be presented at relevant country level meetings, whether academic or governmental.

**Development of a Governance Framework and Information Management Framework/System to Improve the Integration and Effectiveness of Landscape Level Planning by the DEA Natural Resource Management Programmes**

**Sponsors:** Department of Environmental Affairs and Department of Science and Technology
CG Palmer
Project dates: February 2015 – March 2017

The Department of Science and Technology (DST), through its Environmental Services and Technologies (EST) Directorate is managing an Environmental Services Portfolio that has a particular focus on addressing research, development and innovation gaps relating to Ecological Infrastructure (EI). This focus area is particularly aligned to the DST Global Change Grand Challenge. Given this focus, EST has been interacting with the Department of Environmental Affair's (DEA) Natural Resources Management (NRM) Chief Directorate since July 2014 in order to understand synergies and areas for collaboration. This has given rise to exploring a partnership on projects in the Mzimvubu Catchment. This catchment is strategically important to ongoing NRM and EI developments, with potential for lessons to be transferred to other catchments, based on the current interventions in the Mzimvubu. The strategic nature of the Tsitsa sub-catchment of the Mzimvubu is primarily that it is the location two proposed impoundment developments: the Ntabelanga and Laleni dams.

The overall DEA: NRM project is entitled: The Ntabelanga Laleni Ecological Infrastructure Project (NLEIP), and it involves support of both integrated natural resource research (including water as a key resource), and operational interventions in landscape restoration. 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". Within NLEIP, the DST is directly funding 1) research on governance and the development of




***South Africa has nine water management areas (WMAs), each of which will be governed by a Catchment Management Agency (CMA). CMA formation is in progress.***

institutional arrangement, through the IWR, and 2) integrated knowledge systems through the Institute for Natural Resources (INR).

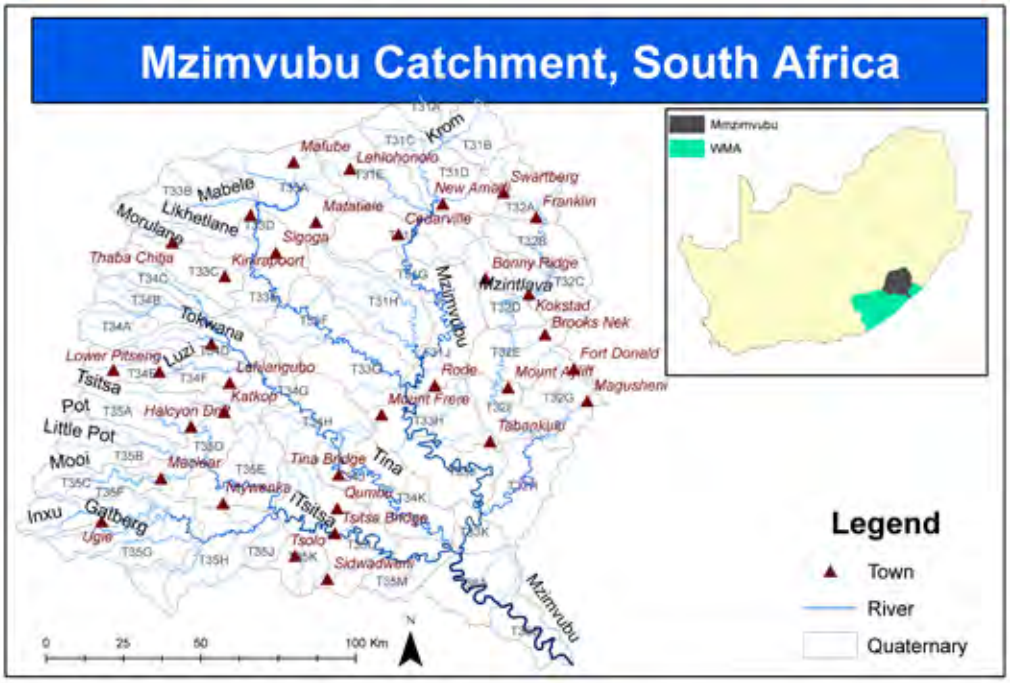
Action research focused on the development of governance processes and institutional structures supports achieving the vision by providing local people with basic information about how catchments function, and providing them with the opportunity to form, and belong to a Catchment Management Forum (CMF). The Mzimvubu to Tsitsikamma Catchment Management agency (MT-CMA) is in the process of being gazetted (it is currently a proto-CMA) and is responsible for water governance in the Mzimvubu-Tsitsikamma Water Management Area (M-T WMA). The Mzimvubu Catchment – just part of the WMA, includes parts of two metropolitan municipalities; six district municipalities, and 37 local municipalities.

The proto-MT-CMA is supporting the formation and rekindling of CMFs across the WMA. The NLEIP project has been identified by the MT-CMA as the agent of change in the formation of a Tsitsa River CMF. (Two other CMFs are being established in the larger Mzimvubu Catchment). Since CMFs are formally acknowledged institutions in the National Water Act (No 36 of 1998), people who are members of a CMF have representative standing with the CMA.

It is important to note that the Tsitsa River sub-catchment is large, and the Ntabelanga Dam is fed by five quaternary catchments. The area includes two local municipalities and traverses the lands of more than two tribal authorities. The aim is to draw all of these existing institutions into active natural resource management decisions and recommendation through the formation and running of the CMF. This process has been supported with an accessible handbook "How to establish and fun a Catchment Management Forum (CMF)", and running a set of five CMF formation workshops for the proto-MT-CMA (including Tsitsa River Catchment).

IWR Research Processes in 2016

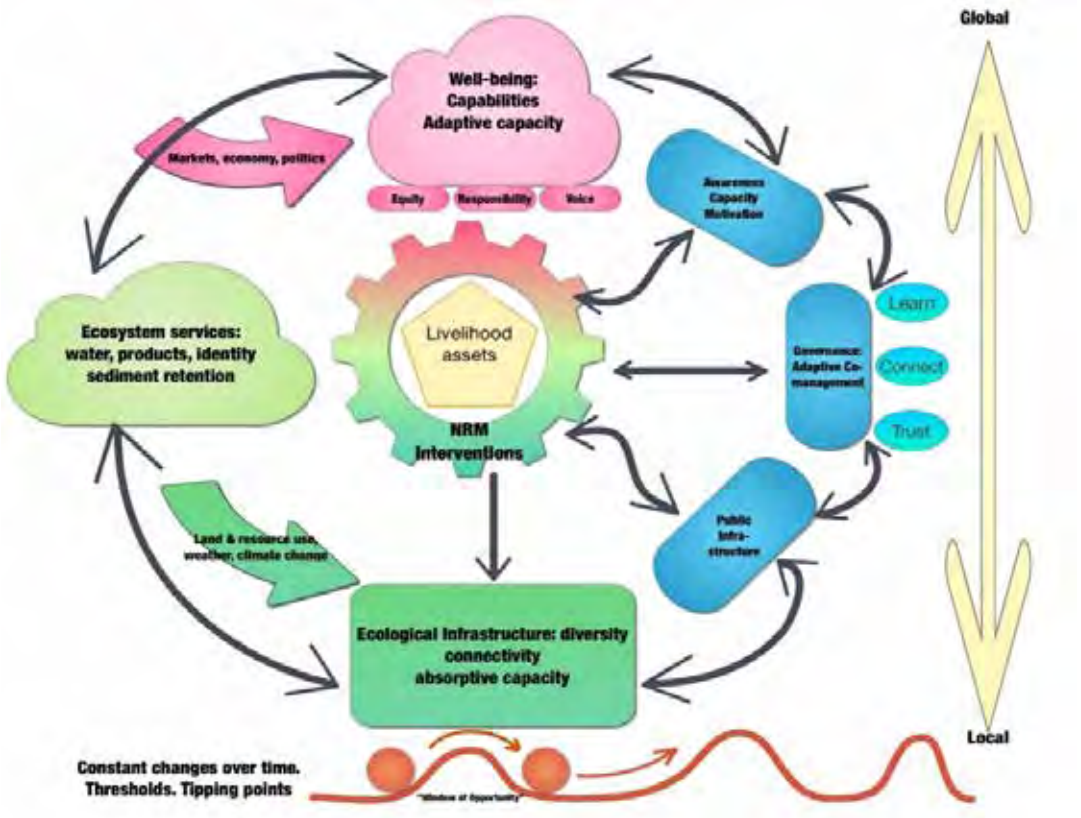
The IWR-UCEWQ research team has strongly influenced the whole NLEIP process through integration with the WRC Integrated Water Resources Management (IWRM) in South Africa: Towards Practising a New Paradigm (TPNP) project. We participated in the development on the overall integrated research design and the concept to track the balance of research across the whole system (Figure 3), 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




***The Mzimvubu River catchment, and its location within the South Africa and the Mzimvubu to Tsitsikamma WMA. The Tsitsa River CMF is likely to be organised from the town Maclear.***

understand sediment movement. (The natural geology and soil structure, combined with extensive grazing and low vegetation cover, sediment loss from the upper catchment threatens the water storage capacity of the proposed dams).

Within NLEIP we lead governance research. We see governance as a strong empowerment and capacity- building pathway to catchment sustainability. Residents can use participation on a CMF to share their knowledge, and to learn about how catchments function, and how land and water management works. They will be able to contribute to the development of the catchment management strategy (CMS) though the development of their own local sub- strategy – in this




***A conceptual diagram of the NLEIP research content, with arrows indicating relational integration (Internal NLEIP report, Fabricius and Biggs 2015)***

case for the Tsitsa River. Once residents become invested in a shared vision of a desired future there is a social basis for sustaining landscape-based livelihoods.

At present the main motivation to attract the interest and involvement of local residents in the formation of the CMF is through the opportunities they have to become involved in the DEA: NRM activities (Figure 4). These include the opportunity to benefit directly (by working in public works programmes, such as all the "Working for…" programmes in restoration teams) or indirectly (through restoration delivering better pastures for livestock). Future plans may include additional innovations such as the flexible use of seasonal fencing for stock improvement and ecosystem infrastructure protection.

The governance team contributed to the overall acceptance of catchments and landscapes as complex social-ecological systems (CSESs) by the DEA: NRM chief directorate – including the most senior levels of management and well as field-based managers. In February 2017 the IWR ran a two-day workshop with the DEA: NRM Operations Southern Programs Directorate which included exploring landscapes as CSESs, strategic adaptive management (SAM), complexity, and transdisciplinarity. Delegates attending the workshop drew up an objectives hierarchy for their directorate based on the adaptive planning process as part of SAM.

***Participants taking part in the 'complexity game' during the February 2017 workshop held in Port Elizabeth with the DEA Operations Southern Programs Directorate***

***DEA Operations Southern Programs Directorate staff work through the objectives hierarchy with Prof Tally Palmer.***

***Participants at the Adaptive Planning workshop in Maclear discuss objectives during the workshop***

More than five PhD and Masters students from the IWR are conducting research in the Tsitsa River catchment. During 2017 the IWR hosted two Honours students who undertook research projects in the area. Prof Tally Palmer, Ms Sinako Mtakati (Honours student), Ms Nosi Mtati, Ms Margaret Wolff and Mrs Helen Holleman ran a two-day adaptive planning workshop in Maclear in June. The workshop allowed participates to take part in imaging the future visions for their catchment and to draw up an objectives hierarchy. Information gathered during this research project will be included in governance planning with the DEA: NRM Chief Directorate during the DEA: NRM Science Management Meeting in December 2017.

# Post Graduate Activities

## Taxonomic and Trait-Based Responses of the Order Ephemeroptera, Plecoptera, Odonata, and Trichoptera (Epot) to Elevated Sediments in the Tsitsa and Associated Rivers, Eastern Cape, South Africa

**Student:** FC Akamagwuna
**Supervisors:** ON Odume and PK Mensah
**Degree:** MSc (Water Resource Science)

Freshwater ecosystems are being increasingly deteriorated by a range of factors and freshwater biodiversity has become the most endangered globally (Strayer and Dudgeon, 2010; Vörösmarty et al., 2010; Kopf et al., 2017). The rapidly growing human population growth, estimated to grow from 7 billion in 2011 to 9.3 billion by 2050 (UN, 2016) and urbanisation has caused severe demand on freshwater resources to increase (Vörösmarty et al., 2010; Wagenhoff, Townsend and Matthaei, 2012; Davis et al., 2015). These phenomena have led to widespread disturbances of freshwater ecosystems including habitat degradation and pollution, flow regulation and water extractions, overexploitation and introduction of alien species (Strayer and Dudgeon, 2010; Steffen et al., 2015; Zhang et al., 2017). Landscape degradation can accelerate the inputs and delivery of nutrients, organics, and other forms of pollutants including elevated sediments into the stream and river ecosystems (Zhang et al., 2017).

The elevated transport of sediments into the aquatic ecosystems impacts on water quality and often affects macroinvertebrate diversity and assemblage structure. The EPOT taxa are sensitive orders of macroinvertebrates and are most pervasively affected by increased instream sediments. The EPOT species respond differently to fine sediment particle sizes. For example, some taxa such as the Baetidae, Caenidae and Aeshnidae are tolerant or moderately tolerant while taxa such as the Hydropsychidae respond differently to sediments (Buendia et al., 2010; Descloux et al., 2014).
Despite the fact that elevated sediments input into the Tsitsa and its associated rivers are the major cause of water quality and biodiversity impairments, very few studies have explicitly assessed the impacts of elevated sediments on water quality and biodiversity using macroinvertebrates. The few studies that have assessed these impacts have previously focused mainly on family level taxonomic resolutions and no study has explicitly integrated both taxonomic and trait-based approach (TBA) to assess the impact of elevated sediments on macroinvertebrates in the Tsitsa and associated rivers. The combined use of taxonomic and traits measures have potentials to add diagnostic and predictive power to aquatic macroinvertebrate-based biomonitoring. Furthermore, evaluating the structural and functional response of selected groups of macroinvertebrates at the species level can improve the sensitive potentials of biomonitoring to sediment effects as species-level assessments have been demonstrated to be more sensitive compared with family-level assessments (Hawkins and Norris, 2000).

This study, therefore, applies taxonomic and trait-based approaches to assess the assemblage response of species of the orders Ephemeroptera, Plecoptera, Odonata and Trichoptera (EPOT) to elevated sediments in the Tsitsa and associated Rivers, with a view to developing a biomonitoring tool for predicting the potential vulnerability of EPOT species to sediment effects.

## Modeling Nutrient and Pesticide Management Practices for Improved Crop Yields and Water Quality in the Eastern Cape, South Africa

**Student:** DJ Choruma
**Supervisors:** ON Odume, S Pietsch and J Bakovich
**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 environmen-

tal pathways of development. In general my research uses computer models 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 quality. 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.

### The Parameterisation, Simplification and Further Testing of a Sediment Transport Model by Application to Data Scarce Semi-Arid Catchments.

**Student:** D Gwapedza
**Supervisors:** AR Slaughter, DA Hughes and SK Mantel
**Degree:** MSc (Hydrology)

This study focuses on parameterising and testing a sediment transport model by application to data scarce catchments. The estimation of soil erosion and sediment transport is important for catchment management. Quantification of reservoir sedimentation is crucial for determining the rate of reservoir storage loss, estimating reservoir lifespan and developing associated mitigation measures. The sediment transport model (WQSED) used in this study incorporates a hydrological model (Pitman) and the Modified Universal Soil Loss Equation (MUSLE). The hydrological component of the model provides the daily flows that drive the erosion and sediment transport model. MUSLE is used to calculate the amount of sediment available for transportation. MUSLE model parameters relate to physical catchment characteristics, which are topography (LS), soil erodibility (K), vegetation cover (C) and the management practice factor (P). A regionalisation procedure to estimate the MUSLE model parameters has been developed using GIS coverages. The model was tested on more than 15 quaternary catchment and was proven capable of giving reasonable estimates. The study has now been upgraded to a PhD and will continue to further develop the model. Further development will include examining MUSLE scale dependency, considering temporal variations in vegetation cover, regional testing and evaluation. Attention will continue to be focused on high erosion areas such as a site in the Eastern Cape in quaternary catchment T35E where a new dam has been proposed (Ntabelanga). The outcome of the research will be a framework for parameter estimation through regionalisation and a simplified model which can estimate erosion and sediment delivery at broad spatial and temporal scales and that can be used by water resource managers with limited expertise in hydrological modelling. The sediment transport model will form part of the Water Quality Systems Assessment Model (WQSAM).

### Integrating Basin Scale Hydrological Models with Detailed Floodplain Hydrodynamic Models in the Congo Basin

**Student:** P Kabuya
**Supervisors:** DA Hughes, M Trigg and R Tshimanga
**Degree:** PhD (Hydrology)

This PhD student project is part of 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).

The Congo Basin has been under many hydrological investigations aimed at understanding the dynamics of the hydrological processes given water resource potentialities of the basin. Often such investigations are unsuccessful largely due to the spatial discretisation of the modeling units that are very coarse, making difficult to capture the spatial variability of different processes. The ungauged nature of the basin, especially its central part, "the cuvette centrale", which makes the parameterisation process of many hydrological models very difficult. Another challenge is the hydrodynamic processes that take place between the fluvial systems and their adjacent wetlands. Many hydrological models do not include this interaction and if they do, the methods used to estimate the parameters that drive the interaction between the main channel and their adjacent floodplains are not appropriate given the complexity.

Therefore, integrating basin scale hydrological models with detailed floodplain hydrodynamic models in the Congo Basin would be a good starting point to address the above-mentioned issues. In this regards, a number of activities including the capacity building sessions as well as the fieldwork have been undertaken during the 2017 year.

## Progress so far

In terms of progress, an integrated framework for the Congo Basin classification was developed with the objective of producing understandable modelling units based on the natural geomorphology (dominant slope and elevation, topographical maps of the natural drainage network as they appear in Google Earth), and anthropogenic activities (urban and mining activities, water monitoring infrastructures). This classification led to 403 sub basins delineated for the whole Congo Basin. The morphological analysis of some wetlands in the southeastern part of the Congo Basin is performed with the intention of understanding how could the variety of physical settings of wetlands be translated into the hydrodynamic connections between the fluvial systems and their respective adjacent floodplains. Another area of progress is the estimation of the disaggregation parameters for the monthly stream flow disaggregation into daily flows. Finally, we are now focusing on the development of the hydrological constraints for the Congo Basin in order to constrain the Pitman model behavioral outputs.

***Aerial view of the braided reach of the Congo River at the entrance of the Cuvette centrale***

***Installation of water level loggers in the Congo Basin***

## Training and workshops

The training session on basin scale hydrological modelling held at Rhodes University from 27 February to 03 March 2017, focused on the use of Pitman model within the SPATSIM framework. In addition to the basic features of the Pitman model, Professor D. Hughes introduced a new modelling framework on the Global option. This approach offers many opportunities such as an increase in the number of modelling units that could be simulated in a single run and the use of the hydrological constraints to constrain the behavioral outputs at each individual incremental sub basin. Students from IWR and CRuHM project presented their research outputs and research proposals, respectively. Another training session held at the University of Bristol, in June 2017 focused on the use of Lisflood FP model that is to be applied in the framework of this research. Professor Paul Bates introduced the basic principles of the hydrodynamic modelling and Dr Jeff Neal demonstrated the use of different tools for data preparation and modelling procedures. Pierre Kabuya presented the progress of his work as well. Another activity is the Royal society DFID Conference held in Tanzania, where different research consortium funded by the Royal society-DFID met together to know each other and share their research experiences. A five minutes presentation was given by each PhD student to give a brief view of his project and the preliminary achievements.

## Fieldwork

As part of the Congo River users Hydraulics and Morphology (CRuHM) programme, a fieldwork trip, led by Professor Raphael Tshimanga from the University of Kinshasa and Doctor Mark Trigg from the University of Leeds, was organised between July and September 2017 in the Congo Basin. The fieldwork was a joint programme implemented in collaboration with the partner institutions namely the University of Kinshasa, Rhodes University and University of Dar es Salaam from sub Saharan Africa and the Universities of Bristol and Leeds. It focused on the middle reach of the Congo River main stem (Kinshasa to Mbandaka) and the lower reach of the Kasai River (Congo's main tributary) in order to conduct a detailed investigation on the hydrology and hydraulics as a response to the information gaps that characterise this part of the basin.

A number of activities was achieved during this expedition, namely:

- Use of GNSS (Global Navigation Satellite System): the Trimble R10 uses the real time extended technology to measure the X, Y, Z values of any location.
- Installation of the water level Loggers: These are the instruments used to monitor the water level fluctuations. Their installation in the Congo Basin

***GNSS Trimble R10 measuring X, Y, Z values of the Congo River banks***

examines the interaction that could exists between the Congo main stem and its adjacent floodplains especially during high flows.
- Measuring of river bathymetry: this was achieved through the intensive use of the Sonar and the ADCP.

## Using a Social-Ecological Perspective 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 directly and indirectly provide services which are important for supporting the livelihoods of most people in rural areas. These include, dry season livestock grazing and watering, water supply for domestic use and irrigation (Sieben et al., 2016; Leguizamo et al., 2016).

Despite their importance, wetlands are increasingly being subjected to enormous pressure as the demand for social and economic development comes into tension with environmental sustainability. It has been estimated that 50% of the world wetlands have been lost or degraded due to agricultural activities, invasion of exotic species and climate change (Drayer & Richter, 2016). Communal areas are the most vulnerable to the impacts of wetland degradation, since they directly use wetlands for the agricultural activities such as livestock grazing. The degradation of wetlands impacts on the ecosystem structure and function, as well as the composition of biotic communities (Hooper et al., 2005). It has been also 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 Mzimvubu River is recognised as high degradation catchment as results 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.

***Cattle grazing on seep wetland***

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 utilised 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 know community understanding about seep wetlands benefits in relation to livestock grazing, social science methodologies, including, interviews and questionnaires were used.

Considering that hill slope seep wetlands provide good and services to local people it is important to use a social-ecological system to investigate the importance of hill slope seep ecosystem structure and functionality in order to suggest conservation or protection strategies. The following objectives have been set for the project:

- To assess the ecological health of hill slope wetlands using Floristic quality assessment Index and Wetland Index Value
- To investigate the potential resilience and vulnerability of the selected seeps vegetation to livestock 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 evaluate the vulnerability of hill slope seep ecosystem to erosion in order to recommend appropriate management strategies.
- To understand farmers value systems and grazing practices in relation to hill slope seeps in order to facilitate their protection.

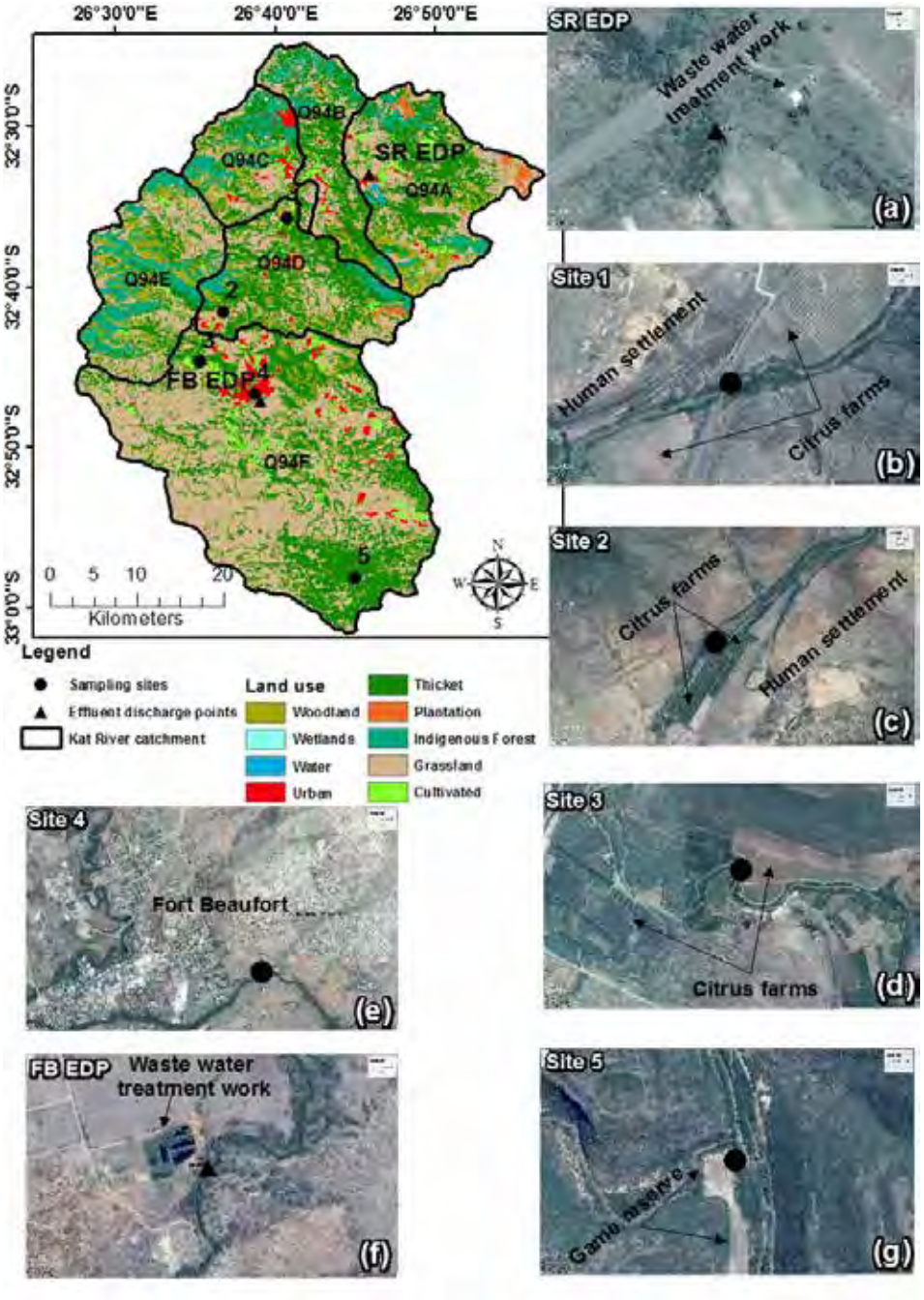
***Household interviews***

## Anthropogenic Impact On Salinity Of the Kat River, Eastern Cape, South Africa

**Student:** NS Mgaba
**Supervisors:** PK Mensah and ON Odume
**Degree:** MSc (Water Resource Science)

I am currently finishing my MSc project which looked at the impact of anthropogenic activities on salinity of Kat River, Eastern Cape, South Africa.

The project looked at anthropogenic activities such as agriculture, land use, discharge, and abstraction of water that are gradually worsened both quantity and quality of the country's water resources. These factors have put tremendous pressure on freshwater resources around the world, leading to changes in quantity and quality of these freshwater resources. Increase in freshwater salinity may lead to socio-economic changes, particularly increased water demand and its subsequent impact on the quality of water resources available for use. The aim of this study was to evaluate the impacts of anthropogenic activities on salinity and biological assemblages of Kat River, with a view to proposing appropriate salinity management strategy for the catchment. The Kat River catchment was chosen for this study because it is a hub of major agriculture activities, including citrus fruits and livestock farming. Communities living in the catchment use water from the river for their daily activities such as drinking and bathing. The study applies biomonitoring of macroinvertebrates, diatoms and physicochemical variables to assess anthropogenic impacts on salinity of the Kat River. Samples were collected bimonthly over one hydrological cycle (December 2015 - November 2016). Results showed that small scale farmers, runoffs from informal settlement and wastewater leaking pipes have an impact on increase of salts increase in Kat River. The combined findings of biomonitoring were used to formulate good management practices for salinity in the Kat River catchment.




***Land use map with google maps of the sampling sites on Kat River, modified from the Department of Environmental Affairs (DEA, 2013-2014) (© GEOTER-RAIMAGE - 2014). In figure 2.7,***
***(a) represents Seymour effluent discharge point;***
***(b) Site 1 and surrounding citrus farms;***
***(c) Site 2 citrus farm and human settlement;***
***(d) Site 3 and citrus farms;***
***(e) Site 4 and Fort Beaufort urban area;***
***(f) Fort Beaufort (FB) effluent discharge point and wastewater treatment works;***
***(g) Site 5 situated at the Great Fish Game Reserve.***

## Mapping and predicting livestock spatial and temporal distributions in the rural communal rangelands of Cala, Eastern Cape, South Africa

**Student:** Qawekazi Mkabile
**Supervisors:** CG Palmer, AR Palmer, SK Mantel
**Degree:** MSc (Water Resource Science)


***Ms Qawekazi Mkabile***

Background of study

Mgwalana is one of the rural areas near Cala in the Eastern Cape Province in South Africa, where communal lands have been utilised by livestock for many years, the area is under-studied and the grasslands that these livestock graze in is perceived as unproductive and degraded; due to extensive agriculture and livestock farming documented from past reports (Perret et al., 2000; Palmer and Ainslie, 2006). Livestock utilize the nearby grasslands in these rural rangelands which could potentially contribute to land cover land cover change (Neeuman, 2009).There has been little knowledge about whether the rangelands are still productive and provide socio-ecological services such as grazing material for livestock in the communal area up to date and thus, the need to assess the distribution of livestock.

Rural communal lands have been perceived as areas that are degraded and have rangelands that have little productivity, also, land-based livelihood strategies make insignificant contributions to overall well-being of the people (Perret et al., 2000; Shackleton et al., 2001). Continuous grazing systems and strategies that enhance the provision of ecosystem goods and services have also not been consistent (O'Farrell et al., 2007).

Such a study contributes in understanding areas that livestock select for grazing as these areas are poorly understood due to inefficient development assessments of community rangeland systems (Rasch et al., 2017). The study integrates biotic and mostly abiotic factors (Slope, Aspect, Elevation, and distance from water) to understand this because livestock distribution is based more on the combination of abiotic and biotic factors than just on specific plant related decisions (Kaufmann et al., 2013). With the appropriate management, grazing as a form of disturbance could actually maintain the structure, function and diversity of the grasslands in the area. However, if poorly managed grazing affects biodiversity in grasslands negatively (Marty, 2005).

***GPS collars placed on cows with the assistance from herders.***

The knowledge of spatial distribution is essential for any assessment of environmental impacts that livestock cause or affect in grasslands, for example soil erosion caused by overgrazing, also it is useful for monitoring land-change over time (Neeuman, 2009). The incorporation of livestock distribution and the drivers of the latter into models permits the locals to know other potential areas within the rural area that their livestock could use in different seasons (Tate et al., 2003).

Lastly, this study could serve as a baseline of information in ecological reports which could raise awareness about livestock needs and management to livestock farmers, community members and policy makers (Ganskopp et al., 2007). Additionally such information could contribute in initiatives such as the restoration and management of the grasslands from undesirable effects (Pykälä, 2003).

Aims and objectives:
This study aims to:
1. Identify and map the distribution of livestock with influential landscape variables that determine their location and
2. predict the distribution of livestock based on influential landscape variables in the rural rangelands

The study objectives are:
I. To identify livestock distribution in the rangelands of Mgwalana
II. To explore landscape variables that influence the distribution of livestock
III. To explore whether there is variation between dry and wet season
IV. To explore the contribution that comes with understanding livestock distribution to natural resource management, particularly in communal rangelands

Data collection (fieldwork):
At the beginning of the wet season (November 2016), GPS collars were placed on cattle to capture track their movement throughout the season, the GPS collars were then collected at the end of the season, the data was extracted from the GPS chip for further analysis. The same process was applied at the beginning of the dry season (July 2017), the GPS collars were placed on cattle and collected again at the end of the season for analysis.

## A Realist Exploration of the Ecosystem Service Concept from a Traditional Ecological Knowledge System in rural Eastern Cape, South Africa

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

The ecosystem services concept refers to the benefits that human beings get from various elements of nature including, but not limited to, drinking water, timber, breathing air, flood control, and pasture for domestic animals. Yet the concept has been predominantly studied and debated using the architecture of scientific epistemology. Over the past

three decades of ecosystem service research there has been little interest from scholars to investigate how ecosystem services are understood from a traditional ecological knowledge system. Given the reality that science is a knowledge system of a few trained specialists, there is a strong case to investigate and document how other knowledge systems such as traditional ecological knowledge conceptualise and understand the concept. There is practical use in conducting this study, not least because the majority of societies that directly live with and significantly depend on these services for their day-to-day living are not well versed in scientific ways of knowing.

*Mr Chenai Murata*

**The Development of an Ecological Response Model (Ecorem) for Integrating Biotic Response, Water Quality, Flow and Catchment Processes in South Africa**

**Student:** SM Ndlovu
**Supervisors:** ON Odume and AR Slaughter
**Degree:** MSc (Water Resource Science)

South Africa has developed methods for assessing water resources and aquatic ecosystem health that are embedded in policy, law, strategy, and practice. These methods (e.g. aquatic biomonitoring tools and models) focus on protection of different components of the river system, including hydrology and hydraulics, fish, macroinvertebrates and riparian vegetation. The Department of Water and Sanitation (DWS) and water resources practitioners apply these methods by measuring flow and collecting biological, physico-chemical, habitat and hydraulics data, which are then interpreted in terms of the ecological status and health of the water resources for water resource assessment and planning. Water quality and stream flow modelling are among well-established approaches used as part of supporting the ecological reserve. Another well-documented approach frequently used to assess river health is biomonitoring, the South African Scoring System (SASS) in particular. However, biotic response modelling is hardly practised, whereas there is adequate ecosystem datasets accessible to simulate, parameterize and calibrate the biotic response of macroinvertebrates to deteriorating water quality.

Therefore, the model (ECOREM) is designed to simulate the variability of macroinvertebrates in response to changing environmental conditions. The ECOREM is conceptually informed by understanding the mechanistic interplay between traits and environmental filters and it will contribute substantially to water resource assessment, management, protection and sustainable use through the following advantages:

1. Predictive capacity through scenario analysis of management and development of water resources.
2. Diagnosis of anthropogenic impacts.
3. Cost reduction by reducing the need for frequent collection of in-situ data.
4. A flexible system for decision making in respect of water resource protection and development.
5. Ability to model ecosystem health and general water resources condition at a range of spatial scales.
6. Provision of aquatic faunal assemblage data to guide development of the ecological Reserve and Resource Quality Objectives for catchments.

Overall, the aim of this project is to develop a novel computer-based model for modelling biotic response of macroinvertebrates to changing external environment. To achieve this, the following objectives form the basis for the project:

- To identify catchment in 31 ecoregions, and integrate biotic response, water quality, flow, catchment processes and impact of freshwater contamination.
- To simulate, parameterise and calibrate the biotic response of macroinvertebrates traits to flow and water quality.
- To demonstrate and test the implementation and accuracy of the ECOREM and make appropriate improvements.

## Taxonomic and Trait-Based Macroinvertebrate Responses in Sediment Impacted Rivers, Eastern Cape, South Africa

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

***Ms P Ntloko***

Increasing sediment concentration in freshwater ecosystems is of great ecological concern. Sediment have been long recognised as the contributing factor in disturbing freshwater ecosystems (Elis, 1936, Jones et al., 2012). Anthropogenic activities are well known as major drivers to sediment as a stressor to in stream biota. Globally, scientific approaches have been used to assess freshwater ecosystem s(Lecerf and Richardson, 2010). However, South Africa is still under a threat of deteriorating freshwater ecosystems. In assessing freshwater ecosystems few approaches are currently used in South Africa. The environmental water quality (EWQ) is the integrated approach that is currently in practice for assessing freshwater ecosystems. This tool links chemical, physical and ecotoxicology characteristics of a water resource to the responses of in stream biota (Scherman et al., 2003, Palmer et al., 2004a). The EWQ approach combines water physico-chemistry, biomonitoring and ecotoxicology information to manage in stream water quality (Odume, 2014). Water physico-chemistry measures and evaluate physical and chemical variables to assess water quality. However, effects of the measured variables on biological organisms are not considered. While, biomonitoring uses resident biota to provide information on freshwater ecosystem health (Odume, 2014), neglecting the cause-effect relationship on resident biota. Ecotoxicology experimentally assesses effects of specific toxicants on aquatic biota, including the identifying potential for causal relation (Odume, 2014). Nevertheless, this integrated approach does not present a better management approach of macroinvertebrates response to fine sediments in freshwater ecosystems. Against these backgrounds, this study assesses the cause-effect relationship of the environmental stressor and its effects on the stream biota by using the trait based approach (TBA); as a tool for predicting the cause of impairment. Although, TBA approach does not solely assess freshwater ecosystem, it is integrated to physico-chemistry and biomonitoring tools for better management of freshwater ecosystems. Traits are defined as any morphological, biochemical, physiological, structural, phenological or behavioural characteristics that determine the fitness of organisms (Nock et al., 2016) in selected environment.

Elevated sediments impact macroinvertebrate through different mechanisms, through physical effects of abrasion, clogging, burial and substrate composition (Sear et al., 2008). Sediments loads have indirect effect on food web changes (energy flow) and food, habitat availability for freshwater invertebrates (Jones et al., 2011). 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. Therefore, this project is aimed at using a trait-based approach in assessing macroinvertebrates vulnerability to elevated sediments. Therefore, the aim of this study is to use taxonomic and trait-based macroinvertebrate responses to understand sediment as a stressor in the Tsitsa River and its tributaries, Eastern Cape, South Africa.

***Mr Emmanuel Vellemu, Ms Pindiwe Ntloko and Mr Mzwanele Mkatali in the field for water samples collection in the Tsitsa River***

**Project objectives**

- To develop a conceptual framework for using trait information for assessing effect of sediments.
- To evaluate sediments effects on traits linked to ecosystem function.
- To develop a trait-based predictive and diagnostic model for understanding macroinvertebrates response to elevated sediments.

This project tends to improve the biomonitoring approach by incorporating a trait-based approach (being it ecological or biological traits) for assessing sediments impact on macroinvertebrates structure and ecosystem function. It is important to develop methods that are directly linked to ecosystem function because the recent study on physico chemical variables suggest protecting structures alone does not always protect species, an important aspect of ecosystem function (Kefford et al., 2012). Species traits offers opportunity for developing better methods and approaches for linking biomonitoring to functional characteristics. We hope that the incorporation of species traits into the existing water quality monitoring approaches will bring change in water resources monitoring in South Africa.

***Ms Siphokazi Tantsi, Mr Mzwanele Mkatali and Mr Emmanuel Vellemu collecting water samples in Pot River, Maclear.***

## Evaluating the Level of Epistemic Justice in the Application of Adaptive Planning Process for Integrated Water Resource Management

**Student:** M Ralekhetla
**Supervisors:** S-A Paphitis and CG Palmer
**Degree:** MSc (Water Resource Science)

Integrated Water Resource Management (IWRM) is a management practice that promotes coordinated development and management of water and other natural resources in a manner that maximises the economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems GWP (2009). Integrated implies that a broad and diverse range of stakeholders, with different knowledge types work together to achieve natural resource management that leads to social equity, environmental sustainability and economic efficiency. Therefore, there will 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 very little. The processes used in engaged projects also have an impact on the level to which injustices are either prevented or perpetuated.

Therefore, the aim of this research is to evaluate and enhance the use of Adaptive Planning Process (Rogers and Luton, 2011), through the addition of a reflective component to advance epistemic justice. Objectives are: 1). To introduce Adaptive Planning Process (APP) and facilitate it with the Makana Water Forum to develop their Sub-Catchment Management Strategy; 2). To develop an evaluation framework for epistemic justice; 3). To assess the level of epistemic justice through written reflections by participants; and 4). Evaluate the effectiveness of adding the reflection component to advance epistemic justice

The Adaptive Planning Process (APP), is a planning component of Strategic Adaptive Management (SAM), which is 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 & Luton (2011). The APP consists of a hierarchy of objectives, beginning with defining the vision for the area, and then moves to broader objectives, which are also expanded into more specific and achievable activities that can be monitored and evaluated during the management

stage. It recognises that the values of those affected by the plan and the context for the environment to be managed are important for scoping the decision making environment. In order for stakeholders to have a joint picture of the context, the process requires them to describe the Values, Social, Technological, Environmental and Ecological, Economic and Political (V-STEEP) characteristics of their area that will affect the plan in order to move towards a joint desired future. In APP application, the facilitator asks everyone to speak in a full room. However, not everyone is comfortable with this, and some will not say their genuine views as they're intimidated by too many audiences. Equality of voice is therefore presumed because there is no explicit checking of whether participants understand the concepts being used, or whether they feel satisfied by the level of inclusion. This study is investigating this epistemic gap.

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

To investigate this, an evaluation tool was developed in consultation with literature, and a criterion that was relevant for this research was selected from different frameworks. Guiding questions to fit the criteria of the evaluation tool were formulated and participants were asked to reflect on the APP as it was facilitated during their water planning workshop. The tool seeks participants' understanding of concepts, participant satisfaction, participant skills development, equality of voice, process flexibility to adapt, usefulness of the process and inclusive facilitation. From the first workshop reflections, participants felt that the process was very inclusive of many stakeholders, but time needed to be allocated to inviting civil society. Others liked how their views were written down and sometimes even discussed further. Some participants thought it provided a good space to network and build relationships among themselves. The things that needed to be improved on, as evident from the reflections included, more engagement between participants, more explanation of concepts, inviting more stakeholder groups, and doing the process over a shorter period to retain all stakeholders until the end. One member mentioned that they got a bit frustrated by being among so many strangers. These are just examples of how reflections could really add value to the process because they allow people to say things that they might otherwise not be able to say out loud in an open space. This could lead to better IWRM for South Africa because people might be more willing to participate when they can safely say their issues without any fear.

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

So far, only the first two objectives have been dealt with, while part of the third one was done in order to report to the participants before the second workshop. The reflections from the second workshop have only been transcribed, and the data form both workshop is being analysed.

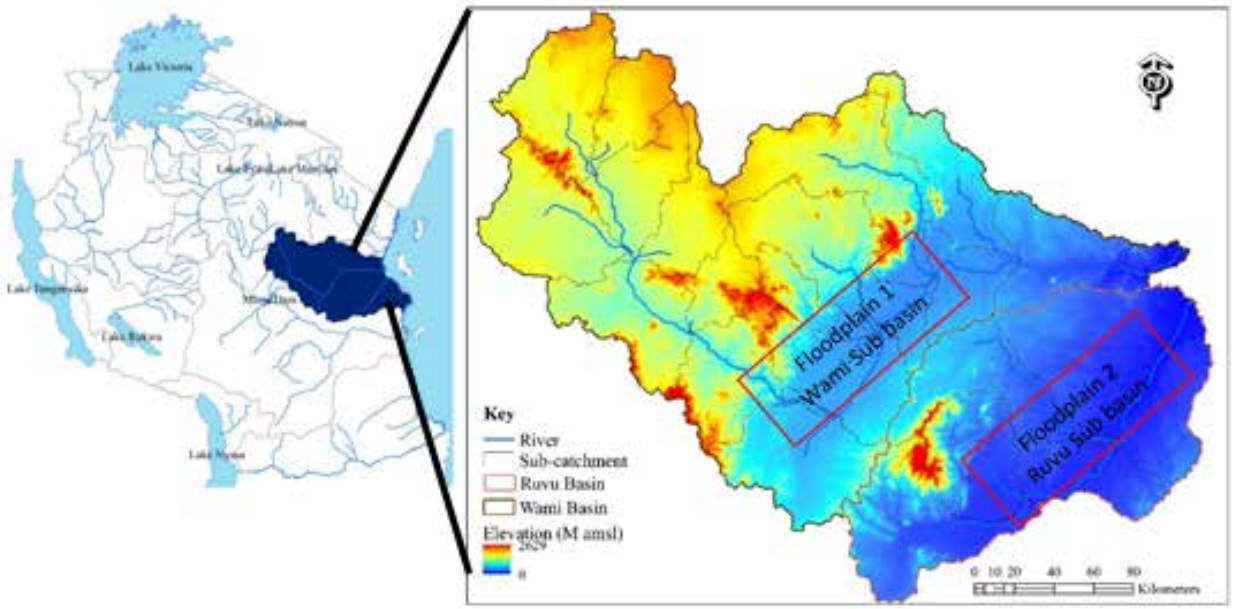
## Uncertainty Analysis in Coupled Hydrological and Hydrodynamic Modelling for Flood Hazard Assessment

**Student:** DS Rugai
**Supervisors:** DA Hughes and SK Mantel
**Degree:** PhD (Hydrology)

The interaction of hydrology with human activities can be beneficial for domestic, industrial and agricultural activities, as well as for hydropower generation. However, it can also threaten human life and cause damage to property through extreme events such as floods. Hydrological modelling has been widely used for the quantification of water resources and impacts of hydrological events. However, the unavailability of sufficient quality input data at appropriate spatial and temporal scales makes the model outputs highly uncertain. Hydrodynamic modelling is widely used for mapping and

assessing flood hazards. The hydrodynamic modelling approach provides additional hazard variables (depth, velocity and duration), information that is not available in the conventional way of floodplain mapping. The hydrodynamic modelling requires a reasonable representation of river and floodplain geometry and topography, data that are not always readily available. The source of these data is mainly through field measurements and in recent years Earth Observation (EO). While field measurement is associated with a high cost and time-consuming, the EO data are characterised by low resolution (for freely available data) and high cost (for high-resolution data). Efforts have been made to extract river bathymetric information from freely available EO data (DEM and Multispectral Remote Sensing Images). However, available data in existing global databases cover only major rivers in Africa. Furthermore, flood hazard analysis requires input data with finer temporal and spatial scales than the one frequently used in catchment water balance models. This difference creates challenges when using hydrological model outputs as upstream boundary conditions for hydrodynamic modelling to assess flood propagation and floodplain storage dynamics.

This study addresses the issues of uncertainty in hydrological modelling and the problems of linking with flood inundation models using freely available EO data. The study is designed to develop an uncertainty framework that includes uncertainty in both the catchment water balance and downstream flooding through a link between a hydrology model and a hydrodynamic model. The study is applied on two floodplains with different characteristics within Wami-Ruvu basin in Tanzania. The study is conducted in three main stages. The first one deals with uncertainty analysis in monthly water balance modelling using a revised Pitman model. The second stage deals with the disaggregation of the simulated monthly discharge to daily discharge using both observed ground and satellite rainfall. The last stage focus on the assessment of flood hazard and floodplain storage dynamics using an integrated 1D-2D hydrodynamic model (LISFLOOD-FP) and quantification of associated uncertainties. The study also investigates the importance of quantifying the effects of flood attenuation within coarse scale hydrological models. The framework will enhance proper decision making regarding land use management and flood mitigation practices by both policymakers, communities and individuals.




***Location of Wami-Ruvu basin in Tanzania***

## A Hydrogeological Investigation of Grahamstown, Assessing both the Dynamics and Quality Associated with the local Groundwater System

**Student:** KN Smetherham
**Supervisors:** DA Hughes and JL Tanner
**Degree:** MSc (Hydrogeology)

Grahamstown has and is currently experiencing major surface water issues relating to low supply, high demand, insufficient treatment capacity and aging infrastructure. Groundwater could potentially act as a supplementary and/or emergency supply but, a lack of historic monitoring data has hindered proper understanding into system dynamics. In 1986 Andrew Stone produced a report relating to the groundwater system in Grahamstown. However, no directed research

or monitoring has been done since and therefore an initial aim of my study was to update these records. Conceptualising the system was a fundamental step to the hydrogeological investigation and involved mapping the average water-table elevations from 31 monitoring boreholes to determine groundwater occurrence and flow. These boreholes were monitored on a ~monthly basis over a year-long period (Figure 1). Other key aspects used for conceptualisation involved the examination of maps (aerial, topographical, geological, hydrogeological), identification of local surface water bodies (dams, rivers, streams), the role of fracture networks and other structural controls as well as the influence of different geological formations on aquifer characteristics.

***Mr K Smetherham***

Grahamstown is positioned at the northern extent of the Cape Fold Belt system and therefore the rocks in the study site experienced compressional forces during this geologic event, causing them to fold and fracture, creating numerous pathways (secondary porosity) through which groundwater can flow. Consequently, there are two aquifer systems beneath Grahamstown, one being the Witpoort Formation comprised of quartzitic sandstone with interbedded shale units, while the other being the Dwyka Formation comprised of glacial tillite. Between these two aquifer systems is an upper Witteberg Group shale unit which acts as an aquitard, limiting interaction. Groundwater sample analysis from both aquifers proved to be a useful tool in confirming the limited interaction between the two systems and further enhanced understanding regarding water-rock interactions and residence time occurring in the subsurface. In general water quality from the Witpoort aquifer is of a better quality than that of the Dwyka aquifer, as evidenced by electrical conductivity levels that range from 17.1 - 40.8 mS/m and 331 - 537 mS/m respectively. Interestingly samples from boreholes drilled into and through the aquitard unit contained raised levels of manganese (0.034 – 0.684 mg/l), suggesting a degree of water-Mn interaction within the shale unit.

***Mr Kyle Smetherham measuring the water-table in a borehole using a dip metre probe***

A local spring (Fairview Spring) in the town is an important source of water for many residents who depend on the resource for their basic water needs. Ongoing ~weekly discharge monitoring (Figure 2) from the Fairview Spring provided a known parameter, the 'observed discharge', and together with other parameters such as recharge, storage, interflow and hydraulic gradient were inputted into a model with the intention to recreate the observed data. Generally, the simulated model correlated well, although at certain phases the model responded positively following a rainfall event while the observed data remained relatively stable. Current explanations for the contrast involve the lack of a runoff parameter and/or the inability of the model to decipher variations in rainfall duration and intensity.

Recharge is arguably the most important parameter to define in any hydrogeological study as it relates to sustainable groundwater use. Quantification of this parameter is difficult, especially in fractured aquifers and numerous methods have been developed. Accurate estimation of recharge was a primary aim in the present study and involved physical methods that made use of water-table changes in monitoring boreholes and their relation to rainfall events, namely the Water-table Fluctuation (WTF) and Cumulative Rainfall Departure (CRD) methods. Furthermore, as mentioned above, a modelling approach at the Fairview Spring was also used to estimate recharge through simulation of various parameters. Recharge estimations from all methods have produced comparable results, ranging from 1-9% recharge and should be developed further.

***Measuring the discharge rate at the Fairview Spring***

***Prof Denis Hughes investigating a local groundwater well***

Groundwater systems are hidden, often believed to be an unlimited resource. To better understand and model these systems it is crucial that long-term monitoring programs are established. Through this research an initial database will be developed that can hopefully act as a building block going forward, enabling local resource managers to implement practices that will lead to the preservation and sustainable use of the resource for many years to come.

## Determining the Hydrological Functioning of the Palmiet Wetlands of the Krom River in the Eastern Cape Of South Africa

**Student:** C Smith
**Supervisor:** JL Tanner
**Degree:** MSc (Hydrology)

***Ms Caitlin Smith and Dr Roger Parsons exploring the Krom River***

Wetlands are considered to be one of the most vital ecosystems on Earth. They are known to regulate water supplies, prevent floods and droughts as well as to cleanse polluted waters, recharge groundwater aquifers and provide important habitats for various floral and faunal species (Mitsch and Gosselink, 2007). Despite their value, 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 wetlands, with serious consequences for water security in many towns in their catchments, including cities such as Port Elizabeth. Furthermore, floods are more prevalent and base flows are less reliable where palmiet wetlands have been damaged or destroyed.

Despite large investments by the State in wetland restoration, serious knowledge gaps in our understanding of wetland structure and function remain, particularly in the hydrological functioning of these systems. This lack of understanding means that many of these restoration initiatives might be poorly designed and are not efficient, or they may even be harmful.

*Prionium serratum* (Palmiet) is a robust plant with stems up to 2 m tall. Palmiet is endemic to the nutrient poor Table Mountain Group sandstones and grows in dense stands that impede river flow, forming wetlands. Palmiet is thought to assist in controlling floods and improving water quality of rivers.

The aims and objectives of the study include:
1. Determine the surface and groundwater dynamics of the Kromme River upper catchment (K90A).
2. Identify the relationship between wetlands and hydrological functioning of the catchment.

The study site is located in K90A, the upper catchment of the Krom River, which enters the Indian Ocean at St Francis Bay. The particular wetland investigated in this study is located in the upper part of the sub-catchment. We have collected water level data from the river, the wetlands, a number of piezometers, and a borehole; undertaken an Electrical Tomography Survey; extensively surveyed the area and carried out water quality and isotope analysis. Our conceptual model of system functioning is that both surface water and groundwater support the Palmiet wetlands which need a consistent supply of water. Alluvial fans are common in the Cape Fold Belt region and are found throughout catchments with Palmiet wetlands. Groundwater sustains the system through preferential flow paths within the alluvial fans, which are recharged by the surrounding sandstone aquifers of the Cape Fold Belt. A groundwater balance model (GYRM) and a mixing cell model are currently being set up to determine if the conceptual model is realistic. The mixing cell model is using the results of the water quality and isotope analysis to trace the origins of the water found within the wetland.

## Ecological Risk of Acid Mine Drainage (AMD) in a Salinising Landscape

**Student:** EC Vellemu
**Supervisors:** PK Mensah, N Griffin and ON Odume
**Degree:** PhD (Water Resource Science)

Acid mine drainage (AMD) and increasing salinity of freshwater ecosystems pose serious threats to water quality in water-stressed South Africa. These threats are exacerbated by mining activities, mainly gold and coal from both active and abandoned mines that continue to release acidic water that is rich in toxic metals and high sulphate concentrations. Therefore, the overarching hypothesis for this study was that "the combination of AMD and sulphate salts confers high ecological risk to the aquatic biota". The study employed both laboratory and field investigations to test this hypothesis and provide appropriate tools to protect freshwater ecosystems from increasing anthropogenic impacts. Firstly, a laboratory investigation was carried out to develop risk-based water quality guidelines (WQGs) for sulphates and treated AMD (TAMD) using the species sensitivity distributions (SSDs) technique.

Five South African freshwater species belonging to five different taxonomic groupings, including Adenophlebia auriculata (insect), Burnupia stenochorias (mollusc), Caridina nilotica (crustacea), Pseudokirchneriella subcapitata (algae) and Oreochromis mossambicus (fish) were exposed to varying concentrations of sodium sulphate ($Na_2SO_4$), magnesium sulphate ($MgSO_4$) and calcium sulphate ($CaSO_4$), as well as TAMD in separate ecotoxicological experiments, applying short-term (96 h) non-renewal and long-term (240 h) renewal exposure test methods. Secondly, a novel trait-based approach (TBA) was also used to predict the vulnerability of taxa to treated acid mine drainage (TAMD). The TBA used a combination of carefully selected traits of organisms that are mechanistically linked to TAMD for their potential vulnerability predictions. Leptoceridae and Leptophlebiidae were selected taxa for evaluation of the trait-based vulnerability predictions to TAMD for laboratory toxicity exposures. This was followed by a field investigation to assess macroinvertebrates community assemblage responses, abundance and richness to a TAMD-impacted stream using the South African Scoring System version 5 (SASS5) protocol. Outcomes from the above three sources were combined in a multi-criteria analysis (MCA) to develop an appropriate water quality management strategy in a form of a trait-based decision-making support tool.

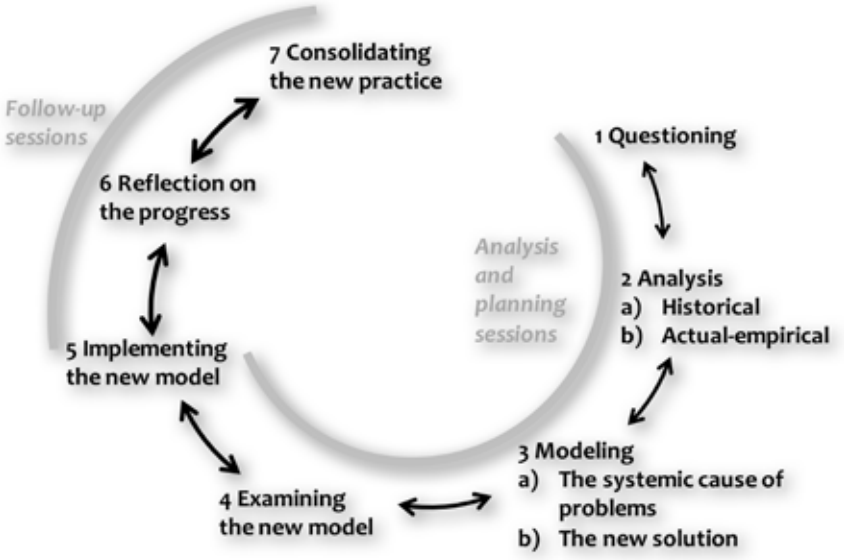
Results of the risk-based WQGs revealed that current sulphate compliance limit for South African freshwater systems is under-protective. The MCA findings suggest that the trait-based decision-making support tool is a useful management strategy for the predicting vulnerability of taxa aquatic stressors including AMD and increasing salinity. Overall, the outcome of this study suggests that AMD poses an ecological risk to aquatic biota, but this becomes riskier in the presence of excess sulphate salts. Albeit, the WQGs for sulphate salts and AMD as well as the developed trait-based decision support tool all contribute novel sound scientific knowledge basis for managing the AMD and increasing salinity in freshwater ecosystems. The study recommends incorporating different life stages of indigenous species tested to determine if their sensitivity to AMD and sulphate would correspond to current findings because early life stages could be more sensitive to aquatic stressors than juveniles or adults. This is important for the derivation of strong and relevant WQGs. The TBA requires further refinement for its incorporation in ecotoxicology on a wide scale.

## An Interventionist Approach to Improving Democratic Water Governance a Case Study of the Makana Water Forum

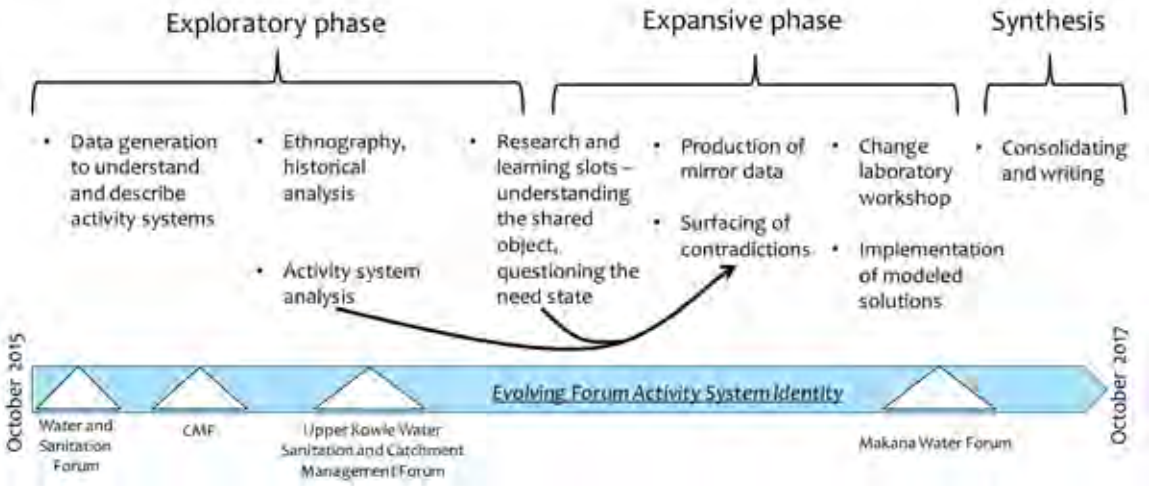
**Student:** MJT Weaver
**Supervisors:** CG Palmer and JH O'Keeffe
**Degree:** PhD (Water Resource Science)


***Despite world renown water legislation mandating decentralized water management and civil society participation in water governance, local government has struggled to deliver on these mandates. Using an interventionist research approach, informed by Cultural Historical Activity Theory (CHAT), I explored the nature of democratic water governance in the Makana Water Forum (MWF) based in Grahamstown, in the Makana Local Municipality (MLM), Eastern Cape.***

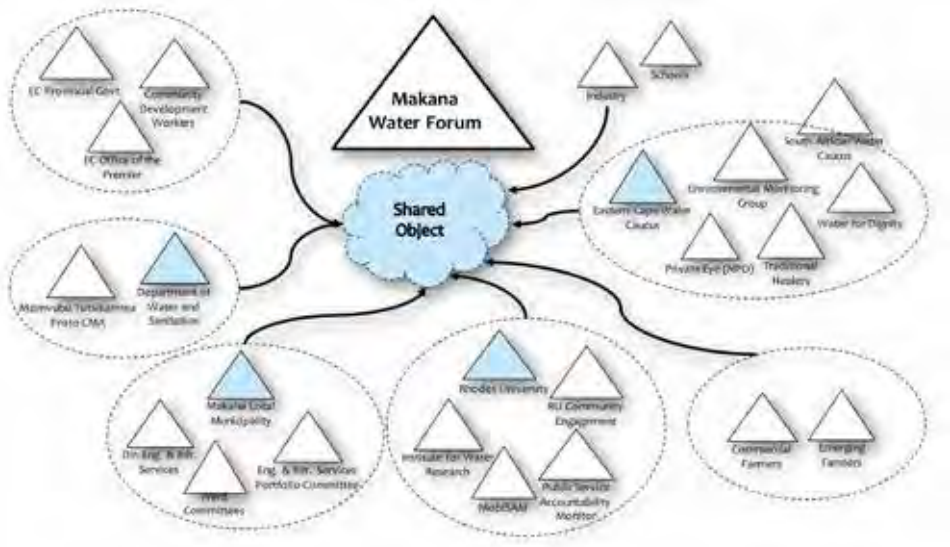

***The Activity System (AS) is the basic unit of analysis of CHAT. It can be used as a tool for describing (according to the 7 listed elements), analysing and modeling individual or collective human activity and emergent contradictions. (Source: Engestrom, Y. (2000). Activity theory as a framework for analyzing and redesigning work. Ergonomics, 43(7), 960–974).***



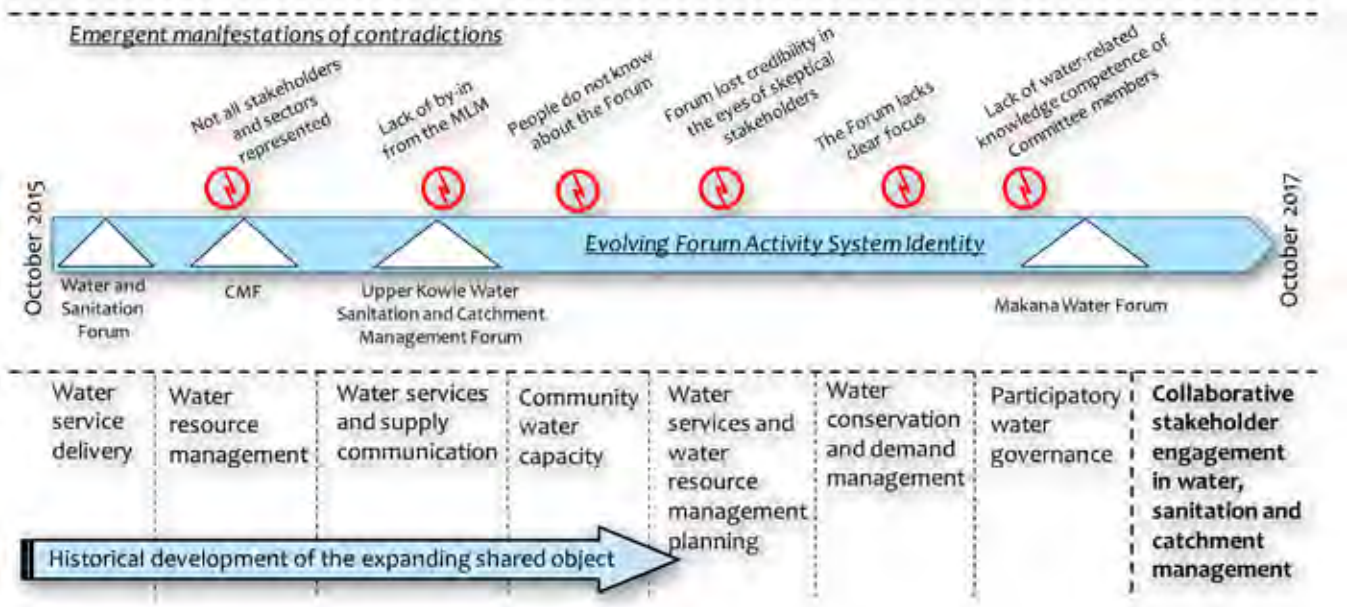

***Identified contradictions can be addressed through a Change Laboratory workshop which guides participants through the 7 learning actions of the expansive learning cycle. (Source: Virkkunen, J., & Newnham, D. S. (2013). The Change Laboratory: A Tool for Collaborative Development of Work and Education). .Rotterdam: Sense Publishers.***




***The research process. Research and learning slots and the change laboratory workshop served as primary intervention engagements***




***A network of ASs participated in the MWF. The incorporation of multiple water-related interests into the MWF focus resulted in the development of a shared object that enabled collaborative work and drove the AS***




***Manifestations of contradictions (e.g. conflicts, dilemmas and problems) occurred throughout the MWF operation. The object evolved in response to feedback from the system in which the MWF existed and as other ASs joined the MWF.***


***The purposive intervention followed the expansive learning cycle to accelerate developmental change in the MWF. A contradiction related to lack of water knowledge capacity of MWF committee members led to the modelling of a new form of activity (using the Activity system triangle) 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 solutions to other contradictions. Progression to the next stage of the expansive learning cycle, reflection and consolidation requires additional engagement.***

## Bridging the Gap Between Local Knowledge and the National Water Act in the Tsitsa River Catchment, Eastern Cape

**Student:** MG Wolff
**Supervisors:** CG Palmer and H Lotz-Sisitka
**Degree:** MEd

The Mzimvubu Water Project forms part of the National Governments Strategic Integrated Projects (SIP3 – South-Eastern node and corridor development, PICC, 2012). The Mzimvubu River is one of the largest, free flowing rivers in South Africa, in one of the poorest and underdeveloped regions. The Mzimvubu Water Project involves the construction of two multi-purpose dams in the Mzimvubu Catchment – the Ntabelanga and Laleni Dams. The dams will be constructed on the Tsitsa River, one of four primary tributaries to the Mzimvubu River (van Tol et al., 2014). The dams are expected to supply new water capacity, for domestic and industrial use, hydroelectric power generation and irrigation development (DWS, 2013). The project will spread over three district municipalities – Joe Gqabi, OR Tambo and Alfred Nzo, in the Eastern Cape.


***Figure 1: Map showing the location of the proposed Ntabelanga and Lalini Dams in the Eastern Cape***

The Department of Environmental Affairs: Natural Resources Management (DEA: NRM) programmes contribute to poverty alleviation through job creation and encourage rural development (SANBI, 2014). In order to mitigate the potential sedimentation of the Ntabelanga Dam, the DEA, through its NRM "Working for" suite of programmes, is investing in restoration projects in the Tsitsa River Catchment. These interventions provide local residents with participatory opportunities through (i) the programmes themselves (local participation and short-term job creation), (ii) the opportunities to become involved in the formation of a Catchment Management Forum (CMF). Such participation can support sustainable resident engagement in the land and water management of the catchment upstream of the Ntabelanga Dam. This project used the NRM intervention to engage with residents in learning-centred workshop to deepen understanding of challenges and in context solutions faced by the residents particularly relating to water and landscape.

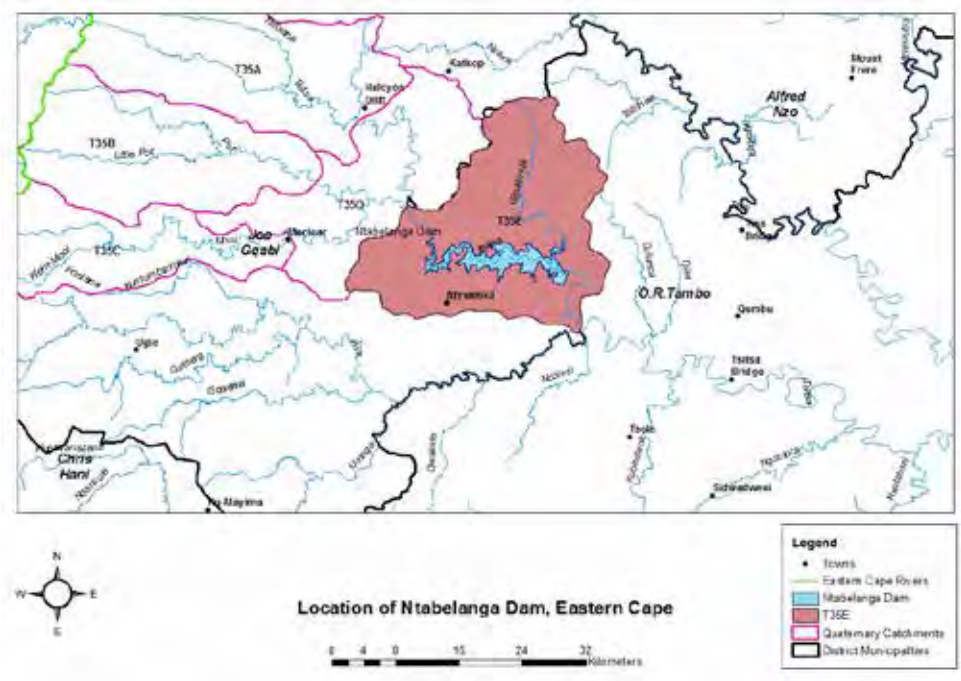



***Figure 2: Map showing the location of the proposed Ntabelanga in quaternary catchment T35E (pink)***

In 2016, the IWR ran five catchment management forum workshops across the Eastern Cape in collaboration with the Department of Water and Sanitation. The learning centred format of these workshops was continued with workshops run in the Tsitsa River Catchment.

In May and November 2016, I ran three separate catchment man-

***Figure 3: Participants engaging during the workshops across the Eastern Cape – working together and sharing challenges and solutions***

agement forum workshops with representatives from the local and district municipalities, traditional authorities and community representatives in the Tsitsa River catchment. The data gathered during these study site specific workshops re-enforced the growing findings from research gathered during the 2016 workshops. Implementation of the National Water Act and the various institutions that fall under the Act, has been and remains challenging. Although there is information and documentation written about the National Water Act, catchment management agencies, water user associations, and, to a lesser extent, catchment management forums, implementation has been more difficult and time-consuming.


***Figure 4: Participants at the Maclear workshop***

Data was analysed using the Activity System Framework from Cultural Historical Activity Theory. Figure 5 shows the elements of the system that can be used to describe the complex relationships between human (individual or collective) actions and the tools used to achieve an outcome. Activity systems are influenced culture and history and by interactions with other activity systems. My research identified five activity systems all of which are influenced by the Water Governance activity system (see Figure 6).

Cultural Historical Activity Theory and activity system analysis allows the surfacing of contradictions (or illuminative hinges) between the elements of the activity system or between activity systems. The contradictions create opportunities for learning and change within the activity system.

My research considered whether a learning centred process to the formation of CMFs will encourage broader participation and sustainability for the catchment management forums as the bridge between the resources of the people living in communities and the aims of the National Water Act. The critical need to engage meaningfully with stakeholders and role players in order to begin building relationships and trust cannot be overemphasised.

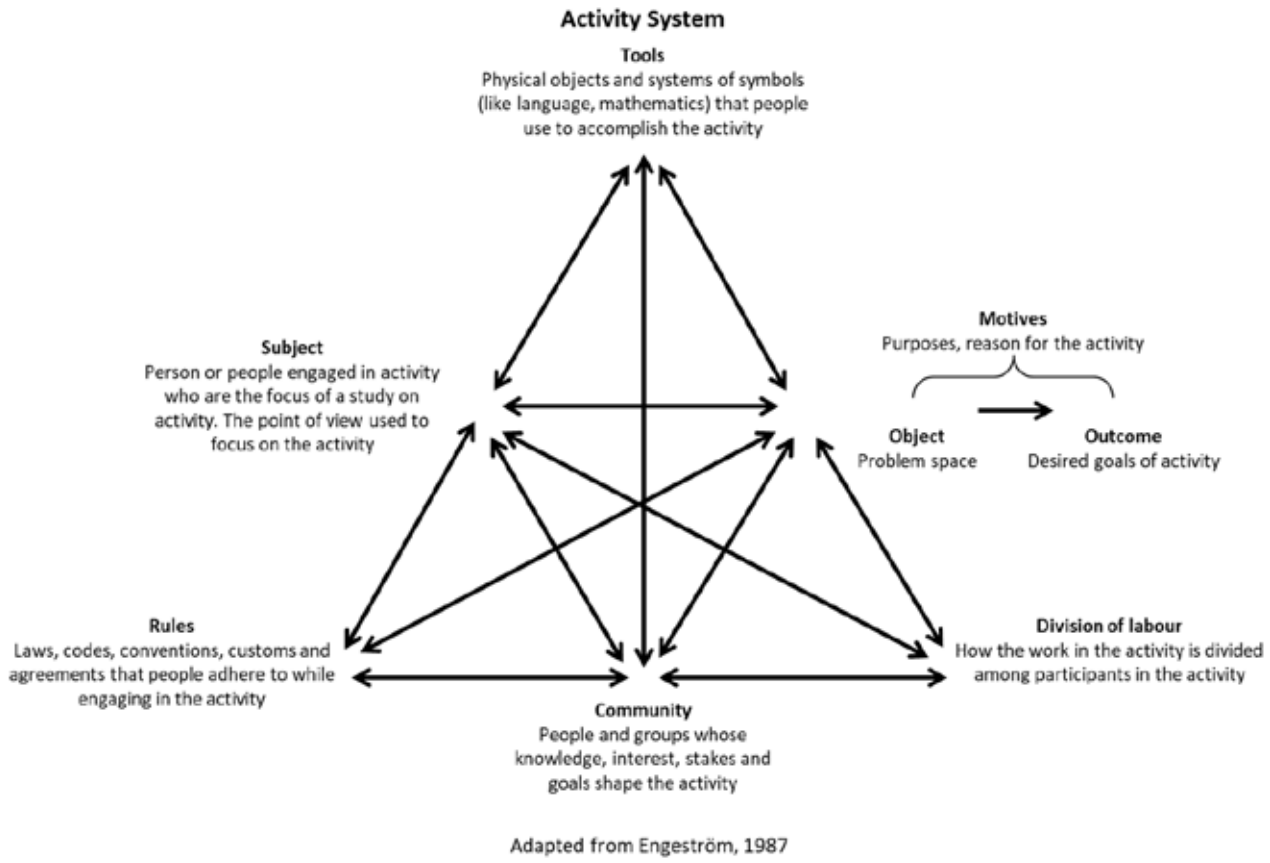



*Figure 5: Elements of the Activity System Framework*

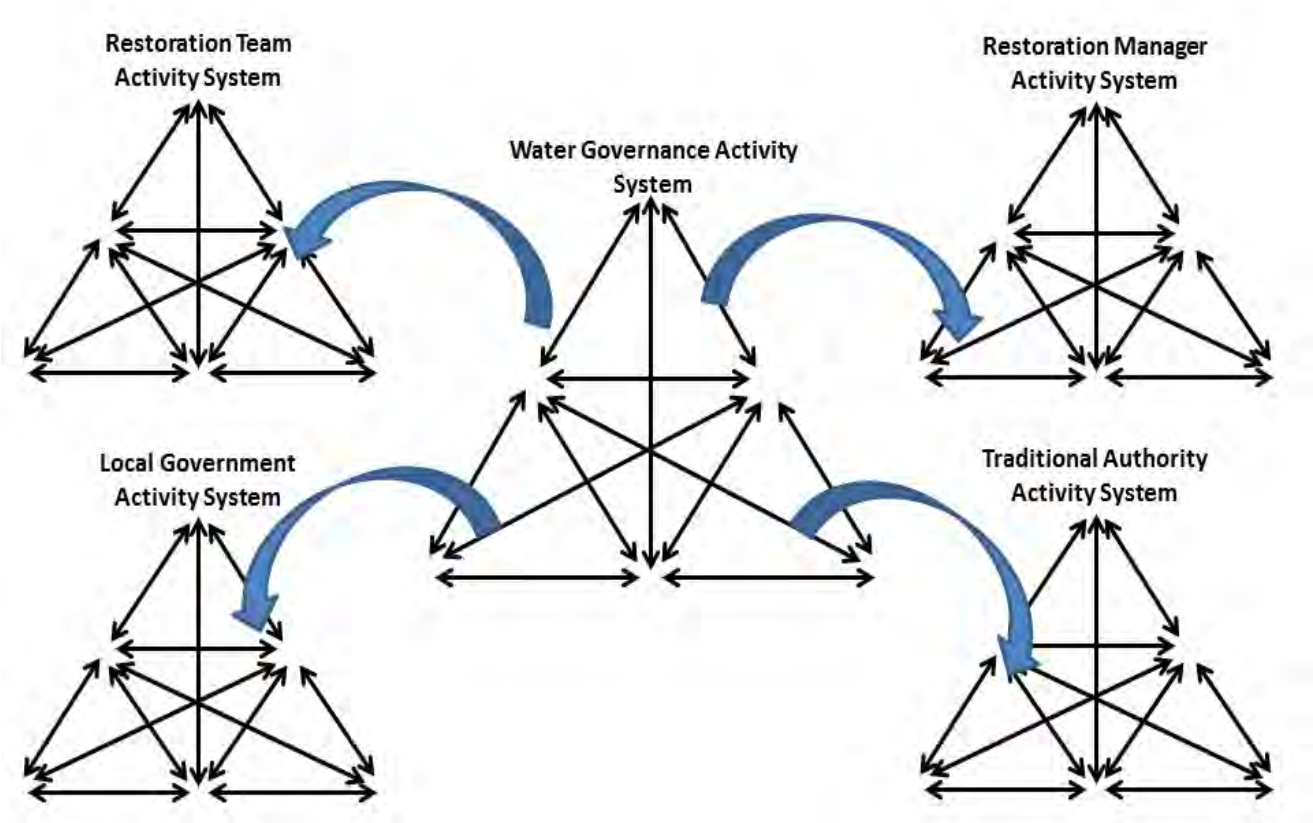



*Figure 6: Activity Systems analysed in the Tsitsa River Catchment*

# Research Output

**Peer Review Journals and Conference Proceedings**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Weaver MJT, O'Keeffe JH, Hamer N and Palmer CG (Geoforum under review). Exploring a civil society organisation response to water service delivery issues in the context of South Africa as a developmental state. Part 2: Knowledge building, learning and active citizenship.

## Chapters in Books

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## Reports

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Carnohan SA, Clifford-Holmes JK, Slinger JH, Pollard S and Biggs H (2017) ResiMod: A collaboratively-built model to assist facilitating strategic conversations in the Olifants River Catchment of South Africa. Presented at the 35th International Conference of the System Dynamics Society, July 17-20, 2017 Cambridge, Massachusetts.

Choruma DJ (2017) Modelling the effects of fertilizer management practices on water quality in selected agricultural catchments in South Africa. Abstract presentation at Interdisciplinary Postgraduate Conference, Rhodes University, organized by Centre for Postgraduate studies, Rhodes University, 29-30 September, 2017.

De Moor FC, Bellingan TA, Barber-James HM and Mantel SK (2017) Insights from South Africa: the importance of geological history in riverine biomonitoring. Poster presented at the 28th International Congress for Conservation Biology (ICCB), Cartagena, Colombia, July 2017.

Gwapedza D, Slaughter AR, Hughes DA and Mantel SK (2017) Sensitivity analysis and regionalisation of the soil loss function within a sediment transport model by application to data scarce semi-arid catchments. IAHS special issue "Water security and the food-water-energy nexus: drivers, responses and feedbacks at local to global scales". Proceedings of the IAHS Scientific Assembly 2017, Port Elizabeth, South Africa, 10–14 July 2017. Proc. IAHS, 94, 1–9, 2017 https://doi.org/10.5194/piahs-94-1-2017 (in press).

Gwapedza D, Slaughter AR, Hughes DA, Mantel SK (2017) Further developing a sediment transport model for South African Catchments. Podium presentation at the 8 th Annual inter-disciplinary postgraduate conference (Rhodes University).

Libala N, Odume ON and Palmer CG (2017) Exploring the importance of Hillslope seep wetlands using a Social Ecological Systems in the Tsitsa River Catchment, South Africa. Oral presentation at the International Congress for Conservation Biology (ICCB 2017) at Cartagena, Colombia, 23 -28 July 2017.

Libala N, Odume ON and Palmer CG (2017) The use of Floristic quality assessment index and Wetland Index tools to assess Hillslope seep wetlands in the Tsitsa River Catchment, South Africa. Oral presentation at the Interdisciplinary Postgraduate Conference (IPGC 2017), Rhodes University, 29-30 September 2017.

Libala N, Mkabile Q, Odume ON and Palmer CG (2017) Growing the Eastern Cape economy through small holder farming opportunities (focusing on livestock production). Oral presentation at the 4th annual Emerging Views on the Eastern Cape Economy Conference, Water Sisulu University, East London, 23 October 2017.

Mkabile Q, Palmer CG, Palmer AR, Mantel S (2017), Mapping and predicting livestock spatial and temporal distributions in the communal rangelands of Cala, Eastern cape, South Africa. Oral presentation at the Interdisciplinary Postgraduate Conference (IPGC 2017), Rhodes University, 29-30 September 2017.

Munnik AV (2017) University of Johannesburg, Development STudies Seminar, 30 March 2017. Citizens science for Activism.

Munnik AV (2017) Rhodes Ph D Seminar, 27 July 2017, Seeing coal like an activist in early 21st Century SA: a case study in social theory choice.

Munnik AV (2017) University of the Witwatersrand, Global Change Institute. Seminar presentation 5 Sept 2017. A transdisciplinary, dialogic exploration of possible role for SA mining industry in establishment of sustainable bio-economy.

Munnik AV (2017) Water Research Commission Symposium 17 - 20 Sept, Adaptation to the New Normal. Water and Equity. Research to support a flourishing society.

Murata C, Perry A, Denison J, Palmer CG and Palmer AR (2017) Dynamics of water access and allocation among competing needs within the homestead: Quantifying water uses in rural Eastern Cape, South Africa. This paper will be presented at the Young Water Professionals Conference in Cape Town, 10-13 December 2017.

Ndlovu SM (2017) The development of an ecological response model (ECOREM) for integrating biotic response, water quality, flow and catchment processes in South Africa. Presented at the Interdisciplinary Postgraduate Conference (IPGC 2017), Rhodes University, Eastern Cape, South Africa, September 29-30th 2017.

Odume ON (2017) Water ethics and governance. Invited guest speaker's presentation at the WRC dialogue on water stress, religion and culture. 27 September 2017. Pretoria, South Africa.

Odume ON (2017) Hygiene promotion – practices, attitudes and barriers: evidence from the Eastern Cape. Invited guest speaker's presentation at the Inaugural Symposium of the National Department of Health on Hygiene Promotion and Handwashing Water AID Southern Africa Regional Workshop. 22 August 2017, Pretoria, South Africa.

Odume ON (2017) Water resource protection – integrated water quality management process in the Crocodile River catchment. Paper presented at the Transformational Learning Workshop 10-13 October 2017. University of Osnabruck, Osnabruck, Germany.

Odume ON (2017) Water quality contestations in the lower sections of the Upper Vaal River catchment. Paper presented at the Transformational Learning Workshop 10-13 October 2017. University of Osnabruck, Osnabruck, Germany.

Palmer CG and Munnik AV (2017) Empowering catchment management forums as institutions for deepening democratic natural resource management, co-learning and participatory governance. Savanna Science Network Meeting, Skukuza, Kruger National Park, 12 – 16 March 2017.

Palmer CG (2017) Water for people, and people for water: water storage and forums. LOCS4Africa 2017: Water and Climate Congress, Birchwood Hotel, 22-24 March 2017.

Palmer AR, Ripley B, Gwate O and Mantel SK (2017) Challenges of long-term carbon flux measurements in the Albany Thicket. Thicket Forum Addo Elephant National Park, South Africa, June 2017.

Ralekhetla M (2017) Enhancing adaptive planning process by increasing epistemic justice for integrated water resource management. Community engagement conference: Towards Social and Epistemic Justice. (Durban University of Technology, South Africa).

Ralekhetla M (2017) Enhancing adaptive planning process by increasing epistemic justice for integrated water resource management. Postgraduate conference: Sustainability for tomorrow (Rhodes University).

Slaughter AR and Mantel SK (2017) Water quality modelling of an impacted semi-arid catchment using flow data from the WEAP model. Paper presented at the IAHS Scientific Assembly 2017, Port Elizabeth, South Africa, 10–14 July 2017.

Slinger JH (2017) Sustainable Ports in Africa: An integrated "Building with Nature" approach to co-create value at the port-city nexus. Presented at the African Ports Evolution Conference, 17-18 October 2017, Durban, South Africa.

Slinger JH, Taneja P, Vellinga T and van Dorsser C (2017) Stakeholder inclusive design for Sustainable Port Development in Africa, Singapore Maritime Technology Conference 2017, 26-28 April, 2017, Singapore.

Smetherham KN, Hughes DA and Tanner JL (2017) Application of water-table fluctuation methods and spring discharge modelling to estimate groundwater recharge in Grahamstown, South Africa. Presented at The Interdisciplinary Postgraduate Conference 2017 "Sustainability for tomorrow", Education Building, Rhodes University, 29-30 September 2017.

Smetherham KN, Hughes DA and Tanner JL (2017). Application of water-table fluctuation methods and spring discharge modelling to estimate groundwater recharge in Grahamstown, South Africa. Presented at the 15th Biennial Groundwater Division (GWD) Conference, Spier Wine Estate, Stellenbosch, 14-18 October 2017.

Smith C and Tanner JL (2017) Determining the hydrological functioning of the endemic Palmiet Wetlands in the Eastern Cape of South Africa. Presented at the biennial conference of the Groundwater Division of the Geological Society of South Africa, Cape Town, South Africa, 16th – 18th October 2017.

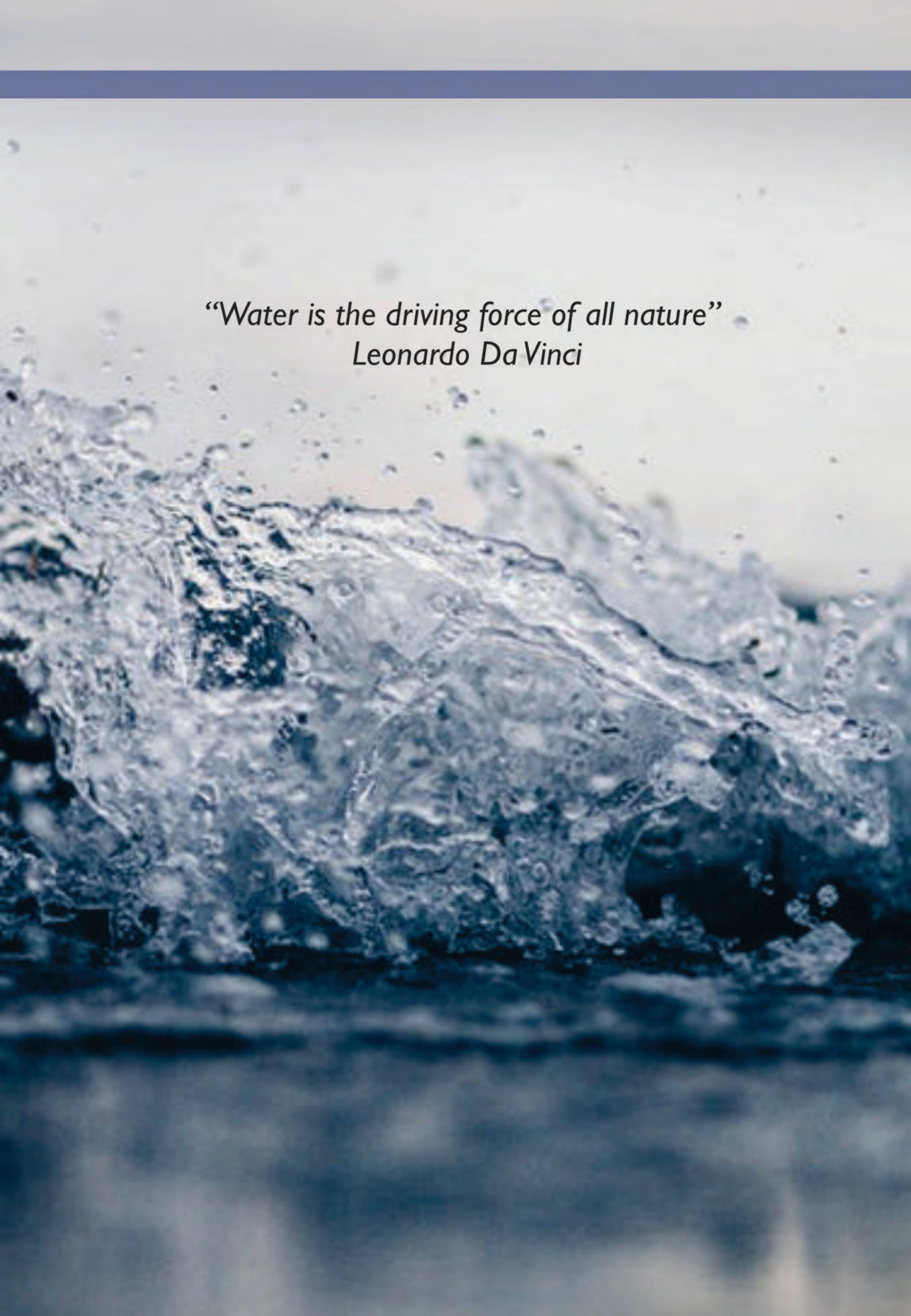
Tanner JL, Hughes DA and Johnstone A (2017) Determining the impacts of land use change on Lake St Lucia. Presented at the biennial conference of the Groundwater Division of the Geological Society of South Africa, Cape Town, South Africa, 16th – 18th October 2017.

Tanner JL and Smith C (2017) Formulating a conceptual model on the functioning of the Palmiet wetlands in the Eastern Cape of South Africa. Presented at the International Association of Hydrological Sciences Scientific Assembly, 10th – 14th July Port Elizabeth, South Africa.

Vellinga T, Slinger JH, Taneja P and Vreugdenhil H (2017) Integrated and Sustainable Port Development in Ghana, Singapore Maritime Technology Conference 2017, 26-28 April, 2017, Singapore.

Weaver MJT (2017) David and Goliath: Strengthening the voice of the 'little Guy' in deepening democratic water governance. International Young Water Professionals (IYWP) Conference 2017, 10-13 December 2017, Cape Town.

Weaver MJT, Palmer CG and O'Keeffe J. An interventionist approach to improving democratic water governance. Podium presentation at the 8th Annual Inter-disciplinary Postgraduate Conference (IPGC), Rhodes University, 29-30 September 2017.


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