INSTITUTE FOR WATER RESEARCH

IWR

2016

ANNUAL REPORT

RHODES UNIVERSITY

Where leaders learn

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Dr Sukhmani Mantel	Senior Research Officer IWR
Ms Juanita McLean	Administration Manager
Dr Paul Mensah	Research Officer IWR
Ms Ntombekhaya Mgaba	Senior Technical Officer
Ms Qawekazi Mkabile	Intern
Mr Mzwanele Mkatali	Technical Assistant
Ms Ntombekhaya Mti	Intern
Dr Nelson Odume	Director of UCEWQ
Prof Tally Palmer	Professor
Dr Andrew Slaughter	Research Officer IWR
Dr Jane Tanner	Research Officer IWR
Ms Margaret Wolff	Part time Project Manager UCEWQ-IWR

ASSOCIATES

Mr Greg Huggins	Research Officer Nomad Consulting
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)
Ms Athina Copteros	PhD (Geography)
Ms Yvonne Chiliboyi	MSc (Water Resource Science)
Mr David Gwapedza	MSc (Hydrology)
Mr Onalenna Gwate	PhD (Water Resource Science)
Mr Haden Jacobs	MSc (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)
Mr Sbongiseni Mazibuko	MSc (Hydrology)
Ms Ntombekhaya Mgaba	MSc (Water Resource Science)
Ms Vuyelwa Mvandaba	MSc (Hydrology); Based at CSIR
Mr Coli Ndzabandzaba	PhD (Hydrology)
Ms Pindiwe Ntloko	PhD (Water Resource Science)
Ms Nadia Oosthuizen	MSc (Hydrology); Based at CSIR
Mr Greg Pienaar	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
Ms Nokulunga Zwezwe	MSc (Hydrology)

2016 GRADUATED STUDENTS

Ms Louise Bryson	MSc (Water Resource Science)
Ms Karabo Chadzingwa	MSc (Environmental Science)
Ms Alex Holland	PhD (Water Resource Science)
Dr Paul Mensah	PGHDE (Postgraduate Diploma in Higher Education)
Mr Ian Preston	MSc (Management)

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INSTITUTE FOR WATER RESEARCH

DIRECTOR'S REPORT

Introduction

This will be the last and final Director's report that I will write for the Institute for Water Research, as I will officially retire at the end of December 2016 after 36 years as part of both the former Hydrological Research Unit and IWR. After 2016 I will continue as an Emeritus Professor of the IWR and University, but will have very little involvement with the management of the Institute. This final year has seen some notable achievements by the IWR and some of the staff members, while at the same time it has been a year of frustration and disappointment in terms of succession planning and the future sustainability of the IWR. I will address these points at the end of this report and initially focus on the more positive aspects of the year.

Prof Denis Hughes (right) with his wife, Dr Ros Dowse (left) and Rhodes Vice-Chancellor, Dr Sizwe Mabizela (centre) at his Retirement Function hosted by Rhodes University.

One of the main highlights from a personal perspective was the news that I had been awarded the Volker Medal which is one of the two International Association of Hydrological Scientists (IAHS) awards that form the IAHS/UNESCO/WMO International Hydrology Prize. It is a very great honour to have my research outputs and other contributions to international hydrology recognised in this way. Certainly part of the motivation for the nomination (submitted by Prof Graham Jewitt of UKZN acting in his role of SA National Representative to IAHS) was associated with the post-graduate students that I have supervised and who came from many different parts of sub-Saharan Africa. Several of these were funded by the Carnegie RISE programme that has been mentioned in these annual reports for the last 9 years. Little did we know when Dr Sukh Mantel and I put together the proposal in 2008 that this would have such a large and positive impact on the IWR. The full text of the citation by the President of IAHS (Prof Hubert Savenije) and the response from myself can be found on the IAHS website at: http://iahs.info/About-IAHS/Competition--Events/International-Hydrology-Prize/International-Hydrology-Prize-Winners/D-Hughes.do.

The Dooge medal (the other part of the International Hydrology prize) was awarded to Prof Jeff McDonnell and both award ceremonies were held in Paris at the Kovacs Colloquium in Paris during June 2016. I am the second South African to receive the medal, the previous prize one being the late Prof Des Midgley (University of the Witswatersrand) in 1996, often considered to be the 'father' of South African hydrology.

Presentation of the Volker Medal, Paris, June 2016 (left to right: Blanca Jiménez-Cisneros (UNESCO), Hubert Savenije (President, IAHS), Denis Hughes (Volker Medal Recipient), Tommaso Abrate (WMO), Christophe Cudennec (Secretary General, IAHS).

Not to be outdone in the area of awards, Prof Tally Palmer received the Gold Medal of the South African Society of Aquatic Scientists (SASAQS) which was presented at their annual conference held at Skukuza in the Kruger National Park during June 2016. The award was a recognition of her outstanding contributions to freshwater research and policy development. I am sure that the UCEWQ Director's report will contain more details of this achievement. Prof Palmer joins two previous gold medalists (Prof Brian Allanson and Prof Jay O'Keeffe), who were both connected with the Institute for Water Research.

Last year's report referred to the impressive representation of IWR students at the 2015 graduation ceremonies with six PhD's, one MSc and one BSc honours degree. It would be a difficult task to keep doing that (or even similar) every year and this year we only had one PhD student graduate (Dr Alex Holland) and one MSc student graduate (Ms

Louise Bryson). Dr Holland is a former staff member of the IWR, having served as Senior Technical Officer as well as a Research Intern in UCEWQ over the period from 2002 to 2012. However, we do have a very healthy crop of post graduate students (23 resident students at my last count) and we should therefore have at least some of these graduating in 2017.

Dr Alex Holland (centre) with Supervisor, Dr Nikite Muller (left of centre), and families at 2016 Graduation.

Other staff highlights were the promotion of Dr Sukh Mantel to Senior Research Officer and the elevation of two postdoctoral fellows to contract Research staff (Dr Nelson Odume and Dr Jane Tanner). Dr Mantel has managed the Rhodes Carnegie RISE programme as the secretariat for the Sub-Saharan Africa Water Resources Network (SSAWRN), while both Nelson and Jane are RISE graduates. This is yet a further testament to the success of the RISE programme and the impact that it has had on the IWR. Dr Odume took over from Prof Palmer as acting Director of UCEWQ during 2015 and was formerly appointed as Director in 2016 when his contract as a research officer in the IWR was finalised. He is therefore the author of the UCEWQ Director's report which immediately follows this part of the IWR annual report and which contains further details of the achievements of UCEWQ.

I continue 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 retain some involvement with 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. I also remain as a co-editor (Journal of Hydrology – Regional Studies), and associate editor for several international journals (Hydrological Sciences Journal, Hydrological Processes, Hydrology Research) and regularly contribute reviews for many more. Prof Palmer serves on the editorial panel of the Institute of Civil Engineers Journal, Water Management. Dr Mantel serves as an Associate Editor of the African Journal of Aquatic Sciences and starting in 2016, she is also the Vice President of the Freshwater Working Group (FWWG) of the Society for Conservation Biology (SCB). As part of the FWWG, she designed the HeartTheRivers artwork (in collaboration with aMan Bloom) using GIS data for the Great Fish River, South Africa; the artwork is being sold as stickers at SCB conferences to raise funds for the Freshwater Conservation Science Student Award.

Society for Conservation Biology (SCB) 'HeartTheRivers' logo.

International links and conferences

As in other years, IWR staff and students have been well represented at a number of international and regional meetings during 2016 (the full details of the papers or posters presented are contained within the Research Outputs list at the end of the annual report). Additional details of activities of the UCEWQ staff and students can be found in the UCEWQ Director's report:

- Prof Hughes, Dr Mantel, Dr Tanner and some of the RISE students attended a Carnegie RISE conference and workshop to discuss future plans for continuing support of post-graduate students in Africa. The meeting was held in Nairobi during April and the conference part was made up of presentations from past and present RISE students.
- Prof Hughes attended the Kovacs Colloquium in Paris (at the UNESCO Headquarters) during June and participated as a panel member during a discussion session on Water-related Sustainable Development Goals (SDGs), Implementation: Knowledge, data, indicators, tolls and innovations. He also attended the IAHS Bureau Meeting to report on the progress of the organisation of the 2017 IAHS international conference to be held in Port Elizabeth, South Africa.
- Dr Andrew Slaughter attended the 8th International Congress on Environmental Modelling and Software (iEMS) conference in Toulouse, France, during July 2016, where he presented a paper entitled: 'The validation of algal growth processes in a water quality model using remote sensing data'. The theme of the conference was: 'Environmental Modelling and Software for Supporting a

Sustainable Future'. The conference dinner was held at the Airbus Museum just outside Toulouse (see photo).

- Prof Hughes, Dr Slaughter, Dr Tanner and Mr Gwapedza (MSc student) attended the 18th SANCIAHS National Hydrology Symposium held at the University of KwaZulu-Natal in Durban during September. All of us presented oral papers.
- Dr Jane Tanner attended the 43rd International Association of Hydrogeologists (IAH) International Congress which celebrated the 60th anniversary of IAH. The Congress was held in Montpellier during September and she presented a paper on the iSimangaliso Park project looking at the impacts of afforestation on the surface water and groundwater balance of the lakes within the Park.
- Dr Mantel, Prof Hughes and most of the RISE PhD students (Ms Eunice Makungu, Mr Coli Ndzabandzaba, Mr Dionis Ruigai and Mr Zwido Lidzhegu) attended (and presented papers or posters) at the 17th annual WaterNet conference held in Gaborone, Botswana during October 2016.

As always, the Institute is very grateful for the travel support that some of these individuals received from Rhodes University.

The restored WWII German Messerschmitt exhibit at the Airbus Museum, Toulouse, France (iEMS conference dinner venue).

Dr Jane Tanner received a research grant from Carnegie RISE to set up a research network which will focus on increasing the awareness of the importance of the interactions between surface water and groundwater in Africa. This network has partnered with the Africa Groundwater Network (AGW-Net) and will specifically focus on fostering stronger links between surface water hydrologists and groundwater hydrologists who work largely in isolation in Africa, education and capacity building in the field of surface and groundwater interactions, and identifying 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. This was a competitive bid that allowed all of the Carnegie RISE PhD graduates of the past to propose start-up projects to enhance the research capacity of African institutions. The award was announced during the conference held in Nairobi in April 2016.

During the IAHS Bureau Meeting at the IUGG conference in Prague in 2015 it was decided that the next IAHS Assembly will be held during July in Port Elizabeth, South Africa. Prof Graham Jewitt (National Representative for SA) heads up the local organising committee, but the task of organising the venue and managing the conference budget is the responsibility of the IWR. All of the necessary agreements between Rhodes University and IAHS, the Boardwalk Conference Centre and Copernicus (who manage the abstracts, full paper submission and online registration system) are in place. I would like to thank the Rhodes Research Office for their assistance in getting all of these agreements finalised.

Consultancy links

I continue to generate some useful income from consultancy projects which is mainly used for student bursaries, some salary support for contract staff and providing additional funds for travel to conferences for staff and students. Dr Tanner has also been involved in some of the consultancy projects. More details are provided in the 'Hydrology Projects' section of the report. It is also important that we do not lose the links with practical problem solving which has been one of the IWR strengths and has provided an immediate market for some of its applied research products. One of the projects that we have been pursuing for some time is a modelling project for the whole of the Dominican Republic based on some collaboration we had with them a few years ago. We are currently in the process of trying to finalise the scope of work and a contract. Although this is not likely to be a high value project (they have limited available funds) it is a project that can be used to advertise the hydrological modelling expertise of the IWR.

Post-graduate students and courses

The Institute continues to attract applications from more potential post-graduate students than we can accommodate in terms of space and supervisory capacity. However, we do accept as many as we can and the list at the start of this report (as well as the student project reports) illustrates the numbers of registered students.

UCEWQ ran a module on Environmental Water Quality as part of the joint Geography/Environmental Science Environmental Water Management Honours course and more details are provided in the UCEWQ Director's report.

RISE Sub-Saharan Africa Water Resources Network

We are now in the final official year of the final phase of the Carnegie RISE funding programme. It is evident that there will be a substantial amount of money left at the end of the year, mainly because of the Rand-Dollar exchange rate changes and quite conservative spending. We have contacted the sponsors and our partner nodes in Mozambique, Botswana and Uganda and have discussed plans on how the remaining funds should be spent. The key points of the plan is that all existing students (at all nodes) who need more financial support to complete their

degrees will be given priority and that it is realistically possible for all nodes to support one more student each (an MSc student for the other nodes and a PhD student for Rhodes). We are still in discussions with the RISE coordinators (the Science Initiative Group at Princeton University) about the exact mechanisms of progress and financial reporting from 2017 onwards.

We have maintained contact with some of the previous RISE students and reference is made elsewhere in this report about the Royal Society (UK) funded project on the Congo River that the IWR is part of, together with Dr Raphael Tshimanga from the University of Kinshasa (DRC).

Concluding remarks

The outgoing Director, Professor Denis Hughes shared a trenchant personal view of the succession planning and staff appointment process between the University and the IWR is his concluding remarks.

In the last week of the University year Professor Tally Palmer was appointed as director, on a 3 year University-funded contract, which will revert to a permanent position when a suitable transformation candidate is identified and applied; and Dr Jane Tanner was appointed as the senior hydrologist on a 5 year contract, renewable on performance. The IWR is pleased to start 2017 with these posts filled.

Contract research staff

We appreciate that the University is potentially facing some very tough times with the crisis around student fees, but there is little doubt that the IWR will also be facing a different kind of crisis in the immediate future. Part of the original IWR proposal was for Rhodes University to allocate some salary resources (from the vacant Senior Lecturer position) to subvent the salaries of those contract research staff who contribute to post-graduate student supervision. It seems unfair that these staff have to struggle to generate enough income from research and consultancy contracts and are then expected to contribute to the subsidy earnings of Rhodes without any compensation. We certainly will find it extremely difficult to maintain the level of post-graduate degree outputs that we have enjoyed over the last few years without their inputs. One approach could be for the University to treat contract researchers who are funded from outside funds in the same way that Emeritus Professors are treated, i.e. decide to pay them a proportion of their subsidy income earnings, through papers and graduated PhD students, to offset the amount of time that they spend generating this income for the University.

The increases in post-graduate numbers and sustained research outputs have been achieved with no real growth in the staff available for supervising post-graduate projects. However, externally funded contract staff (Drs Neil Griffin, Sukhmani Mantel, Andrew Slaughter, Nelson Odume, Jane Tanner and Paul Mensah) have been increasingly contributing to student supervision and it should be recognised that these contributions cost the University very little but still generate subsidy income.

Acknowledgements

We are very grateful for the contributions that the Board of Control make to the successful operation of the Institute, even if these are concentrated in a short period over the annual IWR Open Day. We would like to acknowledge all the support that we receive from the various South African funding agencies and specifically the Water Research Commission (WRC) who have provided the financial backbone of the Institute for many years. We continue to enjoy a strong association with the WRC, not only through projects being undertaken by IWR staff, but also through the reference group meetings of other institutions projects and various policy and planning meetings.

Funding provided by the Unilever Foundation provides a significant contribution to the continued existence and success of the UCEWQ. The unencumbered funding allows UCEWQ staff and students to contribute to research initiatives at both local and national levels, allowing us to partner other researchers, government and industry in the development and implementation of an integrated and holistic approach for managing environmental water quality in water resource management.

The Carnegie Foundation (through the RISE initiative) has been an extremely important source of funding for post-graduate students within the Institute. We have developed excellent relationships with the fund administrators over the last seven years of the project. We are also grateful to the coordinators at the other nodes of the SSAWRN (Botswana, Makerere and Eduardo Mondlane Universities) for their help in ensuring the success of this initiative and this success is also dependent upon the network administration work that is very ably undertaken by Dr Sukhmani Mantel.

We are also grateful for the support of the various divisions of Rhodes University including the staff of the office of the Deputy Vice Chancellor, Research and Development, the Dean of Science and the Science Faculty administration, the Finance Division, the Human Resource Division and the Communications and Development Division. We are very grateful for the travel support given by the Rhodes Research Office to attend local and international conferences. Beneficiaries during 2016 included a number of staff members and students.

Finally, as Director, I would like to offer my personal thanks to all the members of the Institute staff (both research and support staff) and students for their hard work, enthusiasm and loyalty to the aims of the IWR, as well as their support in ensuring the smooth operation of a university research institute. I sincerely hope that the success of the Institute can be maintained in the future, despite some of the difficulties that we are currently facing.

UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY (UCEWQ)

UCEWQ DIRECTOR'S REPORT

Introduction

The Centre remains a leader in the South African water sector, with its staff and students contributing to catchment-based complex social-ecological system research and water resource management, particularly in the fields of governance and institutional arrangements, environmental water quality (chemistry, biomonitoring and ecotoxicology), aquatic ecosystem ecology and ethics. One of the most significant events in the year was the successful handover of the Centre's leadership to Dr Nelson Odume by Prof Tally Palmer, in keeping with the IWR-wide succession plans. This year, staff and students of the Centre received prestigious accolades in recognition of their contributions. The most significant of these is the 2016 Southern African Society of Aquatic Scientists (SASAqS) Gold Medal awarded to Prof Tally Palmer in recognition of her exemplary leadership, exceptional contributions and commitment to freshwater research, teaching and policy development. UCEWQ is indeed proud of this huge honour and recognition! Dr Nelson Odume, who was awarded the 2015 SASAQS Bronze Medal, also received his medal this year as he was not able to attend the 2015 SASAQS conference. Dr Odume also made the list of the 100 Inspiring and Aspiring Young Independent Leaders, an initiative of the Independent Media Group of South Africa. Mr Ian Preston graduated with a Master's in Commerce (Management). Mr Preston was co-supervised by Prof Palmer. Ms Notiswa Libala and Ms Pindiwe Ntloko were awarded the NRF DST Innovation, and Scarce Skills PhD Bursaries, respectively. Ms Libala also received the South Africa System Analysis Centre (SASAC) bursary. SASAC is an initiative of the NRF that is aimed at training a new generation of African system thinkers, knowledgeable in using applied system analysis for addressing national, regional and global challenges. SASAC is firmly collaborating with the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria and in April 2016, Dr Odume and Ms Libala were in Austria as part of South Africa students-supervisors delegation. This visit is already opening windows of collaboration between UCEWQ and researchers from IIASA.

SASAC members in Austria

Mr Ian Preston graduates with an MSc in Management

Left to right: Prof Tally Palmer and Prof Jacqui King (Institute of Water Studies, University of Western Cape) with their Gold Medals awarded to them at 2016 SASAQS Conference held in Skukuza.

From left to right: Ms Notiswa Libala, Ms Margaret Wolff, Ms Khaya Mgaba, Prof Tally Palmer, Dr Nelson Odume, Ms Tia Keighley, Dr Paul Mensah, Ms Phindiwe Ntloko and Mr Matthew Weaver, at 2016 SASAQS Conference held in Skukuza

National, Regional and International Influence

UCEWQ research continues to be highly influential in South Africa, and in particular, in 2016 we actively supported the work of the Mzimvubu to Tsitsikamma Proto-Catchment Management Agency (MTCMA). Prof Tally Palmer, Ms Margaret Wolff and Ms Notiswa Libala co-facilitated and coordinated five catchment management forums in January and February. The ground-breaking project, 'Integrated Water Resources Management – Towards Practising a 'New Paradigm' '(TPNP), comes to an end in early 2017 but it has altered the way people practice water resource management in South Africa. The project team, using the Makana case study, and its systemic, complexity-based principles, negotiated the establishment of a single Upper Kowie River Water, Sanitation and Catchment Forum and produced a terms of reference which was finalised on 28 October 2016. This is ground-breaking because for the first time, a forum is being established at the local government level that looks holistically at the entire water value chain (from resource to services and back to resource). A series of 'How to' handbooks are currently being written to guide the practice and implementation of IWRM in South Africa. These handbooks focus on different aspects of practising and implementing IWRM in South Africa, including how to think in a way that makes IWRM practically possible, how to establish and run a catchment management forum and how to work towards addressing local water issues.

The Centre is deeply committed to also 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. UCEWQ research was showcased at a WRC dialogue in August 2016. The dialogue provides an opportunity for UCEWQ researchers to demonstrate how their research is contributing towards addressing the critical and urgent issues of microbial pollution, eutrophication and household water security, all of which form part of the TPNP project.

The Framework Programme for Research, Education and Training in the Water Sector (FetWater), a flagship collaborative programme between the WRC and the Department of Water and Sanitation (DWS), which aimed at addressing the educational, training and capacity needs in the water sector entered its third phase in 2016. The third phase focuses on developing occupational based qualification in six thematic areas. UCEWQ staff Prof Tally Palmer, Dr Paul Mensah and Dr Nelson Odume are part of the community of experts on two of the six networks. They contribute their expert knowledge in the Water Regulation Requirement, and Water Planning and Implementation Networks.

This year, UCEWQ researchers Dr Nelson Odume and Prof Chris De Wet, who has now re-located to Anthropology to focus on writing his book, completed a WRC project on the role of environmental ethics in social-ecological systems and water resource management. The outcome of this project was hailed at the final steering committee meeting as ground-breaking as it provides a novel systemic-relational perspective for ethically grounded water resource management in South Africa. A set of 11 principles informing the systemic-relational ethical perspective have been developed for ethically grounded water resource management in the context of complex social-ecological systems. This project is now being taking forward into a global context through the European Union funded AfriAlliance Consortium. More information on the AfriAlliance Project is in the projects section.

About six years ago, the Centre started working actively on developing competencies in transdisciplinary (TD) research in complex social-ecological system. The need for this type of research arises out of our realisation that research can only be transformative and impactful if it is done with key stakeholders from all sectors: academics, policy and decision makers and the community. Transdisciplinary research brings different actors together in addressing challenges that face society. This year, the Rhodes University TD research group secured small grant

UCEWQ students: Mr Emmanuel Vellemu (left) and Mr Frank Akamagwuna (right) engaging high school students during the inaugural Rhodes University Faculty of Science Open day.

from the RU Centre for Postgraduate Studies to run a TD workshop for researchers and postgraduate students. This workshop was highly successful and the feedback from participates and facilitators encouraging.

UCEWQ staff and students are committed to active participation in community engagement initiatives. In 2016, Mr Emmanuel Vellemu organised and represented IWR during the Environmental Week at Rhodes University between 18 and 22 April where the Centre demonstrated the importance of water quality for safe water services delivery. UCEWQ students were also involved in the Clear River Campaign on 20 July 2016 helping with clearing of rivers within Grahamstown. This campaign is an initiative of the DWS, in which the department partner with local organisations to connect all South Africans to their sources of water. UCEWQ students also participated in the inaugural Rhodes University Faculty of Science Open day. High School students were engaged and encouraged to take a career in the water sector.

Partnerships, Linkages and Performance

Unilever South Africa remains the core founding partner of the Centre. 2016 was significant because for the first time since 2008, Unilever SA and UCEWQ reverted back to a three year Memorandum of Agreement (MOA). The signing of the MOA represents a milestone in the strategic partnership between Unilever SA and UCEWQ. This achievement would not have been possible without the strategic guidance and input by key staff of Unilever: Mr Bukunmi Akinseye, Mr Heteesh Bhoola, Ms Preola Adam and Ms Rubavathy Abbu. Prof Tally Palmer dedicated endless hours negotiating the terms of the agreement. The Centre remains grateful to these people for this achievement. Going forward, the Centre will work closely with Unilever SA in core strategic objectives within the water sector in ensuring that water is sustainably managed in South Africa for her people and ecosystems.

Unilever SA has identified household water security as a critical element deserving attention. Two critical aspects of Unilever SA interest is greywater re-use and supply of household emergency water. During the WRC dialogue, Ms Abbu spoke about Unilever's Bright Future campaign, particularly the sustainable water practice initiatives in the Sunlight Project. In the context of increasing water scarcity, Unilever product innovation focusses on low water use products. UCEWQ and Unilever SA would work closely on innovations around greywater reuse and household water security. Unilever SA is already implementing a review report on greywater by UCEWQ. In the coming year, UCEWQ and Unilever SA will partner the Mvula Trust on the possible role out of emergency water supply system in the eThekwini metro. Opportunity also exists for collaboration with the Eastern Cape Water Caucus (ECWC) for a similar project in the Eastern Cape. Mr Matthew Weaver, a doctoral student, through his research project, will collaborate with the ECWC to establish ECWC nodes in the Raymond Mhlaba and Makana Local Municipalities with the hope that these nodes will serve as a medium for active participation in water forums. Water for Dignity remains an attractive vehicle for possible promotion of new products and technologies. In 2015, a decision was made for Water for Dignity (WfD) independence, with UCEWQ and Khulumani Support Group as key founding partners. During 2016, several water barrels were distributed to households experiencing regular water outages. Deposits were received for the water barrels, but WfD were not able to sustain this initiative further. Despite WfD's concerted efforts in establishing School Water Forums, WfD faced serious challenges in improving water and sanitation efforts at Andrew Moyake primary school, largely because the school has been threatened with closure. In the coming year, UCEWQ will work closely with WfD to define strategic objectives and implementable plans of action to support the Unilever Project Sapphire launch, and collaborate with the Rhodes Community Engagement office, and volunteer organisations such as *Galela Amanzi.*

Our partnership with the South Africa Young Water Professional (YWP) remains solid. In May this year, Dr Nelson Odume stepped down from office, after serving as Chair Person of the Eastern Cape Chapter for two years. However, within UCEWQ, two of our doctoral students: Mr Matthew Weaver and Ms Notiswa Libala are both on the new provincial committee. We are excited at this opportunity for leadership. Mr Matthew Weaver, Ms Pindiwe Ntloko, Ms Notiswa Libala, Mr David Gwapedza, Mr Sbongiseni Mazibuko, Mr Frank Akamagwuna and Mr Emmanuel Vellemu attended the YWP publication workshop at Nelson Mandela Metropolitan University (NMMU) from the 15 to 18 August. The aim of the workshop was to enhance the publications skills of postgraduate students, and we were very privileged to have the Prof Gustaf Olsson from Lund University in Sweden as a workshop facilitator.

Prof Tally Palmer presented papers at the Savannah Network, SASAqS**,** Complex Systems and WISA conferences and the Rhodes University Community Engagement symposium. All papers were well received. Dr Nelson Odume was invited as an external guest speaker to a workshop on hygiene by WaterAiD Southern Africa. He also presented papers at SASAqS and RISE conferences. Dr Paul Mensah presented papers at SASAqS and RISE conferences. Dr Neil Griffin led a workshop on the use of toxicity testing for water use licensing and authorisation, as part of a broader WRC funded project. In October 2016, Mr Nick Hamer attended the Citizen Engagement in Local Water Governance symposium. The symposium was an opportunity for civil society activists to share their experiences of participating in participatory action research.

UCEWQ students continue to gain professional exposure through conferences and workshops. Ms Margaret Wolff, Ms Notiswa Libala, Ms Tia Keghley, and Mr Matthew

Weaver all presented papers at the SASAqS conference and Rhodes University Annual Community Engaged Learning Symposium. Ms Khaya Mgaba and Ms Pindiwe Ntloko also presented papers at SASAqS conference. Mr Emmanuel Vellemu attended RISE annual general meeting in Nairobi, Kenya. Ms Notiswa Libala attended the 2016 African Doctoral Academy at Stellenbosch University and also participated in a two month SASAC capacity development programme. Ms Athina Copteros co-facilitated the first TD workshop for postgraduate students run at Rhodes University. She also ran a creative movement reflection session for the participants of the action learning course run for Changing Practice participants from the South African Water Caucus. We are really proud of the accomplishments of all our students.

SASAC two month capacity Development programme launch with Minister Naledi Pandor

In 2016, Mr Ian Preston and Ms Karabo Chadzingwa obtained their MSc degrees. Ms Athina Copteros and Mr Gareth Thompson submitted their PhD and MSc theses for examination, respectively. Ms Yvonne Chiliboyi is on the verge of submission. Mr Matthew Weaver's MSc upgrade to a PhD was successful. We congratulate all your hard work. Other students are steadily making progress with their studies.

Our intern programme has become a flagship programme for capacity development. In 2016, Ms Bawinile Mahlaba and Ms Ntombekhaya Mti joined the Centre as interns and we are really delighted that UCEWQ is able to provide opportunity for young people to develop their skills. Ms Khaya Mgaba and Dr Paul Mensah continue to provide leadership and mentorship to our new and old interns. Mr Mzwanele Mkatali, who has been an intern with the Centre for the past three years, started his Honours programme in Chemistry this year. Ms Qawekazi Mkabile who holds a BSc degree in Environmental Geography and Honours in Limnology, joins us this year as a research assistant. She has contributed to data collection and literature review of existing UCEWQ students and staff projects. Ms Mkabile is already gearing up for registering as a full-time student for an MSc programme in Water Resource Science in 2017. Our laboratories and cultures are in excellent condition. This year we joined the National Laboratory Proficiency Testing Scheme.

Our Environmental Water Quality (EWQ) Honours module, which is offered to the Departments of Environmental Science and Geography students, was successful. This year we also decided to initiate the process of offering the EWQ as a short course to professionals working in the water sector. The course has now gone through the Rhodes University accreditation system and is ready to be offered with either Certificates of Competency or Attendance. The EWQ course for professionals will be offer twice a year, beginning in February 2017. Watch out for the advert!

Lastly, I would like to express my deepest appreciation and gratitude to Prof Tally Palmer, who has been a role model and a mentor, providing sterling leadership. I would also like to thank all UCEWQ staff and students for their hard work and support. Without your hard work and effort, we would have achieved nothing. I have every reason to believe that the future is bright and that UCEWQ will continue to grow stronger.

HYDROLOGY PROJECTS

The hydrology group of the Institute consisted during 2016 of Prof Denis Hughes, Dr Andrew Slaughter (focussing on water quality modelling), Dr Jane Tanner (focussing on surface water – groundwater interactions) and eight post-graduate students; Mr Sbongiseni Mazibuko (MSc), Mr Haden Jacobs (MSc), Mr David Gwapedza (MSc), Mr Kyle Smetherham (MSc), Ms Nokulunga Zwezwe (MSc), Mr Coli Ndzabandzaba (PhD), Ms Eunice Makungu (PhD) and Mr Dionis Rugai (PhD). Four of the post-graduate students are part of the Carnegie RISE programme, while some are supported by the IWR and others by additional funders (including some Water Research Commission Projects). The range of topics covered by these student projects include hydrological modelling uncertainty assessment, modelling wetland and floodplain dynamics, sediment modelling, assessment of environmental flow models and understanding surface-groundwater dynamics.

Other staff members contribute to some of the hydrology related projects that the Institute is involved in. Notably, Mr Forsyth continues to be involved in the development and maintenance of the SPATSIM hydrological modelling framework software, as well as supporting other software developments. Dr Mantel has been assisting with the some of the hydrology projects and co-supervises some of the students. Many of the hydrological projects (both research and consultancy) involve collaboration with other organisations, both within South Africa and overseas.

EXTENDING FUNCTIONALITY AND KNOWLEDGE TRANSFER OF THE WATER QUALITY SYSTEMS ASSESSMENT MODEL

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

Development in South Africa is constrained by limited water resources. Although in the past, water quantity has primarily constrained development, the role of water quality is becoming more prominent, as water of compromised quality is costly to treat. Tools exist with which to facilitate management of water quality. Among these, water quality models are useful as they allow the conceptual understanding of processes affecting water quality, model simulations can complement and add to observed water quality data and water quality models can be used to investigate future management scenarios. Unfortunately, as is the case in many developing countries, the available observed water quality data in South Africa are insufficient to accurately apply most international water quality models. For this reason, the development on the Water Quality Systems Assessment Model (WQSAM) began as a previous Water Research Commission (WRC) funded project (K5/2237). WQSAM adopts the approach of linking explicitly to the existing yield (systems) models used routinely in management of water quantity in South Africa, and WQSAM adopts a strategy of Requisite Simplicity in representing only the most important water quality variables and the processes affecting these variables within the context of water resource management.

K5/2237 was successfully completed with WQSAM able to model salinity (TDS) and nutrients. The awarding of K5/2448 allowed the model to be further developed, concentrating on: 1) the validation of algal growth processes in the model by the use of alternative global datasets such as satellite data of chlorophyll a in dams; 2) the incorporation of additional water quality variables such as sulphate (as indicative of acid mine drainage) and *Escherichia coli* as an indicator of faecal contamination; 3) an investigation of WQSAM in relation to modelling the survival of *Vibrio cholerae*, the bacteria responsible for cholera, in fresh surface waters; 4) the development of a formal modelling approach to estimating nutrient loads from non-point sources; and 5) the incorporation of an erosion and sediment transport model within WQSAM. To date, objectives 1–4 have been achieved, whereas objective 5 is partly completed. In relation to objective 5, David Gwapedza, the student on the current project, is investigating the further development and testing of a sediment transport model where the erosion part is based on the Modified Universal Soil Loss Equation (MUSLE). David has successfully validated the MUSLE and has developed a regionalisation scheme for determining the MUSLE parameter values. The next deliverable linked to objective 5 will concentrate on testing and validating the sediment transport part of the model and the incorporation of the model into WQSAM. Of relevance to the sediment transport model is the application of the model to the Ntabelanga catchment, a catchment in

David Gwapedza collecting field data for use within a sediment transport model within the Ntabelanga Catchment, Eastern Cape.

the Eastern Cape plagued by high sediment erosion and in which two reservoirs are planned in the near future. Mr Gwapedza is collaborating with a diverse group of researchers within the catchment, and it is hoped that his research will contribute to the planning of the reservoirs within the catchment.

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

Sponsor: Water Research Commission
JL Tanner, DA Hughes and W Ellery
Project dates: April 2016 - March 2018

The investigation is introduced in Ms 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.

This investigation focuses on improving understanding of the smaller scale surface water and groundwater interaction processes to increase understanding and reduce uncertainty within modelling analysis both at smaller and at larger scales. Unfortunately, there are currently not enough data to reduce the hydrological uncertainty at the sub-catchment scale, and this project aims to try to reduce that uncertainty by improving smaller scale process understanding as well as carrying out more detailed modelling. It is hoped that this project can build on the geomorphological investigation, ultimately leading to a better understanding of the system as a whole.

In addition to the aims outlined in Ms Smith'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

The project is currently in a data collection phase and field instrumentation has been installed to monitor the frequency, depth and duration of inundation of the system. These data will be used to formulate a realistic conceptual model before hydrological and hydrodynamic modelling is carried out. 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.

ESTABLISHING A RESEARCH GROUP ON SURFACE AND GROUNDWATER INTERACTIONS

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 - September 2017

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 will contribute towards a new progamme within the existing Africa Groundwater Network which will focus on increasing the awareness of the importance of surface water and groundwater interactions in Africa.

The programmes 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.

The funding will contribute towards a launch and workshop to be held during the annual meeting in 2017 which will bring together hydrologists and hydrogeologists to discuss key issues around the understanding of and modelling of SW/GW interactions. In addition, the funding will support network members who identify funding opportunities in the area of SW/GW interactions to write research proposals.

UPSTREAM-DOWNSTREAM HYDROLOGICAL LINKAGES IN THE LIMPOPO RIVER BASIN

Sponsor: Water Research Commission/CSIR
DA Hughes
Project dates: April 2015 - March 2018

This is a WRC funded project led by Dr Evison Kapangaziwiri (former IWR PhD student) and Dr Jean-Marc Mwenge Kahinda of the CSIR which is focused on improving the understanding of the hydrology and water resources availability in the whole Limpopo River basin. The main involvement of the IWR is through the supervision of the two MSc students (Ms Vuyelwa Mvandaba and Ms Nadia Oosthuizen) who are employed by the CSIR and registered at Rhodes under supervision by Prof Hughes. Ms Mvandaba is working on a project entitled 'Understanding and quantifying channel transmission loss processes in the Limpopo River basin', while Ms Oosthuizen's MSc project

is on 'Quantification of water resources uncertainties in two sub-basins of the Limpopo River basin'. Both students are making satisfactory progress and have presented part of their work at both the SANCIAHS (Durban, September) and WaterNet (Gaberone, October) conferences.

REFINEMENT OF THE REVISED DESKTOP RESERVE MODEL

Sponsor: Water Research Commission/DWS
DA Hughes and N Zwezwe
Project dates: April 2016 - March 2018

The IWR are involved in this project as sub-consultants to Ms Delana Louw of Rivers for Africa eFlows Consulting (PTY). The background to the project is associated with the long history of the IWR's development of software and models to support the implementation of the ecological Reserve (environmental flow requirements) for the Department of Water and Sanitation (DWS). The so-called Revised Desktop Reserve model was developed some years ago and has been used by many of the DWS consultants in their projects for DWS. However, a number of problems have been identified with respect to the use of the model by non-specialists to perform desktop level Reserve determinations. Part of the project is therefore to re-design the model to make it more user friendly for non-specialists and to build upon the growing national databases of the hydraulic habitat requirements of different fish and macro-invertebrate species that are found in different parts of South Africa. Another component of the project is to develop an improved approach for estimating the high flow requirements that is more explicitly linked to the hydraulic cross-sectional characteristics of a river site. Ms Zwezwe is supporting the project through an MSc project that is designed to look at various aspects of the existing model and the refined version. This includes assisting with the development of improved parameter estimation approaches (using ecological databases), as well as a comprehensive sensitivity analysis which is expected to guide users in the application of the model and where they should focus their attention when applying it in different situations.

CONGO RIVER USER HYDRAULICS AND MORPHOLOGY (CRUHM)

Sponsor: Royal Society (UK)
DA Hughes
Project dates: 2016 - 2020

This is a major project on the Congo River that is lead by the University of Kinshasa, DRC (through Dr Raphael Tshimanga, a former PhD student of the IWR) and includes partnerships with the Universities of Bristol and Leeds in the UK and the University of Dar es Salaam in Tanzania. The project programme includes the training of three PhD students (two from DRC and one from Tanzania), one of whom will begin their studies with the IWR in January 2017. The project is mainly focussed on understanding the hydraulics and morphology of the Congo River and the effects of various future changes on such as water resources, sediment dynamics and the hydraulic characteristics of the river and impacts on navigation. The project inception meeting was held in Kinshasa during July 2016 when the project team elaborated on the details of the different sub-components of the project. The main focus of the IWR involvement will be to offer some training courses in basin scale water resources modelling and assessment and how this can be linked to more detailed hydraulic modelling of large rivers with associated wetlands and floodplains. This will therefore be the main topic of the new PhD student's research programme. Dr Tshimanga completed his PhD on an initial setup of the Pitman hydrological model for the whole of the Congo River basin and the new PhD student will build upon this experience and make some links between the coarse scale modelling of the whole basin with more detailed modelling of the various floodplain and wetland areas using the Lisflood-FP model developed at Bristol University. One of the spin-offs of the project is the availability of a large budget for capital equipment which will enable the IWR to purchase items that could not otherwise be afforded. To begin with we have ordered two very high specification PCs that will help with the efficient running of the uncertainty version of the Pitman model as well as the Lisflood-FP model.

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 the University of Fort Hare's Institute of Social and Economic Research), 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:

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

The project has three focal catchments in the Eastern Cape and the project is funding two postgraduate students at Rhodes University – Onalenna Gwate (PhD candidate, Rhodes University) and Bukho Gusha (PhD candidate, Rhodes University). The third postgraduate student on the project – Perpetua Okoye (MSc, Stellenbosch University) – graduated this year.

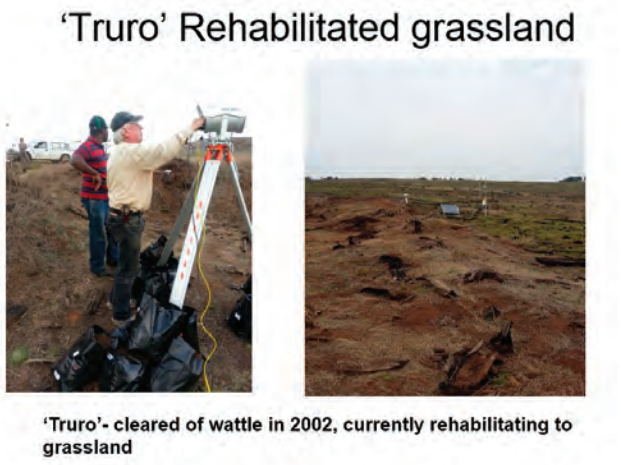
A Large Aperture Scintillometer system installed at a highland sourveld site in quaternary T35B.

The project is progressing on track and six deliverables have been submitted to the WRC. A third year workshop is planned for early 2017. Dr Mantel and Dr Palmer have recently received a three year funding from the NRF under the Indigenous Knowledge Systems call which will extend the work under the WRC funded project in the field of Payment for Ecosystem Services. The NRF project will begin in 2017 and is titled 'IKS to Enhance Rewards for Ecosystem Services in Rangelands Infested with Invasive Alien Plants'.

INFRASTRUCTURE FUNDING INSTRUMENT GRANT FOR EVAPORTRANSPIRATION FLUX

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

Dr Anthony Palmer (Agricultural Research Council) and Dr Mantel motivated for a National Research Foundation (NRF) 2014 call for National Equipment Programme grant for equipment for measuring the carbon and water fluxes using the Eddy Covariance and Scintillometer systems. The funding proposal for R1.8 million (of which R1.249 million is provided by the NRF) was approved and we received all three systems last year. Dr Palmer, Dr Mantel and Mr Gwate (PhD student) have installed one Eddy Covariance system on a secure thicket site outside Grahamstown. A Large Aperture Scintillometer was installed at a site where wattle has been cleared in order to assess the evapotranspiration of the recovering vegetation (see accompanying figure). 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 parameterize and validate global circulation models for climate projections. We are also looking to collaborate with other South African researchers with similar equipment or with need to use this equipment in South Africa.



A Large Aperture Scintillometer system installed at a cleared grassland site which is providing data for Mr Gwate's (left) PhD student under Dr Palmer's (right) supervision.

GENERAL CONSULTANCY PROJECTS

Sponsor: Various consultancy partners
DA Hughes
Ongoing

Prof Hughes has been involved in several water resource assessments that have included quantifying environmental flow requirements using the Revised Desktop Reserve Model.

Prof Hughes has been working with Ecotone (an environmental and ecological consultancy firm based in Johannesburg) on environmental flow and biodiversity assessments for the Zambezi River at Ngonye Falls in Zambia, as well as the Seli River near Bumbuna in Sierra Leone as part of two proposed hydro-power schemes. Both projects involved setting up the Revised Desktop Reserve model based on hydraulics and hydrology data provided by the client and determining an appropriate downstream flow regime under managed conditions that will have a minimal (or acceptable) impact on the ecological functioning of the river.

We continued to work with Jeffares & Green (consulting engineers) during 2016 on a World Bank funded project to look at investment opportunities (including irrigation and hydro-power) in the Okavango River system. This project involves hydrological and yield analysis modelling of the whole system and is the third hydrological modelling project on the Okavango that Prof Hughes has been involved in. The difference is that the main consultants agreed to adopt an uncertainty approach to the modelling, which is unique in terms of practical (rather than research) hydrological modelling projects. The final part of this project allowed the IWR to test a version of the model that includes climate change effects on rainfall and evaporation demand. There is the possibility that the climate change assessments will form part of an extension to this project.

Prof Hughes also acted as a sub-consultant for two water abstraction licence application projects in the Eastern Cape Province. The main part of the work was to establish a hydrological model to simulate natural and present day flow regimes and to determine appropriate environmental flow requirements and to integrate these into the future management of the water resources. One of the projects was on the Tsitsikamma River near Humansdorp and became quite a complex study involving the optimisation of water storage in reservoirs (for irrigation purposes), releases from the reservoirs to support the low flows in the river, as well as pumping from the river to the reservoir during high flows.

Ngonye Falls on the Zambezi River in Zambia

ENVIRONMENTAL WATER QUALITY PROJECTS

BUILDING CAPACITY THROUGH INTERNSHIP TRAINING IN ENVIRONMENTAL WATER QUALITY

N Mgaba
Project Dates: February – December 2016

The IWR-UCEWQ runs an internship programme in which young water research professionals are developed in all aspects of the Institute's work over a short period (6-12 months). Many of the interns we have had in the past were students seeking to gain practical experience in support of their degree or diploma qualification.

The internship training involves variety of scientifically based activities facilitated through supervision, by staff of UCEWQ. The current supervisor is Dr Paul Mensah. This year Miss Bawinile Mahlaba from CPUT secured an internship position at IWR, from June 2016 to December 2016. Through this programme, she has gained skills and understanding in biomonitoring, ecotoxicology, chemical analysis and maintenance of animal culture for toxicity testing. As part of this training, she assists with field and laboratory experiments for both staff and postgraduate students. She works closely with Mr Mzwanele Mkatali, the technical assistant. She is currently working on a short term project as part of her Environmental Management diploma requirements.

Ms Bawinile Mahlaba demonstrating mini SASS to high school students

Ms Bawinile Mahlaba undertaking nutrients analysis

Mr Mzanele Mkatali demonstrating ecotoxicology during environmental week at Rhodes University

Mr Mzwanele Mkatali started at IWR-UCEWQ as an intern in February 2014, but currently works as a technical assistant in the Centre. He is responsible for culture maintenance, whereby he applies the culture and maintenance protocol to feed organisms with the correct ration, measures water quality variables (pH, temperature, DO, EC), water chemistry analysis, cleans holding tanks, and identifies and find solutions to problems associated with the cultures. He also assists with field and laboratory experiments for both staff and postgraduate students, collects macroinvertebrates, diatoms and water samples for monitoring river health.

COMMUNITY OUTREACH AND PUBLIC UNDERSTANDING OF SCIENCE

Each year, IWR-UCEWQ contributes to teaching school students and shelter children basic biological monitoring of rivers and water chemistry as part of its community outreach programs. The purpose of this is to help the children understand how water quality of freshwater resources gets impacted by pollution and the role they can play to prevent this pollution.

This year on Nelson Mandela Day, Prof Tally Palmer led members of the Oasis Group to conduct mini-SASS on the stream in Grahamstown's Botanical Gardens.

Oasis group member learning to use mini-SASS to collect macroinvetebrates

On 12 November, the IWR-UCEWQ in collaboration with Water for Dignity and Rotary Club of Grahamstown had another outreach program, involving boys from the Eluxolweni Street Shelter. The boys were taken on a field trip to the Bloukrans River were they conducted a mini-SASS and participated in monitoring the river's water quality using simple test kits provided by The World Water Monitoring Day organisation (http://www.worldwatermonitoringday.org). The biological monitoring and physicochemical variables of streams and how these relate to the overall health of the river was explained to the boys.

Ms Khaya Mgaba and Eloxulweni Children conducting mini-SASS at Bloukrans River

RICHARDS BAY MINERALS: ENVIRONMENTAL WATER QUALITY

Sponsor: Richards Bay Minerals (RBM)
NJ Griffin, AJ Holland, ON Odume, N Mgaba and M Mkatali
Project Dates: Ongoing to August 2016

Richards Bay Minerals operations may compromise environmental water quality, and subsequently ecological health, of surface waters in or near their current operations. An environmental water quality monitoring programme was developed for RBM in 2006 by IWR-UCEWQ. The monitoring programme incorporates the use of macroinvertebrates and diatoms as biomonitors, and the collection of a range of selected water quality parameters. Since 2006, samples were collected in winter, spring, summer and autumn from sites around the mine in the RBM smelter area and from the as yet unmined Zulti South lease area. Monitoring of the Zulti South lease area was terminated in 2009 as the area is to be mined, and a biomonitoring baseline for mining site rehabilitation had been established. The smelter area is currently monitored in winter and summer only as assessment of past datasets indicated that little extra was gained by quarterly monitoring (one site draining the smelter complex is monitored four times per year).

The current monitoring year was at the end of a severe multi-year drought that was accompanied by several trends in water quality that reveal ongoing stress on rivers around the RBM smelter. The 2015 monitoring cycle revealed salinization, acidification and nitrogen loading at sites in the area. Although nitrogen levels were reduced in the current monitoring cycle, acidification and salinization were found to continue. Salinisation of water resources during periods of low rainfall is a well-known phenomenon and can be seen as a direct effect of the drought in the region. The cause of low pH levels in the area is not known; however, the strong link between salinization and acidification suggests that the drought is the ultimate cause of acidification, although the mechanism by which this happens is not known. Decreased water quality in the area was accompanied by lowered biomonitoring scores. Biomonitoring found that taxa that were not known from the area before, and that were typical of acidic water naturally, were more common than before, to the extent that they were even dominant at some sites. Some rainfall during the year increased water levels, but water quality did not return to normal.

Cattle at a sample site in the Manzamnyana River.

Ms Khaya Mgaba inspecting a sample site on the Mpisini River towards the end of the recent drought.

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

DST-DEA Collaboration on Ecological Infrastructure

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

Action research focussed 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 M-T Water Management Area (M-T WMA) (Figure 1). The Mzimvubu catchment – just part of the WMA, includes parts of two metropolitan municipalities; six district municipalities, and 37 local municipalities (Figure 2).

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. From 2017 each CMF will have the opportunity to contribute to a local Catchment Management strategy (CMS) – which will feed into the overall MT-CMA CMS. Refer to the student report of UCEWQ MEd student Margaret Wolff for details on the CMF formation research.

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 an accessible handbook *"How to form and run a CMF"* , and running at set of five CMF formation workshops for the proto-MT-CMA (including Tsista River CMF), the WRC-funded project: *Towards Practising a New Paradigm for South African IWRM* (TPNP) project.

Figure 1: 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.

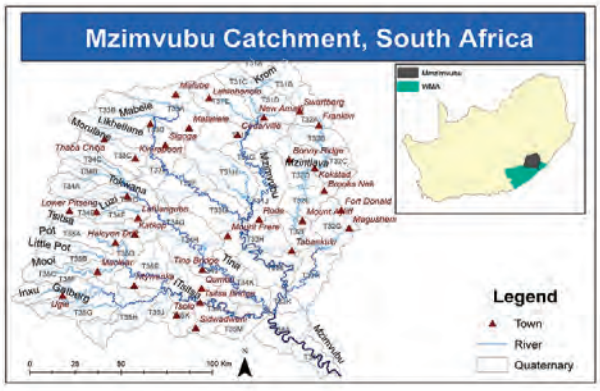


Figure 2: The Mzimvubu River catchment, and its location within the South Africa and the Mzimvubu to Tsitsikamma WMA. The Tsitsa River CMF is likely to be organised from the town Maclear.

IWR Research Processes in 2016

The IWR-UCEWQ research team has strongly influenced the whole NLEIP process through integration with the WRC TPNP project. We participated in the development on the overall integrated research design and the concept of 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 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).

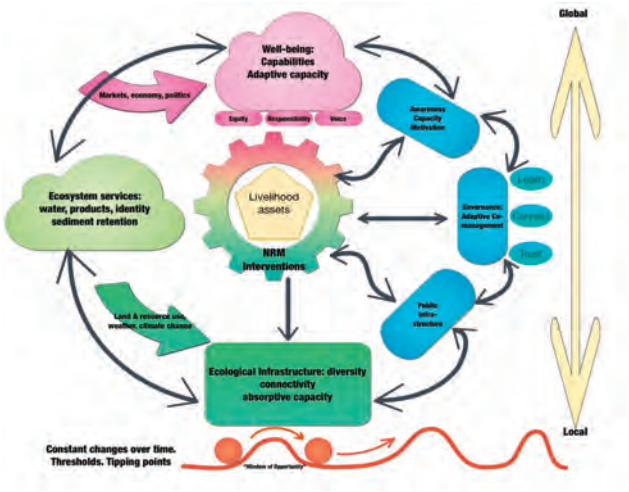


Figure 3: A conceptual diagram of the NLEIP research content, with arrows indicating relational integration (Internal NLEIP report, Fabricius and Biggs 2015)

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 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. (See the doctoral student research report by Ms Notiswa Libala).

The doctoral research of Ms Athina Copteros was also supported by the NLEIP. She explored the use of movement as a medium for innovating engagement by people who are routinely excluded in stakeholder engagement, especially women.

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. Training about the practical implications of treating landscapes as CSES's will be run in the Eastern Cape in February 2017.

Figure 4: Restoration strutures in the Ntabelanga dam catchment area.

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

Sponsor: Water Research Commission
NJ Griffin, ON Odume, PK Mensah and CG Palmer
Project Dates: 1 April 2015 – 28 February 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 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 project team held a workshop in Pretoria that engaged stakeholders from WRC, DWS, the toxicological community and various effluent-producing industries on best approaches to trialing the IWUAB Toolkit. By the end of the workshop, general approaches to sample location identification were agreed on, sampling and sample processing protocols were determined, and potential collaborators in the research programme had been identified. Negotiations aimed at cementing collaboration agreements began after the meeting, and some have been concluded. Stakeholders in those sectors have begun sampling for the project, and toxicological testing following IWUAB Toolkit recommendations has begun. Conclusion of collaboration agreements with industry stakeholders has been stalled by issues of trust, shifts in the business environment, and the difficulty in finding stakeholders that discharge effluent directly to surface water. The project team are approaching other contacts to finalize sampling in this sector as soon as possible.

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), C Thirion (Department of Water and Sanitation)
Collaborating organisation: Department of Freshwater Invertebrates, Albany Museum, Grahamstown
Project Dates: October 2015 – March 2018

The science of freshwater biomonitoring has contributed immensely to monitoring and managing aquatic ecosystems in terms of developing and applying low-cost and efficient tools, collecting and archiving ecosystem data for trend analysis, as well as providing useful data for biodiversity conservation, planning and policy (Dickens and Graham, 2002; Schäfer et al. 2011; Cortes et al. 2016). Nevertheless, there is a growing pressure, in the face of dwindling financial resources, on ecologists to improve current biomonitoring tools and approaches to reduce costs of implementation. Specifically, ecologists need to improve biomonitoring tools in the following areas: i) linking ecosystem function and structure to ecosystem services, and thus providing a more comprehensive assessment of the ecosystems with the assurance of the continuing supply of vital ecosystem services; ii) predictive capacity – providing scenario-based prediction of the potential consequences of the effects of both human induced and naturally occurring activities on ecosystem health and biodiversity; iii) impact diagnostic capacity - providing diagnosis of the cause(s) of impacts, rather than merely indicating that an impact has occurred, which does not necessarily informs and guides resource manager in terms of resource deployment to either remove or reduce the cause of the impact; iv) providing insight into biota resource use, niche partitioning, and potential effects of biodiversity on ecosystem functioning; v) providing insight into the consequences of potential loss of keystone species and ecosystem engineers in any given freshwater ecosystem.

Current biomonitoring approaches used for assessing aquatic ecosystem health in South Africa are anchored on aquatic ecosystems' structural attributes alone because it is presumed that protecting structures would ensure the protection of functions. This project will improve our knowledge and practice of biomonitoring through the documentation of relevant macroinvertebrate traits that can be used for assessment of human-induced perturbation in aquatic ecosystems. Specifically, the use of traits has the potential to add the following to the practice of biomonitoring: i) diagnosis of impacts, ii) biodiversity assemblage prediction, iii) traits-linked ecological function assessment, iv) stability across large spatial scales (i.e. eco-regions); v) relative seasonal and inter-annual stability.

Empirical evidence suggests that particular macroinvertebrate traits (e.g. biological, behavioural, ecological traits) are associated with ecological functions, thereby providing an indirect means for assessing ecosystem functions (Statzner et al*.,* 2001; de Bello et al., 2010). For example, ecosystem functions such as biomass turnover and changes in secondary productivity are reflected by a combination of certain macroinvertebrate traits including body size, adult life span, emergence patterns, and voltinism (Huryn and Wallace, 2000). Further, resource acquisition and processing, nutrient recycling and energy transfer can be assessed indirectly through ecological traits including food and feeding habits. Species traits do not only provide an indirect means for assessing ecosystem functions, it offers an opportunity for developing improved methods and approaches of linking ecotoxicology and biomonitoring to functional characteristics.

Project Aims

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

Progress to date: A framework for applying macroinvertebrate traits in freshwater biomonitoring in South Africa has been developed. A database of traits of South Africa macroinvertebrate is being compiled. It is anticipated that the framework and the database, when complete will stimulate further research and interest in the use of the trait-based approach to water resource assessment and monitoring in South Africa.

ALIGNING AND INTEGRATING BIODIVERSITY AND ENVIRONMENTAL WATER QUALITY INTO THE MINING DEVELOPMENT LIFE-CYCLE

Sponsor: Water Research Commission
AV Munnik, CG Palmer, T Humby, G Thomson T Keighley and NJ Griffin
Project dates: April 2014 – April 2017

This three year project has addressed the contested arena of coal mining in relation to water resource and biodiversity protection. The project has developed and tested an integrated water resource quality management plan and decision support system, to facilitate streamlining of conservation mandates, minimize duplication of effort, and clearly specify roles and responsibilities of different authorities.

The project aims were to:

- Conduct an analysis of available resource and catchment based **tools** aimed at sustainable development of water resources and management.
- Investigate and evaluate the **decision making processes** followed in issuing mining authorization
- Explore the relationship between licensing processes and **ecological infrastructure** from a landscape and connectivity perspective
- Propose an **integrative decision making process** and institutional arrangement required to support licensing for sustainable use of natural capital
- Develop guidelines necessary to understand the **socio-economic value of selected wetlands** demonstrating their importance to society
- Develop and test a multi-sectoral integrative monitoring framework linked to a **decision support system** that will cater for bio-physical, economic and societal needs
- Develop appropriate **capacity** for officials involved in licensing, business, and affected communities

The project worked closely with the Upper Komati Catchment Management Forum (UKCMF), where an Acid Mine Drainage event, polluting the town's drinking water supply dam, took place in January of 2012. The event deprived the town of Carolina's residents of drinking and household water for a period of seven months, imposing several externalities on them, and leading to social unrest. The event also stimulated a number of regulatory responses. An important consideration in case study site choice was that it falls within the area of the Inkomati Usuthu CMA, where water quality regulation is arguably more advanced than in many other parts of the country. It thus allowed a glimpse into the future, when other Water Management Areas will also be regulated by Catchment Management Agencies.

The project team and UKCMF working group developed a 10 step Integrated, Participatory Adaptive Management Process for balancing decision making between coal mining and ecological infrastructure. The working group included citizens participating in the forum, a local environmental study group, an environmental justice activist organisation, mine managers, mine consultants, as well as officials from local government, and the departments of water and sanitation and agriculture.

The research included the creation of a theoretical framework for dealing with understandings of biodiversity, ecosystems, ecosystem services, ecological infrastructure, resource economics, ecological economics, as well as hydro-connectivity in social-ecological systems. Seven wetlands in the area were selected for winter and summer assessments of wetland ecosystem health and ecosystem services in relation to the primary land uses: mining and agriculture. An economic comparison between coal mining and agriculture land uses and impacts on biodiversity was undertaken, as well as a hydropedological study of a severely impacted mining site and options for its rehabilitation, as a basis for costing damage to ecological infrastructure.

An analysis was done of whether and how the current legal tools regulating mining takes into account and protects ecological infrastructure. This was complimented by research into practical experiences of the system and perspectives on it by mine managers, regulators and catchment citizens were undertaken in a formal Cultural Historical Activity Theory (CHAT) analysis, as well as through a series of focus groups and facilitated discussions in the UKCMF. A desk top study of contestations around coal was undertaken. A Knowledge and Decision Support System was developed, available electronically (static and dynamic) as well as in hard copy. UKCMF working group participants were trained in using the system.

The research showed that citizens in a CMF working group are able and willing to engage with issues of land use decision making, have a desire to participate in a new and fairer system for decision making and regulation around coal mining and competing land uses, and that such an alternative decision making system is possible. The results have been presented at meetings including Land Rehabilitation Society of Southern Africa (LaRSSA) and the Southern African Society of Aquatic Scientists (SASAqS). It has also contributed a "How To" guide to the Towards Practising a New Paradigm project.

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 N 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*

The last deliverable for this year titled 'A preliminary species sensitivity approach risk-based guildeline' has been submitted.

INTEGRATED WATER RESOURCE MANAGEMENT IN SOUTH AFRICA: TOWARDS PRACTISING A NEW PARADIGM

Sponsor: Water Research Commission, with case studies supported by the National Research Foundation (THRIP), USAID, and Unilever SA

CG Palmer, AV Munnik, D du Toit, N Hamer, NJ Griffith. JH O'Keeffe, H Biggs, K H Rogers, M Jobson, S Pollard, MJT Weaver, A Sahula, H Retief, M Lipile, N Lipile, X Nzwana, H Holleman.

Collaborators: AWARD, Khulumani Support Group

Project Dates: April 2013 – March 2017

The project, now entitled *Water Resources Management in South Africa: Towards Practising a New Paradigm* (TPNP), started in April 2013, and is summarised in Figure 1.

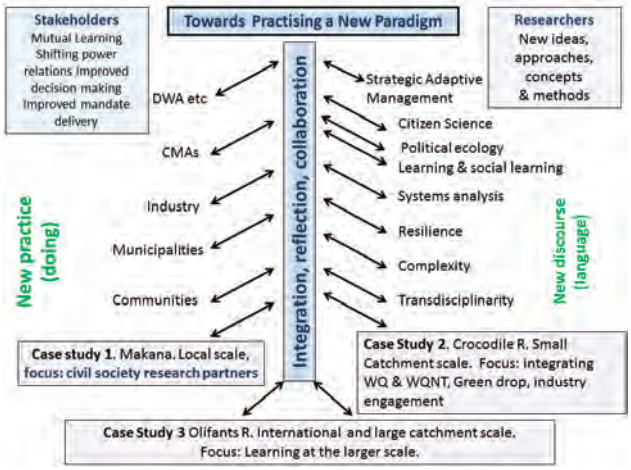


Figure 1: In this 4-year project, the vision is that engaged research undertaken with an understanding that people in catchments comprise complex social ecological systems (C-SES), using appropriate complexity- and systems-based approaches and methods, could result in a deeper embedding of equitable, sustainable and adaptive Integrated Water Resource Management (IWRM) in South Africa. The use of case studies has been expanded over the four-year project, and practices that contribute to the issues of: eutrophication, microbial pollution, resource protection and household water security have been addressed.

"How to…." handbook series

There is an urgent need to communicate proposed practices in accessible ways to a wide range of participants across the water sector, with the aim of giving practical, research-based guidance. This has emerged into a TPNP project aim to produce a "How to" handbook series as a project output. The aim is to disseminate sets of the series to every CMA, proto-CMA, and catchment management forums (CMFs) in South Africa. Progress in 2016 includes:

- Draft 3 of *How to think in a way that makes IWRM practically possible in South Africa.*
  This draft includes the important national and international literature review that was required to validate the assessment of practical applications of systemic approaches. The review, and the synthesis of implementation issues identified, requires further refinement.
- Draft 3 of *How to establish and run a catchment management forum*
  This handbook is now complete.
- Draft 1 of *How to make decisions about coal mines*
  This handbook was reviewed in practice-based workshop by the Upper Komati Forum Acid Mine Drainage working group 1st September 2016, and their recommendations will be included in the final product.

The rest of the "How to" series will be completed in 2017:

- *How to to work towards addressing your local water issues: Learning from Civil society Organisations (CSOs).*
- *How to engage with the Green drop process*
- *How to use Strategic Adaptive Management (SAM) in developing a Catchment Management strategy (CMS)*
- *How to integrate water quality and water quality in*

Catchment Management agency (CMA)
- *How to make progress with water issues in smaller municipalities.*

TPNP Focal Issue Progress

The Terms of Reference for this project specified that progress in new paradigm-based implementation should be demonstrated in respect of three critical water resource issues:
- Eutrophication,
- Microbial pollution, and
- Water resource protection.

In each case: the new paradigm foundational ontology (see box below) moved the research focus on each of these issues from the usual detailed subject-of-interest focus, to a systemic point of influence where implementation steps have proved practical and possible.

> The TPNP ontology – or understanding of the nature of existence, is that people in catchments exist as complex social ecological systems (CSES). Therefore using appropriate complexity- and systems-based approaches and methods, could result in a deeper embedding of equitable, sustainable and adaptive Integrated Water Resource Management (IWRM) in South Africa.

In the case of eutrophication and microbial pollution, the new paradigm approach revealed that understanding and strategically supporting the Department of Water and Sanitation (DWS) Green Drop programme holds the most promise in reducing continued elevated nutrient input into rivers and dams, AND in reducing discharge of inadequately treated sewage into public resources where health-related contamination is a high risk. In exploring the DWS Green-Drop programme we exposed the complexity of tackling movement towards more effective wastewater treatment systems. We are now able to highlight the vital role of integrity and political will as vital to more rapid progress. We have demonstrated that supporting participatory processes in practice was effective in calling to account government, officials and individuals; while encouraging hard-working ethical practitioners to improve Greed drop score. Details were presented in Deliverable 8 Section 3, and will be formulated as a "How to" handbook.

This leads to the point of implementation we have recognised as being critical to support water resource protection. There has been, and is, plenty of effort in respect of research and practice concerning resource directed measures, source directed controls, and the ways in which they work to enable balancing resource use and resource protection. This effort has not prevented widespread water resource condition deterioration. This project recommends the development of strong participatory governance in both local government and catchment institutional arrangements as the most effective pathway to implementing resource protection. Implementation evidence comes from the Crocodile and Olifants River Catchments, and more recently in the Mzimvubu River Catchment, and is presented in the hand book: *How to establish and run a catchment management forum.*

The TPNP presents evidence that for the NWA principles of equity, sustainability and efficiency to become evident in widespread practice the DWS Institutional oversight process is critical. It is through the active participatory engagement between parties at a local level, through CMFs that integrated sustainability practices are embedded. The TPNP provides evidence of implementation of this in the Crocodile River CMF, the Upper Komati CMF, and is pioneering rural uptake in the formation of the Tsitsa River CMF. The TPNP points to similarly pioneering work in the Olifants River Catchment, as part of the USAID-funded project RESILIM_O.

It is important to note that the practical implementation pathways identified in the TPNP, have built on, and further developed, existing government programmes, so that national up scaling is feasible.

Institutional uptake and implementation

An exciting practical uptake and implementation pathway has emerged within the Department of Environmental Affairs: Natural Resource Management (DEA: NRM). In summary, the process to date has been as follows:
- DWS has plans to build two large dams on the Tsitsa River tributary of the Mzimvubu River Catchment, in the Eastern Cape. .
- DEA: NRM received a treasury allocation to undertake landscape restoration in the dam catchment so as to contribute to ensuring the catchment delivers as much water, with as little sediment as possible. (The soils of the Tsitsa River catchment erode easily and vegetation cover is already low is places, which means sediments can easily end up in the dam, reducing storage capacity.)
- DEA: NRM created a research and restoration programme: the Ntabelanga-Laleni Environmental Infrastructure Programme (NLEIP).
- Before the inception of NLEIP, the TPNP project understanding was communicated to DEA: NRM, in two-day Complex Social-Ecological system workshop, attended by DEA senior management (including the relevant Deputy Director General, Chief Directors and Directors).
- As a result NLEIP adopted an integrated, transdisciplinary, CSES-based model to guide the selection research and implementation projects (reference the NLEIP strategic plan).
- The UCEWQ research team was also awarded a research contract from the Department of Science and Technology (DST), via and NLEIP, to build a CMF in the Tsitsa River catchment. This was indirect recognition of governance development as a pathway to both participatory empowerment and sustainability (progress towards both social and environmental justice.)

So, for example – in the emerging Tsitsa River CMF, the TPNP-based research links livestock-based livelihoods with building consensus about how to practically protect hillside seep wetlands (which are critical key resources for late winter grazing and easily degraded), with restoration practices and public works livelihood options. The pathway to local sustainability is through both livestock owners and restoration workers becoming community members of the local CMF.

- Evidence of deepening uptake and implementation of TPNP concepts came 12-15 July 2016 when DEA-NRM held their six monthly MAREP (Management and Research Environmental Planning) workshop under the title "Implementing the complex social-ecological system approach". This time participants included regional managers of the practical restoration programmes administered by DEA: NRM and the question of engaging public works workers, NRM management and local communities was explore. Prof Tally Palmer was a keynote speaker, with Dr Harry Biggs, and she also ran the session of the role of governance and CMFs as pathways towards sustainability.

This work opens the opportunity for a key high-level engagement between DEA and DWS to agree that CMFs become cross-departmental forums for landscape sustainability.

- Regional DEA: NRM managers were actively responsive to the CSES ideas, welcoming attention to integrating the on-the–ground- restoration work with the social dimension of their teams, and local communities. While some fears were expressed about "losing the ecological" there was a demonstrable acceptance of the importance of integrating the social. A follow-up CSES training workshop for Eastern Cape NRM teams is planned for October 2017.

TPNP approaches ARE BEING IMPLEMENTED!

An emergent TPNP issue

During the TPNP research, the issue of house-hold water security emerged as critical issue, and the TPNP project will pro-actively include a hand book on: *How to make progress with water issues in smaller municipalities,* focussing on understanding the challenged facing local government in household water supply – and offering learnings from civil society engagement in Makana (next section). The TPNP project recommends considering ways to upscale tank-based household water storage as a critical interim measure to diffuse public outrage at interrupted, unreliable and absent water supply services.

These issues, and the project recommendations were presented and discussed at a WRC Water Policy Series Dialogue 22 August.

TPNP Case Study Progress

1) Makana Municipality

The work in the Makana Municipality has led to a significant governance breakthrough that is of interest to the DWS Chief Directorate, Institutional Oversight. In working with municipality, firstly from the perspective of household water security, because that was the point of community interest, we have been able to combine two parallel DWS institutional development processes: i) The Minister communicated to local government a directive that "water and sanitation" forums must be established to pay attention the public need for water security and sanitation; and ii) the on-going process of participatory governance through CMFS. In Makana we negotiated the establishment of a single Upper Kowie River Water, Sanitation and Catchment Management Forum and produced a draft terms of reference for this forum, was considered, discussed and accepted at a joint municipal and CMA-led workshop in October 2016.

Again, such institutional arrangements hold considerable promise for inter-governmental co-operation.

Towards practising a new paradigm approaches at the local government scale in respect of water issues will be presented in the hand book: *How to make progress with water issues in smaller municipalities.* Initial results have been published: Clifford-Holmes, Jai K., Palmer, Carolyn G., de Wet, Chris J. and Slinger, Jill H. *Operational manifestations of institutional dysfunction in post-apparthed South Africa*. Water Policy 18 (2016) 998-1014.

2 & 3) Crocodile and Olifants River Catchments (Mpumalanga/Limpopo)

At the start of the TPNP project it was envisaged that the USAID RESILIM_O project would feed directly into the TPNP, providing valuable lessons at the large catchment scale. Due to intellectual property issues, this learning exchange has been limited to two initiatives: i) jointly using the TPNP ontology in the Crocodile River to develop a technology for integrating water quality and quantity for application in CMA IWRM processes in the context of a partnership between the Inkomati-Usuthu CMA (IUCMA) and a group of industry partners and ii) using AWARD reports on the Olifants River in the consideration of scale that is central to the hand book: *How to think in a way that makes IWRM practically possible in South Africa.*

The water quality–quantity integration work was pioneered in the Crocodile River catchment in collaboration with the IUCMA, and with significant industry partnership engagement in the nature of the implementation process. The outcomes will be reported in the handbook: *How to integrate water quality and water quality in a Catchment*

Management Agency (CMA). The TPNP work in the Crocodile River catchment, in partnership with AWARD, was largely funded by an NRF-THRIP project, leveraged for application to the TPNP, and adding considerably to gathering evidence of implementation.

The capacity of a CMA to easily integrate water quality and quantity contributes significantly to an ability to develop and implement an Integrated Water Quality Management (IWQM) process. The Crocodile River work and the emerging Olifants River work contributed to the baseline consideration of developing a National IWQM policy and strategy, which is currently being developed. At a recent meeting with the service provider it was made clear that the TPNP approach will form the basis of conceptual understanding for the policy and strategy. Again – clear evidence of TPNP uptake and implementation.

COMPARATIVE TRANSDISCIPLINARY CASE STUDIES OF CHANGE TOWARDS ENHANCING WATER SECURITY PRACTICES IN THE EASTERN AND SOUTHERN CAPE, SOUTH AFRICA

Sponsor: National Research Foundation, Global Change Society and Sustainability Research Programme
CG Palmer
Project Dates: February 2016 – March 2018

This is a two year DEA project extension in the form of a supplementary grant. The project was motivated to complement the DEA: NRM NLEIP project. The new research question addressed is: How do the links between ecological infrastructure, restoration, and local rural livelihood practices in the Upper Mzimvubu River **enable participation in water governance**? This supplementatry grant partly supported the research of doctoral student Notiswa Libala, and enabled Honours student Ms Chloe Karstadt to extend an aspect of the doctoral research. In addition, as second honours project by Mr Martyn de Jong provided overview data for NLEIP Masters student Ms Margaret Wolff.

1) A comparison of supporting and regulating ecosystem services in eroded and non-eroded hillslope seep wetlands in the upper Mzimvubu catchment: Chloe Karstadt

Wetlands provide ecosystem services that support human wellbeing particularly to rural people living in a subsistence economy. Ecosystem services are damaged when wetlands erode, but very little is known about the vulnerability of hillslope seep wetlands to erosion. The aim of this research was to identify the vulnerability of hillslope seep wetlands to erosion and examine the impact of this on ecosystem services in a rural setting in the Eastern Cape, South Africa. Research was conducted through field work and Geographical Information Systems (GIS). It was

Hillslope seeps are green in the dry season

Hillslope seep vegetation cover measurement

Hillslope seep wetland soil core

found that there was no significant relationship between wetland size relative to its slope but that wetlands with a greater average slope were more eroded than wetlands with a lower average slope. Wetlands with a greater average extent were less eroded than wetlands with a smaller average size. Wetlands with a greater average vegetation cover were also less eroded than wetlands with a lower average vegetation cover. On average sites with no evidence of erosion, were evaluated as providing more regulating and supporting ecosystem services than eroded sites. It is evident from this research that there is a need to better understand the functioning of hillslope seep wetlands.

2) Exploring the potential role of Catchment Management Forums (CMFs) in the emerging Mzimvubu to Tsitsikamma Catchment Agency (CMA) in the Eastern Cape, South Africa: Martyn de Jong

The study explored the potential role that Catchment Management Forums (CMFs) could have in one of the nine Catchment Management Agencies (CMAs), the Mzimvubu to Tsitsikamma CMA (MT CMA), in the Eastern Cape of South Africa. South Africa has troubles with "difficult hydrologies". Troubles are due to the high level of needs and low ability to invest, in terms of institutional and infrastructure investment. Integrated Water Resources Management (IWRM) was encouraged at the Rio Earth summit in 1992 and at the World Summit on Sustainable Development (WSSD) held in Johannesburg. The National Water Act and the Water Services Act (No 98 of 1997) provides a legal framework which adopted IWRM at the catchment level through Catchment Management Agencies (CMAs). CMAs have been found to be more effective when working closely with CMFs which are not formally established under the National Water Act, although the minister may make regulations for consultative forums. Therefore, to explore the potential role of CMFs in the MT CMA, various workshops were held within the CMA. Data collected included recordings and 'concerns and actions' of the participants. The data was analysed using Cultural Historical Activity Theory (CHAT) to examine the potential role that these CMFs could have by analysing tensions between components which were discussed.

CMF Workshop Mthatha January 2016

Mr Brian Fortuin giving feedback at the CMF workshop, Mthatha January 2016

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), H Angala (Rhodes University, South Africa).
Project Dates: November 2016 – October 2017

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.

In a competitive call that sees 125 applications, five were funded, of which our Action Group is one of those funded. 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). Further compounding this reality is that poverty, inequality; social and environmental injustices pervade the African continent. While sustainable utilisation and protection of water resources is essential to addressing some of these social challenges, its achievement would require a fundamental shift in terms of managerial attitude and policy, particularly with regard to balancing and trading off values that influence criteria for water allocation to both society and the environment. How can equity, and social and environmental justice, in its broad sense of including human and ecological constituencies, be achieved in the allocation of water and in the management of water resources?

The Action Group proposes a Systemic-Relational (SR) perspective as an ethically grounded approach to water resource management. In taking the SR perspective, the Action Group will specifically develop processes and methodology that can be used to operationalise the SR perspective in relation to water resource management and practice, both at the catchment and transboundary (transnational) levels, using case studies within the context of IWRM. The SR perspective sees humans as an integral and inherent part of ecosystems and therefore, 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 – we conceptualise this as complex social-ecological system (SES).

Central to the SR perspective is the realisation that values exercise an important influence on the allocation of water for multiple uses and on prioritisation of what is considered important or not, in decision- making processes. The Action Group, taking the SR perspective, believe that a considered and ethically grounded water resource management approach and process should place the ultimate value at the social-ecological system level and that this should guide the development of criteria for balancing and trading off values in terms of water use allocation, participation and democratisation of decision making processes. The SR perspective to ethically-grounded water resource management is systemic, because it recognises that ecological and social components together form an integrated and dynamic complex system and it is relational, inasmuch as these two major components (and their sub-components) are in ongoing complementary and co-supportive interaction (Odume and De Wet 2016). In the practice of IWRM, specifically with regard to water allocation and decision making, the SR approach and methodology explicitly account for the interconnectedness, interdependence, and on-going dynamic interactions of the component of the SES, in which both components are accorded equal analytical and moral weightings.

The central principles of systemic-relational ethically grounded water resource management uphold the social-ecological system (SES) as a whole as having primacy in terms of value, and advocate the active and deliberate decentring of any of the SES components and their constituents /subdivisions in policy and practice. In moving towards a system- centred water resource management approach, The Action Group believes that there are far-reaching implications both in policy and practice. For example, policy would seek to give primacy to the management of the functionality and health of the entire system as an integrated and dynamic unit and to show an appreciation of, and due regard for, all the components of the SES and the different ways in which they interact. This in practice has not happened because it is indeed difficult in the sense that the system approach involves untying multiple knots concurrently, which may be time consuming and in most cases, managers lack experience to manage at the system level. The contribution of the Action Group in taking the SR perspective is to ensure that managers, policy makers and practitioners and academics recognise the complex nature of the SES and to take this into account in terms of the practice of IWRM.

Furthermore, in taking the SR perspective, the Action Group would also explore the role of alternative and new water sources such as greywater as a means of sustaining the health and functionality of the SES within the context of IWRM. The majority of greywater generated in informal settlements in Africa ends up in freshwater resources, and this has significant impact on the quality, health and functionality of the aquatic ecosystems. If the SR perspective, which upholds the primacy of the entire system, is to be followed, then discharges of untreated greywater must be reduced to the barest minimum, and innovative ways and solutions must be developed for testing the quality of greywater and for its reuse. In this regard, the Action Group would test the applicability of a low-cost hydrogen sulphide technology for the rapid testing of the faecal coliform counts in greywater.

Overall aim of the Action Group is to create new knowledge by specifically developing processes and methodology that can be used to operationalise the an ethically-grounded SR perspective in relation to water resource management

and practice, both at the catchment and transboundary (transnational) level.

Objectives:

Objective 1: Use the SR perspective to analyse and critique international case studies of IWRM, share lessons and synthesize knowledge for policy and practice. In the previous Water Research Commission project, four case studies were analysed, lessons learnt from the analyses will be shared with all members of the Action Group. Additional case studies will be identified and analysed as part of the Action Group work.

Objective 2: Actively co-create knowledge and strategies in terms of experimenting with the application of the systemic-relational perspective to ethically-grounded water resource management in terms of balancing water use for livelihood security and environmental sustainability. The South African government has planned to build a dam in the upper Umzimvubu River catchment, which is likely to flood the adjacent land and thus affect the livelihoods of the locals. As indicated above, we will demonstrate and test our ideas in this catchment. The flooding is expected to contribute to loss of livelihood in the form of grazing land. Prof De Wet has an extensive experience on displacement and resettlement arising from the impact of dams. In terms of knowledge co-creation, a team specific workshop will be organised.

Objective 3: Share the processes and methodology associated with the systemic-relational perspective with water resource managers and policy makers, and demonstrates the applicability of its orienting principles in on-the-ground water management through events, conferences, joint publications, policy and technical briefs.

Objective 4: Undertake the pilot testing of the hydrogen-sulphide test kits as a low-cost technology for testing the quality of water and greywater in terms of faecal coliform counts.

Objective 5: Organise a workshop at Southern African level for knowledge- sharing and training for managers and policy makers on the systemic-relational approach to water resource management. This would include a demonstration of the applicability of its orienting principles in on-the-ground water management, as well as the centrality of its ethical approach to integrated, fair and sustainable water management.

GENERAL CONSULTANCY PROJECTS

KENMARE MOMA WETLAND MONITORING

Sponsor: Kenmare Resources plc
NJ Griffin
Project Dates: April - October 2016

A slimes spill from a storage dam in northern Mozambique into a coastal wetland in 2010 threatened the health of the ecosystem, and an ongoing monitoring programme was instituted to assess the extent and severity of the impact. This year's trip contributed to ongoing monitoring of impacted sites with assessment of other potential impacts as identified. The biomonitoring approach selected was based on multivariate comparison of wetland macroinvertebrate communities.

The 2016 results confirmed that the wetland had recovered from 2010 spill as sites impacted by the spill could not be distinguished biologically or physicochemically from sites that were not affected. Notable impacts owing to an apparently diesel leak at one site that were reported on in 2014 were absent in 2016. Finally, the loss of product to the wetland noted at one site in 2014 was found to be ongoing, and recommendations for management of this issue were made.

Sample site in the Topuito wetland in Nampula, Mozambique

WATER AND SOCIETY PROJECTS

THE ROLE OF ENVIRONMENTAL ETHICS IN SOCIAL-ECOLOGICAL SYSTEMS AND WATER RESOURCE MANAGEMENT

Sponsors Water Research Commission
CJ de Wet and ON Odume
Project dates: April 2014 - March 2016

Despite developments in water resource policy, law, monitoring, regulation, management and research, the health and functionality of South African aquatic ecosystems continue to deteriorate. At the same time, there is a growing recognition that humans are integral components of complex social-ecological systems; as such, their beliefs, values and actions have direct implications, whether intended or unintended, for the environment. Human values are integral to the management of natural resources. This research project set out to review the field of environmental ethics in the context of trans-disciplinary research methods, so as to link ethical thinking and practice to current and emerging practices in integrated water resource management (IWRM).

A distinction which has been fundamental to this project, is that between morals or values, and ethics. Morals and values are here taken to refer to what specific individuals or groups of people believe to be good or bad, such as polygyny, or eating meat, or whatever. Ethics are taken to refer to a systematic concern with the principles by which we seek to distinguish between right and wrong in our behaviour towards other people and towards nature. Thus, we can look to the development of agreed ethical principles for water resources use, protection, and management, while providing guidelines that point to accommodating a plurality of individual and group morals/values.

This is extremely important in South Africa, where our historical context has its own ethical imperative to effect transformation towards social justice, which is inextricable from environmental justice. In a highly plural society, the needs and desires of people will differ widely. This project has reviewed research and presented options for developing ethical thinking and practice in IWRM that will assist us in moving towards the realisation of the values of equity, affordability and sustainability, and thus of the priorities of social and environmental justice, as set out by the National Water Act, No 36 of 1998. It has also sought to move beyond the thinking behind the NWA.

The project has been completed, and has submitted reports to the Water Research Commission, which have focused upon

- A literature review of the major theoretical approaches to environmental ethics, as well as of key legislative and administrative provisions in the South African water sector, and of the main values (including equity, sustainability and efficiency) driving these provisions.
- A detailed analytical review of the successes and failures relating to the application internationally of environmental ethics in water management in four different case studies, in: Bangladesh, India, South Africa and the USA.
- An investigation of the relationship between environmental ethics and aquatic ecosystem health. The key finding in this regard was – that, while it is a human construct – ecosystem health needs to be seen within the context of the social- ecological system as a whole.

The Final Report, entitled: "The Role of Environmental Ethics in Social-Ecological Systems and Water Resources Management", was submitted to the Water Research Commission in March 2016. The central argument to emerge from this project is that the social-ecological system needs to be conceptualised and analysed as an integrated complex system - without prior analytical weighting being accorded to any of its components. And that this has correspondingly significant ethical implications for our approach to water management, viz that it is the social-ecological system as an integrated unit, that should be regarded as the central good, or value, to be pursued in seeking to understand ,evaluate, or manage, the social-ecological system, or its components. This perspective has the potentially controversial implication that it requires the conscious and active de-centering (i.e. de-prioritising) of any particular component of the overall social-ecological system, including the human component. The Final Report puts forward a set of principles which the authors see as fundamental to a systemic-relational ethical framework, and makes suggestions for its application, in both policy and practical terms, to water resource management.

The Final Report has been approved and published on the WRC website (in April 2016, as Research Report Number 2342/1/16), together with a summarising Technical Brief, entitled: " What Role for Environmental Ethics in Water Management?"

POSTGRADUATE ACTIVITIES

A NOVEL TRAIT-BASED APPROACH TO BIOMONITORING AND ECOTOXICOLOGICAL EVALUATION OF THE RESPONSE OF SELECTED MACROINVERTEBRATE TAXA TO SEDIMENT EFFECTS.

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

The freshwater ecosystem in South Africa faces serious and constant sediment delivery problems which are mainly carried in fluvial system during high soil erosion. Soil erosion and erodibility of top soil is considered to be a major problem in South Africa. Previous research has indicated that over 70% of the country surface is affected by different intensities of erosion. The top soil freshwater ecosystem in South Africa is highly erodible partly due to the semi-arid nature of the country and other land use practices related to livestock overgrazing.

The process of sediment deposition and erosion in the aquatic ecosystem is regarded as a natural process of the hydro-geomorphic process freshwater ecosystem. However there is a certain amount of sediment necessary for the normal functioning of the freshwater ecosystem, excess loading of which the negative impacts of sediment are expressed. The effects of this sediment load goes beyond the impact on water quality and aquatic biota living in the streams and rivers, it also has cost implications. Fine sediment effects on macroinvertebrates have been classified into direct and indirect effects. The direct effects include clogging of feeding and respiratory apparatus, abrasion and burial. The directs effects has been related to modification of habitats, reduction in the availability and quality of food and alteration of food chain and increased drift.

This study therefore, aims at assessing the effects of elevated sediment on water quality of freshwater resources. Certain objectives have been chosen to achieve this aim: (1) evaluating the community structure of macroinvertebrates specifically the Ephemeroptera, Plecoptera, Odonata and Trichoptera (EPOT) (2) evaluating the community composition of selected traits of the EPOT species, (3) assessing the vulnerability of EPOT traits to sediment effects and (4) assessing the ecotoxicological response of selected traits of the EPOT taxa to fine sediment particles. The macroinvertebrate will be used for the study and this is largely because they reflect the health of the ecosystem in which they inhabit. A trait-based approach to biomonitoring and Ecotoxicological approach will be applied in this study. Trait-based approach will be used because it is a more robust approach to biomonitoring than the current biomonitoring approach used in South Africa, which examines the community structure of macroinvertebrates. It is perceived that assessing the traits of macroinvertebrates, has a more diagnostic ability in terms of detecting the source and cause of impact, i.e. more stressor predictive and can provide a better understanding of the link between ecosystem structure and function.

In this study, sampling of sediment (suspended and settled) will be done in eight selected sites and analysed using the Malvern Mastersizer 3000 particle diffraction analyser into different particle sizes. The South African scoring system version 5 (SASS5) will be used in the sampling and identification of the macroinvertebrates. The sampled EPOT taxa will be analysed in the laboratory, identification will be done to possible species levels. Different multimeric indices will be applied for the analysis of the community structure of the EPOT taxa for the eight study sites.

It is expected that the result obtained from this study will reveal the impact of elevated sediment delivery on water quality of firewater resources and also to delineate the importance of using a trait-based approach to biomonitoring as an additional tool for managing the health of freshwater resources.

Sampling of macroinvertebrates (EPOT) for the study outside Maclear

EVALUATION OF LOW-COST TECHNOLOGY OPTIONS FOR SUSTAINABLE WATER SUPPLY AND SANITATION IN TWO PERI-URBAN AREAS OF LUSAKA, ZAMBIA

Student: Y Chiliboyi
Supervisors: PK Mensah and CJ de Wet
Degree: MSc (Water Resource Science)

In developing countries, Zambia inclusive, access to safe water and sanitation services is a major challenge for millions of peri-urban residents. Presently, at least 70% of the total urban population in Zambia resides in peri-urban areas. Peri-urban settlements are characterized by among others high population growth, high poverty levels and inadequate access to water and sanitation which often result in increased prevalence of diseases. The situation is even made worse because of the position that many local authorities have taken with regard to the implementation of infrastructure and service development in these settlements. Local authorities in developing countries have continuously focused on implementation of traditional and unsustainable technologies for service provision to meet the demand despite the technologies' inability to serve the rapidly growing peri-urban areas. These technologies have high costs, lack proper operation and maintenance, and are not affordable to majority of peri-urban residents. Given the shortfalls of the traditional water supply and sanitation infrastructure currently implemented by local authorities, there is need to explore a variety of appropriate, low-cost and sustainable technologies for the provision of water and sanitation in peri-urban areas. This notwithstanding, it is important that any technology intended to be used by people, especially those living in peri-urban communities, is subjected to a sustainability analysis in order to ensure maximum benefit of the technology. Therefore, understanding the conditions of an area such as local socio-economic conditions, local perceptions and preferences, population size, technical, environmental and institutional aspects will help local authorities plan for water and sanitation facilities that are sustainable.

Therefore, this study was set out to identify and evaluate the existing and possible low-cost technology options for sustainable water supply and sanitation in two selected peri-urban areas of Lusaka, Zambia. This was achieved through a household survey conducted in the selected communities. Questionnaires and focus group discussions were held in the respective areas to obtain baseline data on the current water supply and sanitation situation, the type of technologies used, challenges faced with regard to water and sanitation technologies, and to get the communities perceptions and preferences of the presented feasible technology options. Thereafter, a multi-criteria analysis methodological approach was used to assess the selected technologies by the communities, taking into consideration of the economic, social-cultural, technical, institutional and environmental aspects. The study forms an important basis for proper planning of sustainable water supply and sanitation services in dynamic environments such as peri-urban areas, and also aids in policy formulations and implementations by the government of Zambia for safe water supply and sanitation services.

DRAWING ON PRINCIPLES OF DANCE MOVEMENT THERAPY PRACTICE IN A SOUTH AFRICAN WATER RESEARCH CONTEXT

Student: A Copteros
Supervisors: CG Palmer, R Fox and V Karkou
Degree: PhD

Research that draws on principles of Dance Movement Therapy in a South African water research context has not been done before. In order to initiate this exploration, culturally relevant themes from professional training in the United Kingdom were identified that could be developed in the context of trans-disciplinary water resource management research in South Africa. Hermeneutic phenomenology provided the methodological framing for this study. Interpretative Phenomenological Analysis was used to discover culturally relevant themes based on the recorded perceptions of the phenomenon of the training while it was taking place. The themes of: 'awareness of power and difference'; 'therapeutic adaptability'; 'safety and ownership' and 'connecting with the environment' emerged as overriding themes. Influences from Artistic Inquiry informed the inclusion of a creative embodied response to the themes that emerged.

These themes then informed the application of some relevant principles of Dance Movement Therapy practice within a trans-disciplinary complex social-ecological systems researcher group. Eight members of the group participated in the study. They represented a range of academic research roles, genders and backgrounds. They reflected on their experience of an introductory session and five Dance Movement Therapy based sessions in semi-structured interviews. Using Interpretative Phenomenological Analysis, four themes were identified that capture the quality of the participants' shared experience of the phenomenon: 'community engagement'; 'embodiment'; 'individual and group identity' and 'integration'.

Based on the integration of the themes emerging from the two research objectives, it is concluded that principles of Dance Movement Therapy have a contribution to make to a South African water research context. Core tenets of Dance Movement Therapy such as: inclusion of body and emotion; healing from trauma through embodiment; group processes held with safety and acceptance; and a deep level of connection to self, each other and the wider ecology, address some of the basic challenges of trans-disciplinary complex social ecological systems research practice. The

non-verbal, heuristic and egalitarian nature of Dance Movement Therapy bodes well for its on-going development and adaptation within a South African context.

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 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 will be tested and calibrated using available erosion estimates and dam sedimentation data from previous erosion studies. The model will also be validated under a wide range of different catchment conditions including climate, topography, vegetation and soils. This entails the selection of study catchments across the entire country to capture the varying physical and vegetation characteristics. Notable is that attention will 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. It is envisioned that the sediment transport model will form part of the Water Quality Systems Assessment Model (WQSAM).

DYNAMICS OF RANGELAND PRODUCTION AND WATER USE

Student: O Gwate
Supervisors: AR Palmer and SK Mantel
Degree: PhD (Water Resource Science)

The research focuses on determining dynamics in rangeland production and water use. The study will model evapotranspiration and rangeland production in grasslands affected by invasive alien plants. Understanding trajectories in these across environmental gradients provides an insight to the potential of ecosystem services. In developing scenarios that can convince land users to change their behaviour and land use patterns, it is essential to have an empirical understanding of water use of each component of the ecosystem. Hence, the study will show how decisions on land use options can affect the type, magnitude and mix of services and goods provided by that ecosystem. It will also show what consequences land use trade-offs may have for the people dependent upon them.

MINING AND BIODIVERSITY IN THE UPPER KOMATI CATCHMENT: CONTESTATIONS IN A COMPLEX SOCIAL-BIOPHYSICAL SYSTEM

Student: T Keighley
Supervisors: CG Palmer and AV Munnik
Degree: MSc (Water Resource Science)

Mining in South Africa plays an essential role in the country's economy. However mining (specifically coal mining) is also one of South Africa's most contentious water users and in many cases has proven to be environmentally destructive (e.g. in relation to acid mine drainage); and its practices unsustainable. A major concern is coal mining's negative impact on the biodiversity of the country and the associated ecosystems. These ecosystems, also referred to as ecological infrastructure, provide an array of goods and services to the natural environment and surrounding communities' well-being (economically and quality of life). Examples of what is argued to be one of South Africa's most important, yet threatened ecosystems are wetlands. Wetland ecological infrastructure, as well as most ecosystems (aquatic and terrestrial), is not only vulnerable to mining, as other land uses have proved to have consequential impacts too. However conflicts and concerns have indicated that other land users and uses have too been impacted by mining activities. Therefore, an avenue to ensure the long term sustainable and natural flow of benefits from the landscape, in relation to mining, an understanding of conflicts, opinions, and extent of knowledge, of the different land users and uses is required. With this knowledge future planning can consider careful location and management options for greater sustainable land use and conservation of biodiversity and ecological infrastructure.

A prime case study reflecting the above scenario of ecological infrastructure protection and land use activities, is the well explained incident of acid mine drainage impacting many aspects of biodiversity and community in Carolina, Mpumalanga. The Carolina X11B catchment is a highly used landscape- including land use activities such as: dry land agriculture, livestock grazing, mining, and is part of a water transfer scheme- each contributing

towards the cumulative impacts of the subcatchment. A vast network of wetlands, streams, and springs are also allocated in the subcatchment, making the region a good example of varying contestations within such a complex social-biophysical system. Therefore using wetlands as a key indicator of ecological infrastructure and a nexus of contestation my thesis aims to explore mining, agriculture and wetland ecological infrastructure in the Upper Komati River Catchment taking account of the contestations in this complex social-ecological system.

With a complex social-ecological systems focus, the study is using a transdisciplinary approach to collect data. A contextual analysis of the case study was provided by looking at wetland health and ecosystem services along with the use of user perceptions. Limitations of the methodology used lead me to deepening an ecological understanding of wetland impacts, therefore water chemistry and macroinvertebrate community structures were used. The results of this deeper understanding indicated mining influences, but proved ambiguous in demonstrating coal impacts relative to the role of coal and agricultural in the contestation. The results and understanding from the project along with the use of information derived from a geological based project, it was recommended that in order to protect wetlands and ecological infrastructure we must map remaining hydroconnectivity of a catchment and to stop mining activity all together.

USING A SOCIAL-ECOLOGICAL PERSPECTIVE TO INVESTIGATE THE RESILIENCE AND VULNERABILITY OF SEEP WETLANDS ECOSYSTEM FUNCTIONALITY IN THE UPPER MZIMVUBU RIVER CATCHMENT, EASTERN CAPE, SOUTH AFRICA

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

In South Africa, ecosystem services, particularly in rural areas, are increasingly being subjected to enormous pressure as the demand for social and economic development come into tension with environmental sustainability. Human activities continue to alter the environment on local and global scales, and these alterations are leading to changes in ecosystem structure and function, as well as the composition of biotic communities. Wetland seeps are critical and fragile wetland ecosystems, capable of suppling ecosystem services such as biomass production for grazing. In the upper Mzimvumbu River catchment, wetland seeps are among the critical wetland ecosystems that supply biomass for grazing throughout the year. In the absence of appropriate management strategy and a lack of scientific understanding of the functionality of these ecosystems in terms of their biodiversity-ecosystem functioning, they are disappearing at an increasing rate within the catchment.

Studies established that species losses and subsequent changes in biodiversity can decrease the resilience of ecosystem after a disturbance. It also has been indicated that the response of ecosystem to anthropogenic disturbances, such as grazing, depend on individual species traits and species interactions within a community Therefore, this research will focus on understanding the resilience and vulnerability of seep wetlands ecosystems functionality to disturbances, particularly grazing in terms of biodiversity and the supporting landscape and also engage Cultural Historical Activity Theory (Engeström, 2000) to understand human activities such as livestock grazing, ecosystem structure and functioning.

A social-ecological framing, taking a perspective that takes the overall system as an integrated unit, whose natural and human components are mutually constitutive and co-supportive will be used in this project. Biodiversity resilience and vulnerability in terms of continuing supply of selected ecosystem services e.g. productivity and biomass for grazing, will be evaluated. At the landscape level, the resilience and vulnerability of seep ecosystem to erosion will be evaluated, with a clear focus on erosion and anthropogenic activities such as grazing pattern and associated activities. Factors that could potentially contribute to the resilience and vulnerability of the small rural community in the study area will be investigated in relation to livestock grazing and seep ecosystem functionality.

Methods drawn from both natural and social sciences will be combined in this study as this is an approach that allows the advantages of both the quantitative and qualitative research methods to be utilized in a complementary manner, thus allowing a more comprehensive, in-depth appreciation of the research problem, as well as merging the results from both sides so that the comparison could be made. Eleven Wetland seeps have been selected in the study area. At each seep, basic soil physical and chemical properties will be measured. Patterns of vegetation composition distribution will be evaluated. Wetland Seep ecosystem functioning linked to grazing indices such as productivity, will be investigated. Relevant vegetation functional traits linked to seep functioning will be used to evaluate wetland seep resilience and vulnerability to grazing. In order to understand factors that could potentially influence the human community resilience and vulnerability in relation to availability of grazing land, social science methodologies, including focus group discussion, workshops, interviews and questionnaires will be used.

The overall aim of this project is to use a social-ecological perspective to investigate the resilience and vulnerability of hill slope seep ecosystem functionality. In order to achieve this aim, the following objectives have been set for the project:

- To provide basic soil characteristics of the selected

seep ecosystems as well as their pattern of vegetation community structure
- To investigate the potential resilience and vulnerability of the selected seeps vegetation to livestock grazing using the functional trait approach.
- 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.

Cattle grazing on a seep wetland

Soil sample collection in a seep wetland

CLASSIFICATION OF LARGE WETLANDS IN AFRICA'S ELEVATED DRYLANDS BASED ON THEIR STRUCTURE AND FORMATION USING EARTH OBSERVATION (EO) APPROACHES

Student: Z Lidzhegu
Supervisors: W Ellery and SK Mantel
Degree: PhD (Water Resource Science)

The current research on the geomorphic origin of Arica's large and inaccessibly wetlands. The study uses Geographic Information Sciences (GIS) desktop methodology and Earth Observation (EO) datasets. The project aims to classify large wetlands in Africa's elevated drylands based on factors that determine their formation and shape their structure and hydrological functioning. There is a lack of knowledge and understanding of large wetland's geomorphic origin, structure and hydrological functioning in Africa's elevated drylands. This knowledge gap is exacerbated by challenges such as the continent's aridity, topographic anomalies, and the size and inaccessibility of these wetlands. Since potential evaporation rates greatly exceed precipitation rates and channels are in a long-state of incision as a result of the topographic anomalies, one would expect these conditions to militate against wetland formation. Yet, the continent hosts some of the world's largest wetlands. Although, there are models that have been developed in South Africa to explain the formation of wetlands and classification schemes that group wetlands into functional groups, most of these models and classification schemes cannot be adopted for these large wetlands. Therefore, the current study, is designed to bridge the existing knowledge gap by providing an in-depth understanding of the geomorphic origin, structure, and hydrological functioning of large wetlands such as the Lufira, Kafue, Barotse, Lukanga, Bahi, Busanga, Wembere, Usangu, Luapula, and the Upper Zambezi wetlands.

HYDROLOGICAL MODELING OF CHANNEL WETLAND EXCHANGES IN DIFFERENT LANDSCAPE SETTINGS IN AFRICA

Student: E Makungu
Supervisors: DA Hughes and SK Mantel
Degree: PhD (Hydrology)

Large African river basins contain substantial wetland areas, and understanding the interactions between channels and wetland is a challenging task especially in data-poor basins. Large scale hydrological models with channel-wetland function are suitable for modelling river basins of this kind, however, it is difficult to establish some parameters in data scarce areas. A combined modelling approach that allows the detailed understanding of channel-wetland exchange processes to be obtained from a hydraulic model and use this understanding to parameterise a basin scale (courser time and space resolution) hydrological model is used. The simulated results from a basin scale model are used

to identify the impacts of wetlands on downstream river flow regimes. Since wetlands with different characteristics are expected to function differently, the study focused on three river basins in southern Africa with substantial wetland areas. The overall significance of this study is to improve understanding and efficient modelling for practical purposes at the basin scale.

MACROINVERTEBRATE ASSEMBLAGE RESPONSE TO SALINITY DUE TO ANTHROPOGENIC IMPACTS IN THE KAT RIVER

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

All South African rivers, including the Kat River, are facing the challenge of deteriorating water quality due to anthropogenic activities. The Kat River catchment 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. In the early 1980s, commercial farming of citrus was threatened by high salinity due to decreased water in the river. Therefore, the aim of this study is to evaluate anthropogenic activities impacts on salinity of Kat River and propose appropriate salinity management strategy for the catchment. The study applies biomonitoring of macroinvertebrates and diatoms to assess anthropogenic impacts on salinity of the Kat River. Cultural Historical Activities Theory (CHAT) was used as a framework to investigate farming activities that may impact on salinity of the river water. The combined findings of biomonitoring and CHAT will be used to formulate good management practices for salinity in the Kat River catchment.

Biomonitoring of macroinvertebrates and diatoms, as well as collection of water samples (for physicochemical parameters analysis) from five sites along the Kat River have just been completed. Biomonitoring and water sampling were done bimonthly over one hydrological cycle (December 2015 - October 2016). Currently, biomonitoring records and water samples are being prepared for analysis.

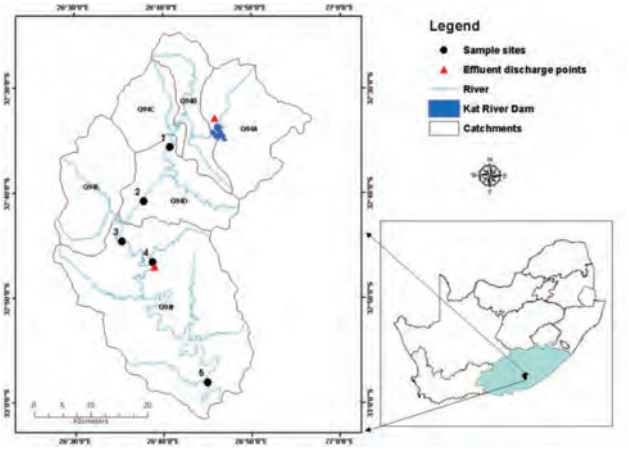


Figure 1: The Kat River, showing sampling sites and geographical setting of the Kat River Valley Catchment within Eastern Cape Province, South Africa

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

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

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

THE DEVELOPMENT OF MACROINVERTEBRATE-BASED NOVEL APPROACHES FOR EVALUATING AND PREDICTING FUNCTIONAL AND STRUCTURAL ECOLOGICAL EFFECTS OF SEDIMENTS IN SELECTED S.A RIVERS.

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

Globally, scientific approaches, institutional arrangements and regulations have been made to manage aquatic ecosystem properties such as structures, functions and processes. However, there is still increasing degradation of freshwater ecosystem in South Africa (Lecerf and Richardson, 2010). Sediments loads have been long recognized as the contributing factor in aquatic ecosystem structure and function (Elis, 1936). In assessing freshwater ecosystems few approaches are currently used in South Africa which includes biomonitoring and ecotoxicology; these only protect the structure such as in freshwater ecosystems abundance of macroinvertebrates indicates the health of streams, however, this does not imply in ecosystem function. Species traits need to be considered such that ecologists need to understand the relationship between macroinvertebrates and their environment (Verberk et al., 2013).

In this study, the environmental problem is sedimentation which alters water quality and impact macroinvertebrates that inhabits the streams. Elevated sediments impact macroinvertebrates in 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.

Project Aims

- Evaluate sediments effects at multiple levels of structural biological organisation in order to make recommendations for management.
- Develop a conceptual framework for using trait information for assessing effect of sediments.
- Evaluate sediments effects on traits linked to ecosystem function.
- Develop a trait-based predictive and diagnostic model for understanding macroinvertebrates response to elevated sediments.

This project aims 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 traits, an important aspect of ecosystem function (Kefford et al., 2012). Species traits offers opportunity for developing better methods and approaches for linking ecotoxicology and 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.

Collection of macroinvertebrates and water samples at the Little Pot River, Maclear, Eastern Cape.

UNCERTAINTY ANALYSIS IN COUPLED HYDROLOGICAL AND HYDRODYNAMIC MODELING 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 is 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 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 measurements are associated with a high cost and time-consuming, the EO data is 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 covers 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 (Figure 1). 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 deals with disaggregation of the simulated monthly discharge to daily discharge using both observed ground and satellite rainfall. The last stage will focus on flood hazard and floodplain storage dynamics assessment using an integrated 1D-2D hydrodynamic model (LISFLOOD-FP). 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 policy makers, communities and individuals.

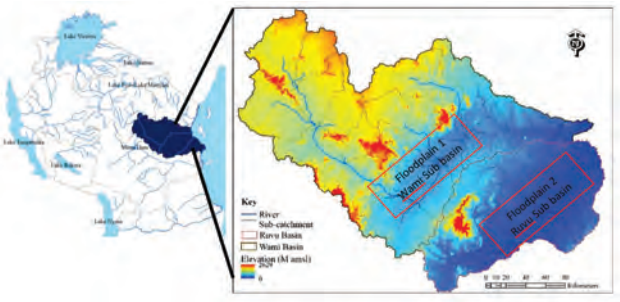


Figure 1: Location of Wami-Ruvu basin in Tanzania

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 (Hydrology)

South Africa is considered a semi-arid country receiving and average annual rainfall of ~460mm, which is approximately half the average annual rainfall for the world. Groundwater is therefore an important water resource in South Africa and many towns were, and still are, established in areas with high-yielding aquifer systems and/or natural springs. Aquifers naturally recharge, however if extraction of groundwater occurs at an unsustainable rate, irreversible changes may impact the system. Likewise contamination from either human-induced or natural factors can result in groundwater resources becoming unusable. It is therefore imperative that constant monitoring and assessment of these systems is done which will allow for appropriate management strategies to be introduced.

In 1986 Andrew Stone produced a scientific report relating to the groundwater system in the town of Grahamstown. No directed research or monitoring has been done since and therefore the basic aim of my study is to 'update' these records and gain a deeper understanding regarding this hidden resource. Grahamstown is situated on deformed, metamorphosed Cape Supergroup rocks (primarily quartzite, shale, sandstone) that have been folded and fractured. Overlying younger Dwyka glacial tillites, belonging to the Karoo Sequence, are also relatively abundant in the study site. A unique Grahamstown Silcrete Formation can be found in the region which formed through progressive chemical weathering and leaching over many years, forming a silica-rich 'cement'. All these formations and rock types, together with their structural

characteristics, have the ability to significantly alter the chemistry and movement of the groundwater.

A conceptual model of the system will form the foundation of the hydrogeological investigation. This will be built by gathering sufficient, reliable data and information as to develop a thorough understanding of how the groundwater system works. As the study evolves, and more data is collected, the conceptual model may also change as new ideas are reviewed. Key aspects that will form the conceptual model involve examination of maps (aerial, topographical, geological, hydrogeological), continuous monitoring of borehole water levels to investigate how the system responds to rainfall fluctuations, identification of local surface water bodies (dams, rivers, streams) and their effect on the water balance, the role of fracture networks and other structural controls as well as the influence of different geological formations on aquifer characteristics. Groundwater quality analysis will also provide a hydrogeochemical input that will aid in better understanding the water-rock interactions taking place in the subsurface and therefore the movement and residence time (age) of local groundwater.

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 discharge monitoring of the spring will aid in assessing its relation to the local groundwater system as well as its response to rainfall events. If the spring proves to be connected to the groundwater system (rather than directed fracture flow above the water table) then it can be used as a type of 'mini-model' which will subsequently result in a greater understanding of the larger conceptual model. In due time a basic 3D software model will be developed using a program such as ArcGIS or SketchUp. This model, together with a physical fracture model, will hopefully provide a fairly accurate 3D visualisation of the system, leading to greater understanding.

Groundwater systems are hidden and often believed to be an unlimited resource. Through this research a knowledge base will develop that can enable local resource managers to establish sustainable practices that will lead to the preservation 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)

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. Palmi*et* is thought to assist in controlling floods and improving water quality of rivers.

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 at Kompanjiesdrif in the upper part of the sub-catchment. The proposed study will investigate the catchment hydrology using an integrated approach as surface water and groundwater are thought to be significant within the upper Krom River catchment, and there is a strong possibility that the wetlands are groundwater dependent. The aims and objectives of the masters study include:

- Determine the surface and groundwater dynamics of the Kromme River upper catchment (K90A).
- Identify the relationship between wetlands and hydrological functioning of the catchment.

COAL MINING AND BIODIVERSITY IN THE UPPER KOMATI RIVER CATCHMENT: THE ROLE OF MINING PRACTICE

Student: G Thomson
Supervisors: CG Palmer and AV Munnik
Degree: MSc (Water Resource Science)

Mining is one of the most contentious water users. The mining sector has assumed that promises of economic growth and job creation will enable environmental concerns to be by-passed with as little interference as possible. More recently, the reality of legacy issues related to the inappropriate sign-off of mining sites has become increasingly clear, with acid mine drainage (AMD) being

a prime example. There are also increasing concerns regarding uncontrolled prospecting.

Climate change is one of the major issues faced in the 21st century, with predictions of heightened water stress for the Southern African region. This coupled with increased population growth is putting a massive strain on the water resources currently available, making it vital to better protect and ensure the longevity of our water resources.

The Carolina Crisis of 2012 highlighted the importance of protecting our water resources, and how easily it can be contaminated to a point where it is not usable. The Carolina crisis supplied researchers with a suitable study site to better understand the role mining operations have in a catchment that has experienced a major pollution incident, and what changes have occurred since.

In order to understand coal mining practice in relation to regulatory provisions, this project critically explored the processes involved within the mining sector, from 'cradle-to-grave', which is known as the coal mining life cycle. In addition, the composite suite of requirements of all the legislative provisions involved in the industry were investigated and the relationship between coal mining practice and environmental protection was explored.

These elements were researched in the Upper Komati by means of a framework called Cultural Historical Activity Theory (CHAT), which gives a holistic understanding of the above-mentioned processes. Cultural Historical Activity Theory also sheds light on the issues, gaps and overlaps currently being experienced in the coal mining sector, and refers to case studies of where these issues have caused environmental degradation.

A complete mining lifecycle in terms of regulatory provisions was compiled, where major issues were uncovered with current legislation in the mining sector that can contribute to the degradation of the water resources in South Africa.

An integrated water resource quality management plan is needed in order to streamline conservation mandates, identify and reduce duplication of effort and specify roles and responsibilities of authorities involved with decision making process. A Decision Support System (DSS) has been proposed, which would involve adaptive, participatory and inclusive management.
This thesis has been submitted and awaiting comments.

ECOLOGICAL RISK OF ACID MINE DRAINAGE (AMD) IN A SALINISING LANDSCAPE

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

Acid mine drainage (AMD) continues to threaten water quality in freshwater ecosystems around the world. It is usually characterised as acidic water with increased levels of metals such as manganese, aluminium and sulphates. The composition and concentration of metals in AMD depends on the mineral deposits from which the drainage originates. The process of AMD generation occurs under natural conditions when the geologic strata containing pyrite and other sulphide bearing minerals are exposed to water and oxygen. In most cases, *Thiobacillus* bacteria speeds up the reaction of the sulphide materials, although it is generally a long process for AMD to manifest under these natural conditions.

Mining activities, predominantly coal and gold mining in South Africa, usually exacerbate the formation of AMD when pyrite rocks are fractured. The fracture of pyrite causes it to oxidise when it has been exposed to oxygen and water. Both working and abandoned mines generate AMD - that can last for centuries or millennia. Occasionally, mine water contains adequate concentrations of calcium and magnesium due to dolomite dissolution that can neutralise the acidity generated during the oxidation of pyrite. However, neutralisation of the acidic water is not entirely effective especially when the surrounding rock contains higher proportions of pyrite than dolomite rocks. Whether neutralised or untreated, AMD released from mining activities ends up in streams due to run-off or seepage into underground aquifers which potentially poses ecological risks to aquatic life. The degree of risk depends on the buffering capacity of the receiving streams and dilution. AMD may cause changes in community structure of species in an ecosystem, which could potentially affect their stability and resilience.

Apart from AMD dilution in receiving streams, pH influences the availability and the breakdown of metals. When acidic water enters a stream it increases the solubility of many metals including lead, copper, cadmium, aluminium and nickel. Metal concentrations tend to increase downstream and can be taken up by organisms, build-up in their system or bio-magnify in higher trophic organisms. Despite the pH changes, sulphate concentrations remain unchanged and are toxic to aquatic organisms. These factors suggest that AMD is therefore a complex composition of whole effluent mixture and presents ecological risks in aquatic ecosystems.

Understanding AMD toxicity as whole effluent in aquatic systems can provide robust and important insight for management of mine water. Although individual contaminants such as salts or metals have a specific impact on aquatic organisms, their effect may be aggravated in receiving streams when added in combination, as occurs in AMD. Toxicity testing of whole effluent (WET) can provide important information as synergistic effects. Relating the effects to the potential toxicological impacts of the AMD is often a challenge as different mines produce different effluents. WET tests help to identify and characterise toxic effects of effluents in ecosystems. Although WET testing does not reliably predict effects in receiving ecosystems,

they are an important first step in risk assessment. WET testing also provides important end points especially when more than one test organism is used during the exposure tests.

Potential impacts of AMD produced during mine activities need to be considered in water management. WET studies are generally limited in scientific studies despite being supported and used in consultancies for governments and private entities. For South Africa in particular, it may be mandatory to conduct toxicity testing to license effluent discharges.

This study is aimed at understanding the ecological risk of AMD in a salinising landscape using the species sensitivity distribution (SSD) approach. The SSD is a common approach used in environmental risk assessment worldwide and is a major analysis used to derive water quality guidelines commonly aimed at protecting over 95% of the species found in a community. The study uses SSDs to estimate protective concentrations for sulphate inorganic salts ($MgSO_4$, Na_2SO_4 and $CaSO_4$) as models for freshwater salinization due to mining. Protective concentrations are important to determine safe dilutions for mine water discharges from treatments processes. These are precursors to designing appropriate freshwater monitoring programs aligned with the protection of water resources as stipulated in the South African National Water Act (Act No. 36, 1998).

Collecting acid mine water (AMD) in Carolina, Mpumalanga

Ecotoxicology experiment at the Institute for Water Research.

THE ROLE OF CIVIL SOCIETY ORGANISATIONS IN REALISING DEVELOPMENTAL IWRM: COMMUNITY CAPACITY BUILDING, CATCHMENT MANAGEMENT FORUMS AND A CATCHMENT MANAGEMENT STRATEGY DEVELOPMENT

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

My research focuses on the role of civil society organisations (CSO) in integrated water resource management (IWRM) processes. From 2014 – 2015 I conducted my masters research on the emergence and practice of a group of citizen based research partners, Water for Dignity (WfD), in response to household water service delivery issues in Grahamstown East (the township of Grahamstown). I further explored the enabling and constraining factors to WfD practice as well as the process of learning of the WfD group. In 2016 I went through the process to upgrade my masters degree to a doctoral level. The expanded doctoral research draws on understandings of CSO function (particularly principles relating to enabling effective practice and learning) to explore the role of CSOs in IWRM processes, namely the development and function of Catchment Management Forums and civil society contributions to the development of a Catchment Management Strategy.

South Africa strives to achieve water resource management that is equitable, sustainable and efficient. One of the strategies to achieve this vision has been to decentralise water resource management to the lowest level of government. Another strategy has been to strive for an integrated (involve all interested water stakeholders) approach to water management, so that all stakeholders have a say in how their water is managed. To realise Integrated Water Resource Management, the Department of Water and Sanitation (DWS) has divided the country into 9 Water Management Areas each of which is managed by a Catchment Management Agency (CMA). The CMA is supported by a collection of Catchment Management Forums (CMF), that comprise of stakeholders (e.g., DWS officials, municipal officials, farmers, civil society organisations, individuals from civil society to name a few) who are interested in actively contributing to the water resource management of their local catchment. CMFs are supposed be representative of all water stakeholders in a catchment area, however it is often marginalised communities who are least represented. Citizens from poor communities largely lack the resource, knowledge and political capacity to meaningfully engage in CMFs. The expanded doctoral research aims to address this capacity gap.

My research is therefore a form of interventionist (seeking to make change) research that engages with a CSO, the

Eastern Cape Water Caucus, to collaboratively build civil society capacity to engage and contribute to CMF development and function, including contributions to the Catchment Management Strategy. The research focuses on two CMFs within the Mzimvubu-Tsitsikamma Water Management Area, the Upper Kowie Water and Sanitation CMF and the Amathole CMF, located in the Makana and Raymond Mhlaba Local Municipality respectively.

The social theory, Cultural Historical Activity Theory (CHAT) is being used to firstly understand the EC Water Caucus and the CMF as human activity systems (an activity system is the basic unit of analysis of CHAT), and secondly to inform the joint practice of these two activity systems as they work towards negotiating and achieving their shared purpose. The cultural and historical contexts of the two activity systems are important to understand how and why the activity systems behave the way they do. So the first phase of the research is a contextual profile of ECWC and the two CMFs as well as a description of the social-ecological systems within which they operate. The second phase of the research is the formative interventionist process, and entails working with the ECWC and CMF members effectively carry out their practice. My core researcher role in the formative interventionist process will be to highlighting contradictions (such as disagreements, tensions or differing motives that inhibit the progress towards the shared objective) and facilitate the negotiation of these contradictions through workshops. According to CHAT literature, it is within these contradictions that learning has the greatest potential to occur. This process will not only inform my research into the role of CSOs in the function of CMFs, but will also enable CMF participants understand what contradictions are constraining their practice and learn how to go about addressing them.

The doctoral research aims to run from 2016 until the end of 2017.

The Eastern Cape Water Caucus is a network of civil society members that aims to enable an egalitarian and loose mix of voices to co-develop knowledge and build capacity for influence, advocacy and activism around water issues.

The Eastern Cape Water Caucus is establishing local water caucus nodes where it facilitates capacity and agency development through engaged participatory processes.

DEVELOPING THE INSTITUTIONAL CAPABILITY OF RURAL COMMUNITIES IN THE NTABELANGA 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, unimpounded 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 two district municipalities – Joe Gqabi and OR Tambo, both 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 dam, the DEA, through its NRM "Working for" suite of programmes, is investing in restoration projects in the Upper Ntabelanga Catchment (UNC) area. These interventions provide local residents with participatory opportunities through i) the programmes themselves (local participation and short term job creation), ii) involvement in the rehabilitation of the area to restore and maintain the landscape and iii) 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 aims to use the NRM intervention to support residents in the formation of a CMF.

During the last year, the team working in the Ntabelanga area has been busy with various research work. My work has involved taking part in five CMF workshops with the Department of Water Sanitation (DWS) at the beginning of the year. During this time, I learnt a great deal about what is required in order to help stakeholders and role players begin to understand the complexity of the water governance arena. The opportunity to speak openly at these workshops was really appreciated by those that took part including the members of the DWS that participated. There were lessons learnt by the UCEWQ and DWS teams. As my research focuses on a learning centred process of CMF formation it has been important for me to observe what works in situations and how co-creation of knowledge and co-learning takes place. The critical need to engage meaningfully with stakeholders and role players in order to begin building relationships and trust is cannot be overemphasised.

The complexity of the Ntabelanga dam area is more easily understood if the turbulent history of the area is taken into consideration. There are multiple layers of governance not only the local and provincial governance boundaries, but also the tribal authority boundaries which increase the level of complexity and the need to build strong, trust based relationships. The lack of communication across and between these multiple levels needs to be understood and unknotted. It is assumed, often incorrectly, that communication happens across vertical and horizontal levels and that communication should also be taking place diagonally. This does not appear to be the case in the many levels of government and institutions across South Africa. The Tsitsa catchment (where the Ntabelanga dam will be constructed) is no exception. My work will focus on the point at which these interactions should be taking place and work in the "messy middle" as this is often the point at which the learning centred process of CMF formation may start to loosen some of the knots of communication (see Figures 1–3).

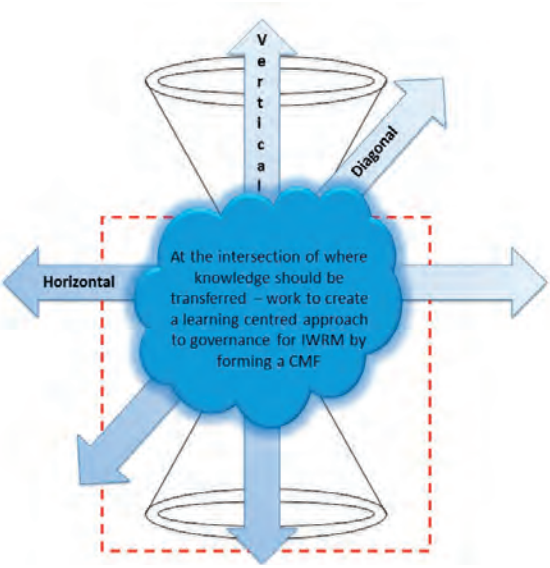


Figure 1: The "messy middle" (blue cloud) – the intersection of lines of communication

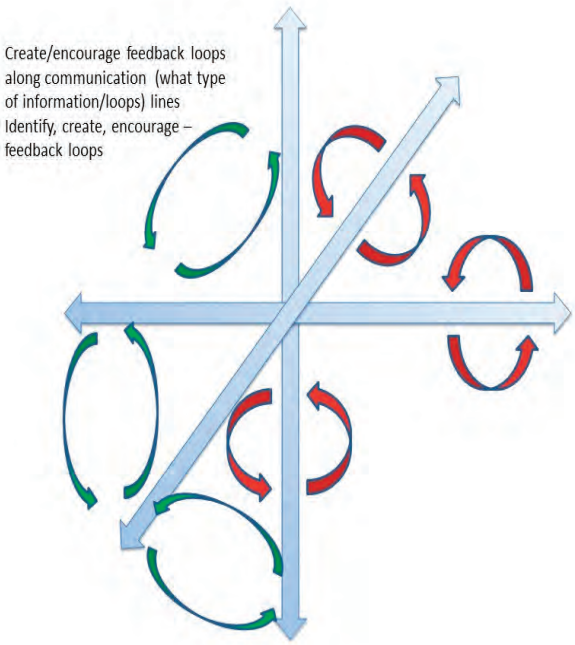


Figure 2: Feedback loops between and within horizontal, vertical and diagonal planes.

During our field trip in May, we ran a workshop with Chief Mabandla and members of the community. The area ruled by Chief Mabandla is in the east of the Elundini Municipality and includes the land where the vast majority of the rehabilitation works and other dam-related interventions will take place. Our research team was the first university team that took the time to invite him to participate in the process of our research. The community members who took part in the workshop were extremely grateful for the time allocated to them in order to make them feel part of

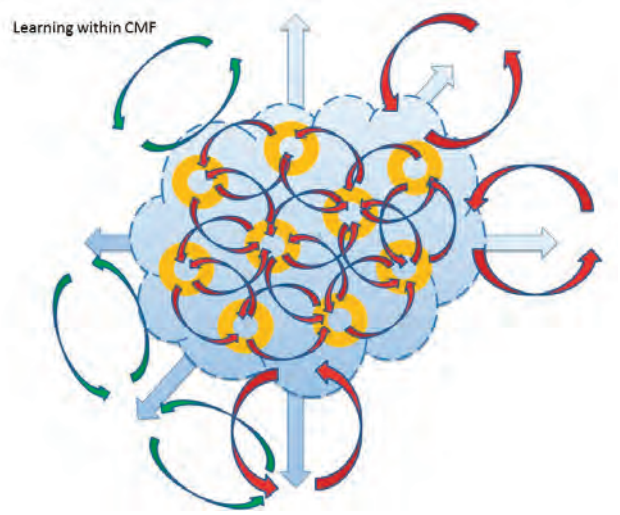


Figure 3: Yellow circles represent stakeholders and role players within a CMF. Figure shows levels of communication required to build relationship and co-create knowledge.

the process and be more informed about the research we are conducting and the work that is taking place in their community. Although our team could not answer all the questions that the stakeholders had, we acknowledged their concerns and have certainly tried to get feedback from various government departments for them. I also interviewed members of a restoration team taking part in the DEA: NRM restoration programme. This gave me insight to the contradictions within the activity system of the restoration team. These are the points at which learning and negotiation could take place. This is certainly an area that could be researched further in future.

I will be running two more workshops in November with the DWS in the Tsitsa catchment area and hope that the research from these context specific workshops will re-enforce the growing findings from my research to date, that although there is lots of information written about CMFs and CMAs and the NWA, the actual implementation has been more difficult and challenging than anticipated and that perhaps a learning centred process to the formation of CMFs will encourage broader participation and sustainability for the CMFs.

Workshop with Chief Mabandla (second from left) and members of the local community.

ASSESSMENT OF THE REVISED DESKTOP RESERVE MODEL (DRDM) FOR THE DETERMINATION OF ENVIRONMENTAL FLOW REQUIREMENTS (EWR)

Student: NP Zwezwe
Supervisors: DA Hughes and SK Mantel
Degree: MSc (Hydrology)

The increased water resources developments such as construction of dams upstream are known to have negative impact on downstream river ecosystem. These developments, together with worldwide water scarcity have led to the increased attention on Environmental Water Requirements (EWR) allocations. EWR's are a portion of water required in order to maintain the river ecosystem. It is important that the river ecosystem is maintained so that they may continue providing human beings with goods and services such as the provision of fresh water. Legislation has been reformed in many countries which include Australia and South Africa in order to incorporate the EWR's. Moreover, numerous methodologies have been developed in order to account and determine EWR's.

In South Africa, a desktop based method for determining EWRs was developed by Hughes and Hannart (2003) which is known as Desktop Reserve Model (RDM). The RDM model was widely and frequently used in South Africa and other countries in detailed EWR determinations which involved inputs from ecological specialists to calibrate site-specific model parameters. However, this method had its weaknesses as a low-confidence method such as overlooking the high flows and neglecting the important aspect of Reserve determination which is the ecological response. As science advanced the RDM was modified and revised in 2014 by Hughes *et al*. (2014) into the Revised Desktop Reserve Model (RDRM). The revision of the model included incorporating the detailed links between hydrology, hydraulics and ecology as well as the flow-stressor habitat response concepts within the model. However, the addition of these concepts and links complicated the model, as such it could only be used by experienced EWR practitioners.

The RDRM has been used in detailed EWR determinations and there now exists some degree of experience in its application by experienced EWR practitioners. This experience has prompted the need for some revisions of both the model structure and the way in which the parameters should be estimated. Therefore, the aim of this project is to assess the parameter estimation within the model. The model assessment will be done by reviewing the past experiences of the model and analysing the obtained final results. This review and analysis will assist in identification of the general patterns to guide the future quantification of regional parameter values within this model. This study will be conducted on the previously investigated EWR sites where the RDRM was used, as well as other sites that are yet to be identified. One of the sites that will be used is the Gouritz Catchment which is located in the Western Cape Province with small portion of this catchment falling into the Eastern Cape Province. This catchment has 10 EWR sites at which the RDRM was used, these sites are currently being reviewed as part of past results analysis. The expected result from this study is a model which can estimate environmental water requirements at a desktop level, which can be used by professionals with no experience in this model, using the guidelines for parameter estimation that will be compiled during this study.

RESEARCH OUTPUT

PEER REVIEW JOURNALS AND CONFERENCE PROCEEDINGS

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Back Cover (from top to bottom): Upper Reaches of Tsitsa River, Eastern Cape; Dr Nelson Odume and Mr David Gwapedza sampling in the Qurhana Tributary, Eastern Cape; Geography Students assisting with digging of pits and augering to reach the water table in the Krom River, Eastern Cape; Mr Emmanuel Vellemu sampling in Qurhana Tributory, Eastern Cape.