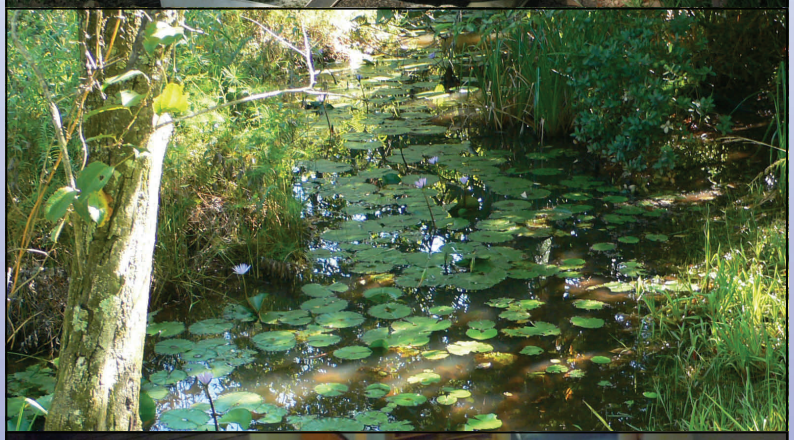

INSTITUTE FOR WATER RESEARCH

IWR

2011

ANNUAL REPORT

RHODES UNIVERSITY

Where leaders learn

STAFF AND MEMBERS OF THE INSTITUTE 2010

STAFF

Mr David Forsyth	*Principal Technical Officer*
Ms Helen Fox	*Part-Time Environmental Officer UCEWQ-IWR*
Ms Pearl Gola	*Jnr Research Officer UCEWQ-IWR*
Mr Andrew Gordon	*Research Officer UCEWQ-IWR*
Dr Neil Griffin	*Research Officer UCEWQ-IWR*
Ms Alex Holland	*Research Intern UCEWQ-IWR*
Mr Greg Huggins	*Research Officer Water for Africa*
Prof Denis Hughes	*Professor | Director of IWR*
Mr Tarqyn Human	*Technical Officer UCEWQ-IWR*
Ms Delana Louw	*Research Officer IWR Source to Sea*
Mr Stephen Mallory	*Research Officer IWR Water Resources*
Dr Sukhmani Mantel	*Research Officer IWR*
Ms Juanita McLean	*Administration Manager*
Ms Daksha Naran	*Senior Technical Officer (from June 2011)*
Prof Tally Palmer	*Professor | Director of UCEWQ*
Ms Candice Roux	*Senior Technical Officer (until March 2011)*
Ms Asipe Sahula	*Research Assistant UCEWQ-IWR*
Dr Andrew Slaughter	*Postdoctoral Fellow*
Mr Pumle Siyo	*Laboratory Assistant UCEWQ-IWR*

ASSOCIATE

Prof Brian Allanson	*Honorary Research Fellow of Rhodes University*
Dr Nikite Muller	*Research Associate*

REGISTERED POSTGRADUATE STUDENTS

Mr Ahmed Desai	*PhD (Hydrology)*
Ms Pearl Gola	*PhD (Water Resource Science)*
Mr Andrew Gordon	*PhD (Water Resource Science)*
Ms Alex Holland	*PhD (Water Resource Science)*
Mr Sbongiseni Mazibuko	*MSc (Hydrology)*
Mr Paul Mensah	*PhD (Water Resource Science)*
Mr Thabiso Mohobane	*PhD (Hydrology)*
Ms Bronwyn Moore	*PhD (Water Resource Science)*
Mr Nelson Odume	*PhD (Water Resource Science)*
Ms Boluwaji Onabolu	*PhD (Water Resource Science)*
Ms Jane Tanner	*PhD (Hydrology)*
Ms Sithabile Tirivarombo	*PhD (Water Resource Science)*
Mr Raphael Tshimanga	*PhD (Hydrology)*
Ms Madeka Tumbo	*PhD (Hydrology); based at The University of Dar es Salaam, Tanzania*
Mr Agostinho Vilanculos	*PhD (Hydrology); based at Eduardo Mondlane University, Mozambique*
Mr Bret Whiteley	*PhD (Hydrology)*

2011 GRADUATED STUDENTS

Mr Evison Kapangaziwiri	*PhD (Hydrology)*
Mr Felike Mekiso	*MSc (Hydrology)*
Ms Irene Naigaga	*PhD (Ichthyology); based at Makerere University, Uganda*
Mr Nelson Odume	*PhD (Water Resource Science)*
Mr Andrew Slaughter	*PhD (Water Resource Science)*

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Front Cover (top to bottom): Flow gauge before Laing Dam on Buffalo River/SASS biomonitoring sampling site, Boksburg Lake/Biomonitoring sampling site at RBM, Richards Bay/Rhodes University Graduation 2011. From left to right: Dr Evison Kapangaziwiri, Dr Nikite Muller, Prof Denis Hughes, Mr Nelson Odume, Dr Andrew Slaughter/Photographs kindly supplied by IWR staff and students.

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Staff photograph taken at the 2010 IWR Open day. (From left to right)
Back Row: D Forsyth, P Mensah, N. Odume, R Tshimanga
Second Row: A Holland, P Gola, S Tirivarombo, A Slaughter, J Tanner, B Onabolu, C Roux, A Mashao
Front Row: S Mantel, A Gordon, T Human, T Palmer, D Hughes, J McLean, S Mallory
Absent: H Fox and N Griffin

Institute for Water Research | Rhodes University | Old Geology Building | Artillery Rd | PO Box 94 | Grahamstown 6140
Tel: +27-46-6224014/2428 or +27-46-6038532/8334 | Fax: +27-46-6229427
Email: iwr@ru.ac.za | Web: http://www.ru.ac.za/iwr

INSTITUTE FOR WATER RESEARCH (IWR)

1. IWR DIRECTOR'S REPORT

Introduction

Ms Daksha Naran was appointed to the post of Senior Technical Officer to replace Ms Candice Roux who left at the end of March 2011, while Ms Asiphe Sahula was appointed on a short-term contract as a Research Assistant in UCEWQ. However, during the year we also revised the terms of employment of three of our long-standing contract support staff. After some lengthy discussions and negotiations between the Institute and Rhodes Human Resources Division, it was decided to put in place a policy that offers greater financial security to contract support staff members who remain with the IWR for many years. The essence of the policy is that after 5 years of service, contract staff members become eligible to join the pension scheme. There are quite substantial financial implications for the IWR, but the general feeling was that this change was necessary. The policy has been implemented for Ms McLean, Mr Forsyth and Mr Human. An additional change in the IWR staff occurred as a result of the appointment of Dr Sukhmani Mantel as a Research Officer after contributing a great deal to the IWR as a Post-Doctoral Fellow for several years. Mr Andrew Gordon was awarded a 3-month Claude Leon Foundation academic leave replacement grant to free up some of his time working on WRC research projects so that he could complete writing his PhD thesis.

The senior staff of the Institute continued to be actively involved in policy development and advisory committees at regional, national and international levels. Prof. Hughes serves on the South African Committee for the UNESCO International Hydrological Programme (IHP) and was chairperson of SANCIAHS (South African Committee for the International Association of Hydrological Sciences) up to November 2011, when he handed over the position to Prof Graham Jewitt of UKZN. Prof Hughes will continue to represent SANCIAHS as the chairperson of the SACNASP (South Africa Council for Natural Scientific Professions) Professional Advisory Committee for the newly established Water Resources Science Field of Practice. This new field of practice was established during 2011 after discussions between SACNASP and SANCIAHS related to many problems involved in the professional registration of hydrologists.

Internationally, Prof Hughes' appointment during 2009 as a vice-president of the IAHS (International Association of Hydrological Sciences) was confirmed by election during the IUGG General Assembly in Melbourne, Australia during July 2009. He retains responsibility for promoting hydrological sciences in developing countries, but will also share the 'hydrological education' portfolio with one of the other newly appointed VP's. He also serves on the Scientific Steering Group for the IAHS PUB (Predictions in Ungauged Basins) programme and is regional coordinator for the southern Africa FRIEND (UNESCO) programme.

Prof Tally Palmer continues to chair the National Water Advisory Committee, made up of several key experts in the field of water resources management and established to advise the Minister of Water Affairs and Forestry on national policy development and implementation. Prof Palmer has been very busy during 2011 canvassing support for various new research initiatives. One of the results of this effort includes a R2 million grant over 2 years from SANPAD to launch research into complex social ecological systems and problem solving in Integrated Water Resources Management, supported by a WRC short term research project grant (R200 000) and a contribution from the NRF Global Change Society and Sustainability programme (R2.99 million over 3 years). Part of this research will include an Eastern Cape Case study using the existing research MOU between Rhodes and Amatola Water and focussed on implementation of water services by the Sundays River Valley Municipality. A short-term grant has also been allocated by the WRC to revitalise the environmental water quality (EWQ) concepts associated with compliance and the water quality aspects of the ecological Reserve.

International links and conferences

As always it has been a busy year for attending international conferences and workshops with several staff members and students being involved in a wide range of meetings. Prof Hughes travelled to Canmore, Alberta in the Eastern Rockies of Canada during May to attend an international workshop on 'Putting PUB (Predictions in Ungauged Basins) into Practice' (see photographs). This meeting involved some detailed discussions and it is expected that a report will be published in early 2012. Soon after returning from Canada, it was off to a workshop on 'Land use change impacts on flooding' held at Imperial College London in June. While flooding impacts are not one of the IWRs major research themes the workshop was valuable in that many aspects of modeling uncertainty were discussed and it helped to cement some long-standing ties that we have with Imperial College. In July the IUGG General Assembly was held in Melbourne Australia. The IWR was represented by Prof Hughes and Mr Raphael Tshimanga. We had four papers in two of the pre-published proceedings (the IAHS Red Books) and delivered 5 presentations, including one as part of a workshop on hydrological education. Prof Hughes attended the IAHS Bureau meetings as part of his responsibilities as a VP, as well an editorial team meeting for the Hydrological Sciences Journal. The conference offered a marvelous opportunity for Mr Tshimanga to meet some of the senior hydrologists whose research work

he had previously read in the scientific literature.

Prof Hughes with the President of IAHS, Dr Gordon Young during the PUB conference in Canmore, Canada.

Field trip to the Columbia Ice Field during the PUB meeting in Canmore, Alberta, Canada.

In August Prof Hughes travelled to Dar es Salaam to attend a workshop and field trip (inland to Iringa and the Great Ruaha catchment area) on the Danish supported CLIVET programme. This project supports three PhD students at the University of Dar es Salaam, one of whom (Ms Madaka Tumbo) is registered at Rhodes. Prof Hughes' final trip was to Kampala to attend the annual meeting of the Carnegie RISE programme and to present the report for SSAWRN (Sub-Saharan Africa Water Resources Network).

The Institute were the hosts for the 15th SANCIAHS National Hydrology Symposium held in Grahamstown in September 2011. We also used this conference as an opportunity to bring together almost all of the staff and students of the RISE SSAWRN programme. All of the students from Rhodes, Makerere (Uganda), Eduardo Mondlane (Mozambique) and the Okavango Research Institute (Botswana) presented papers or posters as part of the formal conference programme. It was very rewarding to have Gold and Silver 'Emerging Scientist' medals presented to Mr Ahmed Desai and Ms Jane Tanner and both are congratulated on very good presentations. These awards were made to four of the younger participants (the other two went to post-graduates at UKZN) at the conference and were based on the opinions of 9 independent adjudicators (see photograph).

The 'Emerging Scientist' medal recipients at the 15th National Hydrology Symposium. From left to right: Jane Tanner (Silver), George Waswa (Silver), Hartley Bulcock (Gold) and Ahmed Desai (Gold).

Dr Andrew Slaughter and Mr Paul Mensah attended the Young Water Professionals conference in Pretoria during July, while Ms Jane Tanner represented the IWR and delivered a paper at the National Groundwater Conference in Pretoria that was held soon after the Natonal Hydrology conference in September. Ms Sithabile Tirivarombo and Mr Nelson Odume represented the IWR at the Waternet Symposium held in Maputo, Mozambique during October 2011 and both presented posters.

A number of collaborations with international water quality specialists occurred. Dr Peter Chapman of Golder Associates Canada, an authority on the assessment of contaminated environments, was a guest of the Institute for Water Research and Unilever Centre for Environmental Water Quality from the 16th- 18th October 2011. He gave a talk to the greater University community on the fundamentals, application and misapplication of ecological risk assessment in environmental monitoring. He also spent a day with the ecotoxicology students within the IWR, providing feedback on their MSc and PhD projects and gave a presentation on the use of ecotoxicology in environmental assessments. Dr Dirk Jungmann of Technische Universitat Dresden (TUD) visited the Institute for Water Research and Unilever Centre for Environmental Water Quality from the 2nd- 4th November 2011. He was seeking to include the IWR within a collaboration between TUD, University of Namibia and Universidade Zambeze, Beira aimed at establishing integrated water quality assessment capacity within Mozambique. The potential for post graduate student ex-

changes between IWR and TUD was also discussed, as was the drafting of a proposal seeking to investigate certain interactions between water quality, quantity and climate change to be submitted to a Germany – South Africa bilateral government funding programme.

Our collaboration with Dr Thorsten Wagener at Penn. State University continues and this year one of his PhD students, Ms Riddi Singh visited the IWR for 2 weeks in November (supported by NRF funds). The purpose of the visit was to share experiences in hydrological uncertainty modelling and to train Ms Singh in the use of some of the techniques that have been developed in the IWR so that she can apply them as part of her own studies.

Prof Palmer has been very active in extending research links across different disciplines within Rhodes (Anthropology and the Environmental Learning Research Centre) and working closely with Wits University and the University of Limpopo, as well as internationally with Trinity College Dublin, Dundalk Institute of Technoloy, a Technical University of Delft, Erasmus University, University of Maastrict and the UNESCO IHE Institute for Water Education.

Consultancy links

While some Institute staff continued to contribute to consultancy projects and we have maintained our links with consultancy groups, there has been less activity in this area over the last few years than in previous years. This trend is inevitable, given the additional work load created by student supervision. It is important that we do not lose the links with practical problem solving which has always been one of the strengths of the IWR and has provided an immediate market for some of its applied research products.

Undergraduate teaching

Dr Griffin (with assistance from Ms Holland and Mr Human for practicals) ran a three week course for 2nd year Environmental Science students based around management of water resources. The Institute continues to contribute to the Department of Environmental Science ENV302 course, with Prof Hughes, Mr Gordon and Dr Mantel covering water quantity, quality and legal issues within the context of water resource management and the South African National Water Act.

The IWR also offered a 1 month Honours course on Environmental Water Quality for Geography and Environmental Science Honours students. Contributions were made by Prof Palmer, Mr Gordon, Dr Griffin, Ms Holland, Mr Human and Mr Odume. Two of these students are planning to join the IWR for their Master's studies in 2012.

Post-graduate students

At the 2011 Rhodes graduation ceremony Dr Evison Kapangaziwiri and Dr Andrew Slaughter received their PhD degrees, while Mr Nelson Odume and Mr Feleke Mekiso both received their MSc degrees, the former with a very well deserved distinction. Mr Odume is the first of the Carnegie RISE SSAWRN students to graduate and he has set the bar for all of the other students supported by this programme. Mr Odume is staying on with the IWR and registered for a PhD in 2011 under the supervision of Prof Palmer.

Graduation 2011, students and supervisors. From left to right: Dr Evison Kapangaziwiri, Dr Nikite Muller, Prof Denis Hughes, Mr Nelson Odume, Dr Andrew Slaughter.

Ms Jane Tanner's proposal to upgrade to a PhD was accepted at the beginning of 2011, while Mr Ahmed Desai and Mr Andrew Gordon have indicated that they intend to submit their PhD theses before the end of the year. We are also hoping that Mr Raphael Tshimanga and Ms Sithabile Tirivarombo will be very close to submission at the end of 2011.

Three new students joined the IWR during 2011. Mr Thabiso Mohobane (PhD, Hydrology) and Mr Sbongiseni Mazibuko (MSc, Hydrology) are sponsored through the RISE SSAWRN programme, while Mr Bret Whiteley (MSc, Hydrology) is currently working in the USA as a consultant and his project is designed to assess the application of a US hydrological/water quality model in a South African context.

Reference has already been made to the 'Emerging Scientist' awards made to Ms Tanner and Mr Desai. It was also gratifying to see that most of the IWR students made very good presentations at the 15th National Hydrology Symposium and many of the conference attendees commented on the strength of the IWR student group.

As noted in previous annual reports, we are still faced with the very real problem of having too many students relative to the available supervisory capacity. Dr Muller is of some help as she continues to supervise some of the students, but the remaining load currently falls mostly on the shoulders of Prof's Hughes and Palmer. Dr Mantel has started to offer supervision support, while Mr Gordon will be supervising students in 2012 now that he has almost completed his PhD. These contributions will be of great value, but the Institute desperately needs an additional staff member who can offer supervision to the present and future hy-

drology post-graduates. If we do not address this situation in the near future it will be necessary to stop accepting hydrology post-graduates as the date for Prof Hughes' retirement approaches.

Post-Doctoral posts

Dr Andrew Slaughter was appointed as a Post-Doctoral Fellow and is working with Dr Mantel and Prof Hughes on the WRC funded project investigating climate change impacts and adaptation strategies for the Amatole Water Board. His main area of research is the development of a practical water quality systems model that can be used to assess the impacts of climate change and development on water quality. The intention is to link the model to an existing and widely used water quantity systems model.

RISE Sub-Saharan Africa Water Resources Network

January 2011 saw the start of the second phase of the Carnegie RISE programme with support guaranteed for a further 3 years. The level of funding is the same as for the first phase (US$800 000 for the whole of the SSAWRN programme over the three year period). However, the budget for the second phase includes in excess of R1 million that was not spent during the first phase and this budget will be sufficient to cover the costs of all the existing students, assuming that they are able to complete within the normal allocated time (2-3 years for an MSc and 3 to 4 years for a PhD). It has already been noted under the report on post-graduate students that we welcomed two new students at the start of 2011, while one of the existing students moved on to a PhD programme having completed his MSc in 2 years. Individual reports on the student projects are also included later in the annual report.

At the end of the SANCIAHS Symposium a short 2-day writing workshop was organised for the RISE SSAWRN students (including those from the other nodes in the network) by Prof Chrissie Boughey of the Centre for Higher Education, Research and Learning. The experience was well received by the students, the main comment being that they wish there had been more time for hands-on training in writing.

Community Outreach and Public Understanding of Science

The Unilever Center for Environmental Water Quality, IWR was contracted by UNICEF in partnership with the Ministry of Public Health and Sanitation Kenya to carry out an assessment of the effectiveness of Household Water Treatment and storage (HWTS) Technologies being promoted in rural communities in Kenya. Presentations were made at the beginning and the end of the study to various stakeholders in Kenya which include:

- National Technical Working Group on Household Water Treatment and Storage.
- Inter-agency collaborative forum on community water supply and sanitation.
- UNICEF Kenya.

The food safety, occupational health, environment, child health, international health and water safety divisions of the Ministry of Public Health Kenya. The information generated will provide policy makers, practitioners and funding agencies with an evidence base for decision making on HWTS technologies. Congratulations to Ms Onobolu for securing and running this project.

One accolade for the Institute's publications was received during the last year. Prof Hughes and Ms Louw were notified that they received that Best Paper Award for 2010 from the Environmental Modelling & Software Journal for their paper entitled 'Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental flow requirements' (see the list of Research Outputs in the annual report for 2010).

Concluding remarks

The Institute has seen tremendous growth in the student group over the last few years, largely initiated by the start of the Carnegie RISE programme. We are seeing a steady crop of students graduating each year (1 MSc in 2008, 1 PhD in 2009, 1 MSc in 2010, 2 PhD and 2 MSc in 2011 and the expectation of at least 2 PhD's in 2012) which is good for the reputation of the IWR and contributes substantially to the Rhodes subsidy income. As noted in previous annual reports we are not seeing a parallel growth in the staff available for supervising post-graduate projects and this is a cause for concern.

Outputs	2005	2006	2007	2008	2009	2010	2011
Peer Reviewed Journals	4	12	8	7	5	11	9
Reports	12	17	33	5	14	18	24
Conference proceedings	2	3	10	2	7	3	4

The Institutes record of publishing in recognised international journals continues to fluctuate, but the impact of having a larger group of post-graduate students is starting to reap benefits. Some of the IWR students have generated publications and the others are continuously encouraged to contribute when they have material and results that can be tested in a peer review system. While journal publications are recognised by the Institute as being important, the reality of the situation is that research reports to funding agencies are of equal importance if the IWR is to continue to attract the funding necessary to survive.

Acknowledgements

We are always very grateful for the contributions that the Board of Control make to the successful operation of the Institute. We would like to acknowledge all of 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 South Africa 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 now become a very important source of funding for post-graduate students within the Institute. We have developed excellent relationships with the fund administrators over the first phase of the project. We are also grateful to the coordinators at the other nodes of the SSAWRN (ORC, Makerere and Eduardo Mondlane Universities) for their help in ensuring the success of this initiative. The IWR is also very grateful to Dr Sukhmani Mantel for the excellent (and sometimes difficult) job that she does as administrator of the network.

We are also grateful for the support of the various divisions of Rhodes University including the staff of the office of the Deputy VC, Research and Development, 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 2011 included Prof Hughes and Mr Tshimanga (IUGG General Assembly in Melbourne), Ms Tirivarombo and Mr Odume (Waternet in Maputo, Mozambique) and Dr Slaughter and Mr Mensah (Young Water Professionals conference in Pretoria).

Finally, as Director, I would like to offer my personal thanks to all the members of the Institute staff and students for their hard work, enthusiasm and loyalty.

UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY

2 UCEWQ DIRECTOR'S REPORT

Introduction

The year 2011 has been a busy and eventful for the Unilever Centre for Environmental Water Quality. The year started optimistically with the renewal of funding support from Unilever for 2011-2013. This was accompanied a review of UCEWQ aims in respect of its special relationship with Unilever. The Centre also worked towards several strategic goals for the year: providing additional support to ensure the completion of four doctoral theses before June 2012, moving towards salary scale alignment with Rhodes University, consolidating our environmental water quality reputation and expanding to promote integrated water resource management through an understanding of social-ecological systems - drawing strongly on the concepts of trandisciplinarity, complexity and resilience.

Unilever

The over arching aim is to ensure UCEWQ is relevant to the Unilever Vision nationally and globally while being an excellent university research Centre. This means 1) ensuring the all the UCEWQ research scholarship, research impact (ensuring research outcomes are USED) and student training is thoughtfully and explicitly made available to Unilever; 2) focussing on specific deliverables in terms of the four aspects of the Unilever Vision, recognising concurrence with the UCEWQ vision; and 3) developing partnerships and relationships that will contribute to achieving the Unilever Vision.

Concurrent Visions

Unilever:

1. We Work to Create a Better Future Every Day
2. We help people feel good, look good and get more out of life with brands and services that are good for them and good for others.
3. We will inspire people to take small everyday actions that can add up to a big difference for the world.
4. We will develop new ways of doing business that will allow us to double the size of our company while reducing our environmental impact."

UCEWQ :

1. We work to catalyse a more sustainable future every day – though action research and engagement in issues of environmental water quality in the context of people living in catchments.
2. We focus on applied research contributing to human well-being founded on a sustainable future.
3. We acknowledge that our science generates independent data and information, and take responsibility for being involved in the value-driven circumstances where the data are used to make decisions and influence behavior.
4. We will contribute data, insights and relationship-building into supporting Unilever business growth

together with reduced environmental impact.

In 2011 UCEWQ post-graduate contributions to Unilever were achieved through the post-graduate work of Helen Fox who has continued to combine academic effort with championing and facilitating the active involvement of school learners, teachers, local government, industry, NGOs and the local community in the clean-up and sustainable use of Boksburg Lake; and Andrew Gordon – who will submit a doctoral thesis in December on the ecological risks posed by direct laundry washing in and near rivers.
In terms of implementing the vision and developing relationships, our engagement with the Unilever Sustainable Living Plan has been most exciting. Unilever South Africa has produced a nationally contextualized version of the global Unilever Sustainable Living Plan, which sets bold goals for halving environmental impact while growing the business. This includes and strong focus on water, mainly on the amount of water used in the life-cycle of a product, but with a realization that water quality also needs to be considered. In using a full life-cycle approach Unilever provides global leadership in water sustainability practices. In 2011 UCEWQ facilitated engagement between Unilever SA and the Water Institute of Southern Africa, the Water Research Commission and the National Research Foundation in the national water discourse, and this will continue actively in 2012.

Complex Social Ecological Systems

UCEWQ has always promoted and explored approaches leading towards integration. In the arena of water quality we coined the now-widely used term "environmental water quality", defining it as the integration of data and knowledge about water chemistry, bio-monitoring and eco-toxicology – in an approach inspired by Peter Chapman's' triad concept. We were delighted to host Peter Chapman at IWR this year. Now we are moving towards a new level of integration. We acknowledge that in any consideration of people living on this planet it is important to recognise that social and ecological systems are inextricably linked, and we will seek to undertake our research in the context of social-ecological systems. This involves taking as full account as possible of social-ecological interactions, feedbacks and dependencies. We also recognise the importance of realising that social-ecological systems are complex. Here we pay tribute to the late Prof Paul Cilliers of the Stellenbosch University Centre for Complexity Studies, and his colleague and successor Prof Jannie Hofmeyr who will be the IWR invited speaker at the 2012 Open Day. Prof Cilliers made general complexity theory accessible to an emerging cohort of natural scientists, including Tally Palmer, willingly engaging in collaboration and co-authorship. Prof Hofmeyr is continuing this engagement.

It is the complexity of social-ecological systems that gives rise to the intractable or "wicked" problems so common in water resource management. The need to take account of multiple perspectives when researching complex systems also drives learning to be more adept at transdisciplinary research. That is research during which the boundaries between disciplines and knowledge systems become porous, and researchers make the effort to become disciplinary multi-linguists and practitioners.

The late Prof Paul Cilliers of the Stellenbosch University Centre for Complexity Studies

UCEWQ has secured funding for two projects that focus on research that explicitly uses these integrating approaches: **From policy to practice: enhancing implementation of water policies for sustainable development and Comparative transdisciplinary case studies of change towards enhancing water security**. In these projects UCEWQ researchers and students will work with researchers from 9 universities across South Africa, Ireland and the Netherlands. There will be 6 UCEWQ post graduates (5 Masters and 1 PhD) within these research projects – 2 Masters within the IWR in Water Resources Science, one in Environmental Science, one in Integrated Development Studies, and a Masters and a PhD in environmental education. All these students will have Tally Palmer as the primary or co-supervisor. Staying with the complexity theme, Tally Palmer co-ordinated a session with Dr Stefanie Freitag of SANPARKS at the international "Resilience" conference in Arizona. The development of a network of researchers seeking to work within the paradigm of complexity, and practical processes of adaptive management were explored. The National Research Foundation has subsequently initiated a "Complexity Forum" in which UCEWQ will participate.

Environmental Water Quality

UCEWQ students and researchers also continue to explore environmental water quality, and have secured WRC funding to provide a review of EWQ in South Africa. Andrew Gordon will take on the leadership of EWQ research in 2012, and research areas that will continue from this year include: the effects of sediments, a commonly used herbi-

cide "Roundup", and DDT on riverine biota; the use of the EWQ approach in linking the management tools of "Green Drop" and the water quality components of the ecological Reserve; and the use of indigenous algae as eco-toxicity test organisms.

Hydrology post graduate students join UCEWQ students, Prof Tally Palmer and UCEWQ Technical Officer Tarqyn Human, in a field trip to collect the freshwater shrimp* Caridina nilotica *for eco-toxicology experiments.

Acknowledgements

In addition to the thanks recorded in the IWR Director's Report we acknowledge the contribution Rhodes University has made to Prof Palmer's salary in 2011. We are pleased to have extended the support we receive from the National Research Foundation, and for the support of the South African Netherlands Research Programme on Alternatives in Development. Finally as UCEWQ Director I would like to thank all the UCEWQ researchers and students, Prof Denis Hughes, and everyone within IWR. Particular thanks to those staff members who look after the cultures – this happens 52 weeks per year and requires a special kind of patience and care. Everyone has worked with enthusiasm and dedication. We have shared laughs and frustrations and I look forward to the coming year.

Hydrology and UCEWQ post graduate students collecting the freshwater shrimp* Caridina nilotica *for eco-toxicology experiments.

3. HYDROLOGY PROJECTS

The hydrology group of the Institute currently consists of Prof. Hughes, 1 Post-Doctoral Fellow (Dr Andrew Slaughter) and five post-graduate students; Mr Tshimanga (PhD), Ms Tirivarombo (PhD), Ms Tanner (PhD), Mr Mohobane (PhD) and Mr Mazibuko (MSc). All five post-graduate students are part of the Carnegie RISE programme. Other staff members contribute to some of the hydrology related projects that the Institute is involved in. Notably, Mr Forsyth continues to be very involved in the on-going development of the SPATSIM hydrological modelling framework software, as well as supporting other software developments. Mr Mallory and Ms Louw (Associated Research Officers) contribute to some of the research projects as well as being consultancy partners. Dr Mantel has also been assisting with some of the hydrology projects and co-supervises some of the students. An additional four external students have been working on hydrologically related projects. Mr Ahmed Desai (PhD) is working on the development of the hydraulic sub-model for a revised desktop Reserved determination model (a WRC Project), Mr Feleke Mekiso on natural isotope and geochemical tracers for assessing wetland processes (completed and graduated in 2011), Ms Madaka Tumbo on climate change impacts in Tanzania (based at Dar es Salaam University and part of a collaboration with Denmark) and Mr Agostinho Vilanculos (PhD), a further RISE student based in Mozambique and working on flood modelling of the Zambezi River. Mr Whiteley (MSc) is working on the application of a water quantity-quality model that has been applied frequently in parts of the USA, but has not been applied in South Africa previously. Many of the hydrological projects (both research and consultancy) involve collaboration with other organisations, both within South Africa and overseas. The various projects are discussed under four main headings 'Implementing uncertainty analysis in water resource assessment and planning', 'Developments and applications of the SPATSIM hydrological modelling framework software', 'Developments in environmental water requirement methods' and 'Climate change adaptation strategies'. The hydrology group has also been involved in various consultancy projects during 2011, mostly associated with Reserve determinations.

IMPLEMENTING UNCERTAINTY ANALYSIS IN WATER RESOURCES ASSESSMENT AND PLANNING.

Sponsor: Water Research Commission and National Research Foundation
DA Hughes and J Tanner
Collaborators: T Wagener (Pennsylvania State University, USA)

April 2011 – March 2014

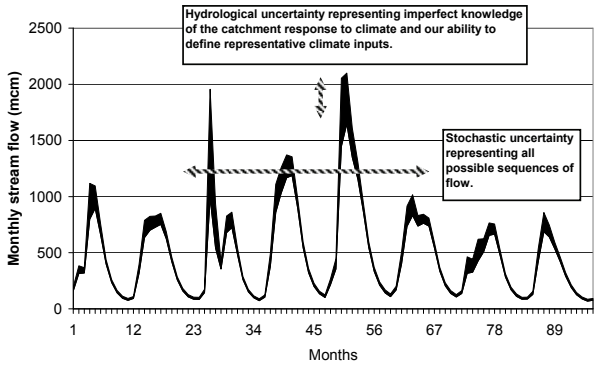
Uncertainty assessment has become a critical issue in hydrological and water resource estimation and is largely related to the confidence that can be expressed in the results of models and other data analysis methods. This confidence (or lack of) translates into risk when the model results are used in decision making and has largely been ignored, or not quantified, in the past. The uncertainty is associated with the fact that we do not have access to perfect data and the models themselves are simplifications of reality. The current project (K5/2056) represents a continuation of a previous 3-year project (K5/1838) that was completed in March 2011 (Hughes et al., 2011). The previous project focussed on establishing the concepts of uncertainty analysis in a South African context as well as developing some appropriate methods for incorporating uncertainty analysis in hydrology and water resources systems models.

A parallel project was supported by the NRF under the Key International Science Capacity (KISC) initiative for the same 3 year duration. The NRF project is designed to increase the awareness of water resource estimation uncertainty amongst South African practitioners through an exchange programme with Dr Thorsten Wagener (a recognised authority on uncertainty analysis) of Pennsylvania State University. The NRF project was also designed to support the organisation of workshops, training programmes and student exchange. Some of the NRF funds were unspent at the end of 2010 and this allowed the IWR to invite one of Dr Wagener's students to visit the IWR. Ms Riddi Singh therefore spent two weeks in the Institute during November 2011. During this time she shared various ideas that are being developed at Penn. State and learned some of the techniques that we are applying here at Rhodes. She will be applying some of our uncertainty analysis methods to headwater catchments of the Olifants River as part of a Penn. State project investigating the hydrological impacts of possible climate change.

The new project is designed to investigate the uncertainties in surface-groundwater interactions in more depth than was covered in the previous project and will also look at a range of issues associated with the practical implementation of uncertainty including the links between uncertainty and existing methods of assessing water resources yield and various approaches to reducing uncertainty. There are clear links between this project and the WRC project that is looking art climate change impacts and adaptation strategies for South African Water Boards.

During 2011 the first two project deliverables were produced; one on the design of surface-groundwater interaction studies and one on the use of stochastic rainfall analysis in water resources assessments. The first was mainly compiled by Ms Jane Tanner as part of her PhD programme. The objective of the report was to identify different interaction environments and, using examples, characterise the necessary conditions and key processes that can be used to differentiate individual interaction types. Part of this process was therefore to develop summary conceptual models of the different interaction environments with a view to testing these ideas in the future using existing documentation, limited field studies and the application of numerical hydrology models. One of the outcomes of this part of the study is the realisation that there is very little information that can be used to conclusively support or reject different hypotheses about the dominant processes controlling surface-groundwater interactions. There are even less data that can be used to quantify such processes.

The second deliverable report focussed on the integration of stochastic uncertainty with hydrological uncertainty (see explanation diagram). The stochastic uncertainty represents our uncertainty in the likely sequences of rainfall or stream flow and is a result of the limited number of observations that are available to represent these sequences. Hydrological uncertainty represents our uncertain knowledge and understanding of how a specific catchment will respond (in terms of stream flow or groundwater recharge, for example) to different climate inputs. Stochastic uncertainty has been used in traditional water resources assessments for many years and part of the project involves determining appropriate methods of including the hydrological uncertainty. The hydrological uncertainty is typically represented by using many different parameter sets with a hydrological model to generate an ensemble of outputs rather than a single output. One of the issues in large catchments with many different sub-areas is that there are a very large number of possible parameter combinations, presenting a statistical sampling problem that is very difficult to resolve. Part of the objective of this research is therefore to define an approach to sampling this parameter space in a way that is statistically correct, practical to implement and hydrologically meaningful. The Institute has formed a partnership with a group of consultants who are frequently used by the Department of Water Affairs (DWA) to determine catchment yields as part of major water resources development schemes. This partnership has submitted a detailed add-on proposal to the WRC and DWA that will allow some of the emerging scientific methods to be tested in practice (and further modified).



Distinction between stochastic and hydrological uncertainty based on a short period of simulated flows.

While some of the details of the uncertainty framework are still being revised, it has already been applied to investigate climate change scenarios in the Okavango River, the Amatola system (Buffalo River catchment near East London) and the Caledon River forming the border between South Africa and Lesotho. Some of this work has either been published or is in the process of being published. The previous project has already generated two PhD's from Rhodes (Dr Sawunyama and Dr Kapangaziwiri), while Ms Tanner, Mr Tshimanga, Ms Tirivarombo, Mr Mohobane and Mr Mazibuko (all RISE students) are either applying some of the methods to their student research projects or contributing to the further development of the concepts.

DEVELOPMENTS AND APPLICATIONS OF THE SPATSIM HYDROLOGICAL MODELLING FRAMEWORK SOFTWARE

Sponsor: Dept. of Water Affairs and Water Research Commission
DA Hughes and DA Forsyth BEEH (UKZN)

April 2008 – March 2011

This is a collaborative project with the School of Bioresources Engineering and Environmental Hydrology (BEEH) at the University of KwaZulu-Natal to develop an improved version of the SPATSIM software which will extend its applicability and sort out some of the design faults associated with the first version. These developments were initially funded by the Water Research Commission, while the current development programme is funded by DWA through the WRC. Part of the focus is on enhancing the use of the framework by the RDM (Resource Directed Measures) office of DWA (or their consultants) for ecological Reserve determinations and implementation. The other focus is on incorporating the ACRU model into the framework (being undertaken by BEEH). After a number of delays it is expected that the project will be finalised and the software will be ready for general distribution at the end of 2011.

Some of the delays were associated with ensuring that the software meets the needs of the Department of Water Affairs, and specifically the RDM Directorate that deals with all of the issues relating to environmental flow assessments. One of the main uses of SPATSIM has been for implementing data analysis methods and simulation models to support the determination of the ecological Reserve, a major component of the National Water Act. The IWR has been developing and maintaining a SPATSIM application (National RDM database) that contains many of the analysis methods as well as a large proportion of the results that have been generated over the last decade or more. It is very important that DWA take over this function and begin to manage these very important data themselves. To achieve this we have had to ensure that SPATSIM is robust and error-free and that there are some key staff in DWA who are adequately trained in its use.

The focus of the work undertaken by Prof Hughes and Mr Forsyth during 2011 has been to ensure that the software is robust and error free and that all of the facilities and models that are essential for efficient use in Reserve determinations have been moved across from the older version of SPATSIM. Mr Forsyth has also developed a check-out/check-in procedure that allows the DWA to release the most up-to-date version of the RDM database to consultants (check-out) and then update the main database with the results generated by the consultants at the end of a specific Reserve determination (check-in). A great deal of care was necessary in the design of this approach to ensure that the National RDM database does not get corrupted by any changes made by consultants in error.

DEVELOPMENTS IN ENVIRONMENTAL WATER REQUIREMENT METHODS

Sponsor: Water Research Commission
DA Hughes, D Louw, N Kleyhans (DWA), A Birkhead (Streamflow Solutions) and A Desai (PhD student)

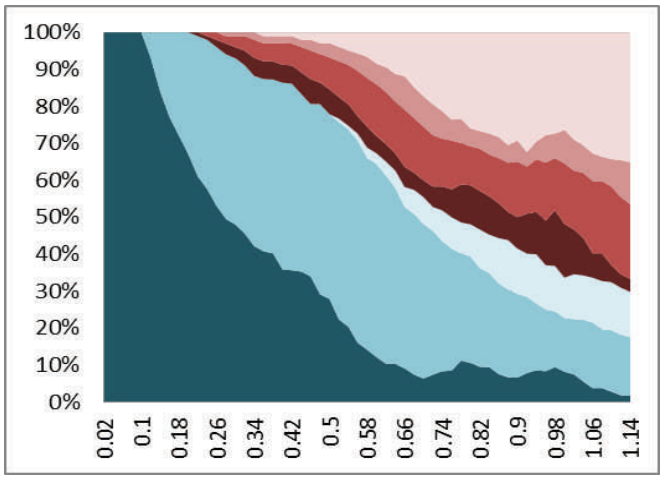
April 2008 – December 2011 (after 18 months extension)

One of the models available within SPATSIM that is used extensively is the Desktop Reserve model that is able to provide a rapid, but low confidence, estimate of an ecological Reserve requirement (equivalent to an environmental flow requirement or EWR). This project was initially a 2 year project designed to improve the Desktop model through the inclusion of hydraulic and ecological submodels (a collaborative project involving the consultancy groups Water for Africa and Streamflow Solutions, DWA and the IWR). At present the model is largely based on hydrology data and some empirical relationships between hydrological variability characteristics and ecological response that were developed some years ago.

The project was designed to incorporate a great deal of the science underlying the determination of environmental water requirements that has been developed over the last few years and yet still ensure that the model can be used for rapid assessments making use of regionalised and readily available data. The project did not progress as quickly as originally intended, partly because of the complexity of the

relationships between hydraulics and ecological response and partly because of difficulties in regionalising hydraulic channel cross-section parameters. However, the software has now been developed to a stage where it can be used operationally and the final report has been submitted to the Water Research Commission.

A major component of this project was the development of the hydraulics sub-model that links the hydrological data to the ecological responses through simulating critical habitat variations within a channel cross-section. The majority of the research work for this part of the project was undertaken by Mr Desai as part of his PhD programme (supervised by Prof Hughes and Dr Birkhead). The hydraulic sub-model is based on defining a representative channel cross-section and it's hydraulic characteristics using available regional information but without the need to complete a field survey. The estimation methods that have been used include some empirical relationships based on previously surveyed channel sites as well as conceptual theory derived from the literature on hydro-geomorphological relationships. The overall objective is to be able to estimate the variations in the frequency of different habitats (defined by combinations of depth and velocity – see example diagram). These variations are used to determine the habitat variations that occur under the natural and present day flow regimes of the river and therefore as guidance for setting future flow regimes to ensure some level of ecological protection. Mr Desai is expected to submit his thesis before the end of 2011.



Relationship between channel water depth and habitat frequency for 7 habitat types (from Dark Blue to Light Red & Bottom Left to Top Right: Slow Very Shallow, Slow Shallow, Slow Deep, Fast Very Shallow, Fast Shallow, Fast Intermediate, Fast Deep).

The final model has been presented to key DWA staff members and the general opinion is that the revised model represents a suitable replacement for the existing Desktop Reserve model. It is now up to DWA (specifically the RDM Directorate) to determine the future training requirements so that the revised model can be implemented in practice.

DEVELOPING CLIMATE CHANGE ADAPTATION MEASURES AND DECISION-SUPPORT SYSTEM FOR SELECTED SOUTH AFRICAN WATER BOARDS

Sponsor: Water Research Commission
DA Hughes, S Mantel, A Slaughter, T Mohobane and A Gordon

April 2010 - March 2013

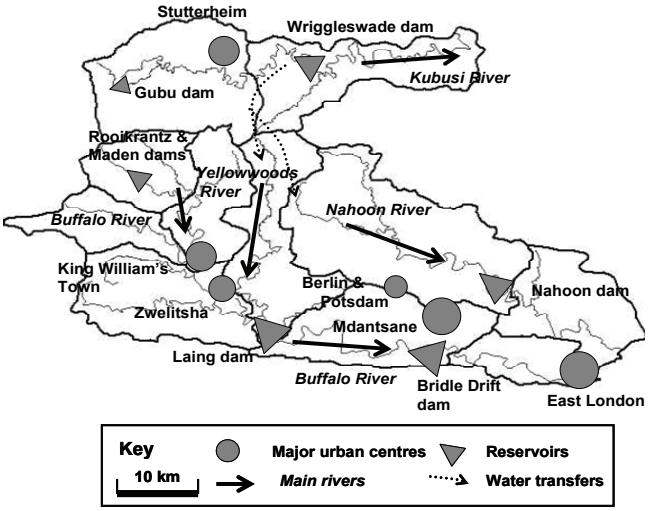
The present project aims to quantify the likely changes in various hydro-climate variables (rainfall, evaporation, groundwater recharge, runoff, water quality, etc.), but also the uncertainty in these changes, as they will impact on future water management plans and sustainable development. The proposed project aims to investigate climate change adaptation measures for two water boards, in the context of developmental changes by developing generic estimation tools, monitoring strategies and a decision support framework. The framework will identify risks, vulnerabilities and adaptation strategies to climate change in order to allow the water boards to fulfill their water supply delivery mandates. The study will undertake the analysis in cooperation with two medium size water boards in South Africa, namely Amatola and Bloem Water Boards.

The aims of this project are:

1. To identify potential impacts and threats to sustainable water services delivery posed by climate change, as well as the uncertainties associated with these, with regards to changes in water quantity, water quality and socio-economic developments. This will be done through application of existing or newly developed estimation tools that can be used to convert downscaled Global Climate Models (GCM) output data to likely changes (including uncertainties) in the variables that impact directly on the operations of water boards (water quantity and quality). Part of the estimation process will include timescales of the expected changes.
2. Develop a methodology for assessing risks and vulnerabilities (including uncertainties in predictions) to climate change for Water Boards and their capacity to fulfill their mandate on water services delivery.
3. Develop a strategy and monitoring network for water audits in order to monitor indicators of change.
4. Derive Thresholds of Potential Concerns (TPCs) for water quality and quantity issues for Water Boards related to raw and potable water, discharges, pricing effects, etc. based on the outputs of the climate models.

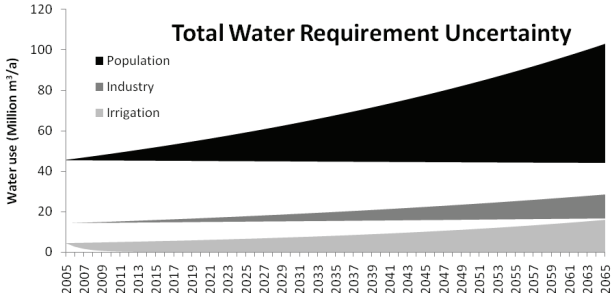
Develop a decision-support framework for an adaptive management strategy to assess and modify water services delivery and development plans of the Water Boards in terms of infrastructure repair and developments, water conservation and demand management, water pricing changes and other associated issues.

The project team consists of three project groups: the Institute for Water Research (IWR) at Rhodes University and two bulk water suppliers, Amatola and Bloem water boards. The IWR project team has primarily worked with modelling the Amatola system (Buffalo, Nahoon and Kubusi Rivers) in the Eastern Cape of South Africa using data from the Amatola Water Board.

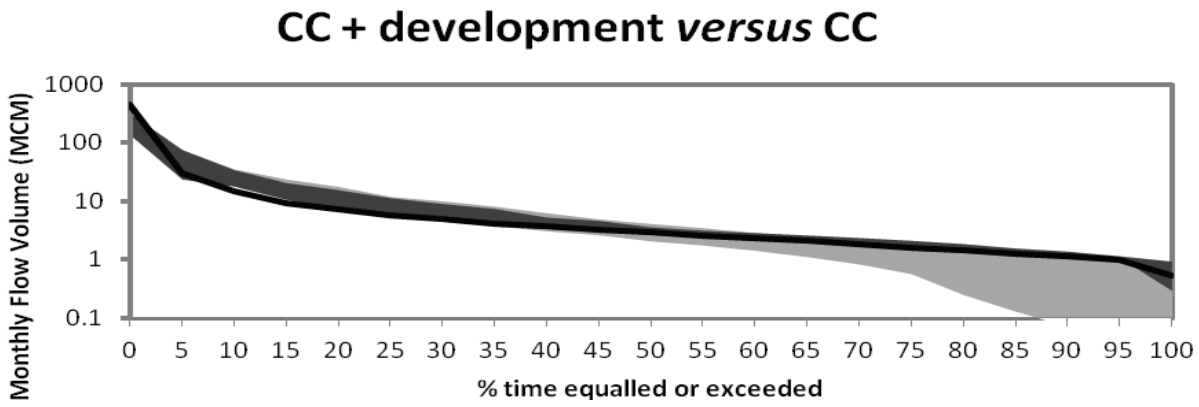


The Amatola system consisting of the 3 major rivers (Buffalo, Amatola and Kubusi Rivers), indicating the catchments, the major towns and reservoirs.

Downscaled climate data for 9 Global Circulation Models (GCMs) were obtained from the Climate Systems Analysis Group at University of Cape Town and the socio-economic development water requirements were obtained from the Department of Water Affair's Reconciliation Strategy.



Projected uncertainty in the water requirements originating from the population, industrial and irrigation sectors for the Amatola system in the near future (2046-65). The values have been extrapolated up to the year 2065 from the values available for the years 2005 and 2030.



Flow duration curve at a lower reach on the Buffalo River under present climate conditions (solid black line; 1921-2005), under the near future climate scenarios (2046-65) with present day water requirements (dark grey band of uncertainty using minimum and maximum values) and under the near future climate scenarios with near future development water requirements (light grey band of uncertainty).

Over the past year the team has conducted hydrological (using Pitman model developed by IWR) as well as water availability and quality modelling (using the Water Evaluation and Assessment Planning WEAP, an off the shelf system level model for water quantity and quality) for the Amatola system. A comparison of the uncertainty in stream water flowing in a lower reach of the Buffalo River under climate change scenarios versus under climate change and development scenarios. Following the second workshop the project team has also started work on a simple water quality model that can be interfaced with Water Resources Yield Model (WRYM) that is used by the DWA.

4. ENVIRONMENTAL WATER QUALITY PROJECTS

DATABASE OF SOUTH AFRICAN SEAWEEDS: PHASE 3

Sponsor: South African Biodiversity Information Facility

NJ Griffin
Collaborators: JJ Bolton (UCT), N Barker (RU), RJ Anderson (DAFF) and ML Gründlingh (CSIR)

February 2010 - September 2011

South Africa's coast has approximately 900 species of seaweeds, of which 40% are endemic to temperate Southern Africa. The taxa found in South Africa make up more than 10% of the world's seaweed flora. Information on the biodiversity and biogeography of South African seaweeds has historically been relatively scarce, with some improvement made since 1980. Most locality-based specimen records are housed in seaweed collections in various herbaria across the country. Most major seaweed collections in herbaria across the country have been georeferenced and digitized and the data made available via African Node of the global Ocean Biogeographic Information System (AfrOBIS), from where they are available to the Global Biodiversity Information Facility (GBIF).

The Pocock collection, housed at the Albany Museum's Selmar Schonland Herbarium (GRA), is the remaining major seaweed collection in South Africa. Specimens in the Pocock collection are largely drawn from the Eastern Cape and therefore from the overlap between the temperate Southern African region (roughly, Western Cape and Namibia) and the tropical Indo-West Pacific (roughly corresponds to KwaZulu-Natal and regions further north). This is an area where seaweed biodiversity is relatively little studied.

All specimen data in the collection have been digitized (18224 records). Samples were collected from 1808 unique localities, 1262 of which have been georeferenced. Uploading of data to AfrOBIS will be undertaken once the remaining sites have been georeferenced.

EVALUATION OF METHODS FOR ASSESSMENT OF ECOTOXICOLOGICAL RISK DUE TO COMPLEX EFFLUENT DISCHARGE

Sponsor: Water Research Commission
NJ Griffin, WJ Muller, AK Gordon, A Slaughter and TJ Human
Collaborators: H Pearson and C Loots (Toxsolutions Kits and Services)

April 2007 - March 2011

The Department of Water Affairs (DWA) have acknowledged that substance-specific methods are not able to fully assess the ecological hazard posed by discharge of complex effluents. The introduction of the Direct Estimation of Ecological Effect Potential (DEEEP) as a more realistic environmental management approach assesses the ecological hazard of complex effluents on freshwater systems. The basis of the DEEEP approach is a series of tests, with lethal and sub-lethal endpoint toxicity tests included, using cultured standard laboratory species as test organisms.

However, there is a lack in South Africa of trained staff and accredited laboratories able to complete ecotoxicity tests. Quality assurance of endpoints is however crucial for legally defensible decisions relating to effluent control, and ISO standardisation particularly for international trade. The introduction of commercial toxicity test kits that use standard laboratory organisms, and are reported to be easy to use and to produce defensible endpoints may alleviate many practical problems with implementation of the DEEEP.

DWA have called for revision of the water quality guidelines with ecologically sensitive species relevant to South Africa, as standard laboratory organisms may not give applicable ecologically protective endpoints. This project compares standard culture-based toxicological methods with tests that use toxicity test kits, as well as with tests that use native or indigenous taxa as test organisms. Comparisons are made on the basis of test endpoints and ease of use, as well the costs of deploying tests in a laboratory.
An analysis of costs involved in toxicity testing reveals that test costs vary considerably. Costs of tests using indigenous organisms are affected mainly by capital costs of equipment and ongoing costs of maintaining cultures of test organisms. Test kits mostly have relatively low capital costs and equipment requirements, but ongoing costs of purchasing kits may make this option less economical where testing rates are high.

Assessment of the responses of test organisms to four complex effluents was undertaken using six test kits and seven tests on indigenous organisms. No differences in results were found when the same tests were undertaken using commercial kits and standard culture-based methods. Potentially promising tests using South African native or indigenous taxa were identified. Problems encountered in obtaining endpoints to tests were noted for consideration in future methodological specifications.

AN EXAMINATION OF WATER QUALITY COMPLIANCE IN SELECTED LOWVELD RIVERS: TOWARDS IMPLEMENTATION OF THE RESERVE

Sponsor: Water Research Commission (K8/984)
CG Palmer and NJ Griffin

Collaborators: S Pollard (AWARD), DR du Toit (AWARD), PA Scherman (Scherman Colloty and Associates cc)

June 2011 - March 2012

Internationally, research to ensure the sustainability of earth systems is focusing on implementation of policy, and the policy-law-practice interface. In South Africa, this trend takes the form of increasingly attending to implementation of the National Water Act (No 36 of 1998) (NWA). In the NWA, the commitment to sustainability is captured in a suite of resource directed measures, of which the ecological and human needs Reserve and resource quality objectives have received the greatest attention. Most of the focus on the ecological Reserve has been on the water quantity component, with substantive, successfully applied research on quantifying environmental flows. However, urgent attention needs to turn to the quality component of the ecological Reserve. Innovative early work on development of methods to quantify water quality resource quality objectives and on integrating these with environmental flows has not found its way into implementation. There are huge gulfs in understanding and practice between resource directed measures (setting objectives to attain particular ecological outcomes), and the source directed methods (licenses for abstraction and discharge that are intended to control environmental stressors).

The deteriorating water quality in South African water bodies suggests a lack of compliance in terms of water quality legislation. In this light, it would be useful to identify specific bottlenecks in implementing water quality control and compliance, and the limitations in compliance requirements that may result in compliance not ensuring adequate resource protection. In this project we will assess how compliance with the ecological Reserve might best be understood, and will examine synergies between the ecological Reserve and the basic human needs Reserve, as well as other with sectors and guidelines. We are developing an analytical and conceptual framework for testing compliance with the water quality component of the ecological Reserve, and are testing and refining this using the Crocodile River (Mpumalanga) as a test case.

SEDIMENT AS A PHYSICAL WATER QUALITY STRESSOR ON MACROINVERTEBRATES: A CONTRIBUTION TO THE DEVELOPMENT OF A WATER QUALITY GUIDELINE FOR SUSPENDED SEDIMENT

Sponsor: Water Research Commission
AK Gordon, CG Palmer, NP Gola, AJ Holland, TJ Human, AS Niba and DN Forbanka

April 2011 – 31 May 2013

The Department of Water Affairs (DWA) has undertaken to revise the South African water quality guidelines (WQGs) for fresh waters initially developed in 1996. The original guidelines did not include a suspended sediment guideline for aquatic ecosystems. However, there is recognition that suspended sediments are an important potential stressor in South African fresh water resources requiring further research to enable the development of a guideline within the revised WQGs. Consequently, the Water Research Commission (WRC) initiated a solicited project with the aim of generating exposure-response data using relevant organisms (indigenous, ecologically and commercially important species) for setting the guideline, and to develop a better understanding of the effects of suspended sediment on our aquatic ecosystems through field based biomonitoring.

The desired objectives for the solicited project are to:

- Establish the most appropriate sediment test material/medium for exposure trials
- To test the effects of suspended sediment particles on selected macroinvertebrates at different levels of biological organization
- Generate an exposure-response relationship framework from the above exposure trials and relevant data in the literature
- Relate exposure-response data developed in the laboratory to natural conditions in the field
- Demonstrate a detailed site specific suspended sediment risk assessment protocol with different levels of complexity
- Recommend further research needed for the development of suspended sediment water quality guidelines.

Suspended sediment exposure-response test exposing mayfly* Tricorythus discolor *to kaolin.

During 2011 an extensive literature survey was undertaken and a database of organism responses to suspended sediment exposure collated. Exposure-response testing of indigenous macroinvertebrates was initiated with two trials exposing the tricorythid mayfly *Tricorythus discolor* to the fine sediment kaolin. Responses determined were mortality, gill damage and two biochemical responses (lipid peroxidation and lactate dehydrogenase). An exposure-response test exposing indigenous shrimp *Caridina nilotica* eggs to kaolin was also initiated with the aim of measuring hatching success and mortality rates.

THRIP – TECHNOLOGY AND HUMAN RESOURCES FOR INDUSTRY PROGRAMME

Sponsors: National Research Foundation / Department of Trade and Industry, Richards Bay Minerals and Unilever
AK Gordon, NJ Griffin, AJ Holland, NP Gola, TJ Human and CG Palmer

2010 - 2012, renewable annually

The THRIP initiative is managed by the National Research Foundation (NRF) and funded by the Department of Trade and Industry (DTI). The aim of the programme is to promote development of technology and human resource skills, whereby the NRF/DTI contributes a portion of the funding provided by UCEWQ's industry partners Richards Bay Minerals and Unilever, toward specific THRIP objectives. With the inclusion of the International School of Tanning Technology (ISTT) as a micro-enterprise partner, the ratio of NRF/DTI funding to industry funding increased from 1:3 during 2010 to 1:2 for 2011. The additional NRF/DTI funds are directed toward refining environmental water quality monitoring tools for use in ISTT operations.

The project was initiated as, for some time, these industries have been questioning the ecological relevance and application of results obtained through the compliance monitoring methods that are used to evaluate and manage their impacts on the environment. The goal of the project is to contribute to the development and refinement of compliance monitoring tools that better reflect the actual ecological impacts occurring, resulting in water resource management that is not too stringent so as to prevent social and economic development, but effective enough to reduce the negative impact of industrial processes on the environment and allow long-term ecological protection.

During 2011, a comparison of available effluent toxicity test methods using one stream of tannery effluent from ISTT was undertaken. Results obtained from tests using standard and indigenous organisms were compared with the results from commercial toxicity test kits. Test comparison was on the basis of test sensitivity, ease of application, and cost of testing. A report on wet-blue effluent, one of the test effluents from this industry partner, in the light of regulations on waste discharge to a water resource has been submitted to ISTT. Collaboration with ISTT will continue into the third year of the study whereby the ecological implications of effluent releases to the aquatic environment will be investigated. Individual streams associated with the tannery process will be determined and their toxicity assessed in order to identify which particular process has the greatest impact on the environment if any. Approaches to mitigate the effects of that particular effluent stream will then be identified. These tasks will have input to the development of a water quality monitoring programme for this micro-enterprise.

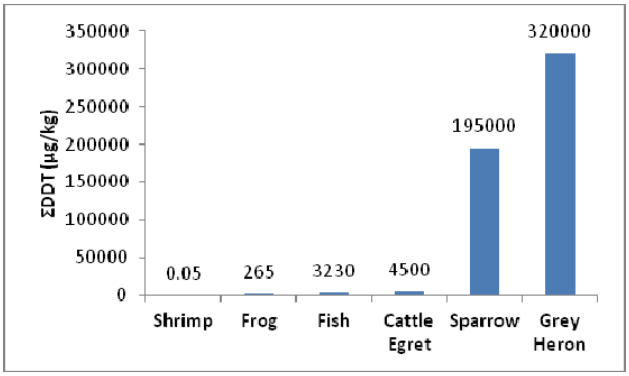
DDT IN A MALARIA CONTROLLED AREA: ENVIRONMENTAL LEVELS AND POSSIBLE EFFECTS ON BIOTA

Sponsor: Water Research Commission
AJ Holland, AK Gordon, TJ Human, WJ Muller and H Bouman (North-West University)

April 2007 – October 2011

In collaboration with the North-West University, a study was undertaken to investigate environmental levels of the insecticide DDT and its metabolites (DDTs) in the Luvuvhu River (Limpopo Province) and determine the possible effects on aquatic macroinvertebrates, snails, frogs, and aquatic birds. DDT is applied in this area through In-house Residual Spraying (IRS) to interrupt the transmission of malaria by mosquito vectors. Various other WRC-funded projects previously conducted in the study area have detected DDTs in water, soil, and fish as well as human breast milk.

Environmental levels of DDTs
During the current study levels of DDTs were detected in all animal groups analysed for DDTs and showed higher bioaccumulation at higher trophic levels.



Levels of DDTs detected in organisms collected in the study area.

No aquatic bird eggs could be collected downstream of Nandoni Dam within the DDT-sprayed area although some breeding colonies were found, which was concerning. It is very possible that the increasing DDT levels in fish in this area found in a previous study might affect the choice of breeding location and breeding success in aquatic birds.

Grey Heron eggs sampled upstream of Nandoni Dam contained very high levels of DDTs, equivalent to the "critical level for reproductive success" established for Brown Pelican in the USA. House Sparrow eggs also contained very high DDT levels, probably due to the proximity of their nests in the thatch the sprayed houses. High levels of DDTs were detected in Sparrow eggs from a village outside the sprayed area. Levels of DDTs were also detected in other animals collected from the non-sprayed area upstream of Nandoni Dam. While frogs and birds can easily move between areas, snails are rather confined to their habitat (pond) and shrimps are unlikely to move upstream against the flow. Detection of DDTs upstream of the DDT-sprayed area suggested some sort of transport of DDT upstream of Nandoni Dam through wind, dust, or possibly illegal use. This problem has been raised in previous studies.

Macroinvertebrate community responses to DDTs

SASS results indicated that ASPT scores in the GSM (gravel/sand/mud) biotope between the non-DDT-sprayed and DDT-sprayed areas differed significantly.

Andy Gordon showing interested locals which invertebrates can be found in the Luvuvhu River.

The GSM biotope is sediment based, which can be influenced by persistent substances (such as DDT), which settle in the sediment. Biotope ASPT scores could possibly be used during SASS analysis to indicate the location of stressors. Multivariate analysis of macroinvertebrate counts did not separate the DDT-sprayed and non-sprayed areas.

RICHARDS BAY MINERALS: ENVIRONMENTAL WATER QUALITY

Sponsor: Richards Bay Minerals (RBM)
AK Gordon, AJ Holland, NJ Griffin and TJ Human

August 2010 – November 2013

The UCEWQ has been undertaking environmental water quality (EWQ) monitoring for Richards Bay Minerals (RBM) in the region of their Smelter Site area since 2006. The EWQ component forms part of RBM's overall environmental monitoring programme and contributes to Rio Tinto's Ecological Target initiative. The EWQ monitoring programme incorporates the use of macroinvertebrates, through the rapid bioassessment scheme SASS (South African Scoring System) and multi-metric analysis of macroinvertebrate communities as well as diatoms, through the use of two indices: the IPS (Index of Pollution Sensitivity) and the Biological Diatom Index Score (BDI-2006). Overall, the various biomonitoring methods confirmed results from previous years in that the Mpisini and Mdibi Rivers were in good condition at the top of their reaches, and that ecological health decreased as one moved downstream. This project exemplifies the advantage of utilising both macroinvertebrates and diatoms as bioindicators. The two approaches are complementary and where macroinvertebrate responses are affected by physical habitat, diatoms can be relied upon to reflect actual water quality impacts.

"Men-at-work" Tarqyn Human and Neil Griffin taking substrate samples.

Future work

Default reference conditions, as proposed by DWA (based on ecological Reserve determination methodology), will be adjusted to yield site specific boundary values for the Richards Bay area.

BOKSBURG LAKE AND WETLAND PROJECT

Sponsor: Unilever
H Fox, AK Gordon and CG Palmer

Renewed on an annual basis

Boksburg Lake is situated in the city center of Boksburg, an industrial and mining town in the East Rand. It is a shallow 150 000 square meter manmade lake, built by the mining commissioner, Montague White and given to the community as a recreational resource in the 1800s. It falls under the Ekurhuleni Metropolitan Municipality (EMM), in the Gauteng province of South Africa. Between the 1960s-90s this lake was the social centre for Boksburg and held high value to the local people.

However, current problems associated with the lake now reflect Beck's (1992) exposition of the 'risk society' resulting from extensive industrial and mining enterprises and rapid, unrestrained development. It is an urban water catchment at risk and the lake reflects this in serious water pollution, crime, deterioration of infrastructure and aesthetics and is now little used by local people. The local risk includes +-300 000 tons of toxic sludge in the lake (Gordon 2008), and the area has been declared a hazardous zone where extensive fish kills, rape and murder are not uncommon.

The Boksburg Lake and Wetland Project is a community driven project aimed at creating partnerships between local residents, local industry and local government (EMM). The goal is to make Boksburg Lake a safe and pleasant recreational resource for residents, a landscape feature of which the Municipality can be proud, and an ecological resource contributing to the long-term ecological sustainability of Boksburg Lake's catchment and downstream watercourse. Over the past six years, funding from Unilever has led to the development of an integrated water quality management plan (IWQMP) which has provided guidance and structure to the project, identifying problems affecting the lake and wetland and suggesting solutions. An on-going goal of the project has been to encourage the EMM to adopt and implement the IWQMP. In mid-2008 the importance of civic engagement in this process was recognised. An environmental education strategy involving schools was developed with the aim of generating enthusiasm and a groundswell of support for effective implementation of urban catchment management within Boksburg. The strategy consists of two main aspects:

- An educational resource pack that mirrors the risk of Boksburg's urban water catchment and provides important knowledge to understand the dynamics of this catchment. This resource pack supports the school curriculum and is used within the classroom context of participating schools.
- The Boksburg Lake Day, held in spring where more than 220 learners from the participating schools spend a day engaging in a range of educational (knowledge, inquiry and action) activities based at the lake. The Unilever Centre for Water Quality, Unilever Boksburg and Ekurhuleni Municipality collaborate in organising this event. The aim of this process has been to represent the environmental risk to learners, re-couple action to consequence (increase a sense of responsibility) and increase agency for meaningful sustainable action.

Boksburg Lake Day

This process aims to mobilize civic society to become an environmental citizenry engaging in social activism and responsible action through social learning in schools while partnering with a range of stakeholders (e.g. EMM, WESSA, Boksburg Historical Association, RandWater, Green Office and Wildlands Conservation Trust). Building on progress made in the last three years, a key goal for 2011 has been to establish community ownership and leadership of the initiative so that it can become increasingly sustainable without depending on external input.

Progress

- Encouragingly a Boksburg Lake Forum has been established that meets monthly. Regular participants include representatives of EMM, teachers, local NGOs, learners, and community members. Mike Mason (previous councilor and still an active citizen) was elected as the chairperson and is in a position to give regular updates of municipal progress in restoring the lake. Other municipal representatives are playing key roles in the forum and showing commitment to the process.
- A teacher's workshop was held in May to introduce more schools to the initiative. Five new schools were exposed to the initiative and received resource packs and three of these have become actively involved by participating in the annual Boksburg Lake Day.
- New partnerships have been developed with Eco Schools (WESSA) and Green Office. Both these NGO's open up exciting opportunities for environmental learning. The majority of schools have indicated that they will register next year to become an eco-school.

This is an important step in taking the project forward.

- A successful Boksburg Lake clean-up day was organized by a subcommittee on the local forum and held on Saturday the 17th of April. Local schools and the general community were invited to attend.
- An evaluation of the process indicates that considerable learning has occurred and numerous schools are now engaging in meaningful environmental action. An interesting finding has been the power of history to inspire positive action, changing litter bugs into litter police. To give some context, learners are confronted by the consequences of their littering habits when they attend the Boksburg Lake Day. They see litter cluttering the banks of the lake and have become aware that litter they drop ends up in the lake through storm water runoff. However, the desire to change is strongly reinforced when they learn about the history of Boksburg Lake (once a prime and beautiful recreational site). They have been given a reference point for what the lake was once like and have realized that they have contributed to its degradation, something countless learners express they want to change.

AN INVESTIGATION INTO THE SENSITIVITY OF INDIGENOUS ALGAL SPECIES FOR APPLICATION IN INTEGRATED WATER RESOURCE MANAGEMENT

Sponsor: ESKOM TERTIARY EDUCATION SUPPORT PROGRAMME
CG Palmer and NP Gola
January 2011 - December 2011

Toxicity tests with micro-algae have been used locally and internationally as part of a battery of tests to assess the hazardous effects of effluent and wastewater discharges on aquatic ecosystems. The most widely used algal toxicity test method is the algal growth inhibition assay with the standard species *Pseudokirchneriella subcapitata*. Toxicity tests with standard species are highly reproducible and generate much needed toxicity data, but tests with indigenous species that are representative of the ecosystem may provide data that are more environmentally realistic. With this in mind the UCEWQ has invested heavily in the development of laboratory facilities for isolating, culturing and maintaining freshwater micro-algae in order to use them in toxicity test. Research using algae adds primary producers to the existing research that UCEWQ has been undertaking with macroinvertebrates such as shrimp and *Daphnia*. The aim of this research is therefore to investigate the relative sensitivity of indigenous algae isolated from local rivers and streams by exposing them to single chemicals and effluents for application in water resource management.

Aligning this research with ESKOM's scientific needs, selected indigenous species and the standard toxicity test species were exposed to ashwater from two ESKOM power plants and a range of other single chemicals such as $CdCl_2$, $K_2Cr_2O_7$, NaCl, Na_2SO_4 and the herbicide Roundup. The data generated from the single chemicals will add to the expanding toxicological database developed and maintained by UCEWQ. The data generated from toxicity tests with the power plant ashwater will provide ESKOM with additional information that will contribute to better understanding of the effects of the effluent on aquatic ecosystems.

5. POSTGRADUATE ACTIVITIES

INVESTIGATING THE RESPONSES OF SOUTH AFRICAN AQUATIC INVERTEBRATES TO LAUNDRY DETERGENT EXPOSURE

Student: Mr AK Gordon
Supervisor: Dr WJ Muller
Degree: PhD (Water Resource Science)

In many rural areas of South Africa, clothes are washed near to or in rivers and streams, resulting in the potential direct input of a commonly used anionic surfactant, linear alkylbenzene sulfonate (LAS) to the aquatic environment. Little is known about the resulting in-stream concentrations or potential effects caused to these rural water courses. In this study, the fate and effects of LAS are investigated in a reach of the Balfour River (Eastern Cape Province, South Africa) which is regularly used as a site for laundry activity. As the use of only one hazard assessment tool or technique rarely provides the adequate information to make a confident assessment of ecological impact, multiple assessment tools will be applied in this study and integrated and evaluated as part of a weight of evidence approach. Samples of river water have been collected upstream of the main washing site and at a number of locations downstream for LAS analysis. In addition, a household survey of the nearby village has been conducted to ascertain washing practices and the amount of detergent used. Macroinvertebrate biomonitoring surveys were undertaken at the river water sampling sites, investigating various macroinvertebrate community level responses, and sub-organism level biomarker responses in specific macroinvertebrate taxa. Lastly, the tolerances of various indigenous invertebrates at different levels of biological organisation (population, individual and sub-organism levels to LAS exposure were determined in the laboratory and, together with relevant international data, were used to derive a preliminary guideline for LAS for South African fresh waters. At its conclusion, the weight of evidence

approach determined no effect to the in-stream biological community of the Balfour River downstream of laundry washing activity.

THE USE OF INDIGENOUS ALGAL SPECIES IN TOXICITY TESTS FOR APPLICATION IN WATER RESOURCE MANAGEMENT

Student: Ms NP Gola
Supervisor: Dr WJ Muller
Degree: PhD (Water Resource Science)

Algae are an ecologically important collection of organisms in aquatic ecosystems, because they form the basis of the aquatic food web, they are therefore essential to organisms at higher levels of organizations. Advances in micro-algal culture technology with development of sophisticated isolation and culture techniques means they can be isolated and cultured for use towards studies on algal growth and genetic characteristics, physiology, culture methods, taxonomy and toxicity testing.

This PhD research is specifically aimed at isolating and culturing micro-algal species for use in toxicity testing, and comparing the sensitivity of local indigenous isolates to that of the standard toxicity test species, *Pseudokirchneriella subcapitata,* using a range of toxicants.

Table 1: Species cultured from different sites of the Palmiet and Keiskamma rivers, Eastern Cape (Bold type indicates species selected for toxicity testing).

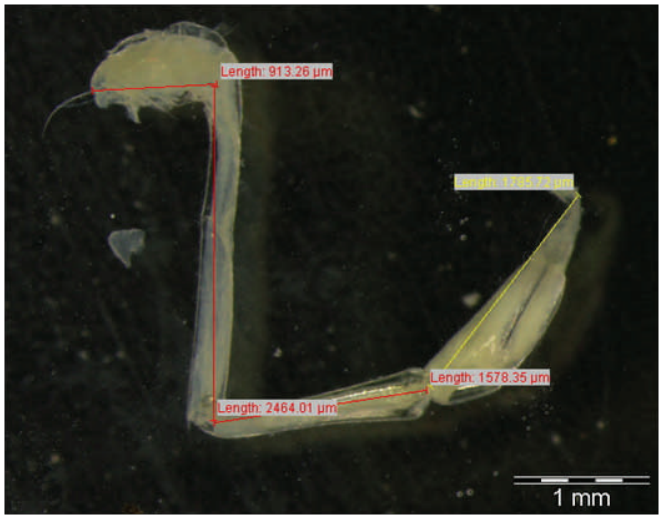
Source	Species ID	Total no. of species
Palmiet	***Chlorella vulgaris***	4
	Stichococcus minutissimus	
	Scenedesmus bicaudatus	
	Monoraphidium minutum	
Keiskamma	*Oocystis lacustris*	4
	Nitzia sp.	
	Chlorella sorokiniana	
	Scenedesmus arcuatus	

Table 1 shows different micro-algal species that have been isolated and cultured from different sites of the Palmiet and Keiskamma rivers in the Eastern Cape, South Africa. There were eight identified axenic cultures (Table 1) initially obtained and from these, three species were selected for use in toxicity tests according to their growth characteristics, and morphology. The selected species were *Chlorella vulgaris* and *Scenedesmus bicaudatus* from the Palmiet River, and *Chlorella sorokiniana* from the Keiskamma River. Toxicity tests exposed these three species, *P. subcapitata* and *C. protothecoides* obtained from a culture collection to a range of toxicants. The following toxicants were used: two reference toxicants ($CdCl_2$ and $K_2Cr_2O_{7)}$, two salts (NaCl and $Na_2SO_{4)}$, a pesticide (Roundup) and ashwater effluent from a coal power plant. The different algal species generally responded variably to chemical stressors from the different toxicants. Therefore using a battery of species that includes local isolates may provide valuable toxicity data that are environmentally realistic and representative of the ecosystem.

INVESTIGATING FLUCTUATING ASYMMETRY OF AQUATIC INVERTEBRATES AS A POSSIBLE INDICATOR OF WATER QUALITY STRESS IN SOUTH AFRICA

Student: Ms AJ Holland
Supervisor: Dr WJ Muller and Mr AK Gordon
Degree: PhD (Water Resource Science)

The measurement of fluctuating asymmetry (FA) – deviations from near perfect symmetry of an individual with bilateral-symmetrical characteristics – has been identified as a possible biological indicator of environmental stress to aquatic macroinvertebrates. Positive attributes of the FA approach include ease of measurement, inexpensive analysis, and the potential to provide early warning of stress exposure prior to manifestation in higher levels of biological organisation, such as population or community changes. FA has been successfully correlated with both environmental and anthropological stress impacts (water temperature variations, heavy metal contamination, nutrient enrichment and salinisation).



Shrimp pereiopod number 1 (left body side).

However, some investigations of FA response as a biological indicator have reported inconclusive results. Consequently the investigations of multiple traits are recommended in order to cover all potential responsive traits. This project investigates the relationship between FA and water quality stress in South African aquatic macroinvertebrates and to assess use of FA measurements as a tool in biomonitoring in South Africa. Potential sites of industrial and pesticide impacts have been identified and selected aquatic macroinvertebrates collected. Multiple traits for the measurement of FA have been identified and are being measured currently. These FA measurements will be correlated with water quality measurements, the South African rapid bioassessment method SASS and macroinvertebrate

community response indices, such as abundance and diversity.

ENVIRONMENTAL WATER QUALITY MANAGEMENT OF GLYPHOSATE-BASED HERBICIDES IN SOUTH AFRICA

Student: Mr PK Mensah
Supervisor: Prof. CG Palmer and Dr WJ Muller
Degree: PhD (Water Resource Science)

Although the use of herbicides is necessary to meet the socio-economic needs of many developing countries, especially in Africa, these bioactive chemicals are known to cause adverse effects in aquatic ecosystems. South African farmers, as well as organizations interested in protecting the country's water resources, make use of glyphosate-based herbicides to control weeds and invading alien plant species. Such herbicides ultimately end up in water bodies indirectly through drifting, leaching, and surface runoff, or directly by foliar spray of nuisance aquatic plants. Unfortunately, there is a paucity of ecotoxicological data on the impacts of these herbicides on aquatic biota. This study seeks to fill this gap. The overall aim is to develop a water quality guideline for the management of glyphosate-based herbicides as part of the integrated water resource management of these bioactive chemicals. Specific objectives are to determine the effects of Roundup® on the freshwater shrimp *Caridina nilotica,* with survival, growth, reproduction and biochemical markers as endpoints; to evaluate the health of the Swartkops River through biomonitoring of macroinvertebrate communities using the South African Scoring System (SASS) and multivariate statistical techniques; and to construct a South African species sensitivity distribution (SSD) based on glyphosate toxicity for the protection of aquatic life.

Preliminary studies, including range finding, definitive acute toxicity tests with neonate, juvenile and adult shrimps, have been completed. Underway are 96 hour acute (lethal) and 21 day chronic (sub-lethal) toxicity tests, using survival, growth, acetylcholinesterase, lipid peroxidation, embryo and gonad developments as endpoints. Biomonitoring of macroinvertebrate communities in the Swartkops River and construction of South African SSDs are also currently underway.

ASSESSING THE UNCERTAINTIES IN WATER RESOURCES MANAGEMENT AS A RESULT OF CLIMATE CHANGE

Student: T Mohobane
Supervisor: Prof. DA Hughes
Degree: PhD (Water Resource Science)

Climate change may impact more on water resources than any other natural resource because of the possible changes in hydro-climatic variability. Projections and predictions of the anticipated impacts of global warming are therefore imperative in order to plan, formulate and implement appropriate adaption strategies well ahead of time. Predictions of the impact of climate change on water resources are, however, influenced by a chain of uncertainties.

Uncertainties in hydrological projections under climate change mainly result from greenhouse gases emission scenarios, downscaling of climate data, selection and structures of climate and hydrological models, as well as inaccuracies in observation records. The current study therefore, aims at evaluating the various sources of uncertainties, identifying their relative significance and exploring methods of reducing such uncertainties. Study areas for this research are two river basins namely, Buffalo in the Eastern Cape Province of South Africa and the Caledon shared by the Free State Province of South Africa and the Kingdom of Lesotho. These two rivers are of economic importance.

BIOLOGICAL TREATMENT OF ACIDIC PRECIOUS METAL REFINING WASTEWATER

Student: B Moore
Supervisor: Dr WJ Muller
Degree: PhD (Water Resource Science)

Precious metal refining generates a large quantity of acidic effluent which cannot be released into the environment. Current treatment of this effluent involves the addition of lime to increase the pH and precipitate soluble metals, removal of the lime, followed by evaporation in industrial evaporators. This process is not only energy intensive, but generates a solid waste which needs to be disposed. Biological systems have been investigated to determine the feasibility of co-treating the acidic effluent with domestic wastewater in an activated sludge system and an anaerobic digester in order to increase the pH and avoid the addition of lime. At the bench scale phase it was determined that an activated sludge system was more suitable than an anaerobic digester for the treatment of the wastewaters. The activated sludge system was replicated at pilot scale and similar findings were obtained. However, during the operation of the pilot system it was determined that an increased contact time between acid effluent and domestic wastewater before feeding the activated sludge system resulted in a steady increase in pH.

Microorganisms growing in the feed tanks were capable of increasing the pH from approximately 5.2 to 6.7 during a two week contact time. Additional studies need to be undertaken to optimize the stabilization system to improve the growth of these microorganisms in order to increase the pH of the blended wastewaters to above 7. Additionally, the activated sludge system assisted in the precipitation of metals, particularly iron which is added to the waste stream in large quantities as a flocculent. Investigation of a secondary treatment step is also recommended as the acid effluent contains high concentrations of ammonia compounds which could not be completely removed by the activated sludge system, and which may interfere with downstream use of the treated effluent.

INTEGRATED ENVIRONMENTAL WATER QUALITY MANAGEMENT OF THE SWARTKOPS RIVER, SOUTH AFRICA USING WATER CHEMISTRY, WHOLE EFFLUENT TOXICITY TESTING AND MACROINVERTEBRATE-BASED BIOMONITORING

Student: ON Odume
Supervisor: Prof. CG Palmer
Degree: PhD (Water Research Science)

Growing human population, urbanization and industrialization have led to increased pollution of freshwater resources and consequent loss of aquatic biodiversity. The Swartkops River, located in a heavily industrialized catchment in the Eastern Cape of South, is no exception as it suffers varying degree of anthropogenic impacts including industrial and domestic wastewater effluent discharges, storm-water run-off as well as run-off from informal settlements. Therefore, to ensure conservation and sustainability of the Swartkops River water resources, there is need for an integrated environmental water quality investigation incorporating aspects of source directed controls (SDC) related to wastewater effluent quality and compliance management, and aspects of resource directed measures (RDM) related to in-stream biological communities, potential effluent in-stream toxicity, and water chemistry. In-stream biological condition will be investigated using macroinvertebrate-based biomonitoring involving taxonomic-based and novel trait-based approaches. The SDC requires that effluent quality be regulated to comply with set discharge water quality limits. The Kelvin Jones wastewater treatment works which discharges into the Swartkops River will be investigated in this study for effluent quality compliance and its potential harmful effects to biological communities will be elucidated. Both chemical and whole effluent toxicity testing will be applied for effluent quality compliance investigation. The specific objectives of this study therefore are: to combine selected macroinvertebrate biological and life-history traits with previously identified suitable taxonomy-based metrics to provide a more detailed water quality assessment of the Swartkops River; to investigate the potential of selected chironomid traits for the development of a chironomid-based traits approach for bioassessment of the Swartkops River; to investigate the relationship between habitat-use and life-history traits of Swartkops River macroinvertebrate; to develop an index of mentum deformities that allows for direct comparison of bioassessment sites in the Swartkops River; to evaluate chronic sub-lethal effects of the Kelvin Jones wastewater whole effluent toxicity to *Chironomus* sp. and toxicity responses to field distributions and traits; to characterised the effluent for selected priority pollutants and ascertain their contributions to the whole effluent toxicity (WET) and in-stream toxicity; to examine the relationship between WET results and chemical-based effluent quality assessment for the Uitenhage Kelvin Jones wastewater treatment work with a view to developing a contextual framework for possible incorporation of WET testing for compliance monitoring and management.

A STUDY OF THE EFFECTIVENESS OF HOUSEHOLD WATER TREATMENT TECHNOLOGIES IN KENYA

Student: B Onabolu
Supervisor: Profs. CG Palmer and L Obi
Degree: PhD (Water Resource Science)

The purpose of this research is to assess the performance of selected household water treatment technologies in sustained use (post-trial) situations in rural communities of Kenya and examine the behavioral determinants of performance in relation to adoption, compliance, promotion and sustained use.

Although much research has been conducted in the area of household water treatment, there is an absence of rigorously obtained scientific evidence of sustained use, positive health impact and water quality improvement over extended periods of use by the different POU technologies. Furthermore, most information on effectiveness are obtained from experiments/efficacy studies which do not reflect the actual post-trial situations.

The study assesses the effectiveness of household water treatment and storage (HWTS) by :

- Assessing knowledge , attitudes and practices of target households and identifying behavior that may potentially affect drinking water quality
- Identifying behavioural determinants of adoption and compliance with selected HWTS technologies
- Determining changes in microbiological water quality from the source to the point of use
- Assessing the effectiveness of HWTS technologies
- Examining user preferences for different doses of chlorinated turbid water
- Determining the potential health impact of HWTS technologies

Data collection and analysis has been carried out and final report is being prepared. Presentations were made to various stakeholders at different fora in Kenya:

- National Technical Working Group on Household Water Treatment and Storage
- Inter- agency collaborative forum on community water supply and sanitation
- UNICEF Kenya
- The food safety, occupational health, environment, child health, international health and water safety divisions of the Ministry of Public Health Kenya.

The information generated will provide policy makers, technocrats and funding agencies with an evidence base for decision making on HWTS technologies.

ASSESSMENT OF THE SURFACE AND GROUND WATER INTERACTION COMPONENTS OF THE PITMAN RAINFALL-RUNOFF MODEL

Student: J Tanner
Supervisor: Prof. DA Hughes
Degree: PhD (Hydrology)

This study aims to improve the conceptual understanding of typical surface and groundwater interaction environments in South Africa thereby reducing some of the uncertainty associated with quantifying their interactions. The approach to defining surface and groundwater interaction environments in this study is considered in a more comprehensive manner than simply defining streams as gaining or losing because the processes involved are more complex than that. There are often many overlaps between different types of environments (for example, an alluvial aquifer overlying a fractured rock aquifer). While conceptualizing some of these environments based on the evidence available is relatively straightforward, many other situations are not clear-cut and further investigation is often necessary. The aim is to utilize newly emerging field-based information, as well as existing information available, on the various processes involved in surface-groundwater interactions (recharge, storage, evaporation losses, discharge to rivers, etc.). The improved understanding of the conceptual processes involved will then be used to test the ability of the modified Pitman Model to adequately represent these processes. If the uncertainties can be reduced by an improved interpretation of existing information coupled with observed data collected by simple field investigations, then it may be concluded that the model has a potential to contribute to integrated water resource planning and management.

HYDROLOGICAL UNCERTAINTY ANALYSIS AND SCENARIO BASED STREAMFLOW MODELLING FOR THE CONGO RIVER BASIN

Student: RM Tshimanga
Supervisor: Prof. DA Hughes
Degree: PhD (Hydrology)

The hydrology of the Congo Basin is poorly understood, yet it is crucial for understanding the dynamics of water resources in Africa. The basin is important in terms of regional cooperation for development of strategies to limit predicted threats of climate change. Possible areas of regional cooperation include virtual water trade to help stabilize political economies, interbasin water transfer to water scarce areas and hydro-electric power development. Hydrological models are important in addressing a range of problems related to water resources assessment, management and development such as analysis of quantity and quality aspects of the catchment runoff processes, reservoir system operation, groundwater development and protection, water resources allocation for various uses, river restoration, etc. Models offer opportunities for filling gaps in the observed data and models can usually be established with limited data and generate sufficiently reliable information for management purposes.

The overall objective of this study is to establish a model for the whole basin using available historical data with the intention of assessing different future scenarios related to climate and environmental change or water resources developments within the basin. One of the secondary objectives is to identify and quantify the main sources of uncertainty in the model outputs so that these can be accounted for as part of risk assessment when management decisions are made.

The initial application of the model (Pitman monthly time-step model) involved manual calibration and the identification of behavioural parameter sets through an ensemble approach using Monte Carlo sampling from uniform parameter distributions. The next step involved an exploration of the behavioural parameter sets in the context of the available basin physical property data (topography, drainage patterns, geology, soils, vegetation, etc.) in an attempt to constrain the plausible parameter sets to those that are conceptually realistic and consistent with real hydrological processes. The third phase involved analysis of scenario of changes and impacts on the hydrology and water resources availability of the Congo Basin.

CLIMATE VARIABILITY AND CHANGE IN WATER RESOURCES MANAGEMENT OF THE ZAMBEZI RIVER BASIN

Student: S Tirivarombo
Supervisor: Prof. DA Hughes
Degree: PhD (Hydrology)

The arid and semi arid southern African region is dominated by high variability in climate. Variability impacts the occurrence and distribution of climatic variables such as precipitation, temperature and evaporation. Climate variability also determines the timing and occurrence of extreme flood and drought events. Climate change is expected to exacerbate the impacts already imposed by variability resulting in significant impacts on water resources. Vulnerable and poor communities are expected to suffer the most from the impacts of a climate change. Vulnerability will be worsened by the fact that the poor cannot afford the costs of implementing timely and appropriate adaptation strategies. The food security status of the region will also be compromised as a result of changing and shifting rainfall patterns. This research aimed to explore climate variability and climate change impacts on the Zambezi River Basin waters. An attempt was made to understand the relationships between climate and basin hydrology, translating the climate change signal as generated from downscaled GCMs into the hydrological component of the basin, assessing vulnerabilities and identifying appropriate adaptation strategies. Activities carried out so far include hydrological model calibration, regional drought analysis, and I am now at the final stage of assessing the climate change scenarios.

ASSESSING SATELLITE REMOTELY SENSED SOIL MOISTURE AND EVAPOTRANSPIRATION FOR THE PITMAN MODEL CALIBRATION

Student: SC Mazibuko
Supervisor: Prof. DA Hughes
Degree: MSc. (Hydrology)

Water resources are under severe pressure induced by human activities which causes changes to the natural hydrological systems and challenge hydrological science and water resources planning tools, such as hydrological models. To improve water resources planning, accurate and reliable prediction tools are useful in representing and analysing water balance components of a hydrological system.

Temporal and spatial variation components of soil moisture and evapotranspiration are important for hydrological modeling as they have significant influence on the physical surface properties of catchments. In developing countries, spatial data comprising these components are scarce. The existing gauging networks measuring such component data provide only point measurements, these limit proper application of hydrology models. This reduces model confidence for water resource planning, and introduce uncertainties in modelling. Remotely sensed data, from satellites have been applied to estimate water balance components to monitor changes in both spatial and temporal scales. With poor gauging networks in the developing countries, satellite data can supplement missing hydrological data and be used to constrain hydrological models by providing improved model parameter estimates and thus reducing uncertainty. This research aims to use satellite data to estimate soil moisture and evapotranspiration data, and calibrate the Pitman model. To date a literature review has been compiled, and currently satellite data processing is being undertaken, which will be followed by modeling exercises.

8. RESEARCH OUTPUTS

PEER REVIEWED JOURNALS AND CONFERENCE PROCEEDINGS

Hughes DA (2011) Regionalisation of models for operational purposes in developing countries: An introduction. *Hydrological Research* 42(5): 331-337.

Hughes DA, Kingston DG and Todd MC (2011) Uncertainty in water resources availability in the Okavango River Basin as a result of climate change. *Hydrol. Earth Syst. Sci.* 15: 931-941.

Hughes DA, Mallory SJL, Haasbroek B and Pegram GGS (2011) Hydrological and Stochastic Uncertainty: Linking Hydrological and Water Resources Yield Models in an Uncertainty Framework. *Risk in water resources management. (Proceedings of Symposium H03, IUGG Conference held in Melbourne, Australia, July 2011), IAHS Publ.* 347: 127-132.

Kapangaziwiri E, Hughes DA, Tanner JL and Slaughter A (2011) Resolving uncertainties in the source of low flows in South African rivers using conceptual and modelling studies. (*Proceedings of IAHS Symposium H01 of the IUGG Scientific Assembly*, Melbourne, Australia, July 2011.

Mayer FL, Ellersieck MR and Slaughter AR (2010) Accuracy assessment of time-concentration-effect models in predicting chronic lethality from acute toxicity data. *Environmental Toxicology and Chemistry* 30: 1-6.

Mensah PK, Muller WJ and Palmer CG (2011) Acute toxicity of Roundup® herbicide to three life stages of the freshwater shrimp *Caridina nilotica* (Decapoda: Atyidae). *Physics and Chemistry of the Earth* 36: 905-909.

Odume ON and Muller WJ (2011) Diversity and structure of Chironomidae communities in relation to water quality differences in the Swartkops River. *Physics and Chemistry of the Earth* 36: 929-938.

Onabolu B, Igboro B, Jimoh OD, Sridhar MkC, Gege A and Onyilo G (2011) Source to point of use drinking water changes and knowledge, attitude and practices in Katsina state, northern Nigeria. *Physics and Chemistry of the Earth*. doi: 10.1016/j.pce.2011.07.038.

Richardson N, Gordon AK, Muller WJ and Whitfield AK (2011) A weight-of-evidence approach to determine estuarine fish health using indicators from multiple levels of biological or-

Sawunyama T, Hughes DA, and Mallory SJL (2011) Evaluation of combined contribution of uncertainty sources to total output uncertainty in water resource estimation in South Africa. *Risk in water resources management. (Proceedings of Symposium H03, IUGG Conference held in Melbourne, Australia, July 2011), IAHS Publ*. 347: 133-138.

Tirivarombo S and Hughes DA (2011) Regional droughts and food security relationships in the Zambezi River Basin. *Physics and Chemistry of the Earth* 36 (2011): 977–983.

Tshimanga RM, Hughes DA and Kapangzawiri E (2011) Understanding hydrological processes and estimating model parameter values in large basins: The case of the Congo River basin. *Conceptual and modelling studies of integrated groundwater, surface water and ecological systems (Proceedings of Symposium H01, IUGG Conference held in Melbourne, Australia, July 2011), IAHS Publ.* 345: 17-22.

Tshimanga RM, Hughes DA and Kapangaziwiri E (2011) Initial Calibration of the Pitman Rainfall-Runoff Model for the Congo River Basin. *Physics and Chemistry of the Earth* 36: 14-15.

IN PRESS AND SUBMITTED ARTICLES

Gordon AK, Mantel SK and Muller WJ (2011) A database of biological effects caused by episodic stressor exposure. *Environmental Toxicology and Chemistry* (accepted).

Hughes DA (2011) Hydrological education and training needs in sub-Saharan Africa: requirements, constraints and progress. *Hydrol. Earth Syst. Sci.* (under review for a special edition).

Hughes DA, Kapangaziwiri E and Tanner J (2011) Spatial scale effects on model parameter estimation and predictive uncertainty in ungauged basins. *Hydrology Research* (under review for a special edition).

Kapangaziwiri E, Hughes DA and Wagener, T (2011) Constraining uncertainty in hydrological predictions for ungauged basins in southern Africa. *Hydrol. Sci. Journ.* (under review). point and diffuse nutrient signatures in stream flows. *Hydrology Research* (submitted).

Mensah PK, Palmer CG and Muller WJ (2011) Acetylcholinesterase activity in the freshwater shrimp *Caridina nilotica*

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CONFERENCE PRESENTATIONS

Gola P and Holland A (2011) Assessing the potential use of indigenous micro-algae in direct toxicity assessment of power sta-

tion ashwater. Paper presented at the Joint International Toxicology Conference of the Cameroon Society for Toxicological Sciences (CSTS) and Society for Environmental Toxicology and Chemistry (SETAC), University of Buea, Buea, Cameroon, 31 May – 3 June 2011.

Desai AY, Hughes DA and Birkhead, AL (2011) Deveopment of a hydraulic sub-model for the Revised Desktop Reserve Model. Presentation at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011. (Awarded an 'Emerging Scientist' Gold medal).

Hughes DA (2011) Applications of PUB in Practice in South Africa. Invited presentation at the PUB (Predictions in Ungauged Basins) in Practice International conference, Canmore, Canada, May 2011.

Hughes DA (2011) Establishing an uncertainty framework for hydrological estimations in South Africa – potential applications to land use change impacts on flood estimation. Invited presentation at an International workshop on Land use change impacts on flooding, Imperial College, London, June 2011.

Hughes DA (2011) Hydrological education and training needs in sub-Saharan Africa: requirements, constraints and progress. Presentation at the Education in Hydrology workshop, IUGG General Assembly, Melbourne, Australia, July 2011.

Hughes DA (2011) Understanding and quantifying uncertainty in hydrology and water resources management. Presentation at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

Hughes DA (2011) Research and Practice for Sustainable Water Resources Management. Keynote presentation at a seminar on Water Resources Research Needs, UCT, Cape Town, October 2011.

Hughes DA, Mantel SK and Mohobane T (2011) An Assessment of the Skill of Down-scaled GCM Products in Simulating Historical Patterns of Rainfall Variability. Poster presented at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

Mazibuko SC and Hughes DA (2011) Assessing soil moisture and groundwater storage variations using AMSR-E and GRACE for the Pitman model calibration. Poster presented at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

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Palmer CG (2011) Developing the practice of resilience thinking at a country scales using a practice-based research initiative: the Akili Complexity and Integration Initiative. International Resilience Conference, Phoenix, Arizona, USA, 11 -16 March 2011.

Palmer CG, Slinger J and Linnane S (2011) From policy to practice: enhancing implementation of water policies for sustainable development. SANPAD International Climate Change Colloquium Durban, South Africa, 21 - 23 November 2011.

Palmer CG (2011) Adaptive management in the planning and execution of transdisciplinary social-ecological research. WRC -DWA Governance Colloquium. Durban, South Africa, November 2011.

Slaughter AR, Hughes DA and Muller WJ (2011) A simple model to separate point and diffuse nutrient signatures in relation to flow within historical monitoring data. Paper presented at the 2nd regional conference of the Young Water Professionals, CSIR International Convention Centre, Pretoria, South Africa, 2 – 5 July 2011.

Slaughter AR, Hughes DA and Muller WJ (2011) A simple TDS mass balance model applied to an irrigation area in the Breede River. Poster presented at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

Tanner JL and Hughes DA (2011) Improving conceptual understanding of the surface and ground water interaction processes. Presentation at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011. (Awarded an 'Emerging Scientist' Silver medal).

Tanner JL and Hughes DA (2011) Resolving uncertainties in surface and groundwater interaction modelling: A case study from South Africa using the Pitman Model. Paper presented at the International Biennial Conference of the Groundwater Division of the Geological Society of South Africa, Pretoria, South Africa 19 - 21 September 2011.

Tirivarombo S and Hughes DA (2011) Drought monitoring as a means of mitigating the impact of extreme events in southern Africa. Poster presented at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

Tirivarombo S and Hughes DA (2011). Integrated wetland modelling for the Kafue Flats. Paper presented at the 12th WaterNet/WARFSA/GWP-SA Symposium, Maputo, Mozambique, 26 - 28 October 2011.

Tshimanga RM, Hughes DA and Kapangaziwiri E (2011) Understanding Hydrological Processes and Estimating Model Parameter Values in Large Basins: The case of the Congo River Basin. Paper presented at the 25th International Union of Geodesy and Geophysics. Melbourne, Australia, 28 June -7 July 2011.

Tshimanga RM and Hughes DA (2011) On a Perceptual Model for Informed Modelling Decisions in Large River Basins: The Case of the Congo Basin. Poster presented at the 15th SANCIAHS National Hydrology Symposium, Rhodes University, South Africa 12 - 14 September 2011.

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Back Cover (top to bottom): SANPAD project team workshop, Delft /Water depth sample site north of dam wall on Katse Dam, Lesotho/Local women washing clothes in Luvumu River, Limpopo Province /School participants Boksburg Lake Day/Photographs kindly supplied by IWR staff and students.


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