

# INSTITUTE FOR WATER RESEARCH



**2012** ANNUAL

REPORT



### STAFF AND MEMBERS OF THE INSTITUTE

#### STAFF

Mr David Forsyth Ms Helen Fox Ms Pearl Gola Dr Andrew Gordon Dr Neil Griffin Mr Greg Huggins **Prof Denis Hughes** Mr Tarqyn Human Ms Delana Louw Mr Stephen Mallory Dr Sukhmani Mantel Ms Juanita McLean Ms Ntombekhaya Mgaba Ms Daksha Naran Mr Jürgen Niedballa Prof Carolyn (Tally) Palmer Mr Tristan Peckham Mr Aphiwe Ponie Ms Asiphe Sahula **Dr** Andrew Slaughter Dr Raphael Tshimanga

Principal Technical Officer PhD student/Part-Time Environmental Officer UCEWQ-IWR (until Mar. 2012) Jnr Research Officer UCEWQ-IWR (until Sept. 2012) Research Officer UCEWQ-IWR Research Officer UCEWQ-IWR Research Officer Water for Africa Professor | Director of IWR Technical Officer UCEWQ-IWR Research Officer IWR Source to Sea Research Officer IWR Water Resources Research Officer IWR Administration Manager Intern Senior Technical Officer Visiting researcher Professor | Director of UCEWQ Intern Intern Research Assistant UCEWQ-IWR

#### ASSOCIATE

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

Postdoctoral Fellow

Postdoctoral Fellow

MEd (Environmental Education)

#### **REGISTERED POSTGRADUATE STUDENTS**

Mr Garth Barnes Ms Louise Bryson Ms Jane Burt Mr Jai Clifford-Holmes Ms Athina Copteros Ms Pearl Gola Ms Alex Holland Mr Haden Jacobs Mr Sbongiseni Mazibuko Mr Paul Mensah Mr Thabiso Mohobane Ms Lara Molony Ms Bronwyn Moore Mr Matthew Muller Mr Nelson Odume Ms Boluwaji Onabolu Ms Asiphe Sahula Ms Jane Tanner Ms Sithabile Tirivarombo Ms Madaka Tumbo Mr Agostinho Vilanculos Mr Bret Whiteley

MSc (Water Resource Science) PhD (Environmental Education) M.Soc.Sc (Integrated Development) PhD (Geography) PhD (Water Resource Science) PhD (Water Resource Science) MSc (Hydrology) MSc (Hydrology) PhD (Water Resource Science, submitted) PhD (Hydrology) MSc (Environmental Science) PhD (Water Resource Science, submitted) MSc (Water Resource Science) PhD (Water Resource Science) PhD (Water Resource Science, submitted) BSc Hons (Environmental Water Management) PhD (Hydrology) PhD (Hydrology, submitted) PhD (Hydrology); based at Eduardo Mondlane University, Mozambique PhD (Hydrology) MSc (Hydrology)

#### **2012 GRADUATED STUDENTS**

Mr Ahmed DesaiPhD (Water Resource Science)Mr Andrew GordonPhD (Water Resource Science)Mr Raphael TshimangaPhD (Hydrology)

#### MEMBERS OF THE BOARD OF CONTROL

Prof Janine Adams Prof Peter Clayton Prof Fred Ellery Prof Denis A Hughes Dr Stanley Liphadzi Prof Heila Lotz-Sisitka Ms Juanita McLean Prof Carolyn (Tally) Palmer Dr Angus Paterson Ms Elizabeth Pretorius Dr Nicole Richoux Dr Dirk Roux Mr Craig Thomson NMMU, Botany Department Chairman; Rhodes University, Dean of Research Rhodes University, Department of Environmental Science Rhodes University, Institute for Water Research WRC (Water Research Commission) Rhodes University, Environmental Learning Research Centre Secretary to BOC and Administration Manager Professor | Director of UCEWQ SAIAB (South African Institute for Aquatic Biodiversity) Unilever SA Rhodes University, Department of Zoology and Entomology SANParks Amatola Water

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Mr R Tshimanga, Dr N Griffin, Mr T Human, Dr A Slaughter, Mr M Muller, Mr D Forsyth, Mr T Mohobane, Ms J Tanner, Ms H Fox Ms L Molony, Mr J Clifford-Holmes, Mr P Mensah, Ms J McLean; Prof D Hughes, Prof C Palmer, Prof J Hofmeyer, Ms S Tirivarombo, Ms B Onabolu Back Row: Greaves Second Row:

Ms A Holland, Ms P Gola, Ms D Naran, Ms A Sahula, Mr S Mazibuko, Mr A Gordon, Dr S Mantel Front Row:

Front Cover (top to bottom): SASS biomonitoring sampling site on Uie River Sundays System/Victoria Girls High school pupils hearing about mini SASS, Botanical Gardens, Grahamstown/Model stream Kelvin Jones waste water treatment works, Uitenhage/Rhodes University Graduation 2012. From left : Dr Raphael Tshimanga, Dr Ahmed Desai, Prof Denis Hughes, Dr Andrew Gordon, Dr Nikite Muller/Mini SASS biomonitoring outing, Botanical gardens, Grahamstown/Photographs kindly supplied by IWR staff and students.

### **INSTITUTE FOR WATER RESEARCH (IWR)**

### **1. IWR DIRECTOR'S REPORT**

#### Introduction

There have been no major changes in the staff complement of the Institute, however Ms Alex Holland resigned her post as a Research Intern within UCEWQ to take up full time post-graduate studies and finish her PhD. The Institute has provided a bursary to help her achieve this goal. While this topic will also be covered in the UCEWQ report, we were also joined during 2012 by two laboratory interns who are working in the IWR as part of their requirements for a Diploma in Analytical Chemistry. Ms Ntombekhaya Mgaba (arrived in February) is registered at NMMU and Mr Aphiwe Ponie (arrived in September) is registered at Walter Sisulu University. Dr Andrew Gordon, who has been with the IWR since 2003 and received his PhD during 2012, left for Cape Town at the end of 2012. However, he will continue to co-supervise post-graduate students and work on research projects with the IWR. One of the other highlights of the year was Prof Tally Palmer's inaugural lecture during September on the topic of 'Water and Transformation in South Africa'. A further highlight was the announcement in November 2012 that Prof Hughes has been awarded the Rhodes University Vice Chancellor's Distinguished Senior Research Medal for 2012.

The senior staff of the Institute continue to be actively involved in policy development and advisory committees at regional, national and international levels. Prof Hughes attended a number of SACNASP (South Africa Council for Natural Scientific Professions) registration meetings as chair of the Professional Advisory Committee for the 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. Prof Hughes is also a Vice President of the International Association of Hydrological Sciences and attended the IAHS Bureau meetings during a conference in Delft during October. 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.

#### International links and conferences

Once again IWR staff have been active in international links through attendance at workshops, conferences and other meetings. Prof Hughes attended a meeting of the DEWFORA project in Sharm-el-Sheikh in February as one of the international advisors. This is a European Union project on 'Improved Drought Early Warning and Forecasting' which is very much aligned with some of the work that is undertaken by the IWR. During May he travelled to Nanjing, China for a meeting of IAHS (International Association of Hydrological Sciences) to discuss the plans for the new Science Decade which will be launched during 2013 as a follow up to the previous decade on Predictions in Ungauged Basins (PUB). The new decade will be all about hydrological change and impacts on society. In July Prof Hughes attended the British Hydrological Society (BHS) National Hydrology Symposium in Dundee, Scotland. In September he travelled to Copenhagen, Denmark for a meeting of the CLIVET project, which supports a Rhodes University registered PhD student (Madaka Tumbo) from Tanzania. CLIVET is a cooperative project between partners in Denmark, Tanzania and South Africa designed to build capacity as well as investigate climate and land use change impacts in the Great Ruaha basin in Tanzania. During October Prof Hughes attended the annual Carnegie RISE meeting in Dar es Salaam, while later in the same month he travelled to Delft in the Netherlands for the 90th Anniversary of IAHS and the PUB Symposium. This was designed to be the end of the PUB decade of science and included a 1day workshop on the new science decade. Prof Hughes gave two invited presentations, both dealing with the importance of transferring science into practice, particularly in the developing world. Dr Raphael Tshimanga and Ms Jane Tanner also attended the IAHS symposium and presented papers. Participation by IWR staff and students at the BHS meeting in Scotland and IAHS symposium in Delft was made possible by partial financial support from Rhodes, while some of Ms Tanner's costs were covered by a young scientist award that she received at the 2011 SAN-CIAHS National Symposium (see the 2011 Director's report).

Prof Palmer attended the Resileince Alliance Science meeting in Montpellier, France during January and presented a paper on 'Processes to build transdisciplinary research teams'. She also attended the SETAC (Society for Ecotoxicology and Chemistry) conference held in Brisbane during July and presented a paper entitled 'Salinity guide-lines and aquatic ecosystem protection: a southern hemisphere perspective'.

Several of the students (Ms Tanner, Ms Bryson, Mr Jacobs) together with Prof Hughes attended the 16th SANCIAHS National Hydrology Symposium held at the University of Pretoria during September. All students presented papers that were well received.

Dr Slaughter presented a paper at the 6th International Congress on Environmental Modelling and Software in Leipzig, Germany during July. His paper was entitled: 'The development of a Water Quality Systems Assessment Model (WQSAM) and its application to the Buffalo River Catchment, Eastern Cape, South Africa' and he received funding from Rhodes University.

Dr Mantel, Dr Gordon and Ms Holland presented papers at the SASSQS conference held at Cape St Francis during July. Funding was supplied partly by Rhodes as well as support for Ms Holland's registration fees from the Eastern Cape Development Corporation. Dr Gordon and Ms Holland also attended the WISA conference in Cape Town.

Most of the Carnegie RISE students, as well as Dr Mantel, Dr Slaughter, Prof Hughes and Mr Muller attended the 13th WaterNet/WARFSA/GWP-SA international conference on integrated water resource management held in Johannesburg during early November. This was the conference that we had selected for bringing together all of the students from the nodes (Rhodes, Makerere, Eduardo Mondlane and Okavango Research Institute) that are part of SSAWRN (Sub-Saharan Africa Water Resources Network) and allowing them the opportunity to share views and experiences amongst themselves as well as with the other young scientists attending the meeting. Over 250 delegates from more than 15 countries attended the symposium and presented under the themes of Water and Environment, Hydrology, Water and Land, Water Resources management, Water Supply and Sanitation, and Water and Society.

Prof Palmer's report on UCEWQ contains further information about international and trans-disciplinary cooperation.

#### **Consultancy links**

There has been much less activity in the field of consultancy than there used to be in former years. This is largely a reflection of the greater commitment of the Institute to post-graduate training and research development and the amount of time spent by senior staff on supervision. Prof Hughes, however, continues to generate some useful income from consultancy projects which provides funds for some student bursaries as well providing additional funds for travel to conferences for staff and students. It is also important that we do not lose the links with practical problem solving which has been one of the IWR strengths and has provided an immediate market for some of its applied research products. UCEWQ maintain a consultancy with Richards Bay Minerals.

During 2012 we were successful in obtaining World Bank funding as part of a US led consortium to undertake an integrated assessment of climate change impacts within a number of large river basins in Africa. The concept is to apply consistent methodologies to all of the selected basins. The IWR will be responsible for the Congo, Orange and Zambesi River basins. It will be a 1-year project and at the time of writing this report we were waiting for further details about the exact manner in which the project will be implemented. It is expected that we will develop an MOU with Dr Tshimanga when he returns to the DRC so that he can do most of the work on the Congo basin. This represents an excellent opportunity for him to develop further research skills and a research profile within the sub-Saharan Africa region.

Prof Hughes has also been involved in training some of the water resources assessment staff of Atkins International in Tanzania in the application of the IWR's modelling tools. Atkins are involved in a major project for the Tanzanian Government related to water resources assessments within the southern coastal catchments of the country.

#### Undergraduate teaching

Dr Griffin ran a three week ENV202 course for 2nd year Environmental Science students based around management of water resources. The Institute continues to contribute to the Department of Environmental Science EN-V302 course on water resources management, with Prof Hughes, Dr Gordon and Dr Mantel covering water quantity, quality and legal issues.

The IWR also offered a 1 month course on Environmental Water Quality for Geography and Environmental Science Honours students. Contributions were made by Prof Palmer, Dr Gordon and Dr Griffin, with some inputs from postgraduate students.

#### Post-graduate students

At the 2012 Rhodes graduation ceremony Dr Andrew Gordon, Dr Raphael Tshimanga and Dr Ahmed Desai received their PhD degrees. Dr Tshimanga is the first of the Carnegie RISE SSAWRN students to obtain a PhD, while we expect at least a further three of the RISE students to complete and be ready for graduation in 2013. At the time of writing this report, the examination process for Ms Sithabile Tirivarombo was complete and she is now only left with the task of making some corrections before completing the process.

Mr Jai Clifford-Holmes was one of 27 African students selected for the Mandela Rhodes scholarship for 2011-2012. He was also awarded a SKILL bursary from the South African VU University Amsterdam Strategic Alliance (SAVUSA), which funded an internship in the Policy Analysis Division of the Faculty of Technology, Policy and Management at the Delft University of Technology (TU Delft) in The Netherlands.

Ms Asiphe Sahula won a prestigious Cannon Collins Graca Machel honours scholarship award to study environmental water management and this was reported on the IWR web site, as well as in Rhodos. Mr Juergen Niedballa from Dresden University of Technology has spent 6 months since June working on the WRC suspended sediment project as part of his Masters degree.

The Institute has been actively engaged in the discussions about the possible Rhodes University bid for a UNECSO Category I Centre (a centre for post-graduate training with the same pattern as the UNESCO IHE in Delft). As part of this process we designed the basic structure of a coursework MSc degree in Water Resources Science that would link with a similar coursework MSc degree in Integrated Development (with a focus on water) proposed by Prof Chris De Wet of Anthropology. The proposal has been discussed by various Rhodes management committees and agreed upon in principle. However, at the end of 2012 it was not clear whether Rhodes is able to allocate sufficient additional staff resources that will be required to initiate this course.

#### **Post-Doctoral posts**

Dr Andrew Slaughter continues to work with Dr Mantel and Prof Hughes on the WRC funded project investigating climate change impacts and adaptation strategies for the Amatola 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 and he has submitted a research proposal to the WRC to extend this work during 2013 and beyond. Dr Raphael Tshimanga completed his PhD degree in February 2012 and worked as a Post-Doctoral Fellow (with RISE funding) during the remainder of 2012 before returning to the Democratic Republic of Congo at the end of 2012 to take up a lecturing position in Kampala University.

#### **RISE Sub-Saharan Africa Water Resources Network**

January 2011 saw the start of the second phase of the Carnegie RISE programme with US\$800 000 for the whole of the SSAWRN programme over the three year period up to the end of 2013. During the October Carnegie RISE annual meeting in Dar es Salaam, we were informed that a third and final 3-year phase of funding has been agreed to between the managers of RISE, the Science Initiative Group (SIG) of Princeton University and the Carnegie Foundation of New York. The difference is that the five networks that are currently funded will compete for the available funds. The SSAWRN nodes (Rhodes, Makerere, Okavango Research Institute and Eduardo Mondlane) discussed the possible ways forward and how we should compile the proposal during the WaterNet conference in November 2012. We will be working further on the future plan and the proposal during the early part of 2013.

#### Community Outreach and Public Understanding of Science

Various water related events were organised within Rhodes University for World Water Week this year running from 27 to 31 August. The IWR, in collaboration with the Kowie Catchment Campaign arranged to demonstrate simple water quality testing and simple biomonitoring techniques to an identified group of school learners and any interested members of the general public. The grade 10 class of Victoria Girls High School consisting of approximately 60 learners participated. Two demonstrations were conducted within the Botanical Gardens, along a stream that is a tributary of the Kowie River. Those who arranged the demonstrations included: Mr Andrew Slaughter, Ms Alex Holland, Mr Haden Jacobs, Mr Mathew Muller, Ms Daksha Naran and Ms Ntombekhaya Mgaba.

The IWR participated in the 2012 regional Eskom Science Festival this year. Ms Daksha Naran, Ms Alex Holland, Mr Mathew Muller and Dr Andrew Slaughter volunteered to judge student projects. Ms Alex Holland and Dr Andrew Slaughter also gave advice to two learners from Riebeek East who were investigating the water quality of the Riebeek East tap water. The learners went on to win the development award at the Science Festival regional competition and qualified to attend the national final competition.

#### **Concluding remarks**

The Institute has seen tremendous growth in postgraduate students over the last few years, largely initiated by the Carnegie RISE programme. We have seen a steady crop of students graduating each year (1 MSc in 2008, 1 PhD in 2009, 1 MSc in 2010, 2 PhD, 2 MSc in 2011, 3 PhD in 2012 and the expectation of at least 3 PhD's in 2013) which contributes substantially to the Rhodes subsidy income. As noted in previous annual reports there has been no real growth in staff available for supervising postgraduate projects and this is a cause for concern.

Outputs	2 0 0 6	2 0 0 7	2 0 0 8	2 0 0 9	2 0 1 0	2 0 1 1	2 0 1 2
Peer Reviewed Journals	12	8	7	5	11	9	12
Reports	17	33	5	14	18	24	10
Conference proceedings	3	10	2	7	3	4	1

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

The Carnegie Foundation (through the RISE initiative) has now become a very important source of funding for postgraduate students within the Institute. We have developed excellent relationships with the fund administrators over the first year 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 very grateful to Dr Sukhmani Mantel for the sometimes difficult job that she does as administrator of the network.

We continue to be very 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 2012 included Prof Hughes, Prof Palmer, Dr Gordon, Dr Mantel, Dr Slaughter, Dr Tshimanga, Ms Tanner and Ms Holland.

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 Centre has consolidated well this year. The main strategic goals have been to develop transdisciplinary, complexity-based (TDC) research practice, and to continue to adapt and refine the relationship between the Centre and Unilever SA. In the process of achieving these goals UCEWQ staff and post graduate students have flourished, papers have been published, new research grant funding has been secured and there is evidence of our research playing a transformative role in the water sector.

### Transdisciplinary and complexity-based (TDC) research practice

All research undertaken by UCEWQ staff and students is founded on the understanding that humans living on earth comprise complex social ecological systems. It is the characteristics of complex systems that give rise to most of the intractable problems that arise in water resource management. Therefore, key foundation approaches to water research that seeks to shift and loosen problem issues, include complexity thinking (because the systems are by their nature complex) and transdisciplinarity (because it offers methods for concurrent knowledge development and sharing across disciplinary boundaries, and among communities, researchers and practitioners).

TDC research practice is promoted in two ways within

UCEWQ: firstly, through post graduate supervision. Nine of the twelve current post-graduate students are supervised by Prof Tally Palmer. Of these, four will graduate in Water Resource Science, three in Education (Environmental Education), and one each in Geography (Human Geography), Anthropology (Integrated Development) and Environmental Science. In each case co-supervision is across areas of disciplinary expertise and both supervisors engage equally, together and with the student, in intellectual development. This process has brought anthropologist Prof Chris de Wet into a close relationship with UCEWQ, and he plans to join the IWR in 2014. In these collaborative processes, critical realism thinking is emerging as a pivotal tool for integrating across science and the humanities. Secondly the largest current UCEWQ project, funded by SANPAD (South African Netherlands Alternatives for Development Programme): "From policy to practice: enhancing implementation of water policies for sustainable development", explicitly includes a process for building a transdisciplinary (TD) research team, and Jane Burt is exploring this TD team -building as part of her doctoral research. The TDC research is undertaken in close collaboration with Prof Heila Lotz-Sisitka (Environmental Learning Research Centre) and Dr Sheona Shackleton (Environmental Science), with whom we share an NRF Global Change, Society and Sustainability grant which supports several of the post-graduate students. This project also draws in Nelson Mandela Metropolitan University and the University of Fort Hare as partners. Prof Tally Palmer was a delegate at the select Resilience Alliance Science meeting in Montpellier, France in January, where she presented the on the process of building TD research teams, and she now participates in the RA TD working group.

The TDC approach was the basis of two major grant proposals this year. The first is a THRIP (Technology and Human Resources for Industry) proposal to develop a collaborative, integrated water quality management process for the Crocodile River. Seven industrial water users in the catchment have pledge R1M in support of this. The second is a large WRC project to develop and apply a "new paradigm" for integrated water resource management practice.

Working within networks or communities of practice is a key feature of TDC research practice. UCEWQ is part of three important and connected research networks. The Resilience Alliance as indicated above. The Southern African Programme for Ecosystem Change and Society (SAPECS), which is co-ordinated by Drs Belinda Reyers (CSIR, Stellenbosch) and Oonsie Biggs (Stockholm Resilience Centre and Stellenbosch University). All UCEWQ projects will be registered with SAPECS. The Complexity forum is a new network supported by the NRF. A UCEWQ-led SANPAD project research team of thirteen researchers and



Tally Palmer, Jill Slinger and Suzanne Linnane at the SANPAD International Project Conference in Durban.

post-graduate students presented the Policy to Practice TDC project at the first Complexity Forum meeting in Stellenbosch, in October, hosted by the Centre for Complexity Studies (Stellenbosch University). The team approach and the content and outcomes of the project to date were well received. Presenting researchers included research partners Drs Jill Slinger (University of Technology Delft) and Suzanne Linnane (Dundalk Institute, Ireland), Prof Kevin Rogers and Rebecca Luton (Centre for Water in the Environment, Wits University); Drs Sheona Shackelton and Georgina Cundill (Environmental Science, Rhodes), Dr Tony Palmer and Ms Andiswa Finca (Agricultural Research Council) and Dr Chris Burman (University of Limpopo). Student presenters were Jai Clifford-Holmes, Matthew Muller, and Lara Molony (Masters) and Jane Burt and Helen Fox (Doctoral).

Finally, Prof Tally Palmer is guest editor of a 2013 special feature of the journal Ecology and Society that show-cases TDC research practice in southern Africa.



From left, Andiswa Finca and Suzanne Linnane, preparing for the UCEWQ session at the Complexity Forum in Stellenbosch.



From left, Georgina Cundill, Jai Clifford Holmes, Matthew Muller and Lara Molony preparing for the UCEWQ session at the Complexity Forum in Stellenbosch.

#### **Unilever SA**

Unilever SA is aligning with Unilever Global in its approach to corporate social responsibility investment. As a result, funding UCEWQ at the current scale is only guaranteed for 2013. UCEWQ is one of only a few current Unilever SA recipients to be invited to re-motivate for support from 2014. UCEWQ will base its motivation on support of the Unilever Sustainable Living Plan, and on the work we do to increase service delivery in South Africa, thus increasing the market for water-based cleaning products. Since research is the core UCEWQ business, the aim is to continue taking the Unilever name into the heart of applied water research in South Africa by working closely with major research funding agencies nationally and internationally; the South African Department of Water Affairs, DWA; and water users at all levels from communities and local government to multinationals.

This year UCEWQ continued to engage actively with the Boksburg Lake day, and in 2013 the project will be replanned. Helen Fox, now a UCEWQ doctoral student, has been a central figure in the success of this project which has involved the local community in a clean-up and awareness of Boksburg Lake.

In May UCEWQ facilitated Unilever SA having a lead role in the biggest South African water conference – the biennial WISA (Water Institute of South Africa) meeting in Cape Town. The one day colloquium "Unilever hosts: Corporate Water Stewardship", involved leaders from DWA, industry and water research. In the opening session presentations were made by the DWA Director General and Chief Operating Officer, CEO of the Water Research Commission, Mr Ross Plumbley, regional Vice-President Research and international guest Dr Jason Morrison (Pacific Institute), Technical Director & CEO Water Mandate. This was followed by a panel discussion facilitated by Dr Guy Pegram (Pegasys) with Mr Ross Plumbley from Unilever, Mr Martin Ginster from SASOL, Mr Trevor Balzer COO DWA, Mr Andre Fourie from SAB Miller, Mr David Brittain from Coca-Cola, Mr Sanjeev Raghubir from Nestle, Mr Nandha Govender from ESKOM, and Dr Christine Colvin from WWF. The outcome of the day was that Unilever would join the DWA-Industry committee chaired by Mr Balzer and Mr Fourie, and that by the next WISA we would aim to have the top thirty water-dependent companies participating in corporate water stewardship in South Africa.

#### UCEWQ staff and students

A highlight of the year was Andrew Gordon's doctoral graduation in April. Andrew has made a substantive contribution to UCEWQ, including leading UCEWQ in 2010, running the Boksburg Lake project for several years and recently in tackling the vexed question of the effects of suspend solids on riverine organisms. In this regard Andrew hosted Juergen Niedballa, as part of a UCEWQ collaboration with the University of Technology Dresden. Andrew's doctoral work on the effects of in-stream clothes' washing using laundry detergent was a significant contribution to Unilever and was presented at SASAqS this year. Sadly he is now leaving UCEWQ and moving to the Western Cape. We all look forward to future collaborations with Andrew, who will continue to supervise UCEWQ post-graduate students.

Pearl Gola has also left UCEWQ, and has joined the National Research Foundation for a career in research management. They are fortunate to have her as part of their team. Pearl is working to complete her research on the use of local freshwater algae in ecotoxicity testing. Newcomers to UCEWQ are interns Tristan Peckham who is working on the ecotoxicity data base; Ntombekhaya Mgaba, an NNMU analytical chemistry diploma student, and Aphiwe Ponie, a Walter Sisulu University analytical chemistry diploma student, both of whom are learning skills in biomonitoring and ecotoxicology, while practising their skills in water chemistry analysis. Technical officer Mr Targyn Human continues to keep all the UCEWQ cultures in good condition, undertakes macroinvertebrate identification and is participating in intern training. Alexandra Holland and Matthew Muller achieved SASS biomonitoring accreditation.

In addition to his algal research interests Dr Neil Griffin anchors data analysis and interpretation in all the UCEWQ projects. He is playing a central role in the further development of water quality methods within ecological Reserve determinations, and will lead sub-teams if the large THRIP and WRC project eventuate in 2013. He presented posters at two conferences this year.

Paul Mensah and Bolu Onobolu worked extremely hard and submitted their doctoral theses during the year. These substantive pieces of work are still under examination. They will be followed next year by Nelson Odume, Helen Fox and Alexandra Holland. Nelson finally achieved setting up an impressive set of artificial experimental streams at the Kelvin Jones Waste Water Treatment Works in Uitenhage – an achievement for both science and negotiation.



A model stream set up at the Kelvin Jones waste water treatment works (a), sampling (b).

Helen Fox also went to conferences in Cape Town and India.

Tally Palmer presented papers at the international SETAC conference in Brisbane, and the Savannah Network confer ence in Skukuza; she was invited to talk on women and research at a the 10th HERS-SA Academy in Cape Town; was a participant in the Wisdom and Ethical Leadership roundtable hosted by the new Rhodes University Allan Grey Centre for Ethical Leadership; and presented her in-

augural lecture in August, entitled "Water and Transforma mation in South Africa".

At the end of a busy and eventful year I would like to extend grateful thanks to all the UCEWQ staff and students, and very particularly to the IWR support team Juanita McLean, David Forsyth and Daksha Naran. We also all enthusiastically congratulate IWR Director, Prof Denis Hughes on being the 2013 recipient of the Vice-Chancellor's Distinguished Senior Research Award.

### 3. HYDROLOGY PROJECTS

The hydrology group of the Institute consisted during 2012 of Prof Hughes, 1 Post-Doctoral Fellow (Dr Andrew Slaughter) and five post-graduate students; Dr Tshimanga (PhD and Post-Doc after March), 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 involved in the development and maintenance 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 the some of the hydrology projects and co-supervises some of the students. An additional four external students have been working on hydrologically related projects. Dr Ahmed Desai completed his thesis on the development of the hydraulic sub-model for a revised desktop Reserved determination model (a WRC Project), Ms Tumbo Madaka is working 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 three main headings 'Implementing uncertainty analysis in water resource assessment and planning', 'Climate change adaptation strategies' and 'General consultancy projects'.

#### IMPLEMENTING UNCERTAINTY ANALYSIS IN WATER RE-SOURCES 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.

The current 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 at climate change impacts and adaptation strategies for South African Water Boards.

The project design refers to two deliverables that were to be generated during 2012. The first of these (Deliverable 4) was not completed on time due to some problems in initiating a change in the project plan. After discussions between the IWR, several consultancy groups, the WRC Reference Group and the Department of Water Affairs (DWA) it was decided to propose an add-on component to the project that would investigate the practical issues of uncertainty analysis through a targeted example based on the Mokolo River catchment (a highly stressed water management area). The idea was that the DWA would fund the additional work through the WRC. Despite many attempts to obtain clarity on the status of the proposal we have been unable to get an answer from DWA on whether they are able and willing to make the necessary funds available. All that we have been able to discover is that the project has been supported by several engineers and scientists within DWA.

Deliverable 5 represents the final report on understanding surface water – groundwater interactions and the uncertainties associated with modelling them. This report essentially contains the same material that Ms Tanner is using for her PhD project. It is intended that this deliverable will be published by the WRC as a separate report during 2013 after it has been reviewed by the WRC Reference Group and further edited by the project staff.

While some of the details of the uncertainty framework and its application 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. This project and the previous one have already generated four PhD's from Rhodes (Dr Sawunyama and Dr Kapangaziwiri on the previous project; Dr Tshimanga and Ms Tirivarombo on the current project), while Ms Tanner, 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.

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

Sponsor: Dept. of Water Affairs and Water Research Commission DA Hughes, S Mantel, A Slaughter, T Mohobane, K Stroebel and B Whiteley

#### 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:

- 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.
- Develop a methodology for assessing risks and vulnerabilities (including uncertainties in predictions) to climate change for Water Boards and their capacity to fulfil their mandate on water services delivery.
- Develop a strategy and monitoring network for water audits in order to monitor indicators of change.
- 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 two main project groups: the Institute for Water Research (IWR) at Rhodes University and Amatola Water Board. Bloem Water Board attended the first meeting of the project but has not responded to further communication since then. Thus, the IWR project team has primarily worked with modelling the Amatole system (Buffalo, Nahoon and Kubusi Rivers) in the Eastern Cape. Downscaled climate data for 9 Global Circulation Models (GCMs) were obtained from the Climate Systems Analysis Group at University of Cape Town and the socioeconomic development water requirements were obtained from the Department of Water Affair's Reconciliation Strategy. Over the past year the team has conducted hydrological (using the 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 Amatole system. Following the second workshop the project team (Andrew Slaughter and Denis Hughes) has been working on a simple water quality model (Water Quality Systems Assessment Model WQSAM) that is being interfaced with the Water Resources Modelling Platform (WReMP). The last annual workshop for the pro ject (September 2012) discussed the Thresholds of Potential Concern and the draft Decision Support System (that will be based on the WQSAM), which will form the final deliverable of the project.

Kelly Stroebel has conducted a social survey of different socio-economic groups in King Williams Town as part of her Honours project in the Environmental Science Department at Rhodes University. She conducted 120 household questionnaires that focused on water use, conservation, and knowledge about climate change impacts and has recently submitted her final project report. Bret Whiteley (part-time MSc student based in the USA) has been investigating the use of the Watershed Assessment Model (WAM) that has been extensively used in the USA to the Buffalo River.

The Amatole system consisting of the 3 major rivers (Buffalo, Nahoon and Kubusi Rivers), indicating the catch-



ments, the major towns and reservoirs.



Projected uncertainty in the water requirements originating from the population, industrial and irrigation sectors for the Amatole 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.

#### **GENERAL CONSULTANCY PROJECTS**

Sponsor: Various Clients DA Hughes

2012—Ongoing

The majority of the consultancy projects are related to our partnerships with Ms Delana Louw and Mr Stephen Mallory and are frequently associated with environmental water requirement determinations. Some are relatively small projects, while others are more extensive. One of the large projects that the IWR was involved with during 2012 was the establishment of environmental flows for the Fish River in Namibia, associated with the development of a new large water supply reservoir (Neckartal Dam). Prof Hughes is involved in the hydrological modelling component of the study and guiding the other specialists in the methods used to establish environmental flows. The study offers many challenges in a large river, with a highly variable flow regime and limited amounts of real data.

Prof Hughes has been involved in training some of the staff of Atkins International on the use of SPATSIM and the Pitman rainfall-runoff model in the coastal catchments of southern Tanzania. Atkins are contracted to the Tanzanian government to develop an integrated water management plan for the region and they are using the Pitman model to determine the water resources availability.

During 2012, the IWR was part of a partnership that was successful in a bid to the World Bank on a project designed to apply consistent methodologies for climate change impact assessments on water resources to a number of large basins in Africa. The IWR will be responsible for the Orange, Zambezi and Congo River basins. Prof Hughes, Dr Mantel, Dr Tshimanga and Mr Mohobane will participate in the project, while we will also be looking for an additional student.

### 4. ENVIRONMENTAL WATER QUALITY PROJECTS

#### SEDIMENT AS A PHYSICAL WATER QUALITY STRESSOR ON MACROINVERTEBRATES: A CONTRIBUTION TO THE DE-VELOPMENT OF A WATER QUALITY GUIDELINE FOR SUS-PENDED SEDIMENT.

Sponsor: Water Research Commission AK Gordon, CG Palmer, TJ Human, A Sahula, J Niedballa, AJ Holland, SG Bennett, AS Niba and DN Forbanka

April 2011 – 31 May 2013

The management of suspended sediments requires an understanding of the biological implications of exposure to this stressor. The two most applicable management tools in this regard are water quality guidelines and field biomonitoring. The development of a water quality guideline for suspended sediment is a goal of this project, as is an understanding of the most appropriate (in terms of sensitivity and practicality) biomonitoring approach for measuring biological effects of suspended sediment.

Work towards developing a water quality guideline for suspended sediment is being achieved through exposureresponse testing of indigenous macroinvertebrates. BSc Hons students Steven Bennett and Asiphe Sahula, together with project staff, have exposed the mayflies *Tricorythus discolor* and *Oligoneuridae sp*, and freshwater shrimp *Caridina nilotica* to fine Kaolin clay particles. Both lethal and sublethal responses have been determined, measured at levels of biological organisation ranging from population to organism (lethality and gill damage) to biochemical responses (lipid peroxidation and lactate dehydrogenase). These data, combined with those from the literature, are used to generate an exposure-response relationship framework.



Scanning electron microscopy image of the gill of mayfly Tricorythus discolor exposed to suspended kaolin clay particles

A common theme in ecotoxicology is the question of applicability of laboratory derived results to natural conditions in the field. Consequently the derived framework will be related to natural conditions. For this purpose a study site in the headwaters of the Umzimvubu River in the north Eastern Cape Province has been identified. Three catchments with rivers of contrasting suspended sediment characteristics have been identified. The Little Pot and Upper Little Pot Rivers have low sediment load, being located in a catchment with little degraded land. In contrast the Luzi River flows through the highly degraded communal lands of the former Transkei. The Tsitsa Tributary falls somewhere in between. Relationships between land-use, suspended sediment and macroinvertebrate community characteristics (determined through biomonitoring) will be explored. The results of which will be used to inform the development of a site specific suspended sediment risk assessment protocol.



Image of contrasting land-use in three catchments of the upper headwaters of the Umzimvubu River, north Eastern Cape Province

#### THRIP – TECHNOLOGY AND HUMAN RESOURCES FOR IN-DUSTRY PROGRAMME.

Sponsor: Sponsors: National Research Foundation (NRF) and Department of Trade and Industry (DTI), Richards Bay Minerals, Unilever, Eskom, International School of Tanning Technology AK Gordon, NJ Griffin, NP Gola, TJ Human, T Peckham and CG Palmer

April 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 together with improving the competitive edge of South Africa's industry through the development of advanced technologies. Under this programme, the NRF/DTI match industry partner funding to support research leading to endpoints of importance to the industry in question. In the last year, UCEWQ's industry partners have been Richards Bay Minerals, Unilever, and Eskom, with the International School of Tanning Technology as a microenterprise partner.

The initial and overarching aim of the project is to investigate the environmental realism of the available environmental water quality (EWQ) monitoring tools. The outcomes of the project will allow the development of site- or industry-specific environmental water quality monitoring programmes to provide increased understanding of environmental impacts and thereby contribute to appropriate water resource management that will reduce the negative impact of industrial processes on the environment and allow long-term ecological protection.

During the last year, we have produced site-specific SASS interpretation guidelines for sample sites around Richard's Bay Minerals, and two research papers on biomonitoring issues affecting the company are in preparation. Testing of the toxicity of various tannery effluent streams for the International School of Tanning Technology is ongoing, with the aim of improving methods for management of tannery waste. In partnership with Eskom, UCEWQ recently initiated a research programme taking a transdisciplinary approach to environmental water quality compliance assessment and management, with a focus on the Sundays and Swartkops Rivers. This project has a considerable focus on building capacity in water management structures. UCEWQ's partnership with Unilever continues with ongoing monitoring of environmental health at Boksburg Lake (management of this project has successfully been transferred to stakeholders), and partnerships for promotion of appropriate water management at WISA 2012 and Scifest 2012.

#### RICHARDS BAY MINERALS: ENVIRONMENTAL WATER QUALITY

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

January 2012 – December 2012

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

Monitoring of sites around the smelter assesses streams around the mine for impacts due to mining operations, small-scale agriculture, residential settlements and other anthropogenic causes. In general, a decrease in water quality with distance downstream is indicated by both macroinvertebrate and diatom biomonitoring scores. Nevertheless, all sites have fair to good overall ecological health. In most cases, no obvious impact driving decreases in water quality could be identified. This is largely a function of the confounding effects of the number of residential settlements found along the monitored rivers. Some recent decrease in water quality in recent samples from an upstream site not associated with human settlement was also detected. The cause of this has not yet been established.

#### AN CRITICAL ANALYSIS OF ENVIRONMENTAL WATER QUALITY IN SOUTH AFRICA: HISTORIC AND CURRENT TRENDS

Sponsor: Water Research Commission (K5/2184) CG Palmer and NJ Griffin

April 2012 - March 2014

South Africa is widely recognized as having an admirable water law, and as being a leader in granting a right to water, in terms of quality and quantity, to the environment. However, the water quality of South African water resources is deteriorating rapidly despite good water quality management structures, strategies, approaches, programmes, instruments, and tools having been developed and implemented nationally over the past decade.

Management of water resources links the complexity of biophysical and ecological systems with the complexity of human social systems. As such, an understanding of how management interventions may impact on the resource requires a transdisciplinary approach in order to holistically incorporate aspects traditionally considered by different disciplines. This approach is reflected in proposals for an integrated approach to water resource management (IWRM).

Some of the issues around the decrease of environmental water quality have been attributed to difficulties in meeting goals in water resource management through management practices and institutional and stakeholder cooperation and coordination. Given this background, the approach to an analysis of trends in environmental water quality in the light of changing legal frameworks and management practices and programmes will require the adoption of one or several appropriate theoretical frameworks. The project is undertaking a review of literature relating to environmental water quality in South Africa on a national scale. This will characterize and critique the methods, programmes etc. put into place for the management of environmental water quality across the country. This will be paralleled by a review of literature on environmental water quality at a national scale. The results of these reviews will be used to inform more detailed case studies on both management practices and their consequences for environmental water quality. Proposed case studies include the Crocodile River (Mpumalanga) and possibly the Olifants River (Mpumalanga and Limpopo). Project outcomes will include guidelines for the management of environmental water quality.

#### AN EXAMINATION OF WATER QUALITY COMPLIANCE IN SELECTED LOWVELD RIVERS: TOWARDS IMPLEMENTA-TION OF THE RESERVE

Sponsor: Water Research Commission (K8/984) CG Palmer, NJ Griffin, S Pollard (AWARD), DR du Toit (AWARD), B Mandikiana (AWARD), PA Scherman (Scherman Colloty and Associates cc)

#### June 2011-August 2012

South Africa's National Water Act (No. 36 of 1998) provides for water in sufficient quantity and of sufficient quality for basic human needs and for maintenance of aquatic ecosystem function. South Africa has been recognized as having excellent water research, policy and law; however, these have not always translated into excellent water resource management. A notable failure has been a decline in the quality of surface waters in the country. This project assessed aspects related to the water quality component of the ecological Reserve, using the Crocodile River in the Inkomati catchment as a case study. The Crocodile River was selected as it has been identified as water-stressed, but has been receiving management attention of late, and has a functional Catchment Management Agency.

The quality and quantity aspects of the ecological Reserve were compared, focusing mainly on Reserve outputs and less on the Reserve processes. This was followed by a critique of methodologies involved in the water quality aspects of the ecological Reserve. Compliance with the ecological Reserve at designated sites along the Crocodile River was assessed. Finally, stakeholders in the catchment were interviewed about their understanding of the Reserve and of compliance with the Reserve and Resource Quality Objectives. Major conclusions are presented below.

The methodologies and approaches underlying the water quality aspects of the ecological Reserve and those underlying the water quantity or flow aspects of the ecological Reserve would benefit from reassessment and harmonization. This would be facilitated by the development of better methods for water quality modelling than are currently available. The existing documentation of a methodology for the determination of the water quality aspects of the ecological Reserve needs to be revised, externally reviewed, finalized and approved by the Department of Water Affairs.

No data were available to assess compliance with water quality aspects of the ecological Reserve at sites further upstream on the Crocodile River, while sites further down the river were all not compliant to some extent. Across all sites where data was available, pH, magnesium sulphate and un-ionized ammonia levels were not compliant with Reserve recommendations. In addition, sites higher on the river tended to be non-compliant with respect to inorganic nitrogen and phosphate levels, while sites lower on the river had elevated levels of sodium chloride. In addition, the lack of monitoring of certain potentially hazardous compounds was noted.

Stakeholders that were interviewed included representatives of regulators, a range of water users, and researchers in the catchment. Stakeholders identified major water quality problems in the catchment as being wastewater treatment works effluent, paper and pulping effluent irrigation, nitrate and phosphate pollution owing to commercial agriculture, and elevated sediment loads owing to soil erosion processes. Stakeholders were largely unaware of ecological Reserve requirements, and managed their water quality impacts using a diverse and wide-ranging number of standards. While stakeholders were aware of and concerned about water quality issues, few attributed significant impacts to their own sector.

#### COMPARATIVE TRANSDISCIPLINARY CASE STUDIES OF CHANGE TOWARDS ENHANCING WATER SECURITY PRAC-TICES IN THE EASTERN AND SOUTHERN CAPE, SOUTH AF-RICA

Sponsor: National Research Foundation (NRF), Global Change Society and Sustainability Research Programme CG Palmer, H Lotz-Sisitka (Environmental Learning Research Centre, RU), S Shackleton (Environmental Science, RU), G Cundill (Environmental Science), C Fabricius (NNMU) and D Roux (SANParks).

November 2011 – December 2013

This project is designed to align with the SANPAD funded project in the Lower Sundays River Valley so project progress has been reported there. Post-graduate students supported by this grant from Rhodes University are : Jane Burt (PhD Environmental Education), Helen Fox (Water Resource Science), Lara Molony (Environmental Science) and Matthew Muller (Water Resource Science); and from NMMU Verouschka Sonn (MSc). Fort Hare University was not able to make use of the masters bursary allocated to them, and we are currently approaching Prof Mahlangu Mbiji (UFH) Director of the Centre for Transdisciplinary (TD) Enquiry so as to engage a group of their students with the project.

The project group meets monthly, with additional special meeting on methodologies of particular interest. Prof Heila Lotz-Sisitka used a special meeting to present a perspec-

tive on Critical Realism. Dr Georgina Cundill was planning to take up a post doctoral position in funded by this grant in 2013, however she has been appointed as a senior lecturer in Environmental Science and we are in the process of appointing the post-doc who will work closely with her. In this way the capacity within the project has been extended. Prof Heila Lotz-Sisitka and Dr Sheona Shackleton have an IDRC project which also enables synergies. The Southern African Programme for Ecosystem Change and Society (SAPECS), has a range of working groups, one of which is on transdisciplinary which is co-ordinated by Drs Belinda Reyers (CSIR, Stellenbosch) and Oonsie Biggs (Stockholm Resilience Centre and Stellenbosch University). This projects will be registered with SAPECS. The SANPAD project has given rise to a substantive list of synthesis papers and getting these published will be the focus for 2013.

#### FROM POLICY TO PRACTICE: ENHANCING IMPLEMENTA-TION OF WATER POLICIES FOR SUSTAINABLE DEVELOPMENT

Sponsor: South African Netherlands Progamme for Alternatives in Development (SANPAD), with a WRC short term research grant

CG Palmer, C de Wet (Anthropology) and S Shackleton (Environmental Science). JH Slinger (TU Delft), S Linnane (Dundalk institute), KH Rogers (University of the Witwatersrand)

#### July 2011- June 2013

This project seeks to develop new approaches to intractable implementation difficulties in integrated water resource management. The project began with the process of building a transdisciplinary team (TD) team, which involved identifying case studies and implementation barriers. Three case studies were identified each at a different landscape and water governance scale. The Great Brak (GB) is at the reach level and addresses the problem of the freshwater needs of the estuary with DWA, the Great Brak community and stakeholders. The Lower Sundays River Valley (LSRV) is at the scale of the sub-catchment (the lower SRV) and local government – a small rural municipality, and seeks pathways to improve functionality of rural local government and governance. The Inkomati catchment is at the large catchment scale and focuses on the process of uptake of strategic adaptive management by the Catchment Management Agency (ICMA). Synthesis of skills and approaches to breaching implementation barriers as applied to IWRM was also needed. The project assembles a transdisciplinary team from: 3 countries (country research leaders are Dr Jill Slinger, Delft University of Technology, Netherlands and Dr Suzanne Linnane, Dundalk Institute of Technology, Dublin, and 9 universities; with 10 post graduate students, 15 researchers, and many participants, across the 3 case studies. Academic and practitioner skills included: Aquatic Ecology, Water Infrastructure, Water Resource Management, Systems and Policy Engineering, Strategic Adaptive Management, Anthropology, Narrative

and Social Learning, Political Geography, Modelling & Game Theory, Resilience, and Environmental Science with a focus on livelihoods & climate change adaptation.

At the initial team workshop Delft, Netherlands, the following team engagement principles were agreed: tolerate discomfort and unresolved tensions, they are often gateways to knowledge exchange and trust; be sensitive to "aha" moments (insights) - whether irritated or not; engage with balanced generosity: listen and share; practice tolerance; be sensitive to "arrivals" of people, opportunities and ideas; create and use reflective opportunities; manage discontinuities (team members and participants come and go); sustain enquiry; and remember everyone involved in the process is a "whole person", with the potential to engage with many ways of knowing. The concepts used, with associated methodologies include: complexity thinking, transdisciplinarity, social ecological systems, strategic adaptive management, critical realism, social learning, and resilience.

Field work in the Great Brak is complete. It included a workshop to develop an historical time-line, and interviews to establish the role of different actors in the process, negotiations, and practice of supplying freshwater to the estuary. Great Brak research leader Jill Slinger (TU Delft) worked with colleagues from TU Delft, Suzanne Linnane (Dundalk Institute), Tony Palmer and Andiswa Finca (Agricultural Research Institute) and Susan Taljaard (CSIR) using game theory and systems analysis. Field work will continue in other case studies through the Global Change Society and Sustainability project. To date, two Strategic Adaptive Management workshops have been held in the LSRV, during which the major problem focus areas were identified. As a result students are working on water stewardship practices (Garth Barnes), the governance processes of the SRV Municipality (Jai-Clifford Holmes), the process and performance of the sewage treatment works (Matthew Muller); and a community-based study (Lara Molony) is looking at the role of rainwater water harvesting and supply regimes on water security issues among various residents. In addition Jane Burt is studying the TD team as part of an exploration of TD practice, and Helen Fox is applying the thinking of critical realism. The project has catalysed engagement between Amatola Water, the Sundays River Valley Municipality and the DWA Rapid Response Unit and the Lower Sundays River Valley Water User Association - this is developing into an effective and transformative pathway towards improved municipal service delivery and capacity. The project team participated in the DWA Rapid Response Unit workshop on the implementation of the DWA Green Drop and Blue Drop programmes. Dr Jill Slinger, Delft engineering student Juan Gonzalez and Jai Clifford Holmes have developed a systems model of the governance and hydrology of the subcatchment. In the Inkomati Prof Kevin Rogers and Rebecca Luton worked to implement strategic adaptive management in terms of the co-operatively developed Catchment



#### Jai Clifford-Holmes in conversation with Sundays River Valley community members

Management Strategy. Dr Chris Burman (U Limpopo) added a narrative analysis to the Inkomati case study to explore the learning-unlearning cycles inherent in a process of active adaptive management.

The whole project was presented at the Complexity Forum (Stellenbosch) by nine researcher and student talks.

The project products will be complete by June 2013 and will include: 1) a synthesis document for use by water resource managers and people involved in water governance and water service delivery within local government and 2) a transdisciplinary complexity-based (TDC) research practice methodology with detailed appendices. These will be published as WRC research reports as a WRC short term research contract also supported this project.



Tally Palmer and Jill Slinger working together at a SANPAD conference.

### **5. POSTGRADUATE ACTIVITIES**

#### AN EXPLORATION OF THE WAY IN WHICH VALUES AND VALUING PROCESSES MIGHT STRENGTHEN SOCIAL LEARNING IN WATER STEWARDSHIP PRACTICES IN SOUTH AFRICA

Student: Mr G Barnes Supervisor: Profs CG Palmer and H Lotz-Sisitka (Environmental Learning Centre, Rhodes University) Degree: MEd (Environmental Education)

Due to the wicked problems presented in Integrated Water Resource Management (IWRM), science and society will need to engage in new ways of knowledge and practice creation in ways that seek to "leave enough and as good" for others (Brown, 1998). The exploration of this new relationship, from the context of held and assigned values, may prove meaningful to an environmental nongovernmental organisation (NGO) seeking to improve water stewardship practices amongst members of the public. Thus, the aim of the study, through examining valuing processes, and expressions of these in held values, is to contribute to the understanding of social learning for social change within a broader IWRM framework so as to improve the practice of water stewardship amongst the public of South Africa.

A qualitative approach is being employed to answer the research question. Moreover, the research is located within multiple case studies, viz. two Catchment Management Forums located within the Upper Vaal Water Management Area. These are the Blesbokspruit and Rietspruit Forums. The selection of these Forums seeks to ensure a better demographic diversity representative of the South African public I want to engage with, in relation to their held and assigned values and the social learning processes associated with these, as stewardship water management practices.

My research questions are:

- How do held and assigned values influence water stewardship practices of the public in two Vaal Barrage catchment management forums?
- What social learning is or could be embedded in the process of shaping values within water stewardship practices?

The goals of my research, therefore, are to use specific case studies:-

- To understand how different members of the public hold and assign value to water.
- To understand how held and assigned values, and the assigning of values (the process), influence water stewardship practices.
- To understand what social learning is embedded in the process of assigning values in water stewardship practices (e.g. what framing and reframing pro-

cesses occur; what new knowledge is shared).

 To understand what social learning results from values-oriented water stewardship practices (e.g. is there evidence of changed practice and awareness at community level).

With a view to informing how 'better' water stewardship practices can be supported amongst members of the public; and thereby informing the construction of an environmental NGO's National Water Strategy so as to influence effective public participation and social learning in IWRM.

Currently, fourteen semi-structured interviews with Forum participants have been conducted, and the minutes of meetings for both Fora are being analysed.

#### A CONCEPTUAL UNDERSTANDING OF SEDIMENTATION IN SOUTH AFRICAN CATCHMENTS BY A SEDIMENT FLOW MODEL

Student: Ms L Bryson Supervisor: Profs DA Hughes and KM Rowntree (Geography, Rhodes University) Degree: MSc (Water Resource Science)

Water quality issues have become significant in South Africa with increasing sediment concentrations in rivers and sediment deposition in reservoirs. These issues have meant that water resource managers will need to focus on the identification and quantification of the source of sediment as well as its delivery process in order to get a proper understanding of sediment dynamics in a catchment. A sediment flow model has been proposed for semi-arid catchments in South Africa to provide a conceptual understanding of sediment dynamics. As runoff is such an important factor in sediment removal and transport it is important that a good hydrological model be linked with the sediment flow model. It was decided to use the Pitman rainfall-runoff model as it is already widely used by water resource managers in the country and has been proven to be a good model.

Climate, topography, land-use and soil are important environmental variables in the removal of sediment by water. These variables are important because sediment removal by water depends on the amount and erosivity of rainfall, slope of the terrain, soil erodibility and extent of the ground cover. The particular influence these factors have on sediment removal can be broadened into factors that control the availability of sediment and factors that control the washoff potential. For instance if a land surface has highly erodible soil with limited vegetation this means there would be high sediment availability. At the same time if the land surface has a steep slope with high rainfall erosivity and amount, there would be a high washoff potential. The combination of these environmental variables would determine the sediment production potential. A useful feature of these variables is that they can effectively be represented as Geographic Information System (GIS) maps as they are all spatial in character. Probability distribution functions of each variable could then be calculated and a map of the sediment production potential could be developed. The amount of active sediment and stored sediment could then be calculated depending on the runoff inputs from the Pitman model.

Once the sediment model has been developed it will be tested on two small catchments in the Karoo, South Africa. These sites have been chosen due to the significant amount of research that has previously been conducted on the drivers of erosion in the catchments. Similarly data collected on the sediment yield histories of the catchments would also be useful when validating the model. Developing this sediment flow model is useful as subsequent advances in sedimentation knowledge necessitates revision of predictive methods used in South Africa. A simple sediment model that can work in data poor environments would be an important tool for water resource managers.

#### A BIOGRAPHY OF TRANS-DISCIPLINARITY WITHIN THE WATER SECTOR: INVESTIGATING THE KNOWLEDGE-PRACTICE INTERFACE .

#### Student: Ms J Burt

Supervisor: Profs CG Palmer, H Lotz-Sisitka and Dr L Price (Environmental Learning Centre, Rhodes University) Degree: PhD (Environmental Education)

This is a newly emerging Phd study in its first year. It is funded under the Global Challenge Society and Sustainability Research Plan under the theme of water and society. The focus of the broader research proposal is an investigation of trans-disciplinary case studies of change towards enhancing water security practices in the eastern and southern Cape, South Africa and will explore key transdisciplinary concepts such as complexity, social learning, resilience, adaptability and social-ecological systems that could be used in various socio-ecological conditions and contexts to generate new knowledge and learning.

The focus of the first year of study has been to understand the landscape of trans-disciplinary approaches. Within the socio-ecological space, trans-disciplinary approaches have emerged in response to the view that resource management science is flawed as a system of thought and practice (Berkes and Folke, 2000).

Many of the writings on Trans-disciplinarity and Interdisciplinarity discuss how research needs to change in order to develop the skills necessary to deal with a complex world (Bhaskar, 2010, Max-Neef, 2005 and Russel et al. 2007). The specialization of the disciplines has led to a very deep understanding of very specific phenomena but not necessarily to the connection between these phenomena in relation to problems in the 'life-world' (Hirsh-Haddon et al. 2008). This has led to a need to understand the role of different knowledge systems (or disciplines) and what they have to offer (Max-Neef, 2008, Bhaskar, 2010, HirshHaddon et al. 2008).

It is within this context of change, for the research project emphasizes that trans-disciplinarity as a way to engage in complex environmental problems is being practiced. The focus of the PhD study over the next year will be to work at this knowledge-practice interface by reviewing the different approaches to trans-disciplinarity and what the advantages and disadvantages of these approaches are for the water sector. It will also engage in trans-disciplinarity in practice by unpacking the approaches of three institutionally based trans-disciplinary programmes in water resource management so as to understand the political/ social advantages/disadvantages to the practitioners of adhering to a particular position and how this plays out and impacts the practice of water resource management.

#### KNOTTED PIPES: A TRANDISCIPLINARY EXPLORATION OF INTERVENTIONS INTO WATER SUPPLY ASPECTS OF THE SUNDAYS RIVER VALLEY MUNICIPALITY'S WATER SER-VICES

Student: Mr JK Clifford-Holmes Supervisor: Profs CG Palmer and C de Wet (Anthropology Department, Rhodes University) Degree: M.Soc.Sci (Integrated Development)

This research investigates the water governance of the Sundays River Valley Municipality (SRVM) water services, with a particular focus on bulk water management and water supply.

The aim of the study is to develop a rich understanding of water services in the SRVM in order to:

- Explore past and current interventions in the water supply aspects of the SRVM water services.
- Design, undertake, and evaluate an action research intervention process as part of the wider SANPAD team's transdisciplinary engagement in the SRVM.
- Distil insights that may be applicable for interventions in other contexts exhibiting similar problems.

The multi-method approach utilized three analytical methods of systems analysis, actor analysis and institutional analysis. The systems analysis component was extended in 2012 through a collaboration with Dr J Slinger from the Policy Analysis division of the Faculty of Technology, Policy and Management, at Delft University of Technology. This collaboration included the application of systems dynamics modelling in the case study, which has helped to facilitate understanding and quantification of the flows of water, finances, and information across the municipal system.

The action research component was fulfilled through investigating the relationship between the Lower Sundays River Water User Association (WUA) and the SRVM. The former is the local bulk water supplier to agricultural users and to the SRVM, which is the water service authority and water service provider to urban commercial and domestic users. This research identified the historically-poor relationship between the two organizations as having operational, systemic and interpersonal elements. These elements are exacerbated by institutional gaps resulting from the relationship between the WUA and the SRVM falling between the water resource management frameworks governed by the National Water Act of 1998, and the water services frameworks governed by the Water Services Act of 1997. The intervention process therefore included report-production, workshop-facilitation, and modelbuilding phases, during which time the Department of Water Affairs, Amatola Water, the SRVM, and the WUA were all collaboratively engaged.

The aim is to upgrade this research from Masters to PhD in order to continue into 2013. The upgrading will entail deepening the conceptual and methodological components of this research, in addition to furthering the action research processes that are currently underway.

#### THE USE OF INDIGENOUS ALGAL SPECIES IN TOXICITY TESTS FOR APPLICATION IN WATER RESOURCE MANAGE-MENT

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

The inclusion of micro-algae in water resource regulation and management in South Africa is fairly recent. The algal growth inhibition test with the standard species Pseudokirchneriella subcapitata is now included in the battery of tests used on monitoring programmes that regulate toxicity of in-stream and industrial wastewater discharges. Although the use of selected standard species in toxicity tests for regulatory and management purposes for in-stream and industrial wastewater is a positive step, there are questions of environmental realism and ecological relevance of the data generated by these standard toxicity bioassays. Micro-algae in particular are extremely variable in their sensitivity to a range of contaminants. No one algal species has consistently emerged as most sensitive to a variety of chemicals. This uncertainty regarding the most sensitive algal species has resulted in international regulatory agencies, such as the US EPA and the OECD, recommending that the algal growth inhibition test be changed from a single standard species to tests with a number of species.

In this research therefore, three species, *Scenedesmus bicaudatus, Chlorella sorokiniana and Chlorella vulgaris,* were isolated from local rivers and exposed to two reference toxicants CdCl<sub>2</sub> and K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in order to assess their potential as toxicity test species. The response of these local isolates to the reference toxicants was also compared to that of *Chlorella protothecoides* obtained from a commercial culture collection, and the standard toxicity test species *Pseudokirchneriella subcapitata*. *Scenedesmus bicaudatus* exhibited high variability in control growth after the exposure period and therefore did not show great potential as a toxicity test species. One of the basic conditions placed on an algal toxicity test species is that it exhibited

exhibits constant and homogenous growth during the toxicity test period. Since *S. bicaudatus* did not meet this basic condition, it was eliminated as a potential toxicity test species.

The commercial species Chlorella protothecoides appeared to be the least sensitive of the remaining four species to both toxicants. The two local isolates (C. sorokiniana and C. vulgaris) showed no differences in sensitivity to both toxicants. The standard species P. subcapitata was not significantly more sensitive to either of the two toxicants Pseudokirchneriella subcapitata than the other species. and the two locally isolated species (C. sorokiniana and C. vulgaris) appeared to be more sensitive to CdCl<sub>2</sub> than K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>. Chlorella protothecoides on the other hand, showed a slightly higher sensitivity (although not statistically significant) to K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> than CdCl<sub>2</sub>. This highlights the variability in response (or sensitivity) of different algal species to toxic substances. This variability in sensitivity can be explained by differences in morphology, physiology and cell cycle specificities of the different algal species.

The two locally isolated *Chlorella* species (*C. sorokiniana* and *C. vulgaris*) proved useful as toxicity test species due to their ability to withstand the prescribed experimental conditions and their relative sensitivity to the two reference toxicants. *Chlorella sorokiniana* was the most sensitive of the four tested species to  $CdCl_2$ , and *C. vulgaris* the most sensitive to  $K_2Cr_2O_7$ . These two locally isolated species were therefore used further in toxicity tests to assess their response to other toxicants such as inorganic salts (NaCl and Na<sub>2</sub>SO<sub>4</sub>) and complex effluents (from a coal power plant and a petro-chemical industry), and comparing them to the standard species and the commercial species.

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

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

The measurement of fluctuating asymmetry (FA) - deviations from near-perfect symmetry of an individual with bilateral-symmetry – has been identified as a possible biological indicator of environmental stress to aquatic macroinvertebrates. Positive attributes of the FA approach, especially attractive for developing countries, include: i) ease of measurement, ii) inexpensive analysis, and iii) 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 anthropogenic stress impacts in aquatic ecosystems in the past but has not yet been investigated in a South African context. This study investigates natural and impacted levels of FA in the indigenous freshwater shrimp, Caridina nilotica, collected from the following South African Rivers: Bushmans River (Eastern Cape) and Vaal River (Gauteng) for natural FA levels and Luvuvhu River (Limpopo Province) as well as Mpisini River (KwaZulu-Natal) for FA levels at impacted sites.



An example of shrimp leg parts measured for fluctuating asymmetry: pereiopod number 1 (walking leg) with palm, carpus and merus indicated.

The length and width of the propodus/palm, carpus and merus of all five pereiopod pairs are measured for each shrimp. The difference between left and right leg measurements is translated into various FA indices, which is correlated to ASPT scores from the South African rapid bioassessment method SASS (South African Scoring System) and selected community response indices, such as abundance and diversity to evaluate the potential of the FA method as a possible biomonitoring tool in South Africa.

#### SIMULATING NUTRIENT FATE AND TRANSPORT IN A LOW ORDER STREAM INFLUENCED BY POINT SOURCE AND DIF-FUSE SOURCE POLLUTION

Student: Mr HM Jacobs Supervisor: Prof DA Hughes Degree: MSc (Hydrology)

Rivers around the world are showing a trend of increasing nutrient loads. The main contributors of nutrients to river systems are agriculture and urban discharge. Agriculture contributes faecal matter and fertilizer through runoff to the total nutrients in the water. Urban areas contribute nutrients through surface runoff and from the treated and sometimes untreated sewerage effluent from sewerage treatment works.. Nutrients in excess increases the growth rate of aquatic plants, known as eutrophication and this is the most widespread water quality problem in the world. Due to human reliance on water resources it is necessary to protect and manage natural ecosystems. In order to effectively manage water systems, water quality models are used as management tools to simulate the transport and fate of nutrients. An illustration of the fate of nutrients in a water body that water quality models attempt to simlate, downstream transport of nutrients, are included in the illustration.



Illustration of the fate of nutrients in water (Hu and Li, 2009).

The aim of this study is to investigate and compare the accuracy and modelling procedure of a simple and a complex water quality model. From a management perspective the best model is one which provides an acceptable answer with the lowest data and parameter input. Third world countries often do not have water quality monitoring schemes for the rivers and thus simpler models have to be used due to the lack of data. The study will look at the short comings of either end of the complexity scale in water quality modelling.

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

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

Evapotranspiration is one the important components of terrestrial water cycle, which has a significant impact on the water budget available for consumptive uses. However, direct measurements of this important component of the hydrological cycle at the various temporal and spatial scales is still a challenging task. This is as result of deficiency of adequate monitoring systems, especially in the developing countries. This situation has an impact on proficient applications of hydrological prediction tools. In the current situation where water resources are threatened as a result of human induced activities and climate change, amongst others, there is a great need for an adequate understanding of the current and future state of water resources. Therefore, planning for water resources using hydrological predictions from hydrological models necessitates a great need for collection of data to improve predictions, especially in the ungauged catchments. Satellite remote sensing techniques have gained attention in earth sciences for their ability to provide the data at the scales required for modelling purposes. The study objectives consist of generating evapotranspiration time series data from the Moderate Resolution Imaging Spectrometer (MODIS) and assessing their reliability for hydrological modelling purposes

with the ultimate goal of reducing uncertainties associated with the model inputs and increasing confidence in model predictions. The first phase of the study was to establish a method for pre-processing, extracting and generating evapotranspiration time series and to generate time series for the period which covers data availability, to make MODIS data compatible with the SPATSIM framework. Second phase was to assess MODIS evapotranspiration reliability in terms of seasonality patterns and with some of observation data, and to set up the Pitman model for all study sites that were selected. The last phase that is currently being undertaken is focused on the hydrological analysis applying the time series of the MODIS evapotranspiration estimates for hydrological prediction and model performance assessment.

#### 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 pesticides is necessary to meet the socio-economic needs of many developing countries, especially in Africa, side effects of these bio-active chemicals have contributed to contaminating aquatic and terrestrial ecosystems. Environmental water quality degradation by pesticides interferes with ecosystem health and poses numerous risks to aquatic life. In South Africa, glyphosatebased herbicides are frequently used to control weeds and invading alien plants, but ultimately end up in freshwater ecosystems. However, there are no South African-based environmental water quality management strategies to monitor these bio-active chemicals. Therefore, this study sought to provide a sound scientific background for the environmental water quality management of glyphosatebased herbicides in South Africa, by conducting both laboratory and field investigations. In the laboratory investigations, aquatic ecotoxicological methods were used to evaluate responses of the freshwater aquatic shrimp Caridina nilotica exposed to Roundup® at different biological system scales, and the responses of multiple South African aquatic species exposed to Roundup® through species sensitivity distribution (SSD). In the field investigations, the effect of Kilo Max WSG on the physicochemical and biological conditions of three selected sites in the Swartkops River before and after a spray episode by Working for Water were evaluated through biomonitoring, using the South African Scoring System version 5 (SASS5) as a sampling protocol. Both Roundup® and Kilo Max WSG are glyphosate-based herbicides. All the data were subjected to relevant statistical analyses. Findings of this study revealed that Roundup® elicited responses at different biological system scales in Caridina nilotica, while SSD estimates were used to derive proposed water quality guidelines for glyphosate-based herbicides in South Africa. The biomonitoring revealed that using glyphosate-based herbicides to control water hyacinth within the Swartkops River had a negligible impact on the physicochemical and biological

conditions. Based on these findings, a conceptual framework that can be used for the integrated environmental water quality management of glyphosate-based herbicides in South Africa was developed as part of integrated water resource management (IWRM).

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

Student: Mr T Mohobane Supervisor: Prof DA Hughes Degree: PhD (Hydrology)

Predictions in climate change and climate variability are essential for sound and meaningful water resources planning and management for future use. Climate projections are attained by the use of general circulation models (GCMs) which are currently the best tools available. The practice of predicting future climate and related impacts on water resources is flawed by various sources of uncertainties, such as those related to the GCMs output.

Three analytical techniques, namely: probability curves, maximum lengths of dry periods and frequency of dry spells were used in the analyses of daily rainfall for the baseline (1961-2000), near-future (2046-65) and far-future (2081-2100) scenarios. The study highlights the uncertainties in the outputs of the general circulation models in terms of the prediction of rainfall, with some models predicting increased rainfall amounts, while others indicating a reduction in rainfall amounts in some of the catchments. GCM data used here is for five river catchments in South Africa, namely: Sabie, Caledon, Amatola, Coastal Rivers and Breede. Projections of nine (9) GCMs were used to simulate the present climate and predict future climate conditions for the five basins. The next phase would be on how to incorporate such uncertainties in informing the decision-making process for future water resources planning and allocation.

#### WATER SECURITY AMONGST IMPOVERISHED HOUSE-HOLDS IN THE SUNDAYS RIVER VALLEY,COMMUNITY EX-PERIENCES AND PERSPECTIVES

Student: Ms L Molony Supervisor: Profs CG Palmer and S Shackleton (Environmental Science, Rhodes University) Degree: MSc (Environmental Science)

This study forms part of two broader projects within the Sundays River Valley (SRV) that are based in the Institute of Water Research funded by SANPAD and GCSSRP respectively.

This study grew out of the need to develop an understanding of the local context and community perspectives regarding water security patterns. The aim of this study is to provide a lens into the water security experiences of two poor communities in the SRV, through assessing water needs, water quality concerns and water security patterns amongst RDP, informal and township households serviced by the SRV municipality. Differential experiences amongst these three groups with regard to securing, accessing and negotiating the use of water have been explored. The areas in which I am conducting research relate to water demand, use, access, service provision and conservation amongst impoverished households with a past of poor service delivery as well as the links between water security and livelihoods within the SRV.

A mixed methods approach will be used combining qualitative and quantitative techniques. Stratified sampling has been utilised to select a mix of RDP, informal and township households within Aquapark and Nomathamsanqa. Structured questionnaires were administered to 90 of these households, 30 in each category. This was then followed by 20 in-depth interviews in order to get a deeper understanding of the water problems as well as GIS mapping of social data.



A women washing her clothes, after fetching water from the community standpipe in Aquapark



A women fetches water with a bucket form the local community standpipe in Nomthamsanqu

The goal of the research is to provide a lens into the communities' current water security situation, and enable the research results to be voice for the community. The results have clearly shown the current high rate of water shortages and cuts in supply, alongside with water quality problems that are the biggest issues facing these communities. Furthermore it became evident that water access is driven and enabled by the household categories, and therefore linkages between poverty and unemployment can be drawn. Through the use of the "water security-livelihoodpoverty nexus" (UNDP, 2006: 175) it is evident that water security is directly linked and tied to one's class, income and social status within the community and these ideas will be explored further in the thesis.



Leakages and broken taps are common in Aquapark (a) and Nomathamsanqu (b)

#### GREEN DROP AS A BRIDGING TOOL BETWEEN THE NWA AND WSA FOR WATER MANAGERS IN SOUTH AFRICA

Student: Mr M Muller Supervisor: Prof CG Palmer and Dr A Gordon Degree: MSc (Water Resource Science)

With the inception of democracy in South Africa in 1994 there was a need to address the vast inequalities to access and use of water resources and services around the country. The need to address the social inequalities more so than environmental protection saw the Water Services Act (No. 108 of 1997) (WSA) and the National Water Act (No. 36 of 1998) (NWA) drafted as separate acts instead of a single act. This creates a divide between protection of water and the environment (NWA) and the delivery and use of water and sanitation services (WSA). Ideally these acts should have been combined as a single act to be used by water managers around South Africa which would help South African water managers embrace the ideals of Integrated Water Resource Management promoted by the NWA. The focus of this research was to assess whether Green Drop, an incentive-based monitoring programme for wastewater treatment works, can act as a linking tool between the two acts. Green Drop is an initiative facilitated by DWA towards the improvement of the wastewater sector. Although GD is an incentive-based programme, it is not optional for municipalities to participate. Municipalities, as Water Service Authorities, are legally required to participate through submission of data (section 62 and 82 of WSA).

The Green Drop programme assesses the entire business of wastewater treatment from the consumer to the environment and the operational and management procedures in between. A small percentage (30%) of this score examines the quality of the effluent being discharged into the river. It is this 30% which determines whether a wastewater treatment works is complying with its license conditions, which are covered by the NWA and the WSA. The other 70% examines the day to day running of the plant, emergency protocols and long term plans. This is illustrated in the figure below.



#### A diagram illustrating the makeup of the Green Drop Programme (indicated in green) and the area that links the NWA (No. 36 of 1998) and the WSA (No. 108 of 1997)

An assessment of the compliance of a small non-industrial sewage treatment works and the effects of the discharge of the works on the Uie River, a small tributary of the Sundays River, was conducted. Little work has been done on the effect of small rural treatment works on small rivers. The motivating question behind the research was "if the treatment works met its license conditions would the river meet its eco specs". The basic class for the river was determined using biomonitoring (Macroinvertebrate Response Assessment Index), habitat (Integrated Habitat Assessment Index) and water chemistry data which were collected monthly for a year. This was then compared to the effluent quality data from the plant to see whether it was complying with its license conditions set by the NWA and the WSA. This also gave an idea of the impacts of the sewage treatment works on the Uie River and whether the Green Drop tool can help answer the motivating question.

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

Student: Mr ON Odume Supervisor: Prof CG Palmer Degree: PhD (Water Resource Science)

The increased pollution of freshwater ecosystems has negatively affected their capacities to provide clean and reliable sources of freshwater to maintain the natural hydrological cycle and biological food webs as well as their provision of food and recycling of nutrients. Although there are several sources of pollution of South Africa's surface freshwater resources, a major contributor is the discharge of wastewater effluents into receiving rivers and streams. Wastewater effluent discharges, which constitute over 50% of the downstream river flow of the Swartkops River, are a major contributor to the observed elevated nutrient levels, metal concentrations, faecal contamination, and excessive algal and macrophyte growth in the river system.

In order to minimise impacts of discharged effluents on receiving freshwater bodies, the South African Department of Water Affairs (DWA) in 2008, introduced an incentivebased green drop regulation programme, which seeks to regulate the management and operations of all wastewater treatment works to ensure final effluent quality compliance. Although some progress has been made, water quality of most effluent receiving rivers and streams including the Swartkops River continue to degrade. Therefore, to ensure that discharged wastewater effluent has minimal ecological impacts on receiving water resources, there is a need to develop new holistic, robust and integrated approaches for measuring and monitoring effluent quality, and quantifying effects on in-stream biota.

The overall aim of this study was to develop an integrated approach for managing environmental water quality in the Swartkops River, using water chemistry, ecotoxicology and macroinvertebrate-based biomonitoring.

The following objectives were set in order to achieve this overall aim:

- To establish macroinvertebrate distribution, ecology and function in the Swartkops River, using both taxonomic and trait measures.
- To identify and investigate useful chironomid traits of diagnostic and predictive value, with a view to developing a chironomid trait-based approach for biomonitoring the Swartkops River, and by extension of rivers in which wastewater effluent discharges contribute significantly to water quality deterioration.
- Investigate potential utilisation of an ecotoxicological approach for understanding the effects of wastewater effluent discharge on in-stream taxonomic and trait measures through the development

of methods that closely model in-stream conditions. To develop a chironomid deformity-based sub-

- lethal bioassessment tool for monitoring the Swartkops River with potential for use in other river systems.
- Develop a conceptual framework for integrated environmental water quality management of the Swartkops River.



Nelson Odume and Paul Mensah setting up the artificial stream system along the banks of the Swartkops River

#### INVESTIGATING THE EFFECTS OF SUSPENDED SEDIMENT EXPOSURE ON THE BIOLOGICAL RESPONSES OF FRESH-WATER SHRIMP, CARIDINA NILOTICA.

Student: Ms A Sahula Supervisor: Dr A Gordon Degree: BSc Hons (Environmental Water Management)

Processes of erosion, sediment release and sediment transport are vital components of the functioning of the Earth's ecosystems. The amount of sediment transported by rivers is important for riverine ecosystems and, of specific interest to this study; it influences the water quality of aquatic ecosystems and their habitats. Increased concentrations of suspended sediment and duration of exposure to suspended sediment can have substantial impact on freshwater macro-invertebrates. In this study, an exposure -response experiment designed to measure the effect of increasing concentrations of suspended kaolin particles on the biological responses of Caridina nilotica is described (exposure periods 1-17 days and 17-71 days). Four toxicological endpoints for freshwater shrimp were produced: number of gravid females produced, mortality, number of juveniles produced and growth measure. The number of gravid females produced is only affected by suspended sediment concentration above NOEC 557 mg/L, while suspended sediment concentrations up to 945 mg/L do not affect juvenile production. However, settled sediment results in less juveniles being produced. The results are compared to the biological responses of other macroinvertebrates exposed to suspended kaolin particles. These results have important implications for aquatic ecosystems

and the development of water quality guidelines.



Laboratory sediment exposure experiment

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

Student: Ms 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 hard rock, fractured 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. Data utilized includes 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 is 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.

#### CLIMATE CHANGE IMPACTS ON THE HYDROLOGY AND WATER USE OPTIONS IN THE GREAT RUAHA RIVER SUB-BASIN, TANZANIA

Student: Ms M Madaka Supervisor: Prof DA Hughes Degree: PhD. (Hydrology)

The Great Ruaha River sub basin is critical to the Tanzania's economy and ecosystems. Water is the key resource in the Great Ruaha Basin, in that without it other resources, natural and human, cannot be sustained. A variety of stakeholder groups depend on water for human and livestock drinking, irrigation, and hydropower generation. The wetlands in the basin owe their existence and nature to the balance between the inflow and outflow of water. Moreover, the distribution of flora and fauna in and around the wetlands is also largely controlled by water availability. Any significant changes in the magnitude or timing of runoff induced by changes in climatic variables and/or land cover would have significant implications to the economic prosperity of the Great Ruaha catchment in particular. This study is designed, therefore, to assess climate change impacts on the hydrology of the Great Ruaha River sub basin. The assessment applies a modelling approach that is physically based but relatively simplistic and easily applicable for the purposes understanding the climate induced changes in the hydrology of the catchment and its implications on water resources management.

## 8. RESEARCH OUTPUTS

#### PEER REVIEWED JOURNALS

- Gordon AK, Mantel SK and Muller NWJ (2012) Review of toxicological effects caused by episodic stressor exposure. *Environmental Toxicology and Chemistry*, 31, 1169-1174.
- Hughes DA (2012) Hydrological education and training needs in sub-Saharan Africa: requirements, constraints and progress. *Hydrology and Earth System Sciences*, 16, 861-871.
- Hughes DA and Mohobane T (2012) Reducing uncertainty in hydrological models using local observed data: examples from South Africa. Proc. 11th National Symposium, British Hydrological Society.
- Kapangaziwiri E, Hughes DA and Wagener T (2012) Constraining uncertainty in hydrological predictions for ungauged basins in southern Africa. *Hydrological Sciences Journal*, 57(5), 1000-1019.
- Kefford BJ, Hickey GL, Gasith A, Ben-David E, Dunlop JE, Palmer CG, Allan K, Choy SC and Piscart C (2012) Global scale variation in the salinity sensitivity of riverine macroinvertebrates: Eastern Australia, France, Israel and South Africa. PLoS ONE, 7 (5), art. no. e35224. doi:10.1371/journal.pone.0035224
- Mensah PK, Muller WJ and Palmer CG (2012) Using growth measures in the freshwater shrimp *Caridina nilotica* as biomarkers of Roundup<sup>®</sup> pollution of South African freshwater systems. *Physics and Chemistry of the Earth*, 50-52, 262-268.
- Mensah PK, Muller WJ and Palmer CG (2012) Acetylcholinesterase activity in the freshwater shrimp *Caridina nilotica* (Decapoda: Atyidae) as a biomarker of the herbicide Roundup<sup>\*</sup> pollution of freshwater systems in South Africa. *Water Science and Technology*, 66(2), 402-408.
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- Odume ON, Muller WJ, Arimoro FO and Palmer CG (2012) The impact of water quality deterioration on macroinvertebrate communities in the Swartkops River, South Africa; a multimetric approach. *African Journal of Aquatic Science*, 37 (2), 191-200.
- Odume ON, Muller WJ, Palmer CG and Arimoro FO (2012) Mentum deformities in Chironomidae communities as indicators of anthropogenic impacts in Swartkops River. *Physics and Chemistry of the Earth*, 50-52, 140-148.
- Rivers-Moore NA, Mantel S and Dallas HF (2012) Prediction of water temperature metrics using spatial modelling in the Eastern and Western Cape, South Africa. *Water SA*, 38, 167-176.
- Tshimanga RM and Hughes DA 2012 Climate change and impacts on the hydrology of the Congo Basin: The case of the northern sub-basins of the Oubangui and Sangha Rivers. *Physics and Chemistry of the Earth*, 50-52, 72-83.

#### CONFERENCE PROCEEDINGS

Hughes, DA (2012) Hydrological impacts of climate change in southern Africa – what do we really know? Paper presented at the 16th South African National Hydrology Symposium, Pretoria, Oct. 2012.

#### IN PRESS AND SUBMITTED ARTICLES

- Dent M, Bodhanya S, Tempelhoff J, Luton R, Palmer AE, Slinger J and Palmer CG (2012) Viewing South African water law principles through a complexity lens: promising pathways and practice towards Some for all Forever. *Ecology and Society* (submitted).
- Hughes DA (2012) Constraining hydrological uncertainty in practicall water resources assessments: An example from South

Africa. *Hydrology Research* (submitted to Special BHS Edition July 2012).

- Hughes DA, Desai AY, Birkhead AL and Louw D (2012) A new approach to rapid, desktop level, environmental flow assessments for rivers in southern Africa. *Hydrological Sciences Journal* (submitted to Special Edition August 2012).
- Hughes DA, Gush M, Tanner J and Dye P (2012) Using targeted short-term field investigations to assess uncertainties in the structure and parameters of a hydrological model. *Hydrological Processes* (submitted August 2012).
- Hughes DA, Kapangaziwiri E and Tanner J (2012) Spatial scale effects on model parameter estimation and predictive uncertainty in ungauged basins. *Hydrology Research* (accepted).
- Hughes DA, Mantel SK and Mohobane T (2012) An assessment of the skill of downscaled GCM outputs in simulating historical patterns of rainfall variability. *Hydrology Research* (submitted Jan 2012).
- Hughes DA, Tshimanga R, Tirivarombo S and Tanner J (2012) Simulating wetland impacts on stream flow in southern Africa using a monthly hydrological model. *Hydrological Processes* (submitted April 2012).
- Phyu YL, Palmer CG, Warne M St.J, Dowse R, Mueller S, Chapman J, Hose GC and Lim RP (2012) Assessing the Chronic Toxicity of Atrazine, Permethrin, and Chlorothalonil to the Cladoceran *Ceriodaphnia* cf. Dubia in Laboratory and Natural River Water Archives of Environmental Contamination and Toxicology (accepted 5 November 2012).
- Linhoss AC, Munoz-Carpena R, Kiker G and Hughes D (2012) Hydrologic modelling, uncertainty, and sensitivity in the Okavango Basin: Insights for scenario assessment. *Journal of Hydrologic Engineering* (Accepted November 2012).
- Műnch Z, Conrad JE, Gibson LA, Palmer AR and Hughes DA (2012) Satellite earth observation as a tool to conceptualize hydrogeological fluxes in the Sandveld, South Africa. *Hydrogeology Journal* (submitted Sept. 2012).
- Rogers K, Luton R, Biggs H, Biggs R-O, Blignaut S, Choles A, Palmer CJ and Tangwe P (2012) Fostering complexity thinking in action research for change in complex social-ecological systems. *Ecology and Society* (accepted November 2012).
- Slaughter A and Hughes DA (2012) Extending a mechanistic massbalance salinity model to account for the effect of saline agricultural return flow. *Environmental Modelling and Software* (submitted March 2012).
- Slaughter A and Hughes DA (2012) A simple model to separately simulate point and diffuse nutrient signatures in stream flows. *Hydrology Research* (accepted September 2012).
- Tanner JL and Hughes DA (2012) Assessing uncertainties in surface and groundwater interaction modelling – A case study from South Africa using the Pitman Model. Proc. Int. Bienniel Conf. of the Groundwater Division of the Geological Society of South Africa, September 2011. International Association of Hydrogeologists – Selected Papers. (submitted).

#### **CHAPTER IN BOOKS**

Hughes, DA, Corral, E and Muller, WJ (2012) Potential for the application of General Purpose Water Accounting in South Africa. In: J.M. Godfrey and K. Chalmers (Eds), Water Accounting: International Approaches to Policy and Decision-making. Edward Elgar, Cheltenham, UK.

#### REPORTS

Gordon AK and Griffin NJ (2012) Environmental water quality monitoring for Richards Bay Minerals: Smelter site area. Unpublished report submitted to Richards Bay Minerals, Richards Bay.

- Gordon AK, Niedballa J and Sahula A (2012) Sediment as a physical water quality stressor on macroinvertebrates: a contribution to the development of a water quality guideline for suspended sediment. Deliverable 6: Winter fieldtrip report. Water Research Commission Project K5/2040.
- Gordon AK and Sahula A (2012) Sediment as a physical water quality stressor on macroinvertebrates: a contribution to the development of a water quality guideline for suspended sediment. Deliverable 5: Summer fieldtrip report. Water Research Commission Project K5/2040.
- Gordon AK (2011) Topuito wetland biomonitoring report. Quarterly reports to Kenmare Moma Titanium Minerals Project Mozambique, on behalf of Coastal and Environmental Services, Grahamstown.
- Mantel SK, Slaughter AS and Hughes D (2012) Report on the outcomes of the third workshop and second annual report. Seventh deliverable for WRC Project K5/2018, Report number K5/2018/7. Water Research Commission, Pretoria, South Africa.
- Palmer CG, Griffin NJ, Scherman P-A, du Toit D, Mandikiana B and Pollard S (in press) A preliminary examination of water quality compliance in a selected lowveld river: towards implementation of the Reserve. (WRC Project No) Report submitted to the Water Research Commission, Gezina, South Africa.
- Slaughter AS and Hughes D (2012) Design and documentation of a decision support system for developing adaptation strategies to climate change. Eighth deliverable for WRC Project K5/2018, Report number K5/2018/8. Water Research Commission, Pretoria, South Africa.
- Slaughter AS, Mantel SK and Hughes D (2012) Design and costing of a monitoring network and initial proposal for a decision support system for water boards. Sixth deliverable for WRC Project K5/2018, Report number K5/2018/6. Water Research Commission, Pretoria, South Africa.
- Slaughter AS, Mantel SK, Hughes D and Whiteley B (2011) Expected climate change and non-climate related changes (quantity, quality and their integration). Fifth deliverable for WRC Project K5/2018, Report number K5/2018/5. Water Research Commission, Pretoria, South Africa.
- Tanner J and Hughes DA (2012) Implementing uncertainty analysis in water resources assessment and planning (WRC Project K5/2056). Deliverable No. 5: Report on SW/GW interaction uncertainty reduction. Water Research Commission, Pretoria, South Africa.

#### **CONFERENCE PRESENTATIONS**

- Bryson LK, Hughes DA and Rowntree KM (2012) A conceptual understanding of sedimentation in South African catchments and the development of a new sediment model. Paper presented at the  $16^{th}$  South African National Hydrology Symposium, Pretoria, 1 3 October 2012.
- Burman C (2012) Narrative & Emergent Path Creation. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch, University, Stellenbosch, 22-24 October 2012.
- Burt J (2012) Unpacking Trans-disciplinarity as an emerging practice. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Clifford-Holmes J (2012) Institutional and system complexity in the turnaround of the SRVM water services. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch, 22-24 October 2012.
- Cundill G (2012) Toward reflexively tracking change in complex systems. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch, 22-

24 October 2012.

- Finca A (2012) Rainwater harvesting in Paterson, SRVM. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch, 22-24 October 2012.
- Fox H (2012) The influence of structures and agents on the value and health of complex social-ecological systems. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch, 22-24 October 2012.
- Gordon AK and Griffin NJ (2012) Comparison of two macroinvertebrate bioassessment approaches applied at selected sites within the Natal Coastal Plain Ecoregion. Southern African Society for Aquatic Sciences Symposium, Cape St Francis, South Africa, 1-5 July 2012. Poster presentation.
- Gordon AK, Sahule A and Palmer CG (2012) Investigating effects of suspended sediment on macroinvertebrates of South African rivers. Southern African Society for Aquatic Sciences Symposium, Cape St Francis, South Africa, 1-5 July 2012.
- Gordon AK and Palmer CG (2012) Responses of selected South African macro-invertebrates to suspended sediment stress. Paper presented at the Water Institute of Southern Africa (WISA), Cape Town International Conference Centre (CTICC), 6-9 May 2012.
- Griffin NJ and Gordon AK (2012) Comparative biomonitoring of rivers and streams using diatoms and invertebrates. Poster presented at Water Institute of Southern Africa (WISA) conference, Cape Town International Conference Centre (CTICC), 6-9 May 2012.
- Griffin NJ, Bolton JJ, Anderson RJ, Barker NP and Gründlingh ML (2012) Database of South African seaweeds, Phase 3: The Pocock collection. Paper presented at the Biodiversity Information Management Forum, Kirstenbosch. 12th - 13th June 2012.
- Holland AJ, Gordon AK and Muller WJ (2012) Investigating fluctuating asymmetry of selected South African aquatic macroinvertebrates as a potential indicator of water quality stress. Paper presented at the Conference of the Water Institute of Southern Africa (WISA), Cape Town International Conference Centre (CTICC), Cape Town, South Africa, 6th - 10th May.
- Holland AJ, Gordon AK and Muller WJ (2012) Investigating fluctuating asymmetry as a potential tool in water quality monitoring. Paper presented at the Conference of the Southern African Society of Aquatic Scientists (SASAqS), Cape St. Francis Resort, Cape St. Francis, South Africa. 1st - 5th July.
- Hughes DA (2012) Making hydrological estimation tools available to practitioners: Closing the gap between science and practice. Invited presentation at the IAHS 'PUB in Practice' Symposium, Delft, Netherlands, Oct. 2012.
- Hughes DA (2012) Research challenges for the new decade: Application of hydrological science in practice. Invited presentation at the IAHS 'PUB in Practice' Symposium, Delft, Netherlands, Oct. 2012.
- Linnane S and Slinger (2012) The Story of the Great Brak: Water and Society. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Luton R and Rogers K (2012) Changing minds and behaviours at the ICMA. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Mantel SK and Gordon AK (2012) How do cumulative impacts of small dams on rivers compare with those of large dams? Paper presented at the SASSqS 2012 conference on Aquatic Ecosystems: Conservation and Connectivity, Cape St. Francis, South Africa, 1–5 July 2012.

Mantel SK, Gordon AK, Muller WJ and Morbi F (2012) Macroin-

vertebrates as indicators of land use practices in an Eastern Cape River. Paper presented at the  $13^{th}$  WaterNet/WARFSA/GWP-SA International Symposium on Integrated Water Resources Management, Johannesburg, South Africa, 31 October – 2 November 2012.

- Mazibuko SC and Hughes DA (2012) Assessing MODIS evapotranspiration estimates for Hydrological modelling application in South Africa. Poster presented at the 13<sup>th</sup> Water-Net/ WARFSA/GWP-SA Symposium, Johannesburg, South Africa, 31 October – 2 November 2012.
- Mensah PK, Palmer CG and Muller W (2012) Derivation of South African water quality guidelines for glyphosate using species sensitivity distribution and its application to water resource management. Paper presented at the 13<sup>th</sup> Waternet/ WARFSA/GWP-SA Symposium, Johannesburg, South Africa, 31 October– 2 November 2012.
- Mohobane T and Hughes DA (2012) Uncertainties in the projections of rainfall in South Africa. Paper presented at 13<sup>th</sup> Waternet international symposium on integrated water resources management. Johannesburg, South Africa 31 October 2 November 2012.
- Molony L (2012) Water security amongst impoverished households in the Sundays River Valley. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Muller M (2012) Complexity and Green Drop. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Odume ON and Palmer CG (2012) Using Chironomidae mentum deformities-based extended toxic score index for bioassessment of the Swartkops River, South Africa. Paper presented at the 13<sup>th</sup> WaterNet/WARFSA/GWP-SA Symposium, Johannesburg, South Africa, 31 October– 2 November 2012.
- Palmer AR (2012) Using GIS for social and bio-physical mapping in an integrated transdisciplinary project. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Palmer CG (2012) Resilient connections: transdisciplinarity, complexity and action research. Resilience Alliance Science meeting, Montpellier, France, 9-13 January 2012.
- Palmer CG (2012) Building a transdisciplinary team. Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Palmer CG (2012) Lower Sundays River Valley: A complex social ecological system. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Palmer CG, Kefford B, Warne M STJ, Jooste S, Muller N, Rossouw N, Dowse R, and Palmer AR (2012) Salinity guidelines and aquatic ecosystem protection: salt tolerance and macroinvertebrate distributions. SETAC Australasia Brisbane, 1-4 July 2012.
- Palmer CG, Slinger J, Linnane S, de Wet C, Rogers K, Shackleton S, Burman C, Cundill G, Mantel S, Palmer T, Taljaard S, Hamer N, Burt J, Fox H, Luton R, Clifford-Holmes J, Muller M, Finca A, Molony L, Barnes G, van den Hurk M, Greter S, Gonzalez J (2012) Complexity-based transdisciplinary research addressing intractable water resource management issues. Paper presented at the Complexity Forum, Institute of Advance Studies Stellenbosch University, Stellenbosch 22-24 October 2012.
- Palmer CG, Taljaard S, Hamer N, Burt J, Fox H, Luton R, Clifford-Holmes J, Muller M, Finca A, Molony L, Barnes G, van den Hurk M, Greter S, Gonzalez J (2012) Complexity-based transdisciplinary research addressing intractable water resource management issues. Complexity Forum,Institute of Advance

Studies Stellenbosch University, Stellenbosch 22-24 October 2012.

- Slaughter AR, Hughes DA and Mantel SK (2012) The development of a Water Systems Assessment Model (WQSAM) and its application to the Buffalo River Catchment, Eastern Cape, South Africa. Paper presented at the 6th International Congress on Environmental Modelling and Software (Managing Resources of a Limited Planet: Pathways and Visions under Uncertainty), Helmholtz Centre for Environmental Research– UFZ, Leipzig, Germany. 1st–5th July 2012.
- Slaughter AR and Mantel SK (2012) A simple model to relate land cover and flow to water quality. Paper presented at the 13th WaterNet /WARFSA/GWP-SA, Birchwood Hotel and OR Tambo Conference Centre, Johannesburg, South Africa. 31<sup>st</sup> October–2<sup>nd</sup> November 2012.
- Slinger J and Clifford-Holmes J (2012) What a tangled web we weave – unraveling the strands of a South African water problem. Paper presented at the Benelux System Dynamics Chapter Conference on Safety, Security and Public Health in a Dynamically Complex World, Delft University of Technology, the Netherlands, 29th June 2012.
- Tanner JL and Hughes DA (2012) Surface groundwater interactions: Process understanding and using models to test hypotheses. Paper presentation at the IAHS 'PUB in Practice' Symposium, Delft, Netherlands, Oct. 2012.
- Tanner JL and Hughes DA (2012) An assessment of the surface and groundwater interaction components of the Pitman Model in the Crocodile River West basin. Paper presented at the 16th South African National Hydrology Symposium, Pretoria, Oct. 2012.
- Tshimanga R and Hughes DA (2012) Assessing the potential use of regional flow duration curves for hydrological predictions in large catchments of the Congo River basin. Paper presented at the 16<sup>th</sup> South African National Hydrology Symposium, Pretoria, Oct. 2012.
- Tshimanga R and Hughes DA (2012) An a priori approach to model parameter estimation and uncertainty analysis in large catchments of the Congo basin. Paper presentation at the IAHS 'PUB in Practice' Symposium, Delft, Netherlands, Oct. 2012.
- Tumbo M (2012). Coupled human environment interactions the adaptive capacity of rural livelihoods: experiences from the Great Ruaha River Sub -Basin, Tanzania. Paper presented at the Planet Under Pressure Conference : "Global Environmental Change and Sustainable Development in Least Developed Countries". Excel, London, 25th to 29th Mar. 2012.

Annual Report compiled, edited and layout by Daksha Naran (Senior Technical Officer)

Back Cover (top to bottom): Mini SASS excursion with Victoria Girls High school pupils, Botanical Gardens, Grahamstown,/ Water Quality determination of Luzi River during high flow, Umzimvubu System/Students examining benthic macroinvertebrates, Swarkops River/Bloukrantz River soon after the October 2012 floods, Grahamstown/Photographs kindly supplied by IWR staff and students.

