DEMONSTRATION OF HOW HEALTHY ECOLOGICAL INFRASTRUCTURE CAN BE UTILIZED TO SECURE WATER FOR THE BENEFIT OF SOCIETY AND THE GREEN ECONOMY THROUGH A PROGRAMMATIC RESEARCH APPROACH BASED ON SELECTED LANDSCAPES

Deliverable #11: Annual Report

February 2018

Submitted to the Water Research Commission
by

Centre for Water Resources Research
University of KwaZulu-Natal

Project K5/2354
**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ACRU</td>
<td>Agricultural Catchments Research Unit</td>
</tr>
<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
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<tr>
<td>CEA</td>
<td>Cost-Effectiveness Analysis</td>
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<tr>
<td>CMA</td>
<td>Catchment Management Agency</td>
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<tr>
<td>CSAs</td>
<td>Critical Source Areas</td>
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<tr>
<td>CSIR</td>
<td>Council of Scientific and Industrial Research</td>
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<td>CWRR</td>
<td>Centre for Water Resources Research</td>
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<tr>
<td>DBSA</td>
<td>Development Bank of South Africa</td>
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<td>EI</td>
<td>Ecological Infrastructure</td>
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<tr>
<td>EGU</td>
<td>European Geosciences Union</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>ICP-OES</td>
<td>Inductively Coupled Plasma – Optical Emission Spectrometry</td>
</tr>
<tr>
<td>INR</td>
<td>Institute of Natural Resources</td>
</tr>
<tr>
<td>IWRM</td>
<td>Integrated Water Resource Management</td>
</tr>
<tr>
<td>LULU</td>
<td>Land Use and Land Cover</td>
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<tr>
<td>NGO</td>
<td>Non Government Organisation</td>
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<tr>
<td>SAEES</td>
<td>School of Agricultural, Earth and Environmental Sciences</td>
</tr>
<tr>
<td>SANBI</td>
<td>South African National Biodiversity Institute</td>
</tr>
<tr>
<td>UEIP</td>
<td>uMgeni Ecological Infrastructure Partnership</td>
</tr>
<tr>
<td>UKZN</td>
<td>University of KwaZulu-Natal</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<tr>
<td>WQIs</td>
<td>Water Quality Indices</td>
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<td>WHO</td>
<td>World Health Organisation</td>
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<td>WRC</td>
<td>Water Research Commission</td>
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1 INTRODUCTION

1.1 WRC Project K5/2354 - Overview

In April 2014, the Centre for Water Resources Research (CWRR) and partners were awarded a 5 year research project through a Water Research Commission (WRC) solicited call.

The project is entitled:

“Demonstration of how healthy ecological infrastructure can be utilized to secure water for the benefit of society and the green economy through a programmatic research approach based on selected landscapes”.

As previously reported, the project seeks to identify sites in the uMgeni catchment at which investment into the protection and/or restoration of EI can produce long-term and sustainable returns in terms of the delivery of water-related ecosystem services. These services could include water quality and quantity, and flood protection. In essence, the project aims to guide catchment managers when deciding “what to do” in the catchment to secure a more sustainable water supply, and where it should be done.

The uMgeni catchment has become a focus area and pilot study site through various initiatives, and the project is now fully integrated within the research portfolio of the uMgeni Ecological Infrastructure Partnership (UEIP) (SANBI, 2013). The project continues to focus its efforts on supporting the service provider partners of the UEIP through research in the pilot study sites where they are investing in EI, and these continue to form the three focus “landscapes” through which this project operates i.e. the upper-uMgeni-Midmar, the Baynespruit in Pietermaritzburg and the Palmiet River catchment in eThekwini.

The approach and deliverables adopted in this project reflect this integrated complexity. An overview of the project has been developed (Figure 1) and an intranet site with access for all team members has been created (https://sites.google.com/site/ueipwrc2354/). All relevant project documents (Deliverables, Sub-Contracts etc) are stored at this location.
Figure 1 Project overview.

1.2 Report Structure

The project will produce 15 Deliverables over four years, all of which are linked to the various project aims. This Annual Report comprises Deliverable 11 of the 15. The remaining four Deliverables will completed two in 2018 and two in 2019, yet activities to address these Aims are ongoing and some are reported here. Thus, Section 2 provides a brief overview of progress towards achieving each Project Aim and Deliverable including Outreach activities, Section 3 provides an update on capacity development and Section 4 provides some concluding comments and the work plan for the forthcoming year.
2 Project Progress

The project has made steady progress over the past year, submitting all Deliverables on target. A pleasing aspect is that several of the students working on the project have now completed their studies.

2.1 Deliverables Completed in reporting period

In addition to this Deliverable, two Deliverables were completed over the past year i.e. Deliverables 8 And 9.

<table>
<thead>
<tr>
<th>Deliverable No.</th>
<th>Deliverable Title</th>
<th>Deliverable Description</th>
<th>Due Date</th>
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<tr>
<td>9</td>
<td>Report on synthesis of quantified costs incurred through the use of poor water quality by various stakeholders</td>
<td>Reports from quantification study on costs of poor water quality and degrading EI to catchment stakeholders. Including journal paper on findings submitted.</td>
<td>31/07/2107</td>
</tr>
<tr>
<td>10</td>
<td>Second report on the water resource quality status from a catchment perspective: The lower-uMngeni</td>
<td>Report on water quality status from lower-uMngeni case study catchments (Baynespruit and Palmiet). Including journal paper on findings submitted.</td>
<td>30/11/2017</td>
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</table>

**Deliverable 9** was completed in July 2017 and explored the economics of investing in ecological infrastructure (EI) within the uMngeni catchment. This is the second of three deliverables which together form the economic component of this EI study, Deliverable 4 reported on the literature review and methodology, Deliverable 9 documented the information and activities, and Deliverable 12 (forthcoming July 2018) will present final conclusions and recommendations. Deliverable 9 highlights the attendant costs associated with the poor water quality of the uMngeni, including the costs associated with damages incurred or income foregone, the cost of increased water treatment, and the cost of water quality monitoring, compliance control and policy development. As reported by Michelle Browne and Lutendo Mugwedi, the economic evaluation studies included two parts:

1) a cost-benefit analysis of wetland rehabilitation along the Mthinzima Stream, upper-uMngeni. This case study is informed by the MSc research project of Nothando S. Buthelezi; and
2) an investigation of the opportunities for investing in EI in the Baynespruit catchment and a cost-effectiveness analysis (CEA) of selected management options to address water security related challenges in the catchment.

The various case studies provide a knowledge base to determine potential costs and benefits of investing in EI relevant to future decision making. Through this process information needs have been highlighted, as have questioned been raised regarding the challenges of such economic determinations.

**Deliverable 10**, entitled 'Report on water quality in identified case study subcatchments of the lower uMgeni- catchment and the relationship between catchment and water quality' was submitted in November of 2017. This report comprised three studies in two different subcatchments of the uMgeni catchment, Baynespruit and Palmiet. Two of the studies were conducted in the Palmiet catchment, one study focused on the effect of urbanization on water quality, and the second studied the pathogenic water quality of the Palmiet River and its potential health risks for communities who interact with the water regularly from the riverside Quarry Road informal settlement. The third study researched the Baynespruit River and investigated the effects of water quality on the presence of heavy metals in the crops grown by the Sobantu community on the floodplains of the river.

Water quality in the Palmiet River was demonstrated to be poor. *E. coli* concentrations in the Palmiet River are high, with 50% of results between 2007 and 2015 exceeding 2 000 cfu/100ml. Organic loading rate is also high with over 50% of samples over 5 mg/l and spikes that exceed 36 mg/l. Fats, oils and grease from industrial sites and fast food outlets are likely to contribute to this. The minimum turbidity in the river is 4 NTU, whilst samples downstream of the industrial area average 100 NTU. The assessed exposure pathways were accidental ingestion during swimming or bathing, surface water for household use such as laundry and consumption of vegetables irrigated with surface water. This analysis showed that children were most likely to be infected. Women’s probability of infection increased due to the additional exposure pathway of household water use. The surface water from the Palmiet River exceeds the World Health Organisation recommended target value for risk of infection.

In the Baynespruit River the presence of *E. coli* and heavy metals (As, Cd, Cu, Pb, Hg, Zn) in the surface water and sediment from the Baynespruit were assessed as well as in the river bank soils. Heavy metals concentrations above the maximum permissible limits were sporadic but were detected at all sampling points at least once. The low frequency of these detections suggest that heavy metal pollution is not problematic for the irrigation of crops. *E. coli* greatly exceeded the permissible limits. The sediments tested at the sampling points were compared to USA Freshwater Sediment Guidelines as such guidelines do not exist for South Africa. As, Cr, Ni, Pb, Fe and Mn levels all exceeded their respective maximum permissible limits in both summer and winter months. Cu and Ag exceeded their respective maximum permissible limits in winter only. Soil samples were taken from fields irrigated from a communal tap, the wetland pond and the Baynespruit River. All three samples had concentrations of Cd, Cu and Zn above the maximum permissible limits, whilst concentrations of Pb exceeded the maximum permissible limit only at farm sites 1 and 2. The concentration of Cr was below the maximum permissible limit at all three sites. Crops were sampled for heavy metals and
the concentration compared to the maximum permissible limits set out by the Food and Agriculture Organisation and the World Health Organisation. Cd was present in spinach, carrots and cabbage at concentrations greater than the maximum permissible limit whereas its presence in maize and pumpkins fell below maximum permissible limits. The Cr and Pb concentrations in all crops across all farming sites exceeded the maximum permissible limit and the concentration of Zn in spinach was above the maximum permissible limit across all farming sites.

These results demonstrate that heavy metals tend to be present at higher levels in the river sediment that in the water itself. This makes its way onto the fields that are located on the primary floodplain of the river as a result of flooding and contaminates the soil. This in turn leads to contamination of crops, particularly broad leafy crops and edible roots.

Both the Palmiet and the Baynespruit Rivers suffer from poor water quality. This is a result of the urbanisation of their respective catchments but is also likely to have a negative effect on human health in the catchment, particularly in communities that rely on the river for bathing, household use and farming.

A key recommendation from studies in both catchments was the need to include sampling and testing of sediment in any analysis of the river’s water quality. Higher concentrations of heavy metals and microorganisms are found in sediments than in surface water and this can provide a better indication of the river’s health than looking at the water quality alone.

These Deliverables are available on the WRC FMS system and on the project intraweb at https://sites.google.com/site/uelpwr2354/documents.

2.2 Reference Group and Project Team

A few changes have taken place for the reference group during 2017. These changes include the replacement of Riaz Jogiat with the current Umgungundlovu District Manager of Municipal Functions, Ms Lungi Ndlovu, in response to changes in that organisation and the addition of Mr Joseph Mulders as requested by the WRC Research Manager. Further additions include: Dr Sean O’Donaghue (eThekwinio Metro), Ms Manisha Maharaj (Dept of Water and Sanitation), and Margaret Wolff (Rhodes Univ).

A few minor changes in the project team occurred in 2017. Susan Risko has joined the project team as a PhD student and Research Assistant, assisting with overall project administration, and providing support for various aspects of the project. Other changes include Interns from the Institute of Natural Resources (INR) with the addition of Ester Ndou, replacing Lutendo Mugwedi. Rebecca Sindall has also joined the project team as a Post-Doctoral Researcher with the Pollution Research Group in collaboration with Dr Chris Buckley.

2.3 Collaboration and Co-Funding

The project continues to work collaboratively with various related and ongoing initiatives active in the uMgeni catchment. The Development Bank of South Africa (DBSA) Green Fund project is complete, but the interest in the products from that project continues to stimulate interest in the ongoing research in K5/2354.
2.3.1 Umgeni Water

Umgeni Water provide direct financial and in-kind support to the project. This includes analysis of samples in the Umgeni Water laboratory, provision of water quality and dam level data to research students and top-up and seed funding for student bursaries.

2.3.2 CLIMWAYS

We have previously reported that the project also collaborates closely with CLIMWAYS. CLIMWAYS is a multi-disciplinary research project that analyses institutional constraints on water resource management and urban climate change adaptation in the cities of Durban and Cape Town. This project ends in 2017, but the work will now continue through this project as part of the Palmiet case study.

2.3.3 ‘uMngeni School of Water Governance Research

Many members of the project team are active in the uMngeni School of Water Governance and will continue to advance research in water governance under the auspices of this project.

During the month of November a meeting of the uMngeni School of Water Governance convened at the offices of the Institute of Natural Resources to discuss a potential research collaboration between this WRC 2354 Ecological Infrastructure Project and an overlapping international project on water governance.

Professor Claudia Pahl-Wostl from the University of Osnabrück in Osnabrück, Germany visited along with a doctoral student, Evelyn Lukat, to discuss a German collaborative project entitled ‘Increasing Good Governance for Achieving the Objectives of Integrated Water Resources Management’ (abbreviated as STEER, based on the German title). The STEER project is utilising a framework approach to study water governance throughout five countries in order to establish a diagnostic toolbox for application in different institutional and natural environments. South Africa, along with Spain, Mongolia, and two German case studies, was identified for inclusion in the study. The field visit during November 2017 was aimed at exploring the situation of water management in the uMngeni catchment. The visit included a joint analysis of the conceptual framework of the project to determine whether it can sufficiently portray the multi-level problem architecture that can be observed in South Africa. The visit also assisted in the identification of opportunities to develop synergies with on-going planned activities of the uMngeni School of Water Governance Research. It is envisioned that the STEER project will provide innovative impulses for the implementation of integrated and adaptive water management.

2.4 Research in support of Pilot Studies

The ongoing research in the Case Study sites seeks to address multiple project aims as detailed in the progress for each site provided below. A fourth case study also is now being incorporated into the project at uMzinyathi.
The research is undertaken through student research projects at each of the case studies, hence, progress is presented by way of short progress reports and/or abstracts of pending and completed articles submitted, or intended, for publication in peer reviewed journals.

2.4.1 Upper-uMngeni-Midmar Case Study

Much research has taken place in the upper-uMngeni over the past year. This has covered several aspects, including a new approach to estimating the extent of invasive alien plants and their impact on water resources and assessment of the water quality of the inflows to the Midmar and Albert Falls Dams. An assessment of the contribution of bulk atmospheric deposition of nitrogen and phosphorus in the Midmar Dam Catchment has also been undertaken. This research has resulted in the preparation of several academic research papers. Silindile Mtshali has explored remote sensing tools to estimate the extent of wattle infestations in the Karkloof catchment, resulting in two proposed papers forming part of her MSc (which has been passed subject to some minor corrections). The first describes the remote sensing application. The second paper investigates the impact of *Acacia meamsii* on the hydrological response in the Karkloof Catchment using the ACRU agrohydrological model.

**Comparing Landsat 8 OLI and SPOT 7 data in mapping Acacia meamsii using an Artificial Neural Network algorithm, in the upper uMngeni Catchment, South Africa**

S. Mtshali, G.P.W. Jewitt, O. Mutanga

**Abstract**

Alien plant invasions can have an adverse effect on biodiversity and water availability as the case with *Acacia meamsii*, which is the most invasive alien plant in South Africa. Typically, the mapping of these alien plant invasions was conducted by field based investigation, performing roadside surveys and incorporating expert knowledge of the study area, however, many have questioned the results. The objective of this study is to use freely available remotely sensed data to map *Acacia meamsii* distribution in the upper uMngeni Catchment using Artificial Neural Networks. We compared the map outputs from two sensors, SPOT 7 and Landsat 8 OLI, characterised by different spatial and spectral resolutions. The accuracy of the thematic maps were assessed by computing confusion matrices of the two images with an independent validation data set. The overall accuracies were 74.39% and 68.29% for the SPOT 7 and Landsat 8 data respectively. Producer accuracies were 76.39% and 68.75%, respectively. The findings from this study suggest that *Acacia meamsii* distribution can be mapped better using SPOT 7, which has a finer spatial resolution. This information can be used in invasive alien plant management in the catchment.

**Keywords:** Image pre-processing; classification; artificial neural networks; spatial and spectral resolution; confusion matrix.
The second paper uses the findings from Paper 1 to estimate the impact of wattle infestation on the water resources of the Karkloof River.

**Impact of Acacia mearnsii on Streamflow Response in the Karkloof Catchment, South Africa**

S. Mtshali, G.P.W. Jewitt

**Abstract**

*Acacia mearnsii* is a dominant invasive species in the Karkloof Catchment, known for significantly reducing streamflow more than the natural vegetation. This is a result of the species having a higher biomass, deeper rooting system and high total evaporation rates than the natural vegetation found in the catchment. The potential of *A. mearnsii* reducing streamflow increases with increasing proximity to the water source. Thus, riparian environments are more susceptible to *A. mearnsii* infestation than in the landscape. In the study, the impact of *A. mearnsii* on the hydrological response in the Karkloof Catchment was assessed using the ACRU agrohydrological model. The distribution of the species was determined using SPOT 7 imagery. The results simulated by the model showed a considerable change in streamflow if the infestation in the riparian zones were to be cleared, especially during the periods of low flows. As a resource-based water security strategy, the removal of *A. mearnsii* in the riparian zones can significantly improve the water yield of the catchment.

**Keywords:** Acacia mearnsii; streamflow; biomass; riparian environments; low flows.
Jean Namugize has focussed his research on the sources of nutrients entering Midmar and Albert Falls Dams. Jean submitted his PhD for examination in September 2017 and it has been passed subject to minor corrections being attended to. Several papers have prepared for submission to journals. Of these, two have been accepted for publication, one is subject to quite major revision and another will be submitted in February 2018.

**Bulk atmospheric deposition of nitrogen and phosphorus in the Midmar Dam Catchment, KwaZulu-Natal, South Africa**

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*Corresponding author, e-mail: najoannes@yahoo.fr

**Abstract**

Ongoing research on water quality in the uMgeni Catchment has indicated a continuous deterioration throughout the catchment since records began and has raised the possibility of the eutrophication of the Midmar Dam in the near future. Typically, groundwater and surface water pollution are the focus of investigation. However, there is limited information on the relative contribution of bulk atmospheric deposition to the external nutrient inputs to Midmar Dam. A two-year study (November 2014 to October 2016), involving fortnightly river sampling and the addition of bulk atmospheric collection of phosphorus and nitrogen, was carried out at 14 river sampling points and four atmospheric collection stations. Results showed that the concentrations of NO₃-, NH₄⁺ and TP are higher in the bulk deposition than in the surface inflows, indicating the potential of a substantial contribution of atmospheric deposition to the nutrients entering the dam. Moreover, bulk atmospheric deposition was the largest source of NH₄⁺ load to the Midmar Dam, while TP and NO₃- come mainly from surface inflows. Findings of this study add to the body of literature applicable of other polluted regions of sub-Saharan Africa, USA and China, and are particularly relevant for developing regions.

**Keywords:** atmospheric deposition, eutrophication, nutrient specific flux, reactive nitrogen, uMgeni Catchment, water quality deterioration

**Status:** To be submitted to African Journal of Aquatic Sciences
Effects of Land Use and Land Cover Changes on Water Quality in the uMgeni River Catchment, South Africa
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Abstract

Land use and land cover change are major drivers of water quality deterioration in watercourses and impoundments. However, understanding of the spatial and temporal variability of land use change characteristics and their link to water quality parameters in catchments is limited. The objective of the study is to assess the linkages between biophysical-chemical water quality parameters and land use and land cover (LULC) classes in the upper reaches of the uMgeni Catchment, a rapidly developing catchment in South Africa. These were assessed using Geographic Information Systems tools and statistical analyses for the years 1994, 2000, 2008 and 2011. The reclassification of LULC data in the uMgeni Catchment resulted into eight LULC classes, i.e. natural vegetation, cultivation, degraded, urban/built-up, waterbodies, plantations, mine and wetlands. Natural vegetation, forest plantations and cultivated areas occupy 85% of the catchment. The noted increase in cultivated, urban/built-up and degraded areas by 6%, 4.5% and 3%, respectively, and other land uses (plantations, mines, wetlands and waterbodies) coincides with a decrease in natural vegetation by 17%. Variability in the concentration of water quality parameters from 1994 to 2011 and a decline in water quality were observed. *Escherichia coli* levels exceeding the recommended guidelines for recreation and public health protection were noted as a major issue in seven of the nine sampling points. In overall, water supply reservoirs in the catchment retained over 20% of nutrients and over 85% of *Escherichia coli*. A relationship between land use types and water quality variables exists. However, the degree and magnitude of these associations vary among sub-catchments and is difficult to quantify. This highlights the complexity and the site-specific nature of relationships between land use types and water quality parameters in the catchment. Thus, this study provides useful findings on the general relationship between land use and land cover and water quality degradation, but highlights the risks of applying simple relationships or adding complex relationships in the management of the catchment.

Key words: Land use/land cover; uMgeni Catchment; South Africa; Water quality deterioration; Nutrient

Status: Accepted for publication in Physics and Chemistry of the Earth
Sensitivity analysis of water quality monitoring frequency in the application of a water quality index for the uMgeni River and its tributaries, KwaZulu-Natal, South Africa

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ABSTRACT

Water quality deterioration is a global issue which is ascribed to both non-point and point sources of pollution. Lack of funding and changing mandates for water quality monitoring results in critical gaps in knowledge to inform management in order to create a secure water future. This study aims to assess the effect of water sampling frequency on water quality index reporting in the upper uMgeni Catchment. A twenty-eight year time series of water quality data from eleven sampling stations, was assessed for pH, electrical conductivity, temperature, turbidity, total suspended solids, Escherichia coli (E. coli) counts, NH4-N, NO3-N, PO4-P and total phosphorous. Statistical packages were used to process the data and water quality indices (WQIs) for eutrophication and recreational water were calculated. It was found that in ten of the eleven stations, the water quality status ranged from marginal to fair for human recreational and eutrophication of waterbodies. However, WQI scores were consistently poor at the Mthinzinga Stream. However, it was found that the higher the monitoring frequency, the lower the WQI calculated, at all sites. This indicates that water quality is poorer than reported, due to a declining monitoring frequency. The findings showed that E. coli and turbidity are influential variables lowering the recreational and eutrophication WQIs, respectively. WQI is shown to be a useful tool for monitoring the changes of water quality in space and over time in the uMgeni Catchment. Therefore, the use of WQIs should not substitute other tools of water quality data interpretation.

Keywords: Monitoring frequency; sensitivity analysis; uMgeni Catchment; water quality guidelines; water quality index

Status: Accepted for publication in WaterSA
Sanele Ngubane completed his MSc in 2016 and recently submitted corrections following peer review for a paper pending acceptance to the Journal of Physics and Chemistry of the Earth (abstract below).


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**Abstract**

Studies throughout the world have shown that human-induced activities have significantly deteriorated the downstream quality of water in many sections of major rivers. In South Africa, deteriorating water quality is recognised as a major risk to water security. Thus, the aim of this study was to identify water quality, in particular, nutrient trends in the upper reaches of the economically important uMgeni Catchment for three key tributaries, namely the Lions and uMgeni rivers and Mthinzima Stream, upstream of an important water supply impoundment i.e. Midmar Dam from 1989 to 2015. The nutrients of concern were nitrogen and phosphorus in the form of ammonium (NH\(_4\)-N) and nitrate (NO\(_3\)-N) and soluble reactive phosphorus (SRP) and total phosphorus (TP), respectively. Statistical trend analyses were conducted using the seasonal Kendall slope estimator (SKSE) to determine the magnitude of the trend and the seasonal Kendall trend test, which determines the significance of a trend. All data were analysed following a method by Vant and Smith (2004). The study showed that the Mthinzima Stream is the most polluted tributary feeding Midmar Dam, with significant increasing trends evident for all variables (\(p < 0.05\)) and NH\(_4\)-N with the highest RSKSE of 42% of the median value per year. Catchment water quality is deteriorating in other tributaries, but trends are not clear in others, which might have been a consequence of data shortage. The significant rapid decrease in water quality in the Mthinzima Stream is linked to the rapid densification and urbanisation in the catchment it drains. The study highlighted the risk to the future water quality of Midmar Dam as well as a need for more frequent and continuous water quality monitoring in the catchment.

**Keywords:** Trend Analysis; nutrients; trend detection; water quality; uMgeni Catchment

**Status:** Referee suggestions addressed with editor.

**Economic Analysis: Mthinzima Case Study**

The general objective of this study is to evaluate the costs and benefits of investing in ecological infrastructure in the form of wetland rehabilitation for improvement in water quality. It is the value of the change in water quality as a result of investment in ecological infrastructure that is of interest in this study. Progress is reported in the form of MSc student Nothando Buthelezi's MSc which due for submission by the end of March this year.
The costs and benefits of investing in ecological infrastructure through the rehabilitation of Mthinzima Wetland was under taken by Nothando Buthelezi. Nothando has submitted her thesis for review to her supervisors and the abstract is presented below. A paper based on this work is in preparation.

**Investments in Ecological Infrastructure: An Ex Ante Assessment of the Costs and Benefits of Rehabilitation in the Mthinzima Wetland in KwaZulu-Natal**

Nothando S. Buthelezi

**ABSTRACT**

The uMngeni River is an important water resource in KwaZulu-Natal, though it is one of the major systems that was identified as having water that may cause a serious health risk to its consumers. The increasing pollution in the upper catchment, supplying the Midmar Dam has been attributed to sewage effluent due to inadequate sewage infrastructure, expanding agricultural lands and household waste from Mpophomeni Township. The Mthinzima wetland is located in Mpophomeni settlement, a 6000 unit settlement that was developed in the 1960s. The Mpophomeni development was poorly planned as there should not have been a large development near a strategic water resource. This is because human development impacts would pose threats to water resources in the area. The Mthinzima River flows adjacent to the settlement where it joins a tributary that dissect Mpophomeni, after which it flows under the district road (R617), through a degraded wetland system and into Midmar Dam.

Two interventions were proposed to reduce the pollution flowing from the Mpophomeni Township into Midmar Dam. A new WWTW would be built in conjunction to rehabilitation of ecological infrastructure. The rehabilitation of ecological infrastructure would be done through wetland rehabilitation. Wetlands are well known for their ability to reduce nutrient loads, pathogens, sediments and other contaminants in water systems that are often a result of human activities. Although wetland services are important especially for water treatment services, assigning value to wetlands/ ecological infrastructure to justify their investment is often difficult because there is no direct market for wetland services. Having knowledge of the value of wetlands treatment capacity and other services they provide, is important to achieve balance between conservation and human activities that degrade them or replace them.

Ecological infrastructure has value that is important for human well-being, often studies that aim to value investments in ecological infrastructure give total economic value of the ecological infrastructure. The purpose of this study was to investigate the incremental change in supply of services from the wetland post rehabilitation, considering the demand, supply and opportunities for those wetland services.

Cost-benefit analysis (CBA) was used for this analysis, it is a widely applied as an appraisal technique particularly for use as an input into public decision-making processes. CBA both helps inform decision-makers and helps hold them accountable for their decisions. The cost benefit analysis technique was used to evaluate whether investments in ecological infrastructure bring about a worthwhile change in ecosystem services. The cost benefit analysis net present value results were all positive, the estimated net present value for change in wetland services post rehabilitation over the period of 20 years was found to between R4144813 and
R3765358 using different discount rates. The net present value of the wetland rehabilitation investment showed an increasing pattern as the waste water treatment plants maintenance costs were assumed to be a higher percentage of the waste water treatment plant. Therefore the study concluded that investments in ecological infrastructure in the form of the Mthinzima wetland rehabilitation was worthwhile as the investment yielded positive marginal results post rehabilitation.

The results of CBA does not govern the choice of investment rather it is a useful tool to test for testing the robustness of a project to alternative assumptions concerning the magnitude of costs and benefits, and the various social demands with respect to the return on invested capital. From this the results of the CBA, the study concluded that investing in wetland rehabilitation of the Mthinzima wetland is robust.

**Keywords**: cost benefit analysis, ecological infrastructure, ecosystem services, economic evaluation, incremental change, waste water treatment

### 2.4.2 Baynespruit Pilot Study

The Baynespruit Pilot Study is undertaken in collaboration with the uMsunduzi Municipality in support of their Baynespruit Rehabilitation Project. This provides a consolidated product for the project including aspects of practical rehabilitation, water quality research and economic evaluation. The work of Jedene Govender was reported on in the 2016 Annual Report. Since then, she has graduated with an MSc. Currently, the project team is in the process of an additional two MSc students to continue the work in the Baynespruit.

**Social Connectivity**

Susan Risko’s PhD research is will contribute to addressing the social connectivity components that feed into Deliverable 14 with a focus on the Msunduzi River. Thus, her research is also assisting with building the configuration for the Baynespruit case study.

**Politics, Economics, and Civil Engagement within Msunduzi Municipality**

Susan Risko

**Abstract**

Governance extends beyond the normative definition of government to include economics and civil engagement, therefore in order to achieve good governance, all three aspects must be considered. This research study aims to understand the root causes of poor water quality of the Msunduzi River from a social perspective. The Msunduzi River runs through the heart of the Provincial capital, Pietermaritzburg, and is in close proximity of the third largest economic hub within South Africa. Previous research demonstrates the widely accepted knowledge that the water quality in the Msunduzi River is poor, identifying biophysical root causes, such as land use or commercial industrial pollutants, however, the overall governance surrounding the problem have not been addressed. Historical events in recent years have confirmed issues around economic instability of the provincial capital and government expenditure. Additionally, industry players, who are heavy water users, pose as missing actors for good water governance. Further compounding the issue, civil engagement is limited, believed to be a result of relaxed concern for democratic participation since the
establishment of South Africa as a democratic republic. The study proposes to investigate three case studies: 1) an urban riverside community in the central business district, 2) a peri urban community surrounding Henley Dam and located on Traditional Authority land, and 3) a peri urban community located along a tributary and containing a wetland. The researcher’s engagement with public Municipal meetings as well as discourse analysis of government documents from local to national are additional methods that will be utilized to answer the research question. Results from this study will enable a better understanding of the problem scale and highlight areas that can be addressed for increased good governance of the Msunduzi River.

2.4.3 Palmiet Case Study

The Palmiet case study is well underway. The interaction with CLIMWAYS has already been noted, and in 2017, this project will take over the funding of two community based researchers.

During the 2017 year Patrick Martel joined the team, supervised by Dr Catherine Sutherland. Successful presentation of his PhD research "A temporal analysis of changing hydrosocial relationships in Durban, South Africa' was presented to an academic panel at a PhD Workshop held by the School of Built Environment and Development Studies from 10 to 14 July 2017 as part of the School’s Higher Degrees procedure. A great compliment for the social relations aspects of the project, Patrick is studying the hydro-social cycle and offers experience with systems dynamics modelling techniques to be explored for this project in 2018 for Deliverables 14 and 15.

Patrick’s research is being formulated into four journal articles:

- The first paper will be entitled 'Historical Geography of Water Services in a Race-divided City: case study of Durban, South Africa' for journal submission in March 2018.
- The second paper, entitled ‘Reconceptualising the role of ecological infrastructure in water services security - Durban’s new water ‘moment’, has been accepted for presentation at the African Centre for Cities International Urban Conference in Cape Town (1 to 3 February 2018) and is aimed for journal submission in May 2018. An abstract is presented below.
- The third paper, entitled ‘Reflecting on the responses to water and climate change challenges in Durban: a comparison of the Aller River Pilot Project and the Palmiet River Rehabilitation Project’, summarizing action research of two river rehabilitation projects, Community Innovation for the Palmiet River Rehabilitation Project and external review for Phase One and Two of the Aller River Pilot Project. Data collection and project engagement are currently underway. Preliminary analysis for this paper was presented at an MSc seminar for the Environment and Development Course in the School of Built Environment and Development Studies.
- The fourth paper is linked to the objective - To construct a theoretical framework drawing on political ecology, the hydrosocial cycle and water governance theories for urban water security around the nexus of water supply, sanitation, and stormwater. This work will be pursued during the latter half of 2018 and early 2019.
Reconceptualising the role of ecological infrastructure in water services security - Durban’s new water ‘moment’

Patrick Martel

Abstract

The history and geography of water and sanitation in Durban has resulted in a complex and unequal system of service provision in the city. This paper traces the history of water and sanitation provision in the city in relation to the geographical context within which this history is embedded. It uses a political-ecology approach, employing the hydro-social cycle as an analytical tool to map out the significant moments of change in water and sanitation provision between 1948 and 2017. It reflects on the forms of governmentality that are evident in the water sector in the city over this period and explores the way in which this has shaped citizens’ experiences and realities of service provision. It therefore adopts a Foucauldian theorisation of power but provides a more nuanced perspective on Foucault’s ideas drawing on the work of Tanya Murray Li. Through this analysis, the paper reflects on the emergence of the discourse of an unequal and spatially differentiated service provision model in the city, which is re-shaped and ‘re-ordered’ as it engages with the everyday lived worlds of ordinary people. It questions whether the universal, but unequal provision of basic services in a fast-changing city that reflects African urbanism can be constructed as being socially unjust, given the historical and geographical context of the city.

Londiwe Dlamini is currently working towards an MSc entitled, ‘Adapting the social-ecological systems framework to enhance ecological infrastructure in an urban setting: The case of the Palmiet river catchment’.

Adapting the social-ecological systems framework to enhance ecological infrastructure in an urban setting: The case of the Palmiet river catchment

The proposed research project is in alignment with the aims of the uMngeni Ecological Infrastructure Partnership (UEIP) project which aims to investigate the benefits of investing in ecological infrastructure within the uMngeni catchment. The Palmiet River catchment is located in the lower uMngeni catchment surrounding parts of the Durban area and thus, is part of a highly urbanised and severely impacted landscape of the catchment. Development around the Palmiet River catchment has severely impacted the river such that there has been a large loss of valuable topsoil, health risks due to contaminated water and increased surface runoff, flooding and erosion of the river bed and river banks (SANBI, undated). Rivers provide valuable ES linked to their river flow dynamics and the interaction with the landscape (Palmer et al., 2009). The ES once offered by the Palmiet River and its surroundings have been compromised by impacts from growing informal settlements constructed in wetland areas and along the banks of the river (SANBI, 2013). Although rivers are dynamic systems that are constantly adapting to changes in sediment and water inputs across the landscape (Palmer et al., 2009); it is important to know how degraded river systems are and how best to remediate the ecosystem in order for it to provide ES.

This study will focus on one of the pilot projects of the UEIP by studying the relationship between hydrology and people/human activities in two sites located within the Palmiet River catchment. The first site is located in the centre of the catchment in the nature reserve where there is minimal direct human influence on the river.
The second site is located in the lower reaches of the catchment where the river runs through an informal settlement before entering the uMngeni River. The comparison of the upper and lower sites in the Palmiet River catchment provide a scenario-based perspective of the trajectory of anthropogenic impacts and resulting river degradation if ecological infrastructure in growing urban cities is omitted.

2.4.4 Mzimyathi Case Study

This is a new study site and activities are soon to be initiated. It provides a case-study of a rapidly densifying, though still predominantly rural catchment which is governed by tribal authority. As such, it reflects the tensions between human expectations, development needs and competing governance systems which occur throughout the catchment and in many other parts of the country.

2.5 Scaling up to the uMngeni Catchment

As outlined in Deliverable 7, the pilot case studies are intended to assist with drawing conclusions up to the uMngeni Catchment level. In order to accomplish this, configurations for each of the case studies need to be developed to produce the water-society-space trialectic. See Appendix 1 for an example trialectic and refer to Deliverable 7.

A workshop was held in September of 2017 to discuss building the configurations for each pilot case study. A configuration template was developed to guide each case study in a manner that could maintain consistency. The template has been included in the Appendix 2 for reference.

Section 3 of the configuration presents discourses for each of the case studies. In order to determine these discourses a discourse analysis is required. As the skillset of the project team and students varies, with a strong leaning towards scientific methodologies, a training workshop was held by Dr Catherine Sutherland in order to better understand the process of social science methods such as discourse analysis. The workshop occurred on November 2nd and initiated the discourse analysis for each of the case studies.

Results from the configurations will wrap up at the end of February 2018 followed by a 6-week review of each case study configuration. From these configurations a system dynamics model will be developed followed by scenario building with governance stakeholders working in the catchment at multiple scales as a ground truthing exercise.

2.5.1 Water Quantity and Ecological Infrastructure

Some research studies have already focused on integrating information for the catchment scale. Catherine Hughes has focused her study on water quality and the role of EI at the catchment scale Her Thesis is now under examination. The +core of the research that she did is reported in two papers submitted as Parts 1 and 2 to WaterSA.
MAPPING OF WATER-RELATED ECOSYSTEM SERVICES IN THE UMNGENI CATCHMENT USING A DAILY TIME-STEP HYDROLOGICAL MODEL FOR PRIORITIZATION OF ECOLOGICAL INFRASTRUCTURE INVESTMENT – PART 1: CONTEXT AND MODELLING APPROACH

Hughes CJ\textsuperscript{1}, de Winnaar G\textsuperscript{2}, Schulze RE\textsuperscript{1}, Mander M\textsuperscript{3}, Jewitt GPW\textsuperscript{1,4}

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Keywords: water, ecosystem services, hydrological modelling, ecological infrastructure, water security

Abstract

South Africa, as a semi-arid country, frequently faces water shortages and in the 2016 and 2017 rainfall seasons experienced a severe drought. Government is under pressure to continue to deliver clean water to the growing population at a high assurance of supply. Studies are now showing that the delivery of water may be sustained not only through built infrastructure such as dams and pipelines, but also through investment in ecological infrastructure. Such investments could include the securing and rehabilitation of naturally functioning ecosystems, including grasslands, riparian zones and wetlands. To this end, methods for mapping and quantifying the delivery of water-related ecosystem services are required. In order to identify and map priority areas for delivery of water-related ecosystem services within the uMngeni catchment, South Africa, recent high-resolution land cover data and a daily time-step hydrological model were used. Part 1 of this study describes the motivation for the study, and the methods used in modelling and mapping the catchment.

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MAPPING OF WATER-RELATED ECOSYSTEM SERVICES IN THE UMNGeni CATCHMENT USING A DAILY TIME-STEP HYDROLOGICAL MODEL FOR PRIORITIZATION OF ECOLOGICAL INFRASTRUCTURE INVESTMENT – PART 2: OUTPUTS

Hughes CJ1*, de Winnaar G2, Schulze RE1, Mander M3, Jewitt GPW1,4

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Keywords: water, ecosystem services, hydrological modelling, ecological infrastructure, rehabilitation

Abstract

The rehabilitation of ecological infrastructure (EI), in addition to increasing the biodiversity, recreational and other less tangible benefits, aims at improving the delivery of clean water to the people of the catchment concerned. It is, however, difficult to quantitatively estimate the potential effects of rehabilitation if, for example, an area of overgrazed grassland is rehabilitated to a well-functioning grassland, or more specifically what the increase in volume of water delivered by the catchment could be. This study aimed to estimate, using a validated daily time step hydrological model, the potential improvements which can be made through the rehabilitation of selected ecological infrastructure in the uMngeni Catchment in KwaZulu-Natal, South Africa, with the first step being to determine the current water-related ecosystem service delivery from the various sub-catchments making up the catchment.

The two key degradation criteria which were modelled are overgrazing and the invasion of upland areas by invasive alien plants, namely Black Wattle (Acacia mearnsii). Although the limitations of hydrological modelling are recognised, as are the practical limitations in terms of rehabilitation of ecosystem functionality, this study provides a hydrologically informed assessment of what the potential benefits of conservation (of the status quo) or rehabilitation of ecological infrastructure could be. Part 2 of this study describes the outputs and learnings of this project.
2.5.2 Water Quality: Sources and sinks of nutrients

Nantale Nsibira’s research provides our first attempt at addressing water quality, rather than water quantity at the catchment scale. Building on a risk based assessment her work is nearing completion and her thesis will be submitted by June 2018. In addition to a paper (abstract below), her work will result in an interactive map of the catchment showing sources and sinks of nutrients in the catchment

*Identifying sources and sinks of sediments and nutrients in the uMsundusi Catchment to guide investment in Ecological Infrastructure*

Nantale Nsibirwa

Abstract

The difficulty of managing non-point source pollution has led to the continued degradation of water quality and is associated with catchment development and land degradation. The uMngeni River Catchment, KwaZulu-Natal, South Africa is under threat of major contamination. High nutrient and bacterial loads from diffuse sources within the catchment are transported by means of rivers and streams into water supply dams. Dealing with this problem is difficult, as the pathways by which nutrients enter the waterbodies differ and are a complex function of the soil type, climate, topography, hydrology, land use and land management. Furthermore, source areas are often not known because of the diffuse nature of the pollution. Relative risk-based approaches are being applied to identify and prioritise the protection and control of Critical Source Areas (CSAs) within the landscape. Risk-based methods are evolving and link well with the efforts to conserve ecological infrastructure.

The primary aim of this study is to identify the CSAs and transport pathways of nutrients in the uMngeni Catchment, utilising a risk-based method for diffuse pollution assessment. Various approaches were reviewed and the SCIMAP Model was selected and applied in the catchment.

Model outputs produced a spatial representation of diffuse pollution risk in the catchment highlighting the CSAs. Locations deemed to be most at risk of causing diffuse pollution are in the upper regions of the catchment where the dominate land use is commercial agriculture.

This thesis contributes towards the efforts and investments in diffuse pollution mitigation within the catchment. In the context of investing in catchment protection and the rehabilitation of ecological infrastructure, the output maps have immediate applicability to water managers as they highlight areas which should be protected and restored.

The figures below show examples of the research output, resulting in a network index map of hydrological connectivity (Figure 2), a diffuse pollution risk map (Figure 3), and in-stream diffuse pollution risk (Figure 4). Additional results have been provided in Appendix 3.
Figure 2 Network index map representing hydrological connectivity in the uMgeni Catchment.

Figure 3 Diffuse pollution risk map of the Critical Source Areas (CSAs) of nutrients in the uMgeni Catchment.
Figure 4 In-stream diffuse pollution risk map of the Critical Source Areas (CSAs) of nutrients in the uMgeni Catchment.
2.5.3 Integrating Water Quantity and Economic Evaluation

The project team made a substantial contribution to a paper recently published in the journal Ecosystem Services. This paper is important is it is the first publication that provides an estimate of the Unit Reference Value (the cost of producing 1 kilolitre of raw water) from Ecological Infrastructure (about r2.50 in the uMgeni Catchment).

*Modelling potential hydrological returns from investing in ecological infrastructure: Case studis from the Baviaanskloof-Tsitsikamma and uMgeni catchments, South Africa*

Myles Mander a, Graham Jewitt b, John Dini c, Julia Glenday d, James Blignaut e, Catherine Hughes b,

Christo Marais f, Kristal Maze g, Benjamin van der Waal g, Anthony Mills h

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d South African Environmental Observation Network, Fynbos Node, Private Bag X07, Claremont 7735, South Africa
e Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
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g Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa
h Department of Soil Science, Stellenbosch University, Matieland 7602, South Africa
i South African Environmental Observation Network, Research Associate, Pretoria, South Africa
j LivingLands, 120 Belvedere Rd, Claremont, Cape Town, South Africa

A shortage of water currently threatens the development of the South African economy and the wellbeing of its people. Climate change, land degradation and an inherently semi-arid, variable climate are making it increasingly difficult for water service providers to deliver sufficient quantity and quality of water to meet escalating demand. Investments in ecological infrastructure are seldom considered as a way of augmenting water supplies and improving water quality over the long-term. However, hydrological modelling shows that protecting and rehabilitating ecological infrastructure could generate meaningful gains in water quantity in two important South African water supply systems, the Baviaanskloof-Tsitsikamma and uMgeni catchments. The costs of such interventions, as estimated using resource economic techniques, are within the same order of magnitude as built infrastructure solutions. Investments in ecological infrastructure can also have a considerable range of other benefits. These findings make a compelling case for large-scale investment in the rehabilitation and protection of ecological infrastructure, which can be a cost-effective option for achieving water resource planning objectives. The types of rehabilitation activities planned would depend on the needs of local water users. Associated long-term monitoring and research would further improve knowledge of these systems, and provide support for the modelled results.
2.6 Conferences, Symposia and other Events attended and hosted

Members of the project team were active in a number of local and international events where project activities were presented and highlighted.

University of the West of England’s Winter Postgraduate Conference
Patrick Martel was sponsored by the International Water Security Network to present his research topic ‘A temporal analysis of changing hydrosocial relationships in Durban, South Africa’ at the University of the West of England’s Winter Postgraduate Conference (1-2 Feb 2017) in Bristol, UK.

Second Study Tour by Sudan Government Officials
The United Nations Environment Programme (UNEP) and the University of KwaZulu Natal (UKZN) entered into an agreement to co-operate under the Wadi El Ku Catchment Management Project, with respect to enhancing Darfur government staff capacity on Integrated Water Resource Management (IWRM). This will be achieved by learning from South Africa’s twenty-plus years of experience in implementing IWRM, through tailor-made study tours to South Africa targeting government staff from Darfur. The overall goal of the exchange agreement was to facilitate the process of establishing a catchment management forum in North Darfur, by exposing Darfuri technical staff and decision makers to how similar fora operate in South Africa.

During February of 2017, the second study tour of the agreement with UNEP occurred. This study tour was designed for high-level decision makers aimed to address the institutional arrangements and establishment of a Catchment Management Agency (CMA). Presentations were given by the Department of Water and Sanitation, South African Catchment Management Agencies and Forums, bulk water suppliers, Water User Associations, and academic and sector experts to provide insight and share experiences of South Africa’s personal journey to achieve Integrated Water Resource Management.

Additionally, the high-level Ministerial study tour focused on the legislation and policies that have helped to shape the water resource sector in South Africa for both surface and ground water resources. Coordination of the water sector was of particular focus from the perspective of the National Department of Water and Sanitation as well as this sector’s collaboration with other sectors such as through the Department of Agriculture and the Department of Environmental Affairs.

The study tour was successfully executed with the assistance of the Breede-Gouritz CMA, one of two fully operational CMAs in South Africa. This arrangement provided the Sudanese Ministerial Delegation with an in-depth view of the inner workings of the institution, as well as it’s placement within the broader governing structure of the National Department of Water and Sanitation. Institutional arrangements were discussed and content varied from operational details in statutes, budgeting, and labour divisions for individual CMAs as well as external collaboration with national departments, formally recognized Water User Associations, and locally organized community groups.

The high-level Ministerial study tour focused on the legislation and policies that have helped to shape the water resource sector in South Africa for both surface and ground water resources. Coordination of the water sector was of particular focus from the perspective of the National Department of Water and Sanitation as well as this
sector's collaboration with other sectors such as through the Department of Agriculture and the Department of Environmental Affairs.

**European Geosciences Union (EGU) General Assembly 2017**
Professor Graham Jewitt attended the EGU General Assembly held in Vienna, Austria April 23\textsuperscript{rd}-28\textsuperscript{th} during 2017 and presented the work performed for deliverable 7. The presentation was entitled, ‘Understanding catchment dynamics through a Space-Society-Water Trialectic’. An abstract of this presentation was provided in the Appendix of Deliverable 8, the 2016 Annual Report.

**International Association of Hydrological Scientists (IAHS) 2017**
The International Association of Hydrological Scientists convened in Port Elizabeth, South Africa between the 10\textsuperscript{th} to 14\textsuperscript{th} of July. The theme was “Water and Development: scientific challenges in addressing societal issues”. This was the first time the IAHS was held in Southern Africa, providing an opportunity for various staff and students of the CWRR to attend, including Jedine Govender.

**WaterNet**

**Conservation Symposium**
CWRR’s MSc student Nantale Nsibirwa was awarded the prestigious KwaZulu-Natal Premier’s Award at the 6th annual Symposium of Contemporary Conservation Practice held in Howick on 6-10 November 2017. The award was based on her exceptional oral presentation at the Symposium combined with a presentation made to a panel of judges. The award supports Nsibirwa financially to attend an international conference in the coming year.

**System Dynamics Workshop organised by the CSIR**
A System Dynamics Workshop organised by the Council of Scientific and Industrial Research (CSIR) and run by Professor Maria Manez from GERICS Climate Service Center Germany was held in Ballito (20 to 24 November 2017) and attended by Doctoral Student, Patrick Martel.

**World Congress of Environmental and Resource Economists held in Gothenburg, Sweden**
Michelle Browne, a PhD student assisting with the economic components of this project, is awaiting a final decision for presentation of her PhD research at the World Congress of Environmental and Resource Economists held in Gothenburg, Sweden 25-29, June 2018. Below is a copy of the submitted abstract.
The Economic Valuation of Wetland Restoration: A Quantitative Review of the Literature

Authors: M Browne, Rhodes University

Key words: Environmental valuation, wetlands, ecological restoration, environmental management

Abstract

In the literature on ecological restoration, several authors have indicated a lack of attention to the outcomes of restoration activities and specifically the economic evaluation of such investments. As a first step in responding to this suggested gap, a quantitative literature review was undertaken to evaluate the current state of knowledge towards identifying research needs. Focussing on the applied economic analysis of wetland restoration activities, the systematic, quantitative literature review process proposed by Pickering and Byrne (2014) was applied. 63 publications over a 21-year period meeting the criteria were identified. Research on the topic is increasing, but remains skewed toward North America and Europe. A diverse cross-disciplinary interest is notable, yet disciplinary collaborations were evident in only a third of publications. Greater attention has been given to habitat provision, water quality improvement and recreation attributes; cultural and regulation benefits have received little attention. A significant finding is that only a third of the studies were undertaken post-restoration, suggesting the need for post-restoration outcome evaluations which are strongly evidence based. Areas for future research include (i) wetland restoration projects in Africa and South America, (ii) the evaluation of outcomes post-restoration, and (iii) integrated approaches of valuing the outcomes of ecological restoration. Future research on the value of wetland restoration will contribute to the relatively small knowledge base, provide insights needed to improve practice and build an evidence base to support meta-analysis and value transfer approaches as practical tools for decision-making.
3 Capacity Building

Progress on student projects has been included in the above sections. A list of students contributing to the project appears below in Table 1. Recent additions in 2016 include Nonthando Buthelezi on economic aspects. During 2017, 2 MSc students, Londiwe Dlamini, Nantale Nsibirwa, and 2 PhDs, Patrick Martel and Susan Risko, joined the project. Nantale Nsibirwa and Sizophilia Mahlobo are the second and third students to progress from Honours to Masters in the project. Completion of theses and dissertations for 2017 includes: Jean Namugize (PhD submitted and examination passed), Catherine Hughes (PhD submitted), Slindile Mtshali (MSc submitted and finalising corrections), and Nonthando Buthelezi (MSc submitted).

In summary, 5 Honours, 4 MSc and 1 PhD have now been produced by the project with several more students in the pipeline.

As reported above, the project team were involved in two study tours by water resources managers and scientists from Sudan, so contributing to the development of capacity in that country and their host institutions.

*Table 1: Students currently registered or degree complete. Students joining the project in 2017 (orange) and those who have completed degrees (green) are highlighted below.*

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Degree</th>
<th>Project Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jean Namugize (degree complete)</td>
<td>2014-2018</td>
<td>PhD</td>
<td>Effects of Land Use and Land Cover Changes on Water Quality of the Upper uMngeni River</td>
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<td>Catherine Hughes (under examination)</td>
<td>2014-2018</td>
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<td>The hydrological benefits of rehabilitation of critical areas catchment - land use change impacts - aliens and degradation</td>
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<td>Simphiwe Ncobo</td>
<td>2015-</td>
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<td>Michelle Browne</td>
<td>2015-</td>
<td>PhD</td>
<td>Costs and benefits of investing in ecological infrastructure</td>
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<tr>
<td>Patrick Martel</td>
<td>2016-</td>
<td>PhD</td>
<td>eThekwini urban hydro-social cycle</td>
</tr>
<tr>
<td>Susan Risko</td>
<td>2017-</td>
<td>PhD</td>
<td>Configuration of the Baynespruit and Stakeholder Connectivity</td>
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<td>Sesethu Matta</td>
<td>2014-</td>
<td>MSc</td>
<td>The Value of Community-based Water Quality Monitoring Initiatives</td>
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<td>Hlengiwe Ndlovu (degree complete)</td>
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<tr>
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<td>Silindile Mtshali</td>
<td>(corrections)</td>
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<td>(degree complete)</td>
<td>2015-2016</td>
<td>MSc</td>
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<td>Semeshan Naidoo</td>
<td>(degree complete)</td>
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<td>Londiwe Dlamini</td>
<td></td>
<td>2017-</td>
<td>MSc</td>
</tr>
<tr>
<td>Sizophila Mahlobo</td>
<td></td>
<td>2018-</td>
<td>MSc</td>
</tr>
<tr>
<td>Nantale Nsibirwa</td>
<td></td>
<td>2014-2014</td>
<td>Hons</td>
</tr>
<tr>
<td>Nokulunga ZveZwe</td>
<td></td>
<td>2014-2014</td>
<td>Hons</td>
</tr>
<tr>
<td>Silindile Mtshali</td>
<td></td>
<td>2014-2014</td>
<td>Hons</td>
</tr>
<tr>
<td>Sheldon Gouws</td>
<td>(degree complete)</td>
<td>2015-2015</td>
<td>Hons</td>
</tr>
<tr>
<td>Sizophila Mahlobo</td>
<td>(degree complete)</td>
<td>2016-2016</td>
<td>Hons</td>
</tr>
</tbody>
</table>
4 Conclusions and Way Forward

In 2017, the project and its associated ventures have been running effectively. Deliverables scheduled for the year have been submitted and progress has been made towards several of the subsequent project Deliverables. All Deliverables were completed in a timely manner. The water quality component as well as the economic components of the study are well underway and the interconnectivity component is in progress developing configurations for each case study. During the early stages of 2018 systems dynamics modelling will be drawn up from each case study. There remains a strong collaboration and interlinkages with other related projects and the project contributes and benefits from its association with the UEIP. A particularly pleasing aspect has been the extent of student involvement in the projects. Students joining the project during the 2017 year include 2 MSc and 2 PhDs. Graduation of students involved in the project include the completion of 5 honours, 4 MSc and 1 PhD degrees to date with another 2 MScs and 2 PhDs due for completion in 2018.

4.1 Work Plan

The work plan for 2018 and the remainder of the project is detailed in Appendix 4. Three Deliverables are due in the 2018 financial year and two in 2019, as listed below:

<table>
<thead>
<tr>
<th>Deliverable No.</th>
<th>Title</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Annual Report</td>
<td>1 February 2018</td>
</tr>
<tr>
<td>12</td>
<td>Report based on the tested evidence demonstrating how intact ecological infrastructure could have alleviated the costs resulting from degraded ecosystems.</td>
<td>31 July 2018</td>
</tr>
<tr>
<td>13</td>
<td>Report on the water resource quality status from a catchment perspective</td>
<td>30 November 2018</td>
</tr>
<tr>
<td>14</td>
<td>Report on the water resource connectivity, inter-dependency between surface and ground water, as well as societal connection, all from a landscape perspective</td>
<td>1 February 2019</td>
</tr>
<tr>
<td>15</td>
<td>Final report including comprehensive conservation management plan for the catchment based on the support by society, business, NGOs, associations and embedded in legislation</td>
<td>30 June 2019</td>
</tr>
</tbody>
</table>
5 References


6 Appendices

6.1 Appendix 1: Example of a society-space-environment trialectic for Knysna (Sutherland, 2016) as reported in Deliverable 7.
6.2 Appendix 2: Configuration Template utilized for each case study.

WRC K5/2354
DELIVERABLE 7
PHASE 1: WATER GOVERNANCE CONFIGURATION TEMPLATE

Case Study Name:

Research Team:

1. **Context (historical, geographical and political context)**
   - Environmental
   - Social
   - Economic
   - Political

2. **Actors (both human and non-human)**
   - Identify all actors at different scales engaging in the case study’s ‘landscape of water governance’
     - Formal arrangements/relations between actors
     - Informal arrangements/relations between actors
     - Missing actors
   - Relations between actors
   - Power relations between actors
   - Actor map
   - Opportunities and constraints for actors

3. **Discourses (including ‘scientific facts’ which either underpin discourses or which becomes discourses in themselves)**
   (Include associated arguments that support each.)
   - Storylines
   - Discourses
   - Associate actors with specific discourses

4. **Materialities (physical realities and contingent conditions)**
   (Mapped in tabular format.)

<table>
<thead>
<tr>
<th>Physical realities</th>
<th>Topography</th>
<th>Geology</th>
<th>Water Availability (surface &amp;</th>
<th>Water Quality</th>
<th>Land Area</th>
<th>Climate</th>
<th>Geopolitics</th>
</tr>
</thead>
</table>

31
5. **Issues and risks**
   - Issues
   - Risks

6. **Knowledge**

<table>
<thead>
<tr>
<th>Source</th>
<th>Form</th>
<th>Format</th>
<th>Accessibility</th>
<th>Authors</th>
<th>Users</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. Primary or</td>
<td>e.g. expert,</td>
<td>e.g. Source</td>
<td></td>
<td></td>
<td></td>
<td>e.g. land use,</td>
</tr>
<tr>
<td>Secondary</td>
<td>tacit,</td>
<td>location</td>
<td></td>
<td></td>
<td></td>
<td>water use etc.</td>
</tr>
<tr>
<td></td>
<td>experiential,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>local</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please also write narratives about how knowledge has been constructed, how it is received, how it is used, how powerful it has been.

7. **Spatial expressions of society-water-space relations**

Any maps that show society-water-environment relations
Potentially GIS maps or other maps and mapping tools to capture:
   - Absolute space
   - Relative space
   - Relational space
   - Representative space
   - Representational space

8. **References**
6.3 Appendix 3: Research Output on Hydrologic Connectivity and Pollution Risk

3.4.1 Hydrological Connectivity

Figure 3.3 shows a network index map representing the hydrological connectivity risk for the uMgweni Catchment. This map is an intermediate layer generated during the SCIMAP modelling process and is a calculation of the $P_i$. Areas with a relatively high and low likelihood of connecting to the river network are depicted in red (risk value of 1) and blue (risk value of 0) respectively.

The map illustrates that areas with a higher risk of connectivity are in the high lying western region of the catchment. Areas with the least risk of connectivity are found in the eastern region of the catchment parts. U20C, U20E and U20F have the highest connectivity risk and U20K and U20L have the lowest connectivity risk. Overall, 36% of the entire catchment area has been assigned a risk between 0.80 – 1 and 10% of the catchment area has been assigned a risk between 0 – 0.20.

Figure 6.1 Network index map representing hydrological connectivity in the uMgweni Catchment
### 3.4.2 Diffuse Pollution Risk

The diffuse pollution risk map is also an intermediate layer generated during the modelling process and is a calculation of the $P_{\text{PC}}$. SCIMAP combines the hydrological connectivity risk and the land use export potentials to locate the CSAs. The diffuse pollution risk map of the CSAs of nutrients in the uMngeni Catchment is shown in Figure 3.4. High risk areas are depicted in red (risk value of 1) and low risk areas in green (risk value of 0).

The final map output produced by the model is shown in Figures 3.5. The map is a calculation of the $C_i$ and indicates the expected in-stream diffuse pollution risk considering the effect of rainfall dilution. The layer is a combination of the connectivity, land use export potentials and rainfall dilution potentials of the area. With these layers one can identify the transport pathways of diffuse pollutants into the main channels. Risk is depicted in multiples of the standard deviation from the mean. Where high risk areas are depicted in red (indicating that the risk is greater than the dilution potential) and low risk areas in green (indicating that the risk can be alleviated by the dilution potential).

Figures 3.4 and 3.5 illustrate that the important areas for the generation and transfer of nutrients are found in the central regions of the catchment. Regions with the least CSAs of nutrients are located mostly in the western headwaters of the catchment. Quaternary catchments U20F, U20G, U20H, U20J, U20K and U20M have the highest diffuse pollution risk and U20A, U20B, U20C, U20D, U20E and U20L have the lowest diffuse pollution risk. Overall, 0.56% of the entire catchment area has been assigned a diffuse pollution risk between 0.70 – 1 and 92% of the catchment area has been assigned a diffuse pollution risk between 0 – 0.20.

A close-up view of the Midmar Sub-catchment (U20C) results are shown in Figure 3.6. The map depicts a combination of the intermediate and the final diffuse pollution risk layers. Key areas for the generation and transfer of nutrients are found in the central and eastern parts of the sub-catchment. Areas least at risk for transferring nutrients into the river network and impoundment are found in the southern most reaches of the sub-catchment. It was found that, 0.82% of the sub-catchment area has been assigned a diffuse pollution risk between 0.70 – 1 and 94% of the sub-catchment area has been assigned a diffuse pollution risk between 0 – 0.20.
Figure 6.2 Diffuse pollution risk map of the Critical Source Areas (CSAs) of nutrients in the uMgeni Catchment

Figure 6.3 In-stream diffuse pollution risk map of the Critical Source Areas (CSAs) of nutrients in the uMgeni Catchment
3.4.3 Walkover Survey

A locality map of the five locations surveyed surrounding Midmar Dam is depicted in Figure 3.7. Table 3.3 presents the findings of the walkover survey and includes each location’s SCIMAP output map. The pictures illustrate the benefits of overlaying model outputs with aerial photography and zooming into a sub-catchment/field scale whereby CSAs are more clearly identifiable. The results confirm that the land uses identified at locations 1, 2, 3 and 4 could potentially contribute to nutrient diffuse pollution. At location 5, the grassland vegetation appeared to not be a source of nutrients. Transport pathways were found to be reasonably accurate in all locations except at location 1, where a manmade drainage system was found. Furthermore, the accuracy of the transport pathways modelled increased with the increase in elevation difference. Locations which had a flatter landscapes and smaller difference in elevation had decreased accuracy of transport pathways.

Figure 6.4 Diffuse pollution risk map of the Critical Source Areas (CSAs) of nutrients in the Midmar Sub-catchment
Figure 6.5 Locality map of the locations surveyed during the walkover in the Midmar Sub-catchment
Table 6.1 Results recorded during the walkover survey in the Midmar Sub-catchment

<table>
<thead>
<tr>
<th>Location 1</th>
<th>SCIMAP Output</th>
<th>Site Description</th>
<th>Land Cover / Use Description</th>
<th>Transport Pathways Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coordinates: -29.494719° 30.141131° Elevation: 1073 m Slope: Relatively flat/low lying area</td>
<td>Farmland / Cropland (no tillage). Dryland maize (harvested). Irrigated pastures which are used for cattle grazing. Cattle appear not to have access to the main river channels instead have troughs for watering.</td>
<td>Farm dam spillways connect to a manmade drainage system. Manmade drainage ditches across the property converge at a central place. Each ditch was identified in the SCIMAP model output. Discrepancy in the transport pathways derived by SCIMAP were found. The model identified more pathways than what was present in reality.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Location 2</td>
<td></td>
<td>Coordinates: -29.554752° 30.188459° Elevation: 1066 m Slope: Relatively flat/low lying area</td>
<td>Degraded grassland area located downstream of a built-up urban area (Mpophomeni Settlement).</td>
<td>All transport pathways derived by SCIMAP were found and are in reality small</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Location 3</th>
<th>Site Description</th>
<th>Land Cover / Use Description</th>
<th>Transport Pathways Description</th>
</tr>
</thead>
</table>
| SCIMAP Output | Coordinates: -29.571130° 30.194423°  
Elevation: 1103 m  
Slope: Gently sloping terrain | Built up urban area (Mpophomeni Settlement).  
Households located near streams have small subsistence agriculture gardens.  
Riparian area of the Mthinzima River has dead tree trunks of exotic plants holding the banks together. | Pathways modelled over the grassland were found and are streams. This includes the Mthinzima River.  
There was no evidence of the transport pathways derived by SCIMAP over the built up urban area. |
| Location 4 | Coordinates: -29.586844° 30.172867°  
Elevation: 1183 m  
Slope: Steeply sloped hills. | Grassland area downstream of a rural low-density settlement area (Cedere Settlement).  
Bush and Shrub land.  
Subsistence agriculture. | All transport pathways derived by SCIMAP were found and are small streams. |
| Location 5 | Coordinates: -29.540382° 30.153218°  
Elevation: 1051 m  
Slope: Relatively flat/low lying area | Conserved grassland area surrounding Midmar Dam.  
Area is grazed by buck and zebra. | All transport pathways derived by SCIMAP were found and are wet grassed gullies. |
6.4 Appendix 4: Detailed Work Plan

[Detailed Work Plan Diagram]