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Integrated water management of the Vaal River catchment

Overview of postgraduate research at the Tshwane University of Technology

INTRODUCTION

The protection of South Africa's limited water resources is mandatory for ensuring the future sustainability of its people and economy. With a growing population and a thriving economy, abuse of the environment, especially rivers, is a convenient side-effect. As a consequence, the continued decrease in available water quantity in rivers and their declining water quality are the two major issues currently facing South Africa. These issues are a threat to the very growth that we are striving towards. Furthermore, change in the global climate is manifesting itself as an additional source of pressure on water resources, with stronger negative consequences being foreseen in southern Africa. Therefore, an urgent compromise has to be agreed on between socio-economic development and the environment in order to adapt to these dynamics before it is too late. To achieve this goal, continued research into developing appropriate solutions to the above issues must have the highest priority.

The Department of Civil Engineering of the Tshwane University of Technology (TUT) is currently working towards this goal under its postgraduate research agenda. The focus of research is on the Vaal River catchment which is made up of the Upper Vaal, the Middle Vaal, part of the Lower Vaal and the Upper Orange water management areas (WMAs). This catchment is one of the proverbial lifelines of the country's economy, contributing over 25% of the country's GDP and having a population of more than 12 million directly depending on it for water.

THE VAAL RIVER CATCHMENT

The Vaal River is known as one of the most 'hardworking' rivers in South Africa and flows across the Upper, Middle and part of the Lower Vaal WMAs. The upper Vaal is the pivotal WMA out of the three because of its extensive level of urbanisation and industrialisation. Therefore, its water resources have been highly developed and utilised. According to the National Water Resource Strategy (NWRS) of 2004, an upward trend in population and economic growth is foreseen in this WMA; hence future requirements of water will have to be met from additional inter-basin transfers from adjacent WMAs. The Middle and Lower Vaal regions are not highly urbanised, but have a higher presence of mines. The population of the latter two WMAs is not

expected to grow drastically. However, the surface water and to a certain extent the ground water resources have already been exploited to the maximum, thus requiring inter-basin transfers to augment the locally available yield.

The water quality in the Vaal River has also been drastically affected due to extensive industrialisation, and especially by the mining sector. As a result, the river environment has been compromised, and salinity and eutrophication are now widespread plagues in the dams and parts of the river. This has a significant impact on water-treatment economics in the region because of the unfair distribution of treatment costs upstream and downstream for the same resource.

With a cautious outlook towards the future possibility of reduction in water availability and worsened water quality, the following postgraduate research is currently ongoing at the TUT.

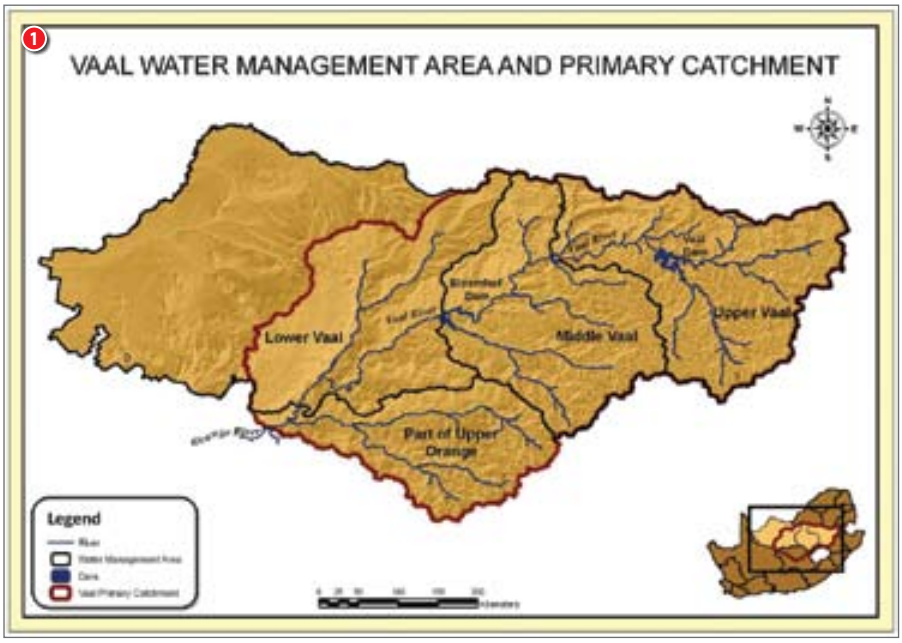
CURRENT POSTGRADUATE PROJECTS

Hydrological and water-quality modelling of the Upper Vaal Water Management Area using a stochastic mechanistic approach

The current trend in hydrological and water quality modelling in South Africa is to utilise the conventional deterministic and complex conceptual-type models. These models suffer from a number of disadvantages that hinder their effective and extensive application in the catchments. The key objective of this study then was to develop alternative, simple stochastic, mechanistic and parsimonious rainfall-flow (R-F) and flow-concentration (F-C) models using the readily available hydro-meteorological and water quality data. The station that was modelled was located on the Vaal River at Goedgeluk.

To model the R-F dynamics, stream flow, evaporation and rainfall data were used to develop a daily time-step model. Stream flow and sulphate concentration data were used to develop a monthly F-C model. In achieving the study objective, an inductive empirical transfer function (TF) approach, known as Data-Based Mechanistic (DBM) modelling, was used. In model identification and estimation, the most parsimonious model structure and associated parameter estimates are inferred statistically from the available time-series data with a minimum of *a priori* assumptions about the form of the model. The TF model identification and optimisation were implemented with the CAPTAIN Toolbox in MATLAB. The R-F model predicted stream flow at the chosen station fairly well, with coefficient of determination R of 56,3% over the entire data period.

An overall conclusion drawn from this study is that the application of the DBM modelling approach in this area has yielded simple, parsimonious and mechanistic models. These models reasonably represent the catchment's hydrological response and the transport of contaminated flows with minimal data requirements. Therefore, the way forward is to initiate a paradigm shift in hydrological modelling to explore DBM techniques as an alternative to solving current modelling discrepancies in design and requirements for raw data.



1 Location plan of the Vaal WMA and catchment

Application of the Water Evaluation and Planning Model (WEAP) to assess the impacts of climate change on future water availability in the Vaal River catchment.

This study proposes to investigate the possible impacts of climate change on the Vaal River's ability to meet future water demand using the WEAP model. This model is an integrated water resource management tool because it encapsulates the hydrological, water allocation, water quality and economic calculation components on a single platform, thus giving it an overall management capability.

Present and future water demands in this catchment were determined in a previous study finalised in 2006 for the Department of Water and Environmental Affairs (DWEA, formerly DWAF). These data will form the basis for the water allocation component of the model. Climate change projections based on regional climate models (RCMs) will then be used to assess the ability of the river in meeting the projected water demands. The study horizon is 2030.

The envisaged output of this study is the development of a decision-support tool to carry out 'what if' analyses of future impact scenarios and possibly assist in formulating the adaptation and mitigation measures necessary for the Vaal River's continued sustainability.

The user-pays principle in abating a water quality crisis

The user-pays principle encourages costing of raw water as a capital resource. The DWEA sells raw water to water boards, generally at a fixed cost determined annually. This cost, however, does not take into account the quality of water that the water boards receive. Water boards are then expected to treat this water to certain specified standards for distribution to local authorities, which then supply the consumers. The end users are then charged based on the volume they consume, presumably at a rate that would recover the operation and maintenance costs of the suppliers and which is agreed on in advance. The result of this could be one of two things, namely that the consumers in different parts of the country pay different rates or that the water boards may be operating at a loss.

Therefore, based on recent and ongoing research in the Vaal River catchment, this study examines the effect of this pricing strategy on the final cost of treatment and ultimately the cost to consumers. A model will be developed which will assist in determining ways in which raw water can be priced to ensure pro rata distribution of the burden of treatment costs to the consumers, based on the quality of the raw water. The focus area for this research is the Vaal River and selected tributaries between the Vaal Dam outlet and the Bloemhof Dam inlet (see Figure 1).

Passive pre-treatment of mine water using roughing filters

Roughing filters can be considered as possible passive pretreatment units for mine water since they efficiently separate fine solid particles over prolonged periods without the addition of chemicals. In this study, horizontal roughing filters (HRFs) have been selected because of their better performance compared with vertical

roughing filters (VRFs). HRFs are also simple to design and have minimal operation and maintenance requirements.

For the purpose of this study, a pilot plant will be constructed at Delcoal mine in Mpumalanga. The design and sizing of the pilot plant will be guided by Wegelin's design criteria. Two different filter media will be tested individually, such as coconut fibre and broken burnt clay, against a control medium of gravel. The choice of the control medium is based on the fact that the design criteria were developed using gravel and also because of the popularity of broken burnt clay as a filter medium. The prototype unit will have three equal compartments with medium sizes decreasing in the direction of flow. The performance of the units will be determined by monitoring the pH and removal efficiency of the iron and manganese content of the influent under the prevailing field and varying climatic conditions.

The output of this study will be determination of the viability of the HRF as a low cost pretreatment option for mine water. This would have significant economic implications for the mines, as well as a much-desired positive impact on the discharge environment.

Development of design criteria for the construction of sand dams

Abstraction of water from sand reservoir deposits is a well-known alternative source of underground water in arid and semi-arid regions with seasonal river flows. Internally, due to the uneven surface of sand particles, voids are created which can store water. Several models developed in the past to simulate sediment transport and depositions in alluvial flow have focused mainly on the prevention of sediments in downstream water resources and have not been optimised for the possible yield of water extractable from the sand deposits behind the barrier wall given various field conditions. This study will therefore establish the relationship between different hydraulic and sediment parameters, such as flow rate, slope, channel characteristics and roughness, with the quality of deposited sediment. A model will eventually be developed for optimising these parameters and for determining the range of barrier heights required to derive maximum water storage in the sand dam.

The results of this study will contribute to the development of affordable alternative water sources that are ideal for the rural dry areas where surface and ground water potential is low.

CONCLUSION

This article has presented an overview of the research currently in progress at the TUT. It is our sincere hope that the findings from these studies can be used in the ongoing battle to safeguard our water resources for a sustainable future. In conclusion, the words of former American President Lyndon B Johnson come to mind. He said that a "nation that fails to plan intelligently for the development and protection of its precious waters will be condemned to wither because of its shortsightedness. The hard lessons of history are clear, written on the deserted sands and ruins of once-proud civilisations". □

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http://www.saice.org.za/downloads/monthly_publications/2009/2009-Civil%20June/#/0