

EXECUTIVE SUMMARY

The main objective of the project was to contribute to the incorporation of uncertainty assessments in water resource decision making in South Africa, thereby quantifying the risks associated with specific decisions about planned future water resource developments. This objective was supported by several specific aims:

1. Develop an understanding of uncertainty and associated risks in water resource management on the basis of literature and known practices, nationally and internationally.
2. Identify and characterise the main sources of uncertainty (focusing on current South African practice and typical situations of data availability).
3. Develop techniques and guidelines for quantifying the uncertainty associated with different models. This will include uncertainty in all relevant areas (hydrological, climate, economic, social, etc.).
4. Determine the effects of uncertainty on water resource management and identify what level of uncertainty is acceptable.
5. Develop guidelines for the communication of uncertainty and the impacts to various stakeholder groups involved within water resource planning and management. This aim will need to address the issue of the links between uncertainty and risk.
6. Develop guidelines for incorporating uncertainty and the associated risk into water resource decision making processes.
7. Identify those areas of uncertainty that can be realistically reduced and which will have the greatest impact on reducing the risks involved with water resource decision making.

While all of these aims have been addressed as part of the project, it was inevitable that a project of this type would raise almost as many additional questions as it would answer those that were posed as part of the project design. The main output from the project has been the development of a framework for uncertainty assessments in water resources availability analyses within South Africa. This framework has been based on international experience, the water resources analysis methods that are commonly applied within South Africa, the data constraints that exist within the country as well as the requirements for water resources management decision making. The framework has been supported by the development of some new approaches to applying existing hydrological models and illustrated by examples of their application. The framework development has certainly contributed to an understanding of uncertainty (Aim 1), is focused on the main areas of uncertainty that have been identified (Aim 2) and is supported by techniques that can be applied in practice (Aim 3). There remain some questions about how best to communicate uncertainty to different stakeholder groups (Aim 5) and consequently how uncertainty affects management, what level of uncertainty is acceptable and how uncertainty affects decision making risk (Aims 4, 5 and 6). The project has identified the main sources of uncertainty and offers some recommendations on approaches to reduce the level of uncertainty. Some of these are achievable in the short-term through changes in technical practices (such as hydrological model parameter estimation), while others require closer engagement in the future between scientists, water resources engineers and policy makers at governmental level (such as improvements in the national rainfall monitoring network).

The framework is discussed in detail in the first three chapters of this report and is largely based on the concept of generating ensemble outputs from hydrological models rather than the traditional approach of a single output. The range of differences between the ensembles represents the degree of uncertainty in our understanding of the hydrological response of a catchment as well as in the climate data used to force the hydrological response. In practice the input uncertainty is represented by using probability distributions (rather than single values) of the model parameters as well as variations in the rainfall and evaporation demand

data used to drive the model. The variability in the parameters and the forcing climate data will depend on our existing knowledge about the catchment and the amount and quality of data that are available to inform that knowledge. The framework includes a method of assessing the ensemble outputs to try and distinguish between those that are not realistic representations and those that can be considered 'behavioural'. This assessment uses regional and local knowledge of hydrological response and is largely based on the integrated use of observations (measured stream flow data, for example) and prior knowledge (previous studies of groundwater recharge, for example). Where high confidence can be expressed in this knowledge, the range of behavioural outputs will be small (low uncertainty), while in other situations a high degree of uncertainty will remain. The concepts are very similar to the traditional approaches to the use of hydrological models involving calibration and validation of a result before being used for decision making. However, the traditional approach could not be applied satisfactorily in ungauged catchments where there are no data to calibrate against, and did not include any explicit quantitative uncertainty information. The new framework is far more flexible and can be applied under all conditions regardless of the quantity and quality of the available data. The report provides the details of the different parts of the framework as well as a number of examples of its application in various regions of South Africa.

It is a strong recommendation of this project that the issue of improving and sustaining the collection of rainfall data within South Africa be discussed in the very near future by all the organisations either responsible for data collection or that use the data. This could be achieved through a highly focused workshop (organized perhaps by the Water Research Commission) that has a mandate to report to the relevant Ministers and the outcomes of which will be used to guide future policy. It is important that at least the Water Research Commission, the Department of Water Affairs, the Department of Agriculture, the SA Weather Service, water resources engineering consultants as well as research organizations are represented at the workshop. It is also important that the individuals representing the government organisations have sufficient authority to influence policy directions. One of the outcomes of the workshop should be a succinct report on the state of rainfall data collection, the implications of not improving the situation and recommendations for future action.

One of the most important considerations from a practical point of view was that the project should not recommend approaches that are completely different, and that would generate completely different results, compared with existing methods used by a large number of water resources practitioners in South Africa. The intention was to recommend enhancements to existing methods such that uncertainty assessments could be explicitly included without the need for completely replacing methods that have been used with reasonable confidence for many years. Specifically, this point relates to the links between hydrological models (used to generate time series of likely natural hydrology) and water resources systems yield models that are used to assess water availability, design storage and abstractions systems and assess future scenarios so that management decisions can be made (see Chapter 4). Some inclusion of uncertainty has always been part of standard practice for yield analyses in South Africa through the use of a stochastic model component in yield models that generate multiple stream flow sequences. However, this approach represents only a form of uncertainty. The project investigated the integration of stochastic uncertainty with hydrological uncertainty (related to climate inputs and model parameter quantification) through the use of a stochastic rainfall model to provide inputs into uncertain hydrological models. The assumption was that this could replace the traditional use of a stochastic stream flow generator within the yield model. While the report presents examples and evidence to suggest that the new approach has many potential advantages, there remain some practical considerations as well as some issues related to the interpretation of the results for decision-making purposes. These will be addressed as part of a future partnership between key groups involved in both research and practice including the Department of Water Affairs. One of the recommendations of this project is that future

updates to the water resources of South Africa studies (WR2020 perhaps?) should be based on improved methods of parameter estimation in ungauged catchments and should include parameter uncertainty.

One of the potential sources of uncertainty in water resources assessments is related to the available information about present day water use. This source of uncertainty also impacts on the interpretation of observed stream flows records and the process of naturalization. The uncertainty in present day flows can be dealt with in either hydrological models or within yield models. Several examples, including uncertainties in groundwater abstraction impacts, afforestation impacts and the effects of small farm dams are presented in the report. It is quite clear that the uncertainties in these components of the water balance of catchments should not be neglected and also that the available information is less than adequate in many situations.

Chapter 5 of the report refers to the analysis and software tools that have been developed during the project. Many of these are associated with the SPATSIM software package that is under common ownership by the IWR, UKZN, the WRC and DWA. Many of these have been developed for a research environment and from a practical point of view it will be necessary to translate some of the software for use with other software that is currently being used by practitioners. This issue will be addressed in the near future.

Being uncertain about the outcome of a scientific or technical analysis should not be seen in a negative light and the explicit inclusion of quantitative expressions of uncertainty should allow improve future decision-making. First of all, realistic expressions of uncertainty will help to identify the gaps and weaknesses in our knowledge and understanding and therefore promote interventions to close those gaps. Secondly, uncertainty should be part of the whole adaptive approach to managing water resources that is advocated by many leading scientists and practitioners worldwide.

Throughout this project attempts have been made to achieve a balance between the development of new approaches based on sound hydrological principles and international experience with the practical considerations associated with the use of models for water resources assessments, planning and management. The degree to which these overall objectives have been achieved can only really be measured by the impact of the project outcomes on the approaches applied in the future. Many of the techniques that have been developed during this project are already being successfully applied by Rhodes University research students in studies as diverse as large scale modelling of the Congo River basin through much smaller scale evaluations of surface-groundwater interactions in South African catchments to various climate change impact assessments. The value of the project results to future hydrological research within South Africa has therefore already been demonstrated. Many of the principles and some of the results of the project have already been internationally peer reviewed through the publication of papers in scientific journals and presentation at international conferences. This process will continue through 2011 as additional material is submitted.

Some of the follow up activities will have to be focused on 'selling' the concepts, the proposed techniques and the recommendations to the broader community of hydrological and water resource engineering practitioners. The project team recognizes that this will never be a simple task and practitioners are often justifiably reluctant to adopt new approaches without a very clear demonstration of the advantages. The authors believe that they have presented a strong argument for including uncertainty in standard practices for water resources estimation in South Africa but it remains to be seen whether these arguments are strong enough to encourage the paradigm shift that will be required.