EXECUTIVE SUMMARY

Introduction

South Africa is a water scarce country. The water situation reports contained in the National Water Resources Strategy (NWRS, First Edition 2004) indicate that an alarming number (more than 50%) of South Africa's water resources are considered to be either fully-allocated or over-allocated. The statistic is concerning given the fact that few economically viable water augmentation options (e.g. the building of dams and inter-basin transfers) exist, as most viable sites have already been developed. Given the limited potential to address the situation with a supply-side solution, focus has shifted to the improvement of water use efficiencies and water resource management. Improved levels of water use efficiency may liberate water with little to no reductions in the production levels associated with the use of the water. However, it has been documented that improved levels of water use efficiency may in fact reduce the water available to downstream water users as a result of reduced return flows associated with gains in water use efficiency (Grové, 1997).

The efficient operation of large dams is particularly important as dams increase the yield of catchments by retaining water during periods of water abundance for use during periods of scarcity. The underlying objective of this research project was to assess options with which efficiencies related to the use of water could be improved, with particular reference to the efficiency of water use from large dams. The original thinking was that water use efficiencies would be improved by the introduction of the water audit system for the following reasons:

- The intensified monitoring of water releases from the dam (associated with the water audit system) would potentially reveal inefficiencies associated with water releases from dams,
- The monitoring of actual water use by downstream users could reveal over-use by water users
- The monitoring of river flows downstream of the dam could reveal the presence of unauthorised water use upstream of the monitoring point. In this way unauthorised users could be prosecuted by water managers.

Clearly, improved monitoring networks and a system (auditing procedures) of reconciling actual water use against the entitlements of the water users to the use the water were central to the originally envisaged water audit system. In the course of the project however, it was discovered that a "use-it-or-lose-it" principle is generally adopted for the management of water use from large dams in South Africa. The implication of the principle is that if a given water user does not use his water use entitlement in a certain time-period (generally a year), the entitlement is lost in that time-period. An investigation of the potential impact of this principle on water use efficiency revealed that the principle does not promote improved water use efficiency.

In contrast, the principle may in fact induce the inefficient use of water. The reasoning relates to the fact that different categories of water users are identified in South Africa (e.g. high, medium and low assurance users). Irrigators, who are responsible for over 50% of South Africa's water use (NWRS, First Edition 2004), are generally awarded lower levels of assurance than industrial and domestic water users. Low assurance water users pay lower water use charges than users with higher water use charges. The assurance levels influence (i) priority levels with which water users are to receive water in times of water scarcity, and (ii) the level of water restrictions faced by the respective categories of water users during periods of water restrictions.

The inefficiency results from the fact that water users do not have incentive to use water more efficiently. The low assurance users in particular have every incentive to use all the water they can, particularly when dams levels start dropping and the impostion of restrictions starts being discussed by water resource managers and stakeholders. These water users will try to use as much water as they can before restrictions are imposed. This action paradoxically leads to dam levels which draw down quicker than they would have if no restrictions were imminent. The quick draw down in dam levels as restriction levels are neared then results in the imposition of restriction levels. Bear in mind that there may be several dam restriction levels, with restrictions becoming more severe as the dam levels lower.

The realisation of the potential negative impact of the use-it-or-lose-it principle of water use from dams on water use efficiency changed the course of the project to a large extent, as an alternative "use-it-or-bank-it" principle was explored, as this was believed have a number of benefits over the existing system, including:

- A water management system based on the "use-it-or-bank it" principle would promote the adoption of water use efficiency by water users. Irrigators for example may adopt irrigations systems and scheduling practices which are more water use efficient, thus requiring less water. The liberated water could then be banked by the irrigator, which could be used at a later stage, or could be traded with other water users.
- The definition of water use entitlements is far clearer under a system based on the "use-it-or-bank-it" principle as opposed to a system based on the "use-it-or-lose-it" principle. One is thus more able to successfully implement a water audit system, which reconciles water use against the entitlements to use the water by various individuals, based on a "use-it-or-bank-it" management system as opposed to the "use-it-or-lose-it" system.

The focus of the project thus shifted away from a purely "operational water audit system", to an understanding of what would be required to implement the new water management system for large dams based on the "use-it-or-bank-it-principle". The

management system based on the "use-it-or-bank-it principle" has been referred to as a Fractional Water Allocation and Capacity Sharing (FWA-CS) water management system in this document, whereas the management system based on the "use-it-or-bank it" principle is referred to as a Priority-based River and Reservoir Operating Rule (PRROR) system. The assessment of the FWA-CS arrangement included an assessment of the National Water Resources Strategy (NWRS, First Edition 2004) and 1998 National Water Act to ensure that it would be legally possible to adopt this new water resource management approach. It was found that nothing in the 1998 National Water Act or National Water Resources Strategy (NWRS, First Edition 2004) disallowed the adoption of the new FWA-CS water management approach. Secondly, it was necessary to assess if the computer models currently used by the Department of Water Affairs and Forestry (DWAF) could in fact support the new water resource management approach. It was found that the Water Resources Yield and Water Resources Planning models used by the DWAF could not in their current form support the FWA-CS water management approach. A model was sourced which could support the FWA-CS water management report. The model, the Mike Basin model, was developed by the Danish Hydraulic Institute. The authors tailored the Mike Basin model to include some functionality required for South African conditions, such as the development of an In-stream Flow Requirement (IFR) module, as well as a module to derive yield curves for water resources.

The project research area

The Mhlathuze Catchment was chosen as the research project area, as it is one of the first catchments in the country in which the Compulsory Licensing process has been initiated, as the catchment is currently deemed to be over-allocated. Furthermore, the catchment is heavily dependent on water stored in a large dam located in the upper reaches of the catchment, i.e. the Goedertrouw Dam. The Mhlathuze Catchment was a suitable research area given the reliance on the Goedertrouw Dam, as well as the fact that the Mhlathuze Catchment is one of the first catchments to undergo the compulsory licensing process in South Africa, as a key objective of the project was to share with the stakeholders and water resource managers involved in the Compulsory Licensing process any relevant findings from this research.

Project objectives and activities undertaken

Objective 1: To develop a water audit system for large dams.

The scope of the deliverable was increased to include the development of an audit system for a catchment. The option to use the WRYM supporting the PRROR institutional arrangement for the further development of the audit system was not pursued as the WRYM was unable to support the FWA-CS institutional arrangement, and was unable to operate on a near-real-time basis (which would be required to calculate water use entitlements during times of water scarcity). Instead, the decision was taken to purchase the Mike Basin planning model (for approximately R40,000),

as the model can support the FWA-CS as well as the PRROR institutional arrangements, and can operate on a daily, weekly or monthly time step. The model was tailored in order to meet the requirements of water resource planners, as the IFR and Yield modules were developed to interact with the Mike Basin model via the COM interface.

Objective 2: To increase the understanding and knowledge of the practicalities, strengths and weaknesses, and potential costs and benefits of developing and implementing a "water audit system" for use by CMAs. Although a fully operational water auditing system was not developed in the course of this project, largely as a result of the increased project scope and assessment and accommodation of the FWA-CS institutional arrangement, the requirements of this aim are discussed within this document. Furthermore, persons in DWAF were consulted on a few occasions to assess if and how the FWA-CS institutional arrangement could be integrated into the operational management of water resources. Stakeholders were also consulted to assess their interest in the institutional arrangement, and the benefits, strengths and weaknesses of the FWA-CS institutional arrangement.

Objective 3: To transfer knowledge/technology to decision makers and stakeholders.
A number of presentations of the FWA-CS institutional arrangement were held with DWAF: Head Office, DWAF: Regional Office as well as stakeholders in the Mhlathuze Catchment. The Mike Basin software has been demonstrated within DWAF.

Objective 4: To assess the feasibility of implementing the water audit system for the management of South Africa's water resources.
Consideration has been given to the 1998 National Water Act, NWRS (First Edition, 2004) and discussions have been held with DWAF:HO, DWAF:RO and Mhlathuze stakeholders in order to report on the feasibility of (i) introducing the FWA-CS institutional arrangement in order to promote water use efficiency from large dams, and (ii) the feasibility of developing and implementing a water audit system.

Project outcomes
The following are notable outcomes of the project:

- It has been recommended to the DWAF by Prof A. Görgens as part of a User Requirements Survey related to the modelling needs to support the Compulsory Licensing process in the Mhlathuze Catchment, that a pilot project be undertaken in which the concept of FWA-CS be further explored.
- In the course of the project the Mike Basin model has been declared an "emerging model" in the DWAF "Guidelines for models to be used for Water Resources Evaluation", Version 2, Nov 2003.

- A few Directorates in DWAF have shown an interest in the use of the Mike Basin model, and other range of Mike models, resulting from the exposure given to the model as a result of this project.
- The earlier version of the Mike Basin model did not accommodate for the fractional allocation of run-of-river flows very well. As a result of the project and communication with the DHI, the Mike Basin model is being modified to better accommodate FWA-CS.
- Modules have been developed which enable the Mike Basin model to be used by water resource planners. Although stochastic hydrology has not been included in this development, it is believed that this will be achievable.
- Stakeholders have been exposed to the concept of FWA-CS, as well as to the PRROR institutional arrangement.
- The monitoring equipment installed in the Mhlathuze Catchment will remain there for the improved management of water resources.

Capacity building

During the course of the project the capacity of a number of individuals and organisations was developed. Details of these are provided in Appendix A of this report.

Conclusions

The following conclusions can be drawn from this research

- Due to the water scarcity in South Africa, the efficient use of the water resources we have available to us is vital.
- The Priority-based River and Reservoir Operating Rule (PRROR) is the currently adopted water management system in South Africa. The PRROR system is founded upon the "use-it-or-lose-it" principle for water use from large dams. This water management system is believed to result in the inefficient use of water from dams. A new water management system, which is based on a "use-it-or-bank-it" principle for water use from large dams was explored, upon which an a water audit system can be developed to promote further water use efficiency.
- The NWRS (First Edition, 2004) and 1998 National Water Act do not prohibit the adoption of an institutional arrangement such as FWA-CS. The FWA-CS institutional arrangement is however a new potential management option, and one which can not be supported by the Water Resources Yield Model (WRYM) and Water Resources Planning Model (WRPM) in their current form.
- The Mike Basin model was purchased and further developed in order to accommodate for FWA-CS in a manner suitable for water resources planning purposes. Without this development the FWA-CS institutional arrangement

would be of little value to stakeholders in the Mhlathuze, as water resources planning is a key component of the Compulsory Licensing process.

- The Mike Basin model was not fully developed into a water auditing system in the course of this project, for either the FWA-CS or the PRROR institutional arrangements, however details of how the auditing system could be developed were discussed.
- Many of the stakeholders in the Mhlathuze Catchment showed an interest in the FWA-CS institutional arrangement, and the Sugar Association of South Africa (SASA), recently renamed to the South African Sugar Research Institute (SASRI), has formally requested that the institutional arrangement be further explored in the course of the Compulsory Licensing process.
- It may be the case that due to the newness of the FWA-CS institutional arrangement, and also due to the pressure to complete the Compulsory Licensing process, particularly in stressed catchments in South Africa, that the FWA-CS institutional arrangement is not initially adopted. However, as the value of water increases in catchments and monitoring systems are improved, and the CMAs become operational and established it is believed that the FWA-CS institutional arrangement will become increasingly more attractive to implement.
- The FWA-CS institutional arrangement is viable in relatively small catchments where water users receive the bulk of their water from dam releases (and not from tributary flows). The flows from tributaries complicate the FWA-CS institutional arrangement in that more monitoring is required, and the apportionment of flows from the tributary flows will be important as water users will want to use as much tributary flow as possible in order to maximise the banking of water in dams.
- It must be highlighted that water banking has been undertaken in the Mhlathuze Catchment during the drought experienced in the 1990's. Furthermore the Catchment is one of the only catchments where water users pay for actual water use, as opposed to paying for their full entitlements. This, combined with a monthly and six monthly water management report related to the water usage in the catchment have resulted in high water use efficiency within the Mhlathuze Catchment.

Recommendations

The following recommendations, resulting form this project, are made:

- Weather data collected using the Automatic Weather Station installed at the Goedertrouw Dam as part of this project showed a very poor correlation with DWAF recorded data. Details for this poor correlation are not clear, and it may be appropriate for this to be further investigated.
- The 1998 National Water Act and NWRS (First Edition, 2004) make very little mention of the exact details in which water resources are managed, i.e.

how the rules that govern the apportionment of water amongst competing water users are reflected in computer models, and how the results are used in the licensing process. Although this is a very technical discussion, it may be one which is required in order to build the capacity of stakeholders in catchments, so that they can better understand how their entitlements are influenced by upstream water users, and how their activities influence downstream water users.

- Accurate weather forecasts could improve the water use efficiency from large dams in that water users may require less water to be released from dams if they know with a suitably high level of confidence that rainfall is expected in the near-future. Due to the travel time associated with water released from the Goedertrouw Dam, it can take up to 2.5 days for the released water to reach water users. In the Mhlathuze Catchment water users will thus require high confidence 3 day forecasts.
- The Mike Basin model makes use of a different solver to the WRYM. A recommendation is that further research be undertaken related to the solvers used for various node and channel hydrological models used locally and internationally, and that the advantages and disadvantages of the respective solvers be compared.
- It is recommended that the ACRU model be integrated via the COM interface with the Mike Basin model. This link will enable ACRU to gain the functionality of a multi-user, multi-reservoir planning model (such as Mike Basin), which even be used on an operational level, as the Mike Basin model can operate at on a daily time-step, and can be hot-started.
- It is recommended that a more detailed legal review be undertaken regarding FWA-CS to assess if slight amendments may be required to the wording of clauses in the 1998 National Water Act to better accommodate FWA-CS.
- It is recommended that the full link between Mike Flood Watch and Mike Basin be explored in order to complete a fully functional water auditing system for catchments, for both PRROR and FWA-CS institutional arrangements. This development will enable the water resource planning model to be operated at an operational (i.e. near real time level). This functionality is required for water audits to be undertaken on a near-real time basis, which is often required during very dry periods.