EXECUTIVE SUMMARY

1. BACKGROUND AND MOTIVATION

The National Water Act (No.36 of 1998) (NWA), enables the Minister of the Department of Water Affairs and Forestry (DWAF) to regulate land-based activities, which reduce streamflow, by declaring such activities to be streamflow reduction activities (SFRAs). Commercial afforestation has been declared a SFRA in terms of the Act. A form of land-use that is not a declared SFRA, but which has a similar impact as afforestation, is that of invasion by alien plants. It is widely accepted that streamflows can be significantly reduced by the invasion of riparian zones and hill slopes by alien vegetation.

In South Africa, two basic methods of streamflow reduction (SFR) estimation have been developed for commercial afforestation and invasive alien plants (IAPs). These are:

1. *Free-standing empirical relationships in the form of the Council for Scientific and Industrial Research (CSIR) SFR curves (Scott and Smith, 1997).*
2. *Component modules in the physically-based, land-use sensitive Agricultural Catchments Research Unit (ACRU) rainfall-runoff catchment model (Smithers and Schulze, 1995).*

The empirical relationships have been used in conjunction with the monthly catchment model (HRU, 1973), while the ACRU Model operates on a daily time step, and finer spatial scale than the Pitman Model. There is a need for a comparison of the outcomes of the two SFR estimation procedures and the development of guidelines for the appropriate use of each method in a water resource evaluation setting.

The SFR estimation methods have been used in studies to determine the potential impacts of SFR due to commercial afforestation and alien vegetation on mean annual runoff (MAR). There have also been a few studies done on SFR impacts on utilisable water (Le Maitre and Görgens, 2001) (Larsen et al, 2001). These have primarily been based on outputs from the monthly Pitman Model. There is a need for a wider, more extensive assessment and comparison of the impacts of SFR, as estimated with the two SFR estimation methods, on reservoir yield and run-of-river supply.

2. OBJECTIVES

1. *To assess and reconcile SFR impacts caused by alien vegetation and commercial afforestation, modelled at different levels of scale and resolution and over a range of bio-climatic regions.*
2. *To quantify SFR impacts caused by alien vegetation and commercial afforestation on reservoir and system yield-reliability characteristics, as well as for run-of-river water supplies for a range of South African river systems.*

3. *To develop generic guidelines for the treatment of scale and resolution in assessment of SFRs due to alien infestation and commercial afforestation in Integrated Water Resources Management (IWRM) in South Africa.*

3. METHODOLOGY

The first step in conducting the study was to identify study systems, which represented a wide range of bio-climatic conditions in South Africa. The project aimed to use existing Pitman, ACRU and Water Resources Yield Model (WRYM) configurations, where possible, and this further requirement played a role in the selection of study systems. Systems selected were the Upper Berg, Upper Sabie and Mhlatuze.

For each system, an ACRU, Pitman (SHELL) and WRYM Model was configured. As far as possible, the same modelling information was used for the ACRU and SHELL configurations of each river system, so that the results from ACRU and SHELL could be compared for each system. The ACRU and SHELL configurations were run for a number of scenarios and deductions were made on the SFR estimated by the two different models under different bio-climatic conditions. The output from ACRU and SHELL was then run through the WRYM to investigate the impacts, on yield, of SFR produced by the two different models under different bio-climatic conditions.

ACRU configurations already existed for Sabie and Mhlatuze. The Berg ACRU configuration was set up for this study. Pitman (SHELL / WRSM90) configurations existed for all three systems. WRYM configurations existed for the Upper Berg and the Mhlatuze. A WRYM configuration had to be set up for the Sabie for this study.

The following important issues were raised in setting up a new ACRU configuration for the Upper Berg.

- *The seasonal distribution of the existing fynbos land use parameters does not truly reflect the seasonal distribution of the water use by fynbos, so the ACRU land use parameters for fynbos were modified.*
- *The total rooting depth for the area is shallow compared to the expected rooting depth of fynbos. An additional depth of 0.25 m was therefore added to the fynbos rooting depth.*
- *In assessing the Upper Berg A-pan data for this study, it was noted that for some subcatchments, in the higher reaches of the catchment, the A-pan evaporation for June to August, was higher than for April and May, which is unlikely to occur in reality (Le Maitre, email, 2004).*

The baseline scenario in this study represents the "natural" land cover as determined by SHELL. In SHELL, the following land and water uses are eliminated from the current scenario to provide the natural scenario:

- *Irrigation and farm dams;*

- *Afforestation;*
- *Alien vegetation;*
- *Dryland sugarcane;*
- *Large reservoirs and bulk water abstractions;*
- *Water transfers into and out of the catchment; and*
- *Return flows / waste discharges.*

Normally in ACRU modelling, the natural scenario is defined as the scenario which contains only Acocks land cover, however, because this study aims to compare the outputs from ACRU and SHELL, an attempt was made to create in ACRU, the same baseline found in SHELL. Hence, in the ACRU baseline, all land and water uses except the seven mentioned in bulleted points above, were left in the model. The seven excluded land and water uses were replaced with the relevant Acocks land cover. The residual land uses in the baseline scenario consist mainly of all dry land cultivation (except dryland sugarcane) and occasionally small urban areas.

The method for determining riparian SFR in SHELL was updated, based on the incremental potential evapotranspiration (ET) of the riparian plants.

Various scenarios of alien vegetation invasion and commercial afforestation were modelled in ACRU and SHELL. Flow sequences from the two models were fed into the WRYM configurations of the study systems. The findings of the SFR modelling and yield modelling were compiled into guidelines for SFR assessments in water resources modelling and analysis.

4. CONCLUSIONS

The following conclusions were drawn from the results of the study.

1. *In calibration of SHELL configurations and verification of ACRU configurations, both models are capable of achieving a reasonable average seasonal correspondence of high and low flows with the observed averages, though the actual averages produced by the two models can differ substantially.*

2. *MAR, simulated by the models, has a strong influence on SFR simulated by the models. Comparison of proportional reductions simulated by the models with proportional reductions from the experimental catchments showed that if the MAR for the models were similar to the MAR for the experimental catchments, the models would produce reductions of the same order of magnitude as the experimental catchments.*

3. ACRU simulation produces much smaller SFR than SHELL simulation.

4. ACRU simulation of the Upper Sabie catchment produces much smaller SFR than expected, based on comparisons of ACRU-simulated SFR for Sabie, with ACRU-simulated SFR simulated for the Berg and Mhlatuze from this study and from the "Gush" tables (Gush et al, 2002).

5. Apparent gains in SFR, after afforestation or invasion by IAPs, may be simulated during dry periods. The simulation of this (in ACRU, or in the SHELL riparian SFR method) depends greatly on the selection of crop factors for the baseline vegetation.

6. Comparative SFR between different tree classes may vary, depending on season and catchment conditions; for example tall shrubs may use more water than medium trees or tall trees. This is also very dependent on crop factors chosen for the different tree species (in ACRU, or in the SHELL riparian SFR method).

7. The output produced by SHELL in terms of SFRs is predictable in that the modeller knows what to expect, based on the values of the input variables used. Empirical methodology used means that the output produced by ACRU, on the other hand, is less predictable, as it is based on the representation of a number of different physical processes.

8. In the assessment of impacts on yield, on average, impacts on yield by SFR due to IAPS and afforestation are greater than the impact on MAR. This indicates that the assessment of impact on yield is important in SFR analysis.

9. The impacts on yield at upstream subcatchments in a catchment can be very different from the impact at the end of the whole catchment. The impact tends to be larger at upstream subcatchments.

10. Assessment of run-of-river yields in smaller upstream catchments is not a useful exercise as these subcatchments tend to dry up in the critical periods.

11. A simulated reduction in MAR can result in a simulated increase in yield of a given assurance, if the portion of the flow sequence occurring during the critical period is dominated by streamflow gains; likewise, a simulated increase in MAR can result in a

simulated reduction in yield of a given assurance, if the portion of the flow sequence occurring during the critical period is dominated by streamflow reductions.

5. RESEARCH RECOMMENDATIONS

Research recommendations drawn from the study are as follows.

1. *If calibration-based models, like Pitman, are to be used extensively in water resources analysis, the availability of reliable observed streamflow data must be improved.*

2. *More field measurements of processes, which impact SFR, are required to gauge the performance of physical models (like ACRU) in simulating these processes. An example of this is the direct measurement of ET by trees.*

3. *Improved (finer scale) mapping of vegetation types within catchments is required to capitalise more on models (like ACRU), which run at small spatial scales. This should also include the distinction between vegetation in riparian and upland areas of catchments, particularly vegetation for inclusion in model configuration baseline scenarios.*

4. *More extensive rainfall gauging is necessary in high altitude catchments, to capture the correct rainfall patterns in catchments with steep MAP gradients, like the Upper Berg and Upper Sabie. Alternatively, relationships that translate rainfall information for the low altitude catchments to information, for the high altitude catchments, need to be developed. The use of radar rainfall mapping to improve aerial rainfall estimates of high-lying ground should be investigated.*

5. *The anomalies observed in the seasonality of the published A-pan data for the Upper Berg, described in Section 3.2.1 of this report, need to be investigated.*

6. GUIDELINES

Based on the results of the study, guidelines were formulated on the following considerations in SFR modelling:

i) *Focus on characteristics of the total flow regime that are relevant to the specific water resource analysis.*
ii) *Distinguish between riparian and upland origins of the SFR impacts.*

iii) *Define a "baseline" or "reference" land-cover scenario against which the SFR-impacted streamflows are to be juxtaposed.*

iv) *Recognise different categories of SFR-causing vegetation types.*

v) *Define the age and species mosaic of SFR-causing vegetation.*

vi) *Define the age and species mosaic of the baseline / natural vegetation.*

vii) *Determine if the analysis should be for an SFR-causing vegetation scenario that is static, or dynamic, in terms of vegetation type mix, age and location.*

viii) *Consider coarser spatial scales for bulk water resource augmentation planning, but finer scales for water allocations under compulsory licensing as well as for site-specific investigations to support conflict resolution.*

ix) *Determine the required temporal scale of the analysis.*

x) *Recognise ambient rainfall or natural land-cover gradients in discretisation of modelling units for SFR impact modelling.*

xi) *Take cognisance of inherent longitudinal differences between aggregated main-stem SFR impacts and impacts in individual tributary subcatchments.*

xii) *Take cognisance of differences in outcome via different models.*

xiii) *Take cognisance of differences in requirements via different models.*