Water demand management scenarios in a water-stressed basin in South Africa

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Abstract

Like the majority of the river basins in South Africa, water resources in the Olifants River Basin are almost fully allocated. Respecting the so-called "reserve" (water flow reservation for basic human needs and the environment) imposed by the new Water Law adds a further dimension, if not difficulty, to water resources management in the basin, especially during the dry periods. Decision makers and local stakeholders, who will soon be called upon to work together in a decentralized manner within catchment management agencies, must therefore be able to get a rapid and simple understanding of the water balances at different levels in the basin. The Water Evaluation and Planning (WEAP) model and its application to the Steelpoort sub-basin of the Olifants are presented in this paper. This model allows the simulation and analysis of various water allocation scenarios and, above all, scenarios of users' behavior. Water demand management is one of the options discussed in more detail here. Simulations are proposed for diverse climatic situations from dry years to normal years and results are discussed. It appears that quality of data (in terms of availability and reliability) is very crucial and must be dealt with carefully and with good judgment. Secondly credible hypotheses have to be made about water uses (losses, return flow) if the results are to be meaningfully used in support of decision-making. The ease of use of the model and its user-friendly interfaces make it particularly useful for discussions and dialogue on water resource management among stakeholders; it can also be used to promote greater awareness and understanding of key issues and concerns among the public

Keywords: water allocation, water demand management, river basin management, South Africa

INTRODUCTION

The progressive new South African water law (Water Act 1998) is expected to bring about fundamental changes in the way in which water is used and shared among different users. A major aim is to ensure a better balance between efficiency, sustainability and equity needs in water allocations (Lévite and Sally 2002). Water must be guaranteed for all, especially to meet the basic human needs of poor people in rural areas who have been disadvantaged for so long. Furthermore, water cannot be simply allocated to meet the increased demand from agriculture, industry and other productive sectors without also satisfying the requirements of aquatic ecosystems and the environmental Reserve. Finally, responsibility for decision-making in respect of water allocations will be decentralized to the level of the future Catchment Management Agencies (CMAs). A system of authorizations for water abstractions is foreseen, with compulsory licensing when the basin is water stressed.

Such is the case of the Olifants river basin, which flows from the highly populated and industrialized Gauteng Province of South Africa to Mozambique. Water resources have already been largely developed in the Olifants basin. Water demand management, especially in the agricultural sector, which is the biggest user, is one of the possible solutions being considered by the South African Department of Water Affairs and Forestry (DWAF). In order to quickly assess alternative water allocation scenarios at basin level, technicians and policy makers will need practical and user-friendly tools. This study sets out to test the usefulness of the Water Evaluation and Planning (WEAP) model in this regard, particularly in assessing scenarios of water demand management, through an application to the Steelpoort sub-basin of the Olifants River.

GENERALITIES AND PRESENTATION OF THE WEAP MODEL

The WEAP model was developed by the Stockholm Environment Institute (SEI). It operates at a monthly step on the basic principle of water balance accounting. The user represents the system in terms of its various sources of supply (e.g. rivers, groundwater, and reservoirs), withdrawals, water demands, and ecosystem requirements, etc.

WEAP applications generally involve the following steps (SEI 2001):

- Problem definition including time frame, spatial boundary, system components and configuration;
- Establishing the 'current accounts', which provides a snapshot of actual water demand, resources and supplies for the system;
- Building scenarios based on different sets of future trends based on policies, technological development, and other factors that affect demand, supply and hydrology;
- Evaluating the scenarios with regard to criteria such as adequacy of water resources, costs, benefits, environmental impacts, etc.

The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if ecosystem requirements are tightened? What if irrigation techniques and crop patterns are altered? What if various demand management strategies are implemented?

An intuitive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. The main functions – loading data, calculating and reviewing results -- are handled through an interactive screen structure. WEAP also has the flexibility to accommodate the evolving needs of the user; e.g. availability of better information, changes in policy, planning requirements or local constraints and conditions.

Greater details about WEAP can be obtained from the SEI web site (http://www.seib.org/weap/).

THE STEELPOORT SUB-BASIN

The Steelpoort River is an important tributary of the Olifants River, contributing useful inflows of fresh water during critical periods; the Olifants itself is one of the reference (or benchmark) basins where the International Water Management Institute (IWMI) focuses much of its research effort in South Africa. The Steelpoort was chosen to pilot-test this application of WEAP also because: (a) IWMI has already worked there extensively (Stimie et al. 2001; Thompson et al. 2001) and (b) it is a relatively simple basin with no large dam and no inter-basin transfers.

The Steelpoort sub-basin has a total area of 7,130 km^2 and is rather elongated in shape (figure1). Figure 1 also shows the main rivers and the quaternary basins, which are the basic hydrological units considered in this study. The prospect of major platinum mines being developed in the basin has led DWAF to recently conduct specific hydrological studies in this regard. A major feature of this basin is that it's Mean Annual Rainfall (MAR) is relatively high (397 million m^3/year) but is also very variable, ranging from 147 to 769 million m^3/year (BKS, 2000).

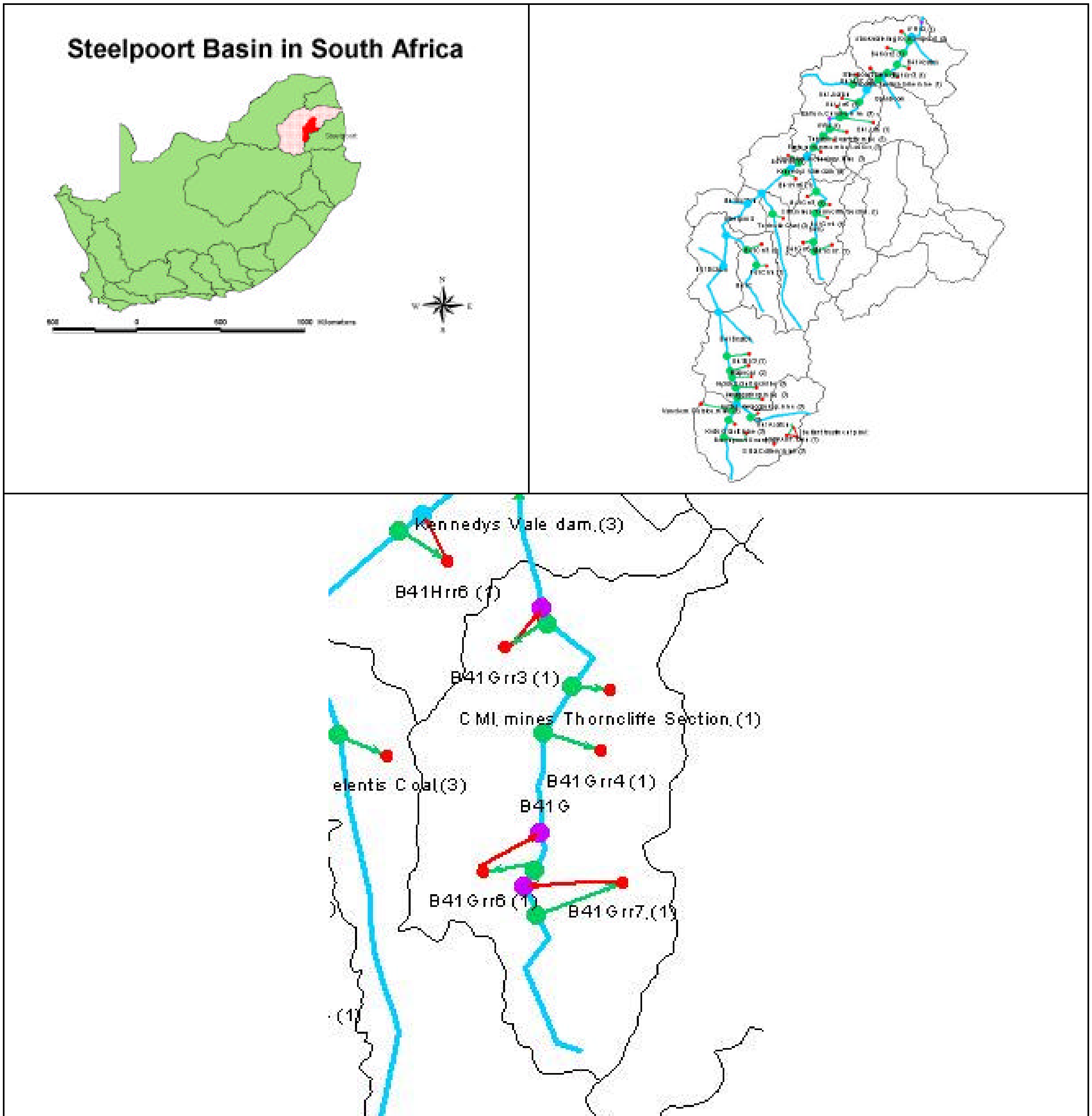

Figure 1: a) Steelpoort basin in South Africa b) Schematic representation of the Steelpoort basin for the WEAP analysis c) detail of schematization

SETTING UP THE WEAP APPLICATION FOR STEELPOORT

As mentioned earlier, data collection is a critical step in setting up WEAP. The authors are thankful to DWAF and BKS for their assistance in this regard.

The characterization of the water system involved collecting and entering in WEAP the following data:

- Water uses (demand site)
- Reservoirs: location, capacity and operation rules
- Flow gauging station (flow requirement and ecological reserve).
- Rivers headflows

Demand

The description of the demand proved to be very tricky. Even with the existence of reports from DWAF and BKS, field visits were necessary for ground-truthing purposes. The new water law in deed has brought about a complete shift in water authorization. Before the introduction of the new law, water users had a relatively large degree of freedom in respect of utilization of water. Now, they are expected to register but they do not always know how much water they really abstract and use. On the other hand, many users do not declare the real figures as they have their own strategies to obtain rights to water or are reluctant to pay the fees.

Only the major water users were described (33 in total: 14 irrigation schemes, 2 towns, 16 mines and 1 stock watering). For each user, the activity level, the water demand (net values after accounting for losses) as well as a return flow (generally 20% for irrigation schemes in accordance with DWAF-BKS hypotheses) was introduced. For several mines, the water consumption values were not available, so this information was estimated in the course of field visits. The evolution of the demand is based on DWAF-BKS estimates (BKS, 2000). Growth rates between 1995 and 2010 are as follows: domestic 10%, livestock 25%, Irrigation 7 % and mining 10 %.

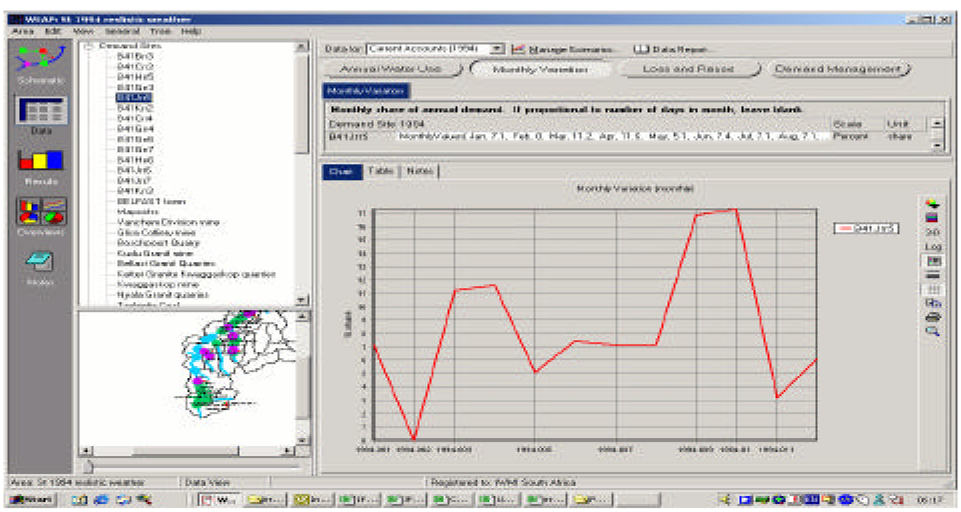

Figure 2: Description of a water user with WEAP

Hydrology

Hydrological data was based on a study of the Steelpoort basin by BKS/CONSULTBURO (1999) using the Water Resources Yield Model (WRYM); the naturalized monthly flows at each node of the WRYM are used. These are introduced as text files into WEAP. The basin has 10 gauging stations, 2 of which are on the Steelpoort River. The adjoining Spekboom sub-basin is not directly taken into account in WEAP but the flows simulated by BKS were entered directly.

The role of groundwater was neglected since there was no knowledge concerning this. Figure 3 shows the flows in the upper part of the Steelpoort sub-basin during 1994, taken as an example of the hydrologic regime in a normal year.

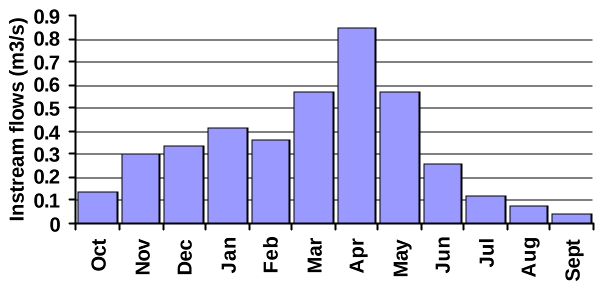

Figure 3: Typical monthly variation of flow in upper part of Steelpoort during a normal year

In WEAP, it is possible to quickly create different climatic situations ranging from very wet to very dry. Following basic statistical analyses (with 76 years of observations), 1994 was chosen as a year of reference.

Ecological Reserve

The National Water Act of South Africa accords an absolute priority to meeting basic human needs and the ecological reserve. Figures on this have recently been released following special studies carried out for determining the reserve (DWAF, 2002a). Points of control referred to as In-stream Flow Requirement (IFR) points are established and in this present study, we focus on IFR 9, situated on the Steelpoort River (upstream of Steelpoort town). The IFRs have been defined for dry years (Drought Flow) and for normal or wet years (Maintenance Flow). It is important to note that there are 2 components in the reserve: low flow and floods/freshets. For the IFR 9, in normal years, the total is about 37 million cubic meters, that is, 21.5% of the MAR.

Table 1: IFR flows at point 9 in normal years (maintenance flow in million cubic meters)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Vol	% MAR
Low Flow	1.232	2.177	2.571	3.348	3.121	2.732	2.67	1.8	1.37	1.26	1.15	1.11	**24.5**	**14.3**
Floods/ Freshets	0.55	0.5	1.41	5.19	2.13	2.17	0.48	0	0	0	0	0	**12.4**	**7.2**
Sum	1.782	2.677	3.981	8.538	5.251	4.902	3.15	1.8	1.37	1.26	1.15	1.11	**36.9**	**21.5**

In WEAP, a specific constraint can be introduced in the flow requirement component (see Figure 4)

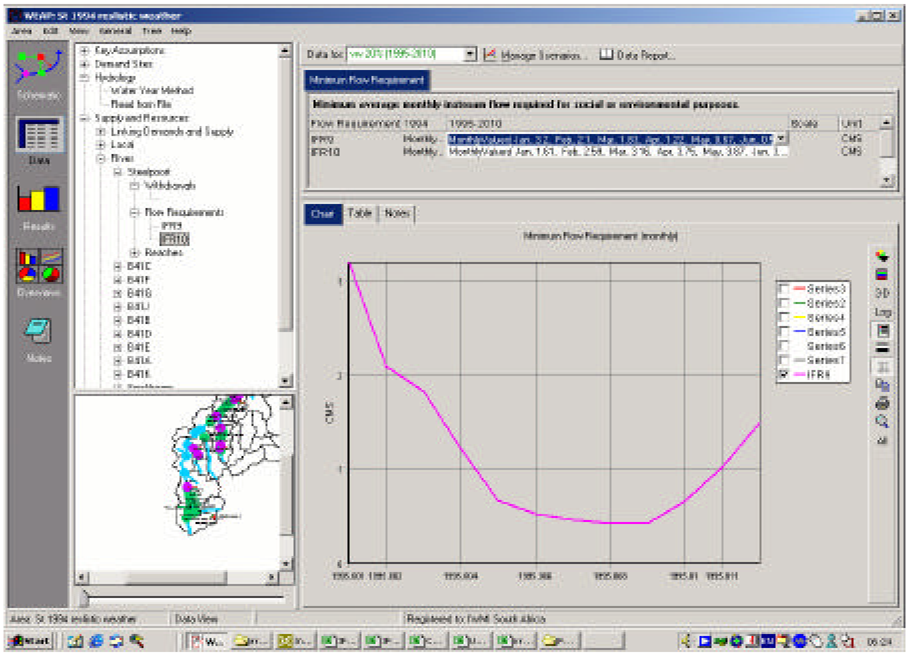

Figure 4: Description of an IFR during normal years

Water demand management options

Water demand management options can be included in WEAP either at specific sites (for example, by studying the possibilities for saving water by individual users) or globally. This study chose to consider the effect of the overall efforts of all users. Three options (at 10%, 20%, and 30%) were considered as reasonable after consultation with knowledgeable local professionals (Charles Crosby, personal communication).

These 'targets' could be achieved through a variety of means such as: licensing, pricing, collective awareness, fines and surcharges during crisis periods, etc. In the National Water Resources Strategy (DWAF, 2002b), water demand management is recognized as a major undertaking.

RESULTS AND DISCUSSION

First simulations

Water users experience periods of unmet demand – Even during normal years, it appears that many users (15 out of 33) already experience unmet demands as shown in figure 5**.** This situation is likely to deteriorate in the future due to the progression of water demand if no measures are taken to address them.

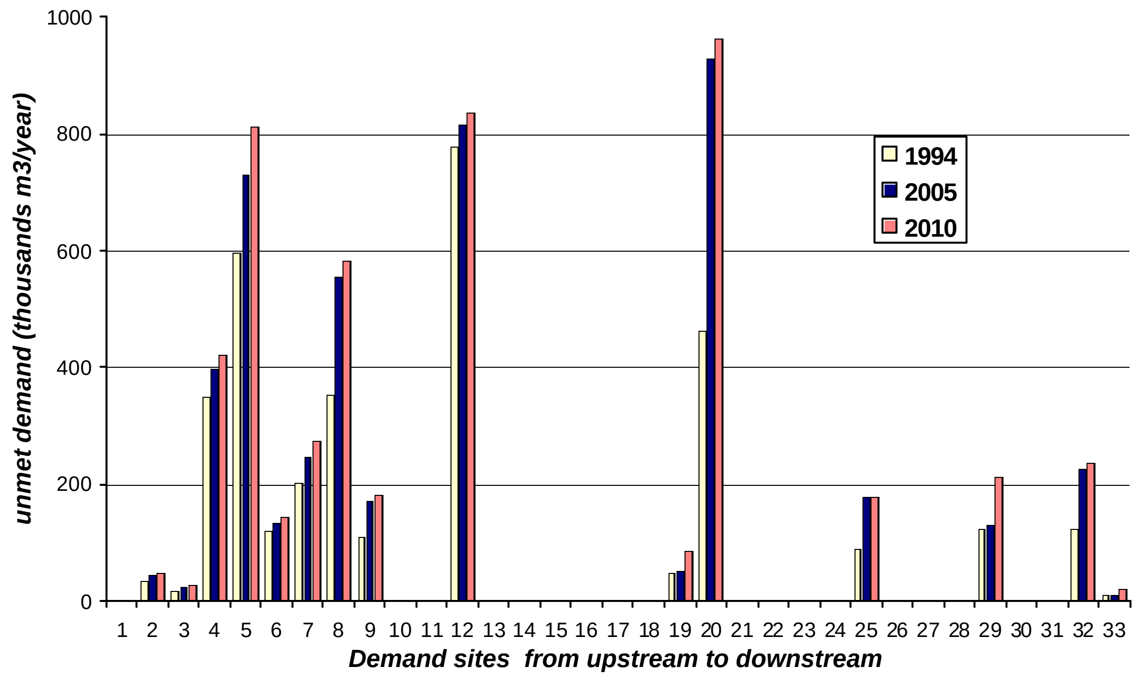

Figure 5: WEAP simulation results: Annual unmet demand (in thousands m^3) during normal years

This result merits careful analysis as it contradicts the earlier BKS work on CMAs (BKS, 2000). But in more recent studies (see annex of the National Water Resource strategy, First edition, August 2002), DWAF does consider a negative balance for the Steelpoort basin, suggesting the possibility of problems in the future.

It has been observed that many users have devised their own strategies to cope with shortages: e.g. using boreholes or developing their own storage systems. These "shortages" sometimes represent half of the demand in some cases (e.g. Eastern Chrome Mine Lannex). But, in general, they are of limited magnitudes (e.g. 20% in the case of irrigation schemes). It is therefore necessary to carefully verify these results through further field surveys in order to ascertain the possible effects of data uncertainties and the extent to which water-users adopt alternative coping strategies.

The reserve will be difficult to achieve during certain periods -- For the IFR point 9, which is in the middle of the basin, the simulation with WEAP suggests that the requirements for the months of December and January will be difficult to be meet in normal years. It must be remembered that the environment requirements are high in this period (see table 1) and that in a normal year, peak flow only occurs in April.

Water demand management scenarios

The simulation results shown in figure 6 demonstrate that with normal years and no water demand management efforts, the requirements of up to 15 users would not be met. Moreover, for certain users, even extreme water demand management efforts (30%) would not be enough. This is possibly a consequence of their position in the basin, and merits further investigation. On the other hand, at certain other locations, limited efforts appear to be sufficient to meet local requirements.

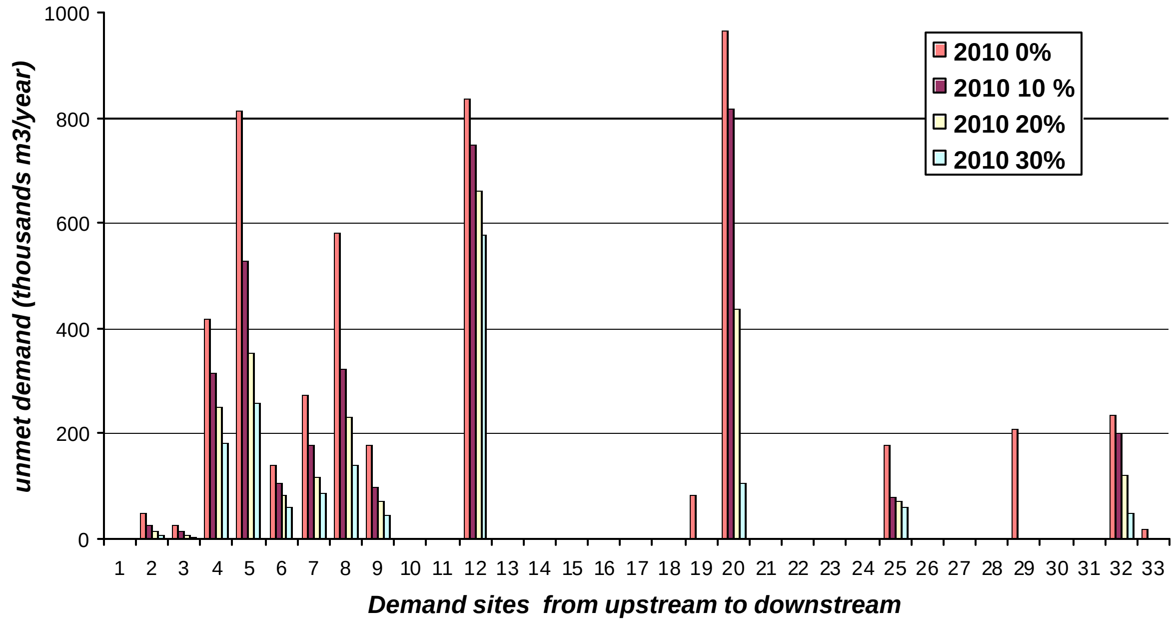

Figure 6: Annual unmet demand (in thousands m^3) from WEAP simulations over 15 normal years with Water Demand Management (WDM)

<u>*Demand management can help achieve reserve requirements*</u> – Figure 7 shows that without water demand management efforts (grey pattern), some IFR 9 targets cannot be met, even during normal hydrological years. However, the WEAP simulations show that with just 10% water demand management effort, the reserve targets could all be achieved (black pattern).

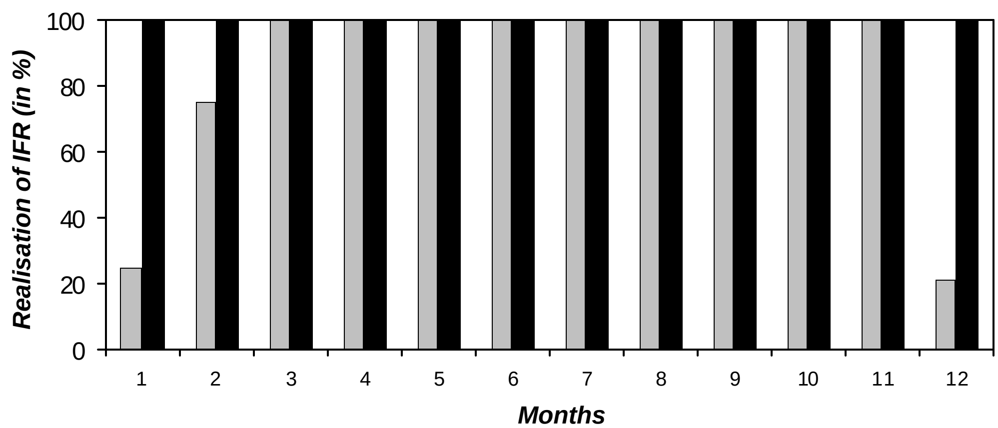

Figure 7: Achieving the Reserve at IFR 9 in two cases, WEAP simulations over 15 normal years: without WDM (in grey); with 10% WDM (in black)

<u>*Demand management alone will not suffice during dry years*</u> – In the case of dry years, the simulation results (figure 8) show that 19 users would experience problems instead of the 15 during normal years. Even water demand reduction of 30% would resolve only a few cases. This suggests that demand management alone would not be enough and that, probably, other measures would also have to be envisaged.

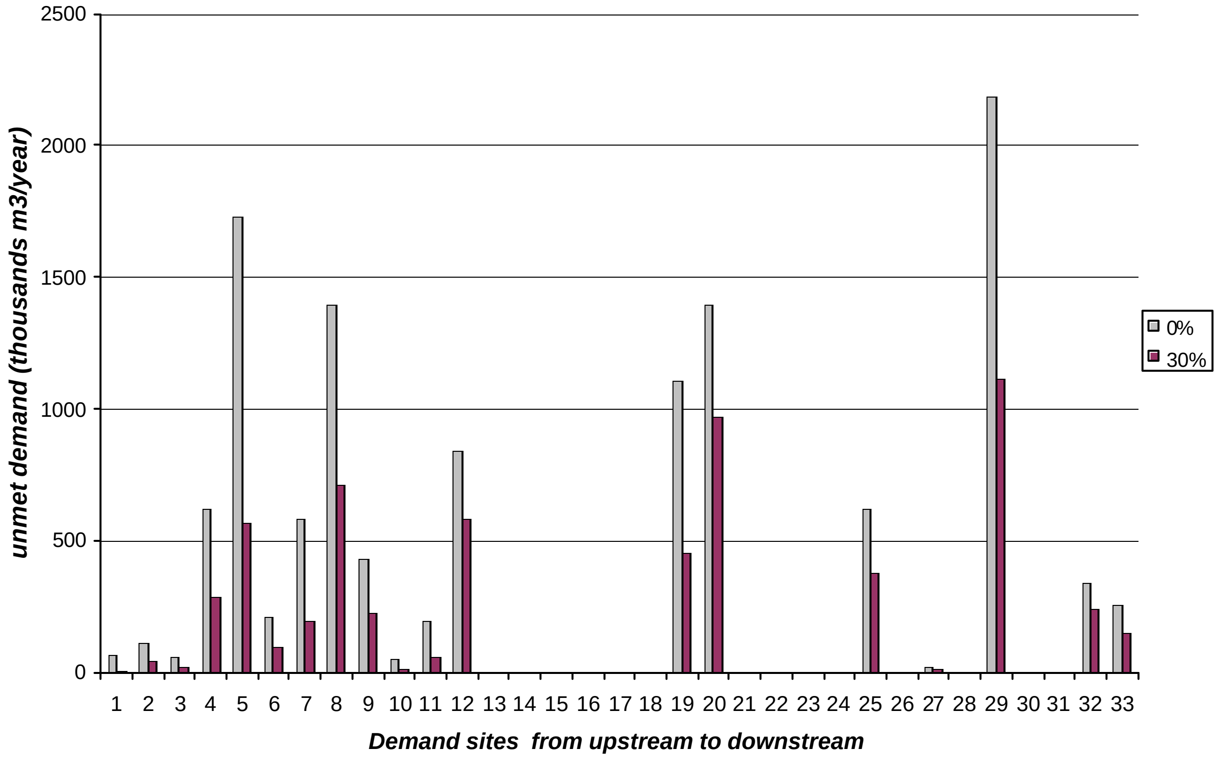

Figure 8: **Annual unmet demand (in thousands m^3) from WEAP simulations with dry years**

CONCLUSION

This study represents a first attempt at applying and testing the WEAP model as a means of addressing water allocation questions in a water-stressed river basin in South Africa.

At this early stage we are not yet in a position to make firm recommendations with regard to the management of the Steelpoort river basin that was used as our study example. A number of assumptions need to be verified and some of the data and hypotheses require refinement in consultation with the principal actors in the basin such as the Department of Water Affairs and Forestry.

For example, the assumption that groundwater does not play a major role (as a source of water for users and also as a source of water for the base flow in the river) could easily alter the results of the study. It was also observed that, in the absence of large storage dams in the basin, water users and water management were very dependent on river flows and levels. Water users appear to have developed their own strategies to confront such circumstances -- farmers who dig pools in the river, mines that sink boreholes or develop their own storage facilities. Careful verification of declarations made by users in this regard is indicated.

This study so far has also brought to light some limitations of the model. In particular, the options of dry, normal and wet years available in WEAP, though very simple and easy to use, may not adequately capture the large variability of hydrologic phenomena in the South African context where extremes are very common, even when working with a monthly time-step.

Nevertheless, one clear lesson that has emerged is that the WEAP model is potentially a useful tool for a rapid assessment of water allocation decisions in a river basin. Its user-friendly interface gives it the added capability of facilitating dialogue among the various stakeholders with an interest in water allocation and management in the basin.

Follow-up action is being undertaken in all these respects. Further investigations and dialogues in the field with water users have been embarked upon. Data and results are being shared in order to stimulate debate and discussion with a view to refining this work and coming out with meaningful results that are useful for decision makers and all stakeholders alike.

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