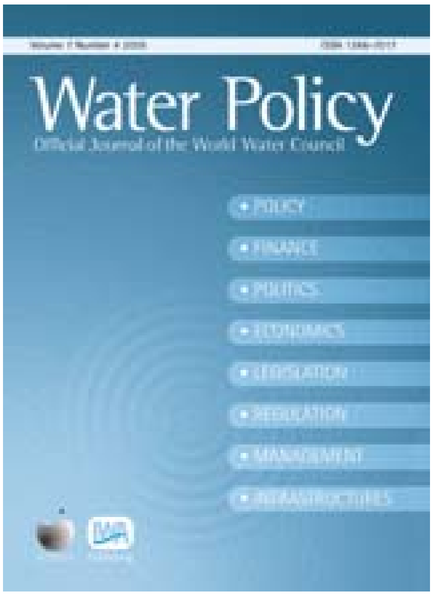
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Development of the South African Water Resource Classification System (WRCS): a tool towards the sustainable, equitable and efficient use of water resources in a developing country

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Abstract

Despite the transition to democracy in 1994, South Africa still had apartheid legislation on the statute books and the allocation of water was regulated by the 1956 Water Act. Accordingly, post-apartheid South Africa underwent a water sector reform process culminating in the new National Water Act (No. 36) of 1998. One component of the Act is the requirement for a classification system to determine different classes of water resources. The classification system provides a definition of the classes that are to be used and a seven-step procedure to be followed in order to recommend a class. The class outlines those attributes society requires of different water resources. The economic, social and ecological implications of choosing a class are established and communicated to all interested and affected parties during the classification process. This paper outlines the socioeconomic and political context in which the WRCS was developed and outlines the seven-step procedure.

Keywords: Ecological; Economic; Social; South Africa; Transformation; Water Resource Classification System

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1. Introduction

South Africa is a water-limited country (Ashton & Turton, 2009) with a variable rainfall (Tyson, 1986) and runoff pattern (Walling, 1996). Many of the country's reliable sources of water supply (e.g. the Lesotho Highlands) are located far from its major cities, requiring lengthy water transfers, impoundments and other water supply infrastructure to meet the growing urban demand (DWAF, 2004a). These interventions have a detrimental ecological impact (Davies & Day, 1998), but are nevertheless crucial for socioeconomic development, a key focus of the present government (DWAF, 2006a). An additional, perhaps greater water resource-related challenge faced by South Africa is undoing the legacy of apartheid planning which led to widespread inequalities in terms of access to and use of the nation's water resources (DWAF, 2006a). To overturn this legacy and to legislate for sustainability, legislation was promulgated in 1998 that provided a legal framework within which the Department of Water and Environmental Affairs (DWAE, the regulator and custodian charged with managing the country's water resources) is required to allocate and protect water resources for the benefit of all, while recognizing that past imbalances need to be corrected. The process of redressing past imbalances and allocating water resources for equity is termed the water allocation reform process (DWAF, 2006a; Seetal, 2006) and is discussed in more detail later.

The provision of water to ensure sustainable long-term use (which is intimately linked to the water allocation reform process) takes precedence over all other allocations (DWAF, 2006a). The underpinning philosophy is that if resources are not protected for use for current and future generations, they may all be allocated to consumptive use. Conversely, sustainability recognizes that overprotection may have opportunity costs in the form of lost economic production and societal welfare. The goal of sustainability is therefore to allocate water resources to maximize societal welfare and effectively deal with the core issues of redressing historical inequality and reducing poverty. This internationally recognized ambition (cf. Baron *et al.*, 2002; Turton & Henwood, 2002; Poff *et al.*, 2003; Richter *et al.*, 2003; Reed & de Wit, 2003; Chaves & Alipaz, 2007) is also a fundamental goal of integrated water resources management (IWRM) (Boon *et al.*, 2000; Gippel, 2000; Postel & Richter, 2003; Agarwal *et al.*, 2004; Jonch-Clausen, 2004; Schulze *et al.*, 2004; Snellen & Schrevel, 2004). The support tool that South Africa's water legislation makes provision for to meet both societal and ecological needs for freshwater (surface and groundwater) is the water resource classification system (WRCS).

This paper has two broad objectives: first, to outline the socioeconomic and political context in which this tool (the WRCS) was developed and second to provide a summary of the step-wise procedures that are applied to a catchment(s) in order to arrive at a spatially explicit decision about the future desired condition of the water resources within that catchment.

2. South Africa in the 1990s: the socioeconomic and political context of the WRCS

2.1. Water reform process

The development of the WRCS needs to be understood in its socioeconomic and political context. In April 1994 South Africa achieved a peaceful transition to democracy (Spitz & Chaskalson, 2000). Despite the transition, much of the apartheid legislation remained on the statute books. The allocation of water resources was (still) regulated by the 1956 Water Act (Act No. 54 of 1956) which limited access to the use of water resources by assigning so called “riparian water use rights”—implying priority was given to land owners whose properties were alongside rivers or streams. Since land ownership was regulated by the 1913 Land Act which restricted the rights of black South Africans to own land, only a select group of (mostly white) South Africans enjoyed significant access to water resources. Further, as the 1956 Water Act was concerned mainly with water supply (the water resource development mode in the work of Shah & van Koppen (2006)), it made no provision for intergenerational equity nor did it provide for a transparent decision-making system (or process) to manage water resources with the goal of reducing poverty or of achieving ecological sustainability. This situation was untenable in a democracy and a water sector reform process was initiated in 1995 (DWAF, 1997) by Kader Asmal, the then Minister of Water Affairs and Forestry. The timing of this was favorable: the transition to democracy had created a near-euphoric optimism about major changes and this provided a unique opportunity to address all aspects of the water cycle.

The South African water sector reform process was influenced by a major international paradigm shift towards IWRM. Although the concept of IWRM had been around as early as 1933 (Snellen & Schrevel, 2004), it took shape at the 1977 International Water Conference at Mar Del Plata and was mainstreamed at the International Conference on Water and the Environment in Dublin in January 1992 and the United Nations Conference on Environment and Development later that year in Rio de Janeiro. Leading up to these key milestones had been a growing recognition of the need to ensure the sustainable use of water resources (Brundtland, 1987), not only for the benefit of people, but also for aquatic ecosystem function and the goods and services that healthy ecosystems provide for society (Costanza, 1992; Rogers *et al.*, 1998; Postel, 2000). One outcome of this paradigm shift was the explicit incorporation of the concept of sustainable development into the new South African Constitution in 1996. This, together with the concepts of equity and historic redress (these latter two being a response to South Africa’s discriminatory past), formed the two strategic pillars of the water reform process:

- Sustainable development is enshrined in the South African Constitution even though the concept is inherently complicated to quantify and therefore difficult to legislate. It is referred to in Paragraph 24 of the South African Bill of Rights, which says that,

  “Everyone has the right to an environment that is not harmful to their health or wellbeing; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.”

- Historic redress is a legal imperative that is evident in almost every aspect of the Constitution. The main purpose of the notion of historic redress is to attain a level of equity, or fairness, after the historic injustices in order that social stability and development can be built in for the future.

These two concepts were embedded in the Water Law Principles (DWAF, 1996a) and in the White Paper on National Water Policy (DWAF, 1997) before being incorporated into the (new) National Water

Act (NWA) (No. 36 of 1998). The NWA makes it clear that water is recognized as a powerful tool for restructuring society; this is evident in the wording of the Preamble to the NWA that recognizes,

> *the discriminatory laws and practices of the past (which) have prevented equal access to water and to use water resources effectively and efficiently; ... (while recognizing central Government's role in ensuring the) redistribution of water (for the benefit of all).*

To achieve the aspirations of the NWA it was necessary to transform DWAF to permit political and institutional change. Prior to 1994, the Department of Water Affairs and Forestry (DWAF)[1] was operated according to the attitudes and methods of the old order, enforcing the laws of the land and applying the politics of patronage (Picard, 2005). These functionaries mostly favored the *status quo* and thus 70% of the country's water resources were allocated mainly to white farmers for irrigation, many of whom were subsidized (Turton, 2000). However, the new NWA required DWAF to use, develop, conserve, manage and control water resources for the benefit of all South Africans. In order to implement the NWA, a number of internal institutional changes were needed within DWAF. As a result, the water reform process faced considerable challenges: resistance to institutional change and acceptance of the two foundational principles of the NWA, sustainability and equity.

2.2. Implementing "sustainability" and "equity"

Once the NWA had been established and its founding principles began to take root within DWAF, the organization took increasingly bold steps to give effect to its water resources protection mandate as prescribed in Chapter 3 of the NWA. Initially this involved the establishment of an office within the Chief Directorate: Scientific Services. This later evolved into the Chief Directorate: Resource Directed Measures (RDM) within the policy and regulation branch of DWAF with various line function responsibilities including water resources classification, resource quality audit and surface and groundwater reserve requirements. As it was not feasible to develop and implement various provisions simultaneously, the NWA made provision for the progressive development and implementation of strategies and tools to give effect to the Act. Central to the vision of this new Act was the development and subsequent application of a so-called "classification system"—the WRCS—which the Act defines as "...a set of guidelines and procedures for determining different classes of water resources" (Chapter 3, Part 1, Section 2(a)). In the Act, the term "class" refers to a legally enforceable condition for a given water resource and it outlines a set of both resource quantity and quality attributes (RQOs) that DWAF and society require of that water resource. For example, "Class I" resources might be prioritized for protection and this classification could be appropriate for certain rivers that flow through the Kruger National Park on account of their value for biodiversity and ecotourism. A river reach near a platinum mine might be set as a "Class III" resource because of the high economic value of utilizing that water for the mining process (and the associated reduction in water quality and quantity available for ecological purposes). Given the imperative for democratic governance in post-apartheid South Africa, the NWA envisions this process of recommending the class for each significant water resource as a consultative one in which both the stakeholders and DWAE recommend a class for a water resource. The final

[1] Prior to 2009 DWAE was known as DWAF.

decision on a class, however, is made by the Minister of Water and Environmental Affairs, taking into consideration the recommendations of stakeholders.

Once the minister has set the class (through publishing it in the South African *Government Gazette*) it is binding on all authorities or institutions when exercising any power, or performing any duty under the NWA. In addition to describing the desired condition of the resource, the class also prescribes the volume, distribution and quality of water which must be reserved for aquatic ecosystem function (i.e. the ecological reserve required to achieve that class) and for basic human needs (i.e. the basic human needs (BHN) reserve which is currently stipulated to be 25 liters of water per person per day). The ecological and BHN reserves have been described elsewhere (e.g. King & Louw, 1998; DWAF, 1999; Hughes & Hannart, 2003; King *et al.*, 2003; Sherwill *et al.*, 2003; Van Wyk *et al.*, 2006). Only after these two needs have been met may the remaining portion of a water resource be allocated for off-stream use (DWAF, 2006a). Consequently, the decision on the class influences access to, use of and benefit from water resources for farmers, businesses, previously disadvantaged communities and other residents alike. It therefore has considerable equity and socioeconomic implications, which makes applying the WRCS an inherently social, political, economic and legal process. Accordingly, the practice of applying the WRCS in classifying water resources (the classification process) does not occur in isolation, but is fundamentally linked to other IWRM processes.

Although a full description of the larger South African IWRM process is beyond the scope of this paper, it is important to note that the classification process is embedded centrally within the water allocation reform process and the iterative development of a catchment management strategy (CMS) (Figure 1). The water allocation reform process emphasizes redressing past historical injustices while at the same time promoting social stability and economic growth (DWAF, 2006a). In particular, the process promotes water allocation that:

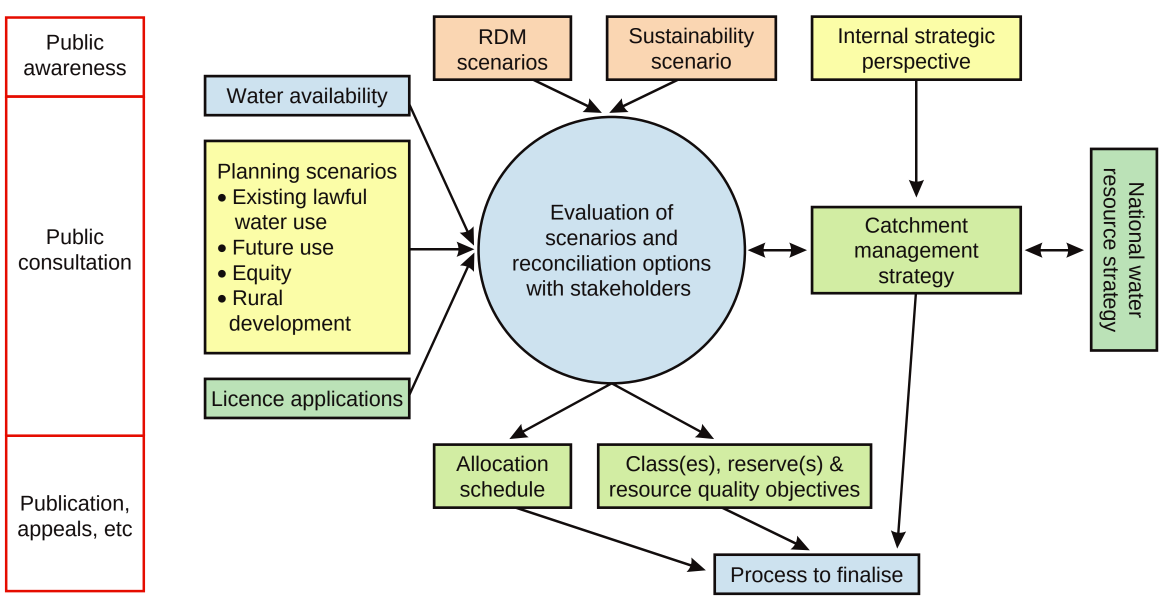

Fig. 1. Schematic indicating the WRCS nested within the broader IWRM process (source: DWAF, 2007a).

- takes proactive steps to meet the water needs of historically disadvantaged individuals (HDIs) and the poor;
- ensures participation by these groups;
- encourages participation of agencies to build capacity to use water productively;
- promotes the sustainable use of water resources; and
- promotes the beneficial and efficient use of water in the public interest.

Six guidelines have been identified to inform the process (DWAF, 2006a), one of which, Guideline 6, makes clear that in keeping with the requirements of the NWA, the water allocation reform process must ensure that the requirements of the class, reserve and RQOs are first met before allocating water for off-stream use (Table 1). A key component of the larger IWRM process is therefore a catchment-based consultative process for evaluating potential water allocation (planning scenarios in Figure 1) and resource condition (RDM and sustainability scenarios in Figure 1) scenarios with stakeholders to assess the economic, social and ecological trade-offs that will be required as part of the CMS (Figure 1).

2.3. The process of developing the WRCS

The classification system prescribed by the NWA is intended to integrate with other IWRM procedures. This, however, created a causality dilemma for DWAF since many of these procedures were themselves not yet finalized. The drafters of the NWA recognized that there would be a transition period before the prescribed classification system could be fully developed and implemented; the NWA therefore makes provision for the preliminary determination of the class, reserve and RQOs. Thus, between 1998 and 2009 (prior to the prior to the gazetting of the WRCS as a regulation) a variety of methods with varying levels of confidence were developed (e.g. building block methodology (BBM)—King & Louw, 1998; flow–stressor response (FSR)—O'Keeffe *et al.*, 2002; downstream response to instream flow transformation (DRIFT)—King *et al.*, 2003; groundwater classification—Colvin *et al.*, 2005) and applied to targeted catchments in order to recommend the preliminary class, reserve and

Table 1. Guidelines for the water allocation reform process (source: DWAF, 2006a).

Guideline 1: Redress race and gender imbalances—A primary focus of the water allocation process is to redress past race and gender imbalances in water use.
Guideline 2: Capacity development—Water allocation processes must be supported by capacity development programs that promote the use of water to improve livelihoods as well as the productive use of water by all users. These capacity development programs must also help HDIs and the poor participate actively and equitably in the process of informing the allocation of water.
Guideline 3: Broad-based black economic empowerment (BBBEE)—The water allocation process must contribute to BBBEE and gender equity by facilitating black- and women-owned enterprises for water.
Guideline 4: Local, provincial and national planning initiatives—The water allocation process must respond to local, provincial and national planning initiatives, as well as to South Africa's international obligations and regional initiatives.
Guideline 5: Fair, reasonable and consistent—The water allocation process must be undertaken in a fair, reasonable and consistent manner and existing lawful use must not be arbitrarily curtailed.
Guideline 6: Phased attainment of development and environmental objectives.—The water allocation process must give effect to the protection of water resources as outlined in the NWA by promoting the phased attainment of both developmental and environmental objectives.

RQOs (Pienaar, 2005). Initially, the focus of these tools was ecological, which led to a perception that the class was about protecting "fish and bugs", "giving consultants jobs" and having "less water in your stomach" (Sherwill *et al.*, 2003). However, it is clear from the NWA that the classification system should provide an assessment of the socioeconomic implications of a class and not simply an assessment of the current and desired ecological condition of the water resource. It also became increasingly clear that whatever system was developed, it would have to be transparent, consultative and defensible in the way it sought to embody the underlying principles of equity, efficiency and sustainability.

The process of developing such a system could be highly contestable, as the outcome was likely to require changes in existing social and economic structures. For this reason DWAF (2006b) developed a set of principles, based on sound scientific knowledge and informed by the spirit and letter of the South African constitution in guiding the development of the WRCS (Table 2). These principles were intended to make the development of the WRCS transparent and reasonably predictable and to reduce the level of potential contestation. The outcome of the development of the classification system was a five-volume report (DWAF, 2007a, b, c, d, e) outlining the proposed system. The WRCS consists of a seven-step procedure that should be followed in order to recommend a class and the definition of three classes; Class I, Class II and Class III (Table 3).

Having outlined the sociopolitical context in which the WRCS was designed, we report a summary of the actual step-by-step procedure described in the system by which South African water resources are to be classified.

3. Overview of the water resource classification system's seven steps

The ultimate goal of the WRCS is to recommend a normative desired condition for each water resource in a given catchment. To do this, the WRCS lays out a set of "procedures", grouped together into seven major steps (see online Appendix 1: http://www.iwaponline.com/wp/113.pdf). These steps are followed in sequence, although where feasible, some of the steps can be done in parallel.

In the first step, the team responsible for classifying the catchment(s) water resources begins by identifying and describing all potential water resources (e.g. rivers, wetlands, aquifers) and all existing lawful water users and then develops a representation of the catchment as a simplified network of spatial management units. Each of these management units is represented by a modeling "node" and the nodes are grouped into sub-regions called integrated water management units (IMWUs) on the basis of social, economic and hydrological similarity.

The second step defines methods for linking different water use scenarios within a region to the social wellbeing of the people who live there, the region's economic prosperity and to the overall health of its ecosystems. Steps 1 and 2 occur in parallel for most catchments.

The third step involves quantifying the volume, distribution and timing of categories of environmental flows (termed ecological water requirements (EWRs) in South African parlance) at each of the nodes identified in Step 1.

In order to provide the information needed in Steps 4 through 6, flows are calculated for at least four increasing levels (or categories) of ecological sustainability (Table 4) at each node. In the fourth step, a set of approximately 6–10 different scenarios are developed that capture a range of possible future desired conditions for the catchment's water resources. The fifth step provides guidelines for evaluating the economic, social and ecological implications of each of these scenarios. Stakeholders are involved

Table 2. Guiding principles that inform the scope and intent of the WRCS (source: DWAF, 2006b).

Principle 1: Balance and trade-off for optimal use
The chosen class should balance protection of the resource with its utilization in line with societal norms and values. Utilization of the resource provides economic and social benefits; it also has the potential, however, to compromise ecosystem integrity, which has economic and social costs. This balance will require trade-offs. The WRCS should therefore broadly outline the implications of different classes to facilitate informed decision making.

Principle 2: Sustainability
The principal reason for the protection of water resources is to maintain ecosystem integrity at a level that ensures the continued delivery of desired ecosystem goods, services and attributes (EGSAs) for use. The WRCS therefore needs to provide a framework to help facilitate the sustainable and equitable use of water resources. It is also recognized that there is a sustainability baseline that if crossed, could result in the non-delivery of the EGSAs necessary for economic growth, poverty alleviation and the redress of historical inequality. As there is a degree of uncertainty about the exact position of this baseline and, as the risks of exceeding the limits of sustainability are considerable, a cautious approach should be adopted.

Principle 3: National interest and consistency
A class of a water resource may produce solutions that are acceptable at a local level, but are sub-optimal when considered at a national level. Catchment-level decisions therefore need to be evaluated against national-level interests (and where appropriate, international-level constraints, e.g. international obligations). The WRCS should also outline a clear intention with respect to the characteristics of different classes and provide for consistency in this regard.

Principle 4: Transparency
Stakeholders should be consulted both in the development of the WRCS and in the process of classifying the nation's water resources. The approach should be legitimate and transparent and ensure that the evaluation method used for determining trade-offs is fair. As the class has considerable economic, social and ecological implications, stakeholders will need to be informed in a meaningful way of the potential impacts on and risks (and benefits) of the WRCS to them. Further, stakeholders will need to be informed about the level of uncertainty that accompanies many of the economic, social and ecological predictions inherent in the classification (and "larger") process.

Principle 5: Implementability
The WRCS needs to be used, at reasonable cost, by trained staff at an operational level. The institutional and transactional costs associated with making a decision about the class should be as low as possible. The WRCS should also be sufficiently robust to make a decision in the light of imperfect knowledge. The final outcome of the classification process should take into consideration the impact of existing entitlements to use water (for both abstraction and disposal) as well as regional- and national-development objectives.

Principle 6: Interdependency of the hydrological cycle
All components of a water resource are linked. As such, the WRCS needs to account for the interlinkage between all resources dependent on water; watercourse, surface water, estuary or aquifer.

Principle 7: Legally defensible and scientifically robust
The WRCS should be legally defensible and scientifically robust. It should be based on sound socioeconomic and ecological principles in line with IWRM goals. The WRCS and classification process should be legally defensible, apply due diligence in the decision-making process and prevent legal liability accruing to DWAF or the stakeholders. It should also be consistent with South Africa's international obligations and other environmental legislation both at a national and an international level. The guidelines should indicate the best available tools and data sets to be used in the classification process. These will need to be updated regularly to account for developments in science and technology.

Principle 8: Management scales
The scale at which the WRCS is applied should be appropriate to the problem at hand. The end result of the classification process will be the recommendation of a class for a resource. The implications of this need to be understood, implemented and checked on multiple scales.

Principle 9: Auditable and enforceable
The WRCS needs to be auditable and enforceable to ensure that it is put into operation. Thus, the regulator will need to ensure that a transparent, permanent record of the procedures, information and logic used for classifying a particular resource is created and maintained. The outcomes of the WRCS also need to be monitored and enforced.

Continued

Table 2. (*continued*)

Principle 10: Lowest level of contestation and the highest level of legitimacy
Given the strategic importance of the WRCS, the principle of lowest level of contestation and highest level of legitimacy should be applied. This requires consultation with, and the highest level of buy-in from, internal (DWAF) and external strategic stakeholders and interested and affected parties.
Principle 11: Utilization of existing tools, data and information
The WRCS will use existing tools, data and information wherever possible. Where applicable, existing tools, data and information will be modified or extended to meet the requirements of the WRCS. Unless there is an urgent need to do so, no new tools, data or information will be developed or collected.

throughout the WRCS process, but in the sixth step play a particular role. Accordingly, this step provides guidance for stakeholder consultation on the scenarios and their implications.

The seventh step allows for the final selection of an overall catchment configuration of classes by the Minister of Water and Environmental Affairs. When published in the *Government Gazette*, this decision about the desired condition of water resources in the catchment becomes legally binding.

The following sections elaborate each of these seven steps, highlighting the links to other IWRM processes and describe where the individual steps contribute to meeting the letter and spirit of the NWA.

3.1. Step 1: Delineate the units of analysis and describe the status quo of the water resource system

The goal of the first step is to represent the catchment targeted for classification as a linked network of water management sub-units; this requires data gathering to provide the information needed to make sub-unit delineation decisions. The information needs include social data (the number of people living in the catchment, their spatial distribution, their wellbeing in terms of education, health, income, education, land tenure), economic data (the primary economic sectors and their turnover and the use and value of aquatic ecosystems (cf. Costanza *et al.*, 1997; Hanley & Black, 2006)), hydrological data (catchment and sub-catchment naturalized monthly flow data and where available, present-day daily time series), information about existing water supply infrastructure (dams, canals etc.), existing allocations of water to the various sectors and users, information on aquatic ecosystem biodiversity (cf. Roux *et al.*, 2006), ecosystem condition and sensitivity (cf. Kleynhans, 2000). Much of this information is readily available for most South African catchments (cf. DWAF, 2004b).

In the delineation sub-steps, the information and data that have been assembled are used to divide the catchment into relatively homogenous socioeconomic zones and to represent the hydrological and water allocation system as a simplified network of linked nodes. This provides a spatially-explicit modeling framework that links the classification process to the water allocation reform process. The hydrological boundaries (quaternary catchment scale) and the nodes are then overlaid on the socioeconomic zones in a geographic information system to define between five and eight IWMUs. For the development of the

Table 3. Proposed water resource classes for South Africa.

Class I: Minimally used—The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is minimally altered from its predevelopment condition.
Class II: Moderately used—The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is moderately altered from its predevelopment condition.
Class III: Heavily used—The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

Table 4. Ecological categories used in South Africa (source: Postel & Richter, 2003). In the WRCS, Category 'D' represents the lowest acceptable flow regime that is still considered to provide some minimum baseline level of ecological sustainability.

Category	Flow regime	Ecological condition
A (natural)	Close to natural condition	Negligible modification of in-stream and riparian habitats and biota
B (good)	Largely natural with few modifications	Ecosystems essentially in a good state. Biota largely intact
C (fair)	Moderately modified	A few sensitive species may be lost; populations of some species likely to decline; tolerant or opportunistic species may become more abundant
D (poor)	Largely modified	Habitat diversity and availability have declined; mostly only tolerant species present and they are often diseased; population dynamics have been disrupted (e.g. biota can no longer breed; alien species have invaded the ecosystem)

WRCS, the Olifants-Doring region was chosen as a "proof of concept" catchment to demonstrate how the various procedures could be applied in practice. Figure 2 shows this catchment, its quaternary hydrological catchments, the seven socioeconomic zones identified and the resulting IWMUs. Each IMWU contains multiple nodes nested within it (between three and 15 in the case of the Olifants-Doring) and becomes the primary spatial unit for which a class will ultimately be set. These IMWUs and the nodes nested within them provide the basis for all the subsequent analysis in Steps 2 to 6 and is the geographic "template" used for linking the ecological condition and its socioeconomic implications.

Once the delineation is complete, the present state of the water resource system is described and quantified within each of the IWMUs. This includes water availability (i.e. yield at a specified level of service), existing water supply infrastructure, the major water using sectors and the present ecological condition of each node

To summarize, the main inputs to Step 1 are human population data from the most recent national census, quaternary-scale hydrological data (e.g. Midgley *et al.*, 1994), economic data (e.g. DWAF, 2004b), aquatic ecosystem biodiversity data (e.g. Nel *et al.*, 2007) and information about existing water management (e.g. infrastructure, supply–demand balance, current allocation schedules and existing lawful use). The first three outcomes of Step 1 are: (1) a "node network diagram" of the significant water resource units within the catchment, (2) a set of IWMU polygons and (3) a descriptive summary of the present-day ecological status and importance of each water resource. Once the valuation and decision analysis relationships have been finalized in Step 2 (see below), the fourth and fifth outcomes of Step 1 can be completed, namely (4) quantifying the present-day economic value of the water use and ecosystem condition and (5) an assessment of the present-day community wellbeing, both on the scale of IWMUs.

3.2. Step 2: Link the condition of the water resource to indicators of social and economic value

The goal of the second step is to establish a quantitative framework for determining how economic value and social wellbeing are affected by changes in the aquatic ecosystem condition and by different water use scenarios. To do this, a shortlist of relevant ecosystem indicators for which changes in economic value or social wellbeing can be predicted for a given change in ecological condition is drawn up. For example, the relative abundance of an important indictor fish might be selected as an ecosystem indicator because an increase or decrease in abundance can be related quantitatively to changes in water quantity, quality, distribution and timing and to socioeconomic wellbeing. The second sub-step involves developing a set of relationships (or refining an existing set) that links node-scale water use and

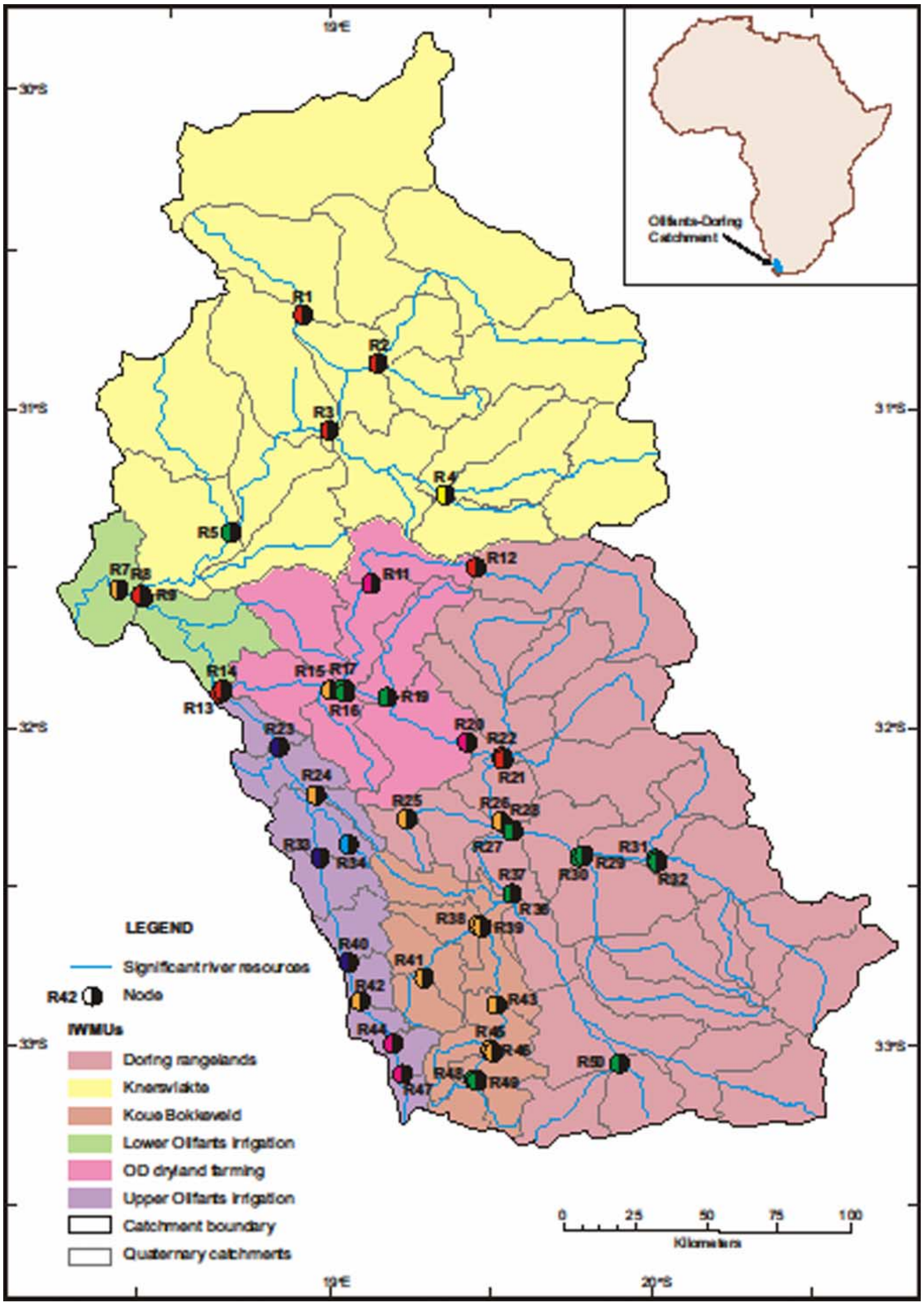

Fig. 2. Example of the delineation process undertaken in Step 1 for the "proof of concept" catchment, the Olifants-Doring.

ecosystem condition to IWMU-scale economic output and social wellbeing. A scoring system is defined based on both cost–benefit analysis (CBA) and multi-criteria analysis (MCA). This scoring system provides a transparent and objective basis for comparing class configuration scenarios for each IMWU against each other in Steps 5 and 6.

Two sets of quantitative relationship are therefore developed in Step 2. The first set of relationships forms the valuation framework (see online Appendix 2: http://www.iwaponline.com/wp/113.pdf) by quantifying the broad-scale economic and social implications (outputs) of given levels of ecosystem condition and associated ecosystem services (inputs). The second set of relationships forms the decision-analysis framework (see online Appendix 3: http://www.iwaponline.com/wp/113.pdf) by quantifying three overall index scores—an ecosystem score, a regional economic prosperity score and a social wellbeing score for a given set of economic and social indicators. These relationships are then applied to the data gathered in Step 1 to give baseline estimates of the present value of water use within each IWMU in terms of the three scores. This baseline provides a quantified social and economic *status quo* against which the scenarios will be compared in Step 6.

3.3. Step 3: Quantify the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes

At this point in the classification procedure, IWMUs have been identified (Step 1), frameworks for valuation and decision-analysis have been decided (Step 2) and the ecological, social and economic *status quo* described (Step 1). Because the WRCS is a scenario-based process, the next step is to quantify the volume, distribution and timing of a range of potential EWR options at each of the nodes. This is done for at least four increasing levels (“categories”) of ecological sustainability (Table 4) and wherever possible, is based on site-specific data collected in high confidence comprehensive reserve determinations (King & Brown, 2006). For this reason, the classification procedure specifies that ideally comprehensive reserve studies will already have been completed and if they have not, that they be done as part of the classification process. Because these so-called “high-confidence” data will typically be available only for a limited number of the nodes in any given catchment, some kind of extrapolation will inevitably have to be made to the other nodes. Step 3 therefore sets out guidance for the extrapolation process using rapid assessment methods such as the Hughes & Hannart (2003) desktop reserve model and the Water for Africa (2008) extrapolation procedure. (Table 5).

The outcome of Step 3 is a set of time series, rule curves and statistical flow summary tables for at least four categories of environmental flow at each node. Based on these node-scale environmental flow scenarios, the team then establish and quantify the changes predicted in each of the relevant ecosystem components identified in Step 2.

3.4. Step 4: Determine an ecologically sustainable base configuration scenario and establish the starter configuration scenarios

A catchment with 50 nodes and four possible ecological conditions for each node offers in the order of 10^{29} potential configuration scenarios; too many for each to be examined individually. The goal of Step 4 therefore is to arrive at a manageably small subset of at least five different “starter” scenarios that cover a wide range of the present-day situation and future desired conditions of the targeted catchment(s) water

Table 5. Example of three types of starter configurations.

Node	Quaternary catchment	ESBC	Planning scenario 1	IEC
1	E31G	C	C	C
2	E31B	C	C	C
3	E31F	D	C	C
4	E32A	B	C	C
5	E33A	D	C	C
7	E33H	D	C	A/B
8	E33C	D	C	C
9	E33F	D	B	A/B
11	E40C	D	C	A/B
12	E40A	B	C	A/B
13	E10K	D	B	A/B
14	E24M	D	C	A/B
15	E24L	D	B	A/B
16	E24K	D	C	B
17	E40D	D	B	B
19	E24J	D	B	B
20	E24H	D	B	B
21	E24C	D	C	C
22	E24E	D	C	C
23	E10G	D	D	D
24	E10H	C	D	D
25	E24A	B	A/B	A/B
26	E24B	C	B	A/B
27	E23K	D	C	C
28	E22G	D	C	A/B
29	E23F	D	C	C
30	E23G	C	C	C
31	E23E	D	C	C
32	E23A	B	C	C
33	E10E	D	B	A/B
34	E10E	D	B	B
36	E22A	C	B	A/B
37	E21K	C	B	A/B
38	E21H	B	B	B
39	E21F	D	B	B
40	E10D	D	C	C
41	E21G	A	B	B
42	E10C	C	C	A/B
43	E21E	C	B	A/B
44	E10B	D	C	B
45	E21D	B	B	A/B
46	E21C	C	C	A/B
47	E10A	D	C	B
48	E21A	B	B	A/B
49	E21B	C	B	A/B
50	E22C	B	C	C
51	E33H	D	C	B

resources. These are referred to as “starter” scenarios because they have not yet been screened to see if they meet water quality requirements, nor have they been discussed with stakeholders. Once the screening process takes place in Step 5 they become “preliminary” scenarios and once they have been reviewed by stakeholders they can be considered “final” scenarios.

Three types of scenario need to be considered. First, because the NWA mandates the sustainable use of water resources, there must be at least one scenario that specifies a minimum level of environmental flow (quantity, quality and distribution) to ensure that a sustainable “bottom-line” condition is not threatened. This is called the ecologically sustainable base configuration (ESBC) scenario and in Step 4, an iterative heuristic algorithm can be applied to determine this configuration and to make sure that it satisfies a basic set of hydrological and ecological constraints. Second, because the WRCS does not occur in isolation and is fundamentally linked to the larger IWRM process, a set of scenarios must be developed based on water planning needs. These planning-driven configuration scenarios (probably numbering between 1 and 4) take account of existing lawful use of water resources and also incorporate equity considerations and the projected future demand for water. This group of scenarios is intended to reflect the economic and social aspirations of water users and planners, but also needs to be informed by the ESBC so that the water resources are maintained sustainably in an adequate condition. The WRCS therefore provides a common platform for integrating sustainability requirements with the need for equity and for current and future socioeconomic development, thus fulfilling its legal obligations in terms of the NWA.

The third and final group of starter scenarios identified in Step 4 is based on protection considerations: these scenarios are referred to as the resource condition configuration scenarios. The first one simply uses the present ecological status of each node, the second one raises the present ecological status at each node by one level (this is known as the “improved ecological condition” or IEC scenario), the third one, subject to the rules of the ESBC, reduces the ecological category by one level at each node (known as lower ecological condition, or LEC) and the fourth one modifies IEC slightly by assigning the highest possible ecological category to each node with a “high” ecological sensitivity and importance value.

The outcome of Step 4 is a table (Table 5) which summarizes 8 to 10 possible starter configuration scenarios for further analysis in Step 5. Scenarios can also be visualized by showing them in network diagram format and using different colors for each ecological category (see online Appendix 4: http://www.iwaponline.com/wp/113.pdf), or in map format.

3.5. Step 5: Evaluate scenarios within the IWRM process

Before examining a scenario’s social, economic and ecological implications, the configuration must first be checked for internal consistency in terms of water quantity and quality. Although the ESBC scenario and the four resource condition starter scenarios are all screened and pretested in Step 4 to ensure that the reserve requirements can be met (i.e. that the water balance at each node meets the EWRs from Step 3), none of the starter scenarios has yet been fully tested to see whether they can actually meet existing lawful water use requirements (i.e. licensed abstractions). To do this, a water resources yield model (WRYM) is needed that incorporates existing lawful use abstractions together with the associated rules for assurance and curtailment. Step 5 therefore begins with a set of simulations to compute the water available for use (WAFU) by running the WRYM for each scenario. (Most of South Africa’s catchments (especially the water-stressed catchments) have existing WRYM that are “fit for purpose”). The goal is to test whether a given configuration of classes for a water management unit is able to provide sufficient quantity of water for existing lawful use, for future water demands and for equity and development needs for an agreed level of service as specified by the NWA. In cases where there is a failure to meet the demand for one of the starter scenarios, it will be necessary to adjust some of the upstream node categories and then to recompute the WAFU throughout the catchment. This is done iteratively until WAFU requirements are met, or, if no feasible solution can be found, a starter scenario is deemed unworkable and is discarded.

At this point, each of the 8 to 10 starter scenarios will have been tested with the WRYM to ensure that it meets the water quantity requirements of the ecological categories and consequently, to determine the WAFU. However, the scenarios have not yet been evaluated for water quality; this requires a water quality model that can estimate loads and concentrations at each node under each scenario. As in Step 4 (but this time for water quality rather than quantity), ecological category water quality requirements are tested and if necessary adjusted iteratively until they are met. Once this has been achieved, the water quality requirements of potential water users are identified (DWAF, 1996b).

Running a water quality model and comparing its output against the EWRs produces a list of nodes for which the water quality is not fit for BHN and/or the ecosystem users. BHN and ecosystem needs are considered first because of the priority given to the reserve in the NWA; only after having established that it meets the water quality standards for the reserve (or adjusted the scenario in terms of flow and/or pollution to meet those standards), are they evaluated as to whether they meet the "fitness for use" targets required by the South African Water Quality Guidelines (DWAF, 1996b). At this point, there are essentially two options for improving the water quality at a given node: (1) diluting the load by raising the ecological condition at one or more of its upstream nodes (thereby increasing the volume of water at the node), or (2) reducing the load by treating the waste/effluent or reducing the input of pollution. Because the dilution option raises the EWRs and therefore alters the water availability upstream, the WRYM must be run again for the adjusted scenario(s). This process is iterative and must be run until a configuration is found that meets both the water balance and water quality requirements of the ecological categories. Once the water quality is fit for BHN and ecosystem users at each node, it can be compared to the ideal fitness for use targets for the other water users. If it fails at any given node, the same two options apply, that is, dilute the load and/or reduce the load. However, a third option can be considered which is to acknowledge that water quality at that node fails to meet a particular standard and then to assess its implications for economic turnover and social wellbeing in the remainder of Step 6.

Once the starter scenarios have been tested for water quantity (i.e. the catchment is not over-allocated) and quality, they can be considered preliminary scenarios, each of which describes both a potential future allocation of water within the region and a future desired condition of each resource. These preliminary scenarios are now known to be feasible from a water quantity and quality perspective, but have not yet been evaluated from the perspective of the various water user sectors by estimating their relative economic and societal benefits, nor have they been examined relative to one another for the non-market ecological benefits they provide. The next part of Step 5 therefore involves estimating the sectoral turnover for each preliminary scenario (using standard macro-economic analysis methods) and the turnover from ecosystem goods, services and attributes (EGSAs, using valuation methods decided in Steps 1 to 3). These, in turn, become inputs for the decision-analysis framework developed in Step 2 and allow the computation of three scores for each IWMU, namely ecosystem health, social wellbeing and regional economic prosperity.

These summary scores can be further disaggregated to examine, for example, the change in percentage of non-poor residents in that sub-region, the number of jobs associated with a certain scenario and the non-market value of certain goods and services (e.g. human health, intangible values).

The summary scores can also be aggregated up to the level of the entire catchment(s) to compare the overall outcomes, weighted for all the IMWUs together. An example of how these scores might be represented for the overall Olifants-Doring catchment is presented in Figure 3.

To summarize, the outcome of Step 5 will be a set of tables specifying the ecological category configuration for each of the 8 to 10 preliminary scenarios, the associated water availability and water quality for all the major water-use sectors and the resulting ecosystem health, social wellbeing and regional economic prosperity. Although the scenarios have been pretested, refined and evaluated internally within DWAF, they should still be thought of as "preliminary scenarios", because they have not yet been evaluated by the stakeholders. That process takes place in Step 6.

3.6. Step 6: Evaluate scenarios with stakeholders

It is anticipated that stakeholder engagement with the classification process will be as part of a larger IWRM DWAE-led process so as to avoid stakeholder confusion and fatigue. This will involve consultation with stakeholders from the outset of the water allocation reform process, the development of the CMS and the classification process. A discussion of this larger IWRM stakeholder process is beyond the scope of this paper. Step 6, however, requires specific input from stakeholders and therefore warrants a step in the classification procedure. Because of the changes in South Africa's water management context outlined in the first half of this article, stakeholder consultation is an essential aspect of the process of recommending a class configuration within a catchment(s) targeted for classification.

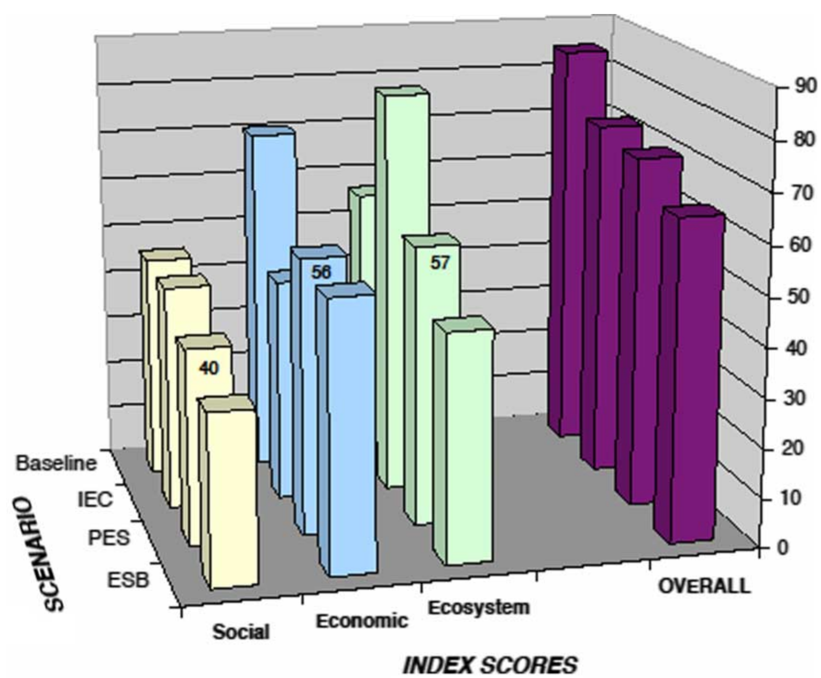

Fig. 3. Example of how the three score system could be represented for the overall aggregate performance for the IWMUs in the Olifants-Doring "proof of concept" catchment.

Step 6 has three main goals. The first is to ensure that a broad range of possibilities has been identified in Steps 4 and 5; the second is to get feedback on whether the trade-offs between economic benefits, social benefits and ecosystem benefits have been reasonably well represented. The third goal is to give a democratic voice to the various stakeholder groups for whom the final decision regarding the class for each of the water resources will have an impact on their lives and livelihoods so that the vision for the future desired condition of the catchment is driven, at least in part, by the people who live and work within that catchment.

Step 6 therefore involves a set of workshops with stakeholders in which information is shared and the various scenarios are presented together with a summary of their socioeconomic and ecological implications. Two types of stakeholder response are anticipated: their response to whether the range of options identified is sufficiently inclusive (or whether additional scenarios ought also to be considered) and their response to the implications of the scenarios identified in Steps 4 and 5.

After the first round of workshops, if new scenarios have been generated, the classification team goes back to Step 5 and evaluates these new and/or revised scenarios for WAFU, water quality, economic and societal implications and then holds a second round of stakeholder workshops with these new results. At these workshops, the primary goal is to seek consensus for a shortlist of scenarios and ideally also for the single scenario considered most desirable.

Before a shortlist can be agreed, stakeholders must first agree that the suite of scenarios under consideration does not leave out any critically important options; at this point, it may be necessary one last time to generate additional scenarios which must then be taken back to Step 5 for re-evaluation. Once stakeholders have agreed that the suite of options adequately covers the best possibilities, they sign-off formally on the agreed-upon shortlist, ideally also putting forward a consensus recommendation to DWAE for the preferred class for each IWMU within the catchment(s). This is referred to as the class configuration of the catchment and consists of the recommended class for each IWMU and the nested ecological categories that make up that class. The preliminary guidelines of the distribution of ecological categories making a class are presented in Table 6. These will need to be developed further through application of the WRCS to provide an evidence base for future guidance. In the event that no single scenario can be agreed on by all the stakeholders, the outcome of Step 6 is simply the shortlist of the leading two to three configuration options together with the reasons provided by the stakeholder groups.

3.7. Step 7: Gazette the class configuration

The final step of the classification procedure is to present the summary information from the preceding six steps to the Minister of Water and Environmental Affairs for a final decision on the catchment class configuration. This ultimate decision includes several components: first, the class is set for each IWMU;

Table 6. Preliminary guidelines for determining the IWMU class (source: DWAF, 2007b).

IWMU class	Percentage ecological category representation at units represented by nodes in an IWMU					
		$\geqq$ A/B	$\geqq$ B	$\geqq$ C	$\geqq$ D	$<$ D
Class I		$\geqq$ 40	$\geqq$ 60	$\geqq$ 80	$\geqq$ 99	–
Class II		–	$\geqq$ 40	$\geqq$ 70	$\geqq$ 95	–
Class III	Either	–	–	$\geqq$ 30	$\geqq$ 80	–
	Or		–	–	100	–

second, within each IWMU, the desired ecological condition for each node is specified; third, the reserve is set for each water resource (node); fourth, the allocation schedule is finalized; and fifth, RQOs are set. All five of these together are published in the parliamentary *Government Gazette* for a period of time to allow for public comment and when finally published, become legally binding.

4. Discussion and conclusion

We have argued that the development of the WRCS was historically contingent and needs to be understood in the context of South Africa's specific situation. The WRCS emerged from the political transformation process which provided a window of opportunity to legislate for the sustainable and equitable use of the nation's water resources. It sets out a framework which requires the integration of different disciplines; although the integration achieved in the "proof of concept" catchment was imperfect, future research and effort will need to be targeted in this direction to move the science forward and provide future benefits.

The WRCS also plays a pivotal role in South Africa's larger IWRM process, particularly in the water allocation reform process which requires consideration of the class. Accordingly, the class has a direct bearing on a range of broader societal and environmental issues. The three classes presented in Table 3 and the seven steps outlined earlier are due for publication as a regulation in the South African parliamentary *Government Gazette* in 2009 and after a compulsory consultation period, will become legally binding on all authorities or institutions exercising any power under the NWA.

The regulations have been drafted to take account of the fact that the WRCS was developed using a "proof of concept" catchment which demonstrated that while classification is technically and logistically feasible, there are many scientific and methodological advancements and improvements that will need to be made in the future. The regulations stipulate the three classes that will apply and the seven steps that need to be undertaken without prescribing the tools, models or methods needed to recommend a class configuration (and its socioeconomic and ecological implications). In this sense, the progressive use and implementation of the WRCS mirrors South African societal reform; it makes provision for historic redress for equity (through its link with the water allocation reform process, the exposition of socioeconomic benefits, the transparent process and the inclusive nature of the stakeholder process) and for sustainability (through the class, reserve and RQOs), while acknowledging that we "learn by doing", thereby improving the WRCS over time.

An obvious question that arises, however, is will the WRCS contribute to equitable and sustainable water allocation in South Africa and in so doing contribute to building a fairer and more just society which, after all, is the underlying ambition of IWRM. Critics of IWRM have argued that while many developing countries have reformed their water sectors and taken on an IWRM framework through declaring water as state property, instituting water withdrawal permits, pricing for domestic use and creating river basin organizations, little real progress has been made (Shah & van Koppen, 2006). One reason that they offer for this is that many countries took on IWRM without properly acknowledging their particular institutional and sociopolitical context and that in some countries, such as Tanzania, no attempt was made to deliver what people needed most: more and better-managed infrastructure (Shah & van Koppen, 2006).

Does South Africa fall into this trap? Shah & van Koppen (2006) argue that while IWRM has delivered improved governance of water resources in South Africa, it leaves 95% of its people out of its domain. About 10% of the total water allocated in South Africa (2.3×10^8 m^3) is allocated to Schedule 1 users, mostly rural black South Africans whose use is neither subject to licenses nor billable. If the WRCS fails to help increase access to productive use of water by these users or, indeed, if it denies increased access, it will fail. The larger IWRM process must find a way to bring all of South Africa's citizens into its ambit. We therefore argue that the success of the WRCS will be determined as much by the process of classifying the nation's water resources as the technical merits of the system.

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