A preliminary exploration of two approaches for documenting 'mental models' held by stakeholders in the Crocodile Catchment, South Africa

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Executive Summary

The international think tank, the Resilience Alliance in 2006 set up a workgroup to explore the effect that mental models held by different stakeholders, and stakeholder groupings, might have on natural resource use and management, or in their more specific approach, on resilience of social-ecological systems. This study, conducted in South Africa, is intended to provide a relevant practical example on which to develop further understanding of mental models.

Mental models, put simply, are what people use to understand and interpret phenomena of everyday life. These models are frameworks of concepts and relationships that underpin how people understand, filter and process information and contribute to understanding, reasoning, prediction and action. These have been investigated across many fields and are of interest to natural resource management because of the need to understand stakeholders' constructions (mental models) of how systems function. This provides the opportunity to present alternative options, assist building shared understanding amongst resource users and managers, and thereby support negotiation for change towards more sustainable resource management.

This report reflects an attempt to try to understand issues of compliance with the water legislation by eliciting mental models which may underlie much of the intrinsic motivation of stakeholders to take particular collective actions, develop specific practices and ultimately behave in particular ways. Recent concern has been expressed that, in spite of world-acclaimed legislation such as the National Water Act 36 of 1998, the ecological condition of many South African rivers continues to deteriorate.

The Crocodile Catchment was chosen for this study as it is under the authority of the Inkomati Catchment Management Agency (ICMA), the first of 19 catchment management agencies to be established under the South African Water Act. It could also draw on the previous Kruger National Park Rivers Research Programme.

A multi-disciplinary team of researchers, representing various biophysical and social sciences, designed the process for testing the applicability and viability of two methods for eliciting and representing elements of mental models. These two methods, the Consensus Analysis method and the ARDI method, were tested with respect to their utility in identifying elements of mental models. Both methods were used to explore specific questions within the context of understanding whether differing views about the catchment would yield insight on non-compliance with environmental flows (the Ecological Reserve).

The Consensus Analysis method aims to understand the level of consensus among the different interviewees and stakeholder groups with respect to four key questions. The use of language as an indicator of understanding of content is central to the method's depiction of the level of consensus within and between a particular group of stakeholders. In this method seventy six people were interviewed in two phases. The first phase interviews were with water users and managers across the catchments. The second phase focused on irrigators and 'conservationists' to see if these groups shared similar beliefs or knowledge about water use and management in the catchment. Challenges with this method included the logistics of conducting sufficient interviews across a broad geographic area in the time available.

The ARDI method focuses on developing a schematic representation of individual or group understanding of key elements of the social ecological system. Ten individual mental models were elicited from water resource users and managers; the collective mental model process could not be completed in the time available. The ARDI assessment's systems diagrams provide insight into sustainability through showing how stakeholders and resources interact. It also illuminates drivers of the system, as understood by different stakeholders and the way in which these stakeholders understand the system to function.

This research found that with respect to sustainability, the Reserve and compliance with the Reserve, both methods suggested that the Reserve is a concept that is not well understood. If people were familiar with the Reserve as a tool, then more detailed understanding was often lacking or limited. In addition, both the CA and ARDI methods identified non-compliance as an important issue for stakeholders in the catchment. However additional work would be required to explore the actual nature and intent of the non compliance as this was beyond the scope of the current application of the two methods.

In many ways, CA could be seen as a screening technique to, for instance, define specific thematic areas that water management needs to address within the catchment. What is valuable is that both methods highlight the nature and extent to which stakeholders perceive problems relating to WRM in the catchment. This information is useful in engaging water managers and broader stakeholder groups in subsequent stages of collaborative work as it provides a basis from which to tackle problems.

This research found that with respect to the techniques for eliciting mental models, both methods accommodate high levels of representation and inclusivity and are therefore in accordance with participatory water resources management as required by the NWA. They both generate a sense of involvement and 'buy-in' in that they draw information and engagement from a broad spectrum of stakeholders. The demands of the methods for time and funds need to be carefully considered. Issues of resources and finances need to be factored into the broad application of the techniques so as to derive a clear picture of the costs and benefits.

As far as application of mental models in the South African catchment management context is concerned, clearly in the multiple-stakeholder arena called for by IWRM under the NWA it would be valuable to employ tools that set out to understand how, why and where differences in conceptual understanding, language use, meaning and practices might arise. It may be useful to identify a process that would contribute to the development of CMS and that built on the results of this work. We identified four processes that could contribute to the development of sustainable CMS, including:

1. Stakeholder analysis to identify major stakeholder groups and power relationships using social network analysis.
2. This could be followed by Consensus Analysis of key questions and actions related to the social, economic and ecological sustainability of water use.
3. Participatory modelling to explore action, outcome relationships using ARDI-like techniques to identify pathways to sustainability and a broadly acceptable vision.
4. Monitoring and learning to support progress to goals through techniques such as: Bayesian Belief Network (BBN) modelling to support ongoing monitoring and evaluation of key factors and progress towards goals

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BHNR	Basic Human Needs Reserve
CMA	Catchment Management Agency
CMC	Catchment Management Committee
CMF	Catchment Management Forum
CMS	Catchment Management Strategy
DWAF	Department of Water Affairs and Forestry
ER	Ecological Reserve
ICM	Integrated Catchment Management
IWRM	Integrated Water Resources Management
NGO	Non-Governmental Organisation
NWA	National Water Act (No. 36 of 1998)
NWRS	National Water Resource Strategy
RDM	Resource Directed Measures
SDC	Source Directed Controls
WMA	Water Management Area
WMI	Water Management Institution
WRC	Water Research Commission
WUA	Water User Association

1. Background

Over the past few years concerns have been expressed that the ecological condition of many South African rivers continues to deteriorate in spite of world-acclaimed legislation, such as the National Water Act 36 of 1998 (NWA). As an example of reaction to this concern, there is, at the time of writing of this report, a pilot program funded by the Water Research Commission, “The Shared Rivers Initiative” (WRC K6 1711), looking mainly at water use, management and governance practices, in an effort to improve this situation. Despite a sound conceptual environment (for example as emerged from the Kruger National Park Rivers Research Programme, (Breen et al., 1997) and supportive legislation, transformation at the level of water resources management practice is proceeding slower than expected. Observers now often refer to an “implementation lag” with varying degrees of empathy or frustration. The current focus of implementation agencies is on identifying and influencing factors likely to lead to more effective and timely implementation of the NWA, which is based *inter alia*, on the principles of sustainability. A cardinal consequence of the lack of implementation is poor compliance with the principles enshrined in the NWA. It was in this immediate context that the notion of ‘mental models’ came under consideration; could the lack of compliance with the NWA be understood in relation to the different conceptualisations or mental models of water use and water resource dynamics held by different stakeholder groups? A mental model refers to the way people construct an understanding of their world, enabling them to think about concepts and processes, to map their relationship to these, and to anticipate or plan their responses.

The research presented in this report was an attempt to explore the utility of understanding mental models as an aid to understanding non-compliance. Where practices (collective or individual) lead to less sustainable outcomes or a violation of the law, we need to understand how and where these practices emanate if we hope to achieve change. By understanding how stakeholders perceive the systems within which they live and function we may be in a better position to present alternative options and thereby negotiate change. Facilitated techniques may benefit from taking stakeholder mental models into account when seeking to build a shared understanding between the many parties involved in the co-operative governance of water. In many ways water resource management can be seen, especially in a mainly semi-arid country like South Africa, as a pertinent microcosm of resource management in general. As a result, there may be wide interest in trying to understand stakeholders’ conceptions (mental models) of how a system functions and how resources that are part of these systems can best be managed. If such techniques are found to be useful, then their application across several sectors of resource management might prove useful. To our knowledge, this is one of the first explicit attempts to document mental models, albeit provisionally and in an exploratory manner, in any natural resource field in southern Africa.

In 2006 a mental models working group was established within the Resilience Alliance (http://www.resalliance.org) to explore the contributions that the mental models of different stakeholders and stakeholder groupings made to natural resource dynamics and the resilience of social-ecological systems. One of the authors of this report, Harry Biggs, who had been involved in sustainable river management work in South Africa, was invited to join this group, and at an initial meeting held in Australia, had suggested that study in South Africa might provide a relevant practical example on which to develop further understanding of mental models. The fact that water management practices associated with the NWA are currently being developed and implemented at the time of this study made this opportunity all the more attractive and relevant. Furthermore, the development of multiple stakeholder water management bodies in the form of the Catchment Management Agencies (CMAs) increased the potential relevance of understanding of stakeholder mental models and their consequences for water management particularly relevant.

Mental models have a wider theoretical and applied audience, for instance, amongst cognitive psychologists (Johnson-Laird, 1983), organizational theorists (Walsh and Ungson, 1991), business management theorists (Axelrod, 1976; Senge, 1990), human decision making in high reliability systems (Endsley, 1995), system dynamics modelling (Doyle and Ford, 1998) and knowledge management (Davison and Blackman, 2005). As such, understanding of mental models is also likely to be applicable in areas far outside of the natural resource use arena which constitutes the context for this particular study.

This report will examine the concept of mental models, describe why the Crocodile River was chosen as a study site, and give a brief overview of catchment attributes. After that there is a short general introduction to methods, followed by more detailed sections on the two main methods used, the results obtained and a brief interpretation. Finally there is an overall discussion of what we learnt, and a section on potential practical ways forward.

2. Mental models

2.1. Introduction to mental models

Very simplistically mental models are the internal representations of the world that people use to understand and interpret phenomena of everyday life. These models remain poorly understood as is their relationship to human behaviour. They may be conceived of as frameworks of concepts and relationships that underpin how people filter, process and store information, including their conceptualisations of the world or some elements of the world. They contribute to human reasoning, interpolation, prediction and action (Dearborn and Simon, 1958,;Kearney and Kaplan, 1997; Endsley, 1995).

An individual holds their own mental models of the world that are believed to be informed by social processes and the mental models of others with whom they interact as well as the experiences of the individual. Members of institutions, organizations and groups may co-construct mental models of specific topics or issues which lead to the development of specific understanding and practices that may be unique to that particular institution or group (Carley, 1997; Kraiger and Wentzel, 1997; Vennix, 1999). In fact for a member of a group to function within the group requires that there is at least some shared constructs that make up the mental models of the constituent members (Klimoski and Mohammed, 1994).

Across the social science disciplines there have been many attempts to explain the link between how people perceive the world and how this relates to and translates into understanding and action (see Wood, 2000, for a recent review). As a result there are a number of terms and concepts that are similar to mental models in trying to explain how people construct and react to their world , examples being: frames (Perri 6, 2005), schema (Barlett, 1932, after Garro, 2000) and phenomenography (Marton, 1994).

The foundations for the concept of mental models was laid in 1942 by Kenneth Craik who proposed that thought parallels reality through symbols that form a small scale model and so enables the mind to evaluate various alternatives and to predict what may happen based on previous experience. From Craik's introduction, the term mental model languished until 1983 when two books were published (Johnson-Laird, 1983; Gentner, 1983) that laid further theoretical foundation for the mental models concept. Since then the term mental models has expanded rapidly across many fields, including management (Senge, 1990; Hill and Levenhagen, 1995), team performance (Stout et al., 1999), knowledge management (Davison and Blackman, 1995), risk (Bostrom et al., 1994; Morgan et al., 2001; Zaksek and Arvai, 2004) and so may be described differently in these various settings.

2.2. Definition of mental models

In its simplest form, a mental model is considered to be an internal representation of the world that supports understanding, reasoning and prediction and that drives action. For the purpose of this analysis we conceived mental models to comprise human representations of objects, their relationships and dynamics as well as the attributes or characteristics of these and the person's valence (cognitive and emotional) to the objects, relationships and dynamics (Figure 1).

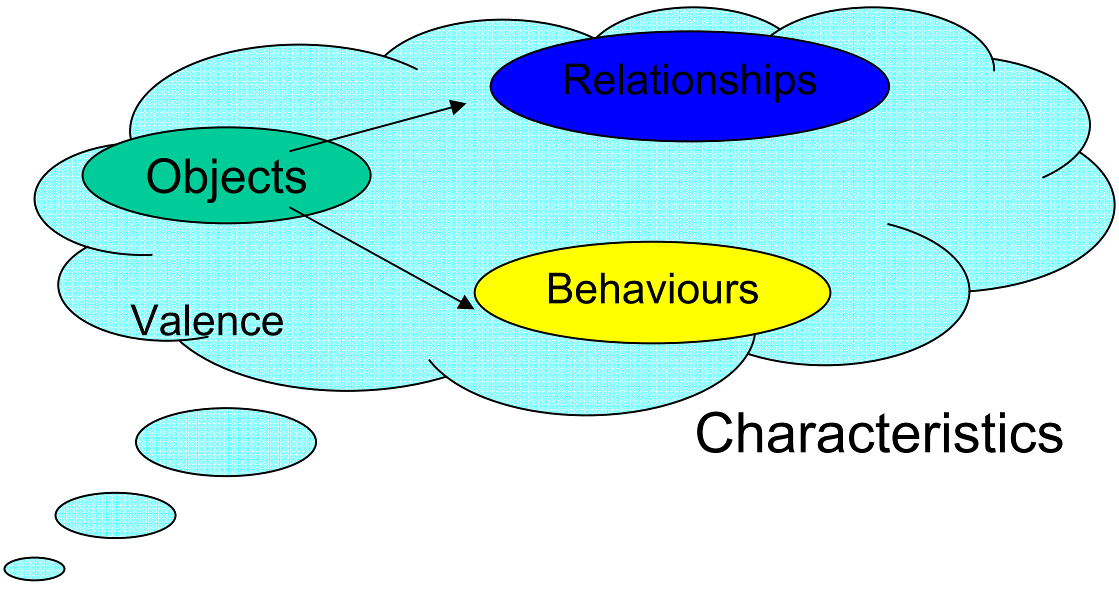


Figure 1. Schematic representation of the components of mental models used to guide this analysis.

The emergence of a mental model is informed by concepts, knowledge, information and experiences that are ultimately mediated by language, values and the social world. A mental model, whether articulated or not, facilitates the process of making meaning. If 'new' information presents a problem for meanings that a person holds, the person may simply reinforce their held meanings or reconstruct new meaning.

This new meaning might result in a new or adapted mental model. Such adaptation of the mental model is more likely if the new information fits with the existing mental model (Kearney and Kaplan, 1997). If adjustment is not possible then the information may be ignored or reinterpreted (Kearney and Kaplan, 1997; Jamieson, 2006). If people lack detailed knowledge of a specific phenomenon then they create meaning by applying concepts drawn from their understanding of other similar phenomena (Kempton, 1997).

A mental model is never complete but represents only part of a complex situation (Vennix, 1999). It may contain incorrect information and conflicting beliefs or it may hold several inconsistent models within the same domain (Read et al., 1994). Unless incorrect information is discredited and displaced, incorrect models may often persist – possibly even alongside the more accurate ones (Kempton, 1997; Gentner, 2002).

When individuals function in a group, institution or organization they might share a mental model of a particular aspect of their reality. This means that they are part of the process of forming a collective mental model. Collective mental models can take various forms:

- A shared mental model is the extent to which a group of individuals share a similar representation of a phenomenon or situation and allows for multiple levels or sets of shared knowledge (Langan-Fox et al., 2001).
- A team mental model refers to the collective understanding in a team and so refers to the overall degree of similarity between the mental models of individual team members (Klimoski and Mohammed, 1994).
- A cultural mental model refers to the extent that people in a society share a culture which encapsulates the experiences of past generations and provides for the intergenerational transfer of unifying perceptions. It enables a member of that society to organize their experiences and be able to communicate with others about them and provides shared explanations for phenomena outside of the immediate experience of the members of the society in the form of religions, myths and dogmas (Denzau and North, 1993).

The amount of 'sharedness' in shared mental models varies in several ways: the uniformity of sharing or the relationship between perceptions of the individual and the team; degree of sharing or how widely the perceptions must be shared; and the awareness of sharing of whether team members are aware of the shared perceptions (Carley, 1997).

A high degree of overlap between mental models may increase the ability to communicate with others. In areas where collaboration, negotiation and interaction between different groups are required articulating mental models, may help to:

- understand the range of mental models in proscribed arena
- broaden the definition and understanding of a problem through comparing the mental models of resource users and managers
- stimulate and facilitate communication and learning amongst resource users and managers.

We recognise however that overlap is not always beneficial; when seeking solutions to novel problems it may well be useful to have a diversity of mental models from which novel solutions may emerge.

2.3. Documenting mental models

How easy, or not, it is to elicit and represent a mental model is the subject of some discussion in the literature. As a cognitive phenomenon, a mental model exists only in the mind and Doyle and Ford (1998) warn researchers about confusing elicited or mapped representations of a mental model with the mental model itself. Following the work of Argyris and Schon (1978), it is suggested by Carley (1997) that some researchers consider a mental model employs tacit knowledge or 'model in use' and what is obtained (for example, when prompted by a researcher) is an 'elicited model': others believe that a mental model is an emergent structure that only crystallizes as it is articulated by the individual. Whatever form this cognition process takes, as researchers we deal with what is presented by the individual which is mediated by social processes.

Eliciting mental models generally involves one or more of three methods (Carley and Palmquist, 1992): content analysis, concept mapping, or procedural analysis with methods such as scenario development emerging more recently. These different methods can be used either singly or in combination and with individuals or groups.

The most commonly used method is content analysis which takes the language expressed by an individual and uses it to create a 'map' of concepts and ideas. The individual is usually prompted through oral (open ended or semi-structured interviews) or written (questionnaires or examination of documents) tools or even a combination of both (e.g. Bostrom et al., 1994). The mental models are then often represented through a cognitive map such as an influence diagram (e.g. Atman et al., 1994; Morgan et al., 2001). Development of these cognitive maps allows comparison and so can be used to compare the mental models of different individuals or groups and over time. Similarly concept mapping is a technique for visualising relationships among concepts that is attributed to the work of Novak (Novak and Canas, 2008).

Another common method used to elicit mental models is procedural mapping which prompts a person to 'think aloud' as they work through a given task and describe implicit and explicit procedures (Carley and Palmquist, 1992; Niewhohner et al., 2004). This approach focuses on the sequence of task-related decisions and does not reveal knowledge around a topic and so may require a further probe into individuals' understanding (e.g. Niewohner et al., 2004).

Emerging methods for elicitation include the use of scenarios to elicit understanding of concepts. In using this method the researcher presents the subject with a detailed description of a phenomena and asks them to explain it in their own words, or to be more predictive and describe 'what happens next' (e.g. Stoll-Kleemann et al., 2001; Sterman and Booth Sweeney, 2007).

2.4. Understanding mental models in a natural resource management setting

Although the concept is often used in relation to natural resources management (NRM), research that addresses mental models and their relationships to human decision making, behaviour or learning are rare. Where research has been conducted it documents elements of mental models (Abel et al., 1998; Pahl-Wostl, 2002; Hare and Pahl-Wostl, 2002) whilst speculating on the managerial or decision making importance (Kolkman et al., 2005).

Understandings of the mental models of different groups may be important where:

- Conflicts exist or are emerging between stakeholder groups and understanding among those groups of the conceptualisations of each group could be used to identify evidence to resolve the bases of the different conceptualisations.
- We seek to understand the complex relationships between people and ecosystems from a cognitive perspective.
- Society seeks to define desirable futures and plausible paths to achieve these.
- We need to document the knowledge of specific groups in society.
- We seek to understand how specific processes give rise to or limit social learning.
- A group seeks solutions to complex problems.

3. Choice of study site: the Crocodile Catchment of the Inkomati Catchment Management Agency

Under the South African Water Act, 19 Water Management Areas (WMAs) have been established and the planned devolution of responsibility to 19 catchment management agencies has begun. The Inkomati Catchment Management Agency (ICMA) was the first one in the country to be declared and, at the time of this study in 2007, had been in existence for approximately one year. The original idea of choosing the Crocodile Catchment (see Figure 2) within the Inkomati WMA stemmed from the advanced deployment of the National Water Act described above, and also from the possibility of assimilating existing knowledge from the Kruger National Park (KNP) Rivers Research Programme into the research process.

The KNP programme had studied five major rivers crossing the Park: the Luvuvhu (a tributary of the Limpopo); the Olifants and its major tributary in the lowveld of South Africa, the Letaba; the Sabie; and the Crocodile. The last two rivers make up part of the Inkomati WMA. The most intensively studied river in the Kruger National Park Rivers Research Programme is the Sabie (O'Keeffe and Rogers, 2003) and its major tributary the Sand. However, the Sabie is itself relatively pristine and free of the major contentions in other rivers, while its Sand subcatchment is quite the opposite, but has been very well studied, particularly in the Save the Sand Programme (Pollard et al., 1998). The Olifants-Letaba-Luvuvhu systems have well-described problems and attributes of their own (O'Keeffe and Rogers, 2003) but their Catchment Management Agencies are not established as for the Inkomati WMA. That left the clear choice of the Crocodile for this study: in this catchment the successful implementation of the National Water Act is likely to be challenged by issues of over allocation, poor compliance and weak long term planning for sustainability.

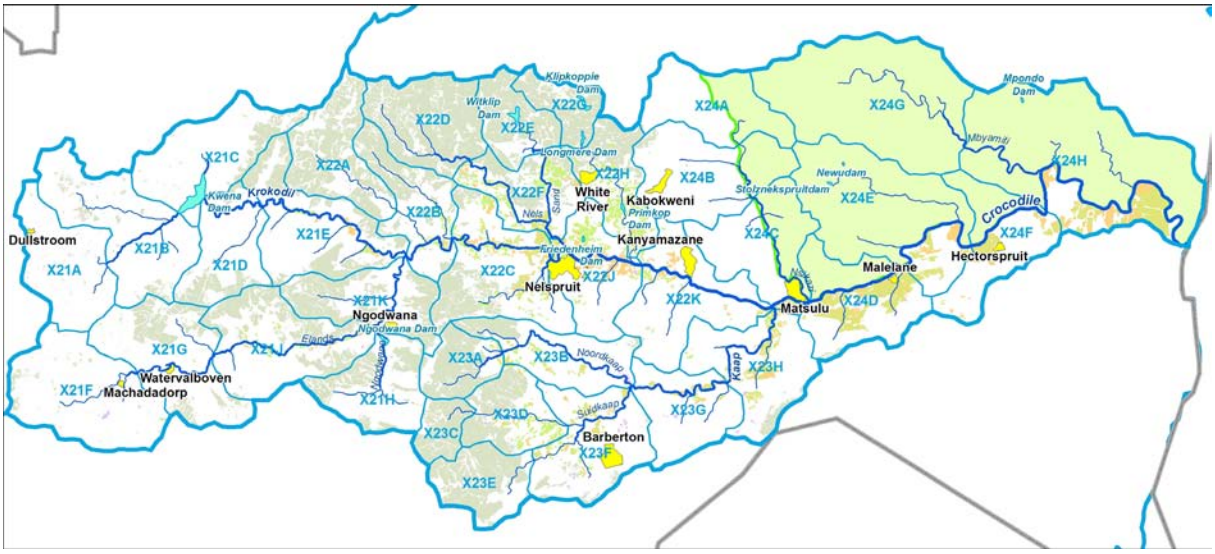


Figure 2. Map of the Crocodile River within the Inkomati Water Management Area.

As the first CMA to be established the Inkomati CMA is being delegated and assigned new responsibilities and powers. This is an ongoing process of transformation, with the Department of Water Affairs and Forestry (the previous management authority) acting as interim transitional authority. This process is important in understanding how sampling for interviews and discussion groups took place which is described in section 4.

The summary of the attributes of the Crocodile River, which forms the remainder of this section 3, is taken from Mphuti (unpublished data) who has recently collated a variety of descriptive sources.

The Crocodile River drains a catchment of about 10 400 km^2, with a total main-stem length of approximately 320 km. It forms the southern boundary of Kruger National Park, and is the largest tributary of the Komati River. The catchment is characterised by varied topography and exceptional biodiversity. It has high mean annual precipitation (1600 mm pa) in the mountainous western headwater zone, far lower in the lowveld but with high mean potential evaporation (1600 mm), causing low flows in the dry season. The stream flow is further reduced by afforestation, which covers 177 455 ha in the upper catchment.

The gross surface water resource (Table 1) is derived mostly from run-of-river flows but is augmented by the Kwena Dam and other smaller dams, which supplement the run-of-river abstractions during periods of low flow. There is uncertainty surrounding the estimated impact of invasive alien plants due to some unknown factors such as how big an area is infested, the species of alien invasive plant, the location (riparian/non- riparian) and a lack of knowledge relating to how much water alien plant species actually use.

Table 1. Estimated water availability in the Crocodile sub-catchment for 2003 at 1:50 year assurance (DWAF 2004). Gross surface water resource is water recorded as surface runoff in river flows. Transfers 'in' refers to water transferred from the Lomati catchment.

Resource category	Available/impact (million m^3/annum)
Gross surface water resource:	364
Subtract:	
- Ecological Reserve	105
- Invasive alien plants	57
Net surface water resource	**202**
Ground water	8
Return flows	42
Total local yield	**252**
Transfer in	12
Grand Total	**264**

Table 2. Estimated local water requirements in the Crocodile sub-area for the year 2003 at a 1:50 year assurance (DWAF 2004). Transfer 'out' refers to water for Mozambique.

User sector	Water requirement/ Impact on yield (million m^3/annum)
Irrigation	257
Forestry	42
Urban	35
Industrial and mining	23
Rural	7
Total requirements	**364**
Transfer out	49
Grand Total	**413**

The water demand in this catchment is high due to the irrigation (particularly sugarcane) and forestry activities. Heath and Claassen (1999) reported the following land uses (and hence associated water uses) in the catchment: the irrigated area spans 95 000 ha; afforested area covers 172 200 ha; dry land agriculture takes up a space of 290 000 ha and there are 45.9 people per square kilometre.

From Table 1 and 2 it is clear that the there exists a potential negative water balance in the catchment due to the high water demand exhibited by irrigation. The Crocodile River Catchment has the highest negative water balance (-149 Mm^3/a) in the Inkomati WMA. It is estimated that this water balance will reach -169 Mm^3/a by the year 2025. The current water balance in Crocodile River Catchment is currently met, but that will change with operating rules that require implementation of the Reserve and meeting the international obligations of water for Mozambique as in treaties and agreements.

4. The research process and methods

A multi-disciplinary team of researchers representing various biophysical and social sciences designed the process for testing the applicability and viability of two methods for eliciting and representing elements of mental models, namely: (i) the Consensus Analysis Method (CA) and (ii) the ARDI Method. Although the methods are different they were both applied to specific questions within the context of understanding whether differing views about the catchment would yield insight on non-compliance with environmental flows (the Ecological Reserve). As it was not possible to obtain data on actual compliance with the provisions of the Water Act it was not possible to formally test the relationships between different views and compliance. The process was expected to facilitate the qualitative exploration and provisional evaluation of the potential of using these methods in understanding mental models of stakeholders in a complex and contested arena. The two methods were used to elicit and represent elements of mental models from a diversity of stakeholder groups. By articulating these elements of stakeholder mental models both methods sought to identify stakeholders' shared and diverging viewpoints on environmental flows and non-compliance with the Ecological Reserve (the Ecological Reserve is the quantitative and qualitative articulation of an environmental flow regime for a specific river as required in terms of the NWA).

The Consensus Analysis Method aimed to understand the level of consensus among the different interviewees and stakeholder groups with respect to four key questions (described in Section 4.1). The use of language as an indicator of understanding of content is central to the method's depiction of the level of consensus within and between a particular group of stakeholders.

The ARDI method focuses on developing a schematic representation or concept map of individual or group understanding of four key elements (described in Section 4.2) of the system under discussion (in this case the Crocodile River).

Before the testing of the two methods took place, the research team met with several key senior DWAF personnel in Pretoria. This was partly to brief them about the ideas of the team, but also to seek advice and their opinions of the potential of such work. (Note that at the completion of the fieldwork several of these officials attended the feedback sessions that took part in the Kruger National Park and Pretoria shortly after completion of the field work. We capture their inputs under the general discussion (see Section 5).

The selection of individuals for participation in either of the two methods was guided by the categories of representation on the Inkomati CMA, which include the following:

- Commercial agriculture
- Existing agriculture by historically disadvantaged individuals
- Potential agricultural water use by historically disadvantaged individuals
- Stream flow reduction activity / forestry industry
- Tourism and recreation
- Organised conservation
- Productive use of water by the poor
- Civil society - resource protection / sustainable development

- Local Government - Integrated Planning
- Local Government - Water Services Authority
- Local Government - Traditional Leaders / Authorities
- Mpumalanga Provincial Government
- Limpopo Provincial Government
- Independent non-executive - integrated water resources management

Representatives from all relevant (those operative/resident in the Crocodile River Catchment) water-user groups were invited by the team to participate in the research. Given the large number of representative groups on the CMA and the time available to the research team, there was an inevitable focusing on certain groups.

An eight member research team tested the two methods over a 10-day period. The two methods ran in parallel and engaged a total of 95 individuals: 76 took part in the Consensus Analysis process and 19 in the ARDI process Individuals from various stakeholder groups were invited to participate in one of the two methods (as determined by identity/representation and logistical arrangement). The representativeness and size of the sampling was constrained by a) the diversity of stakeholder groups who were located across a large geographic area; and b) the complications arising from running two different methods in parallel at the same time (see discussion in Section 5.1).

Each of the two methods and their results are described in the following sections. Thereafter we present a general discussion and evaluation of the methods.

4.1. Method 1: Consensus Analysis

Consensus Analysis is a research technique developed in cognitive anthropology. It assumes that culture – comprised of systems of mental constructions (i.e. mental models[1]) or knowledge that individuals use to interpret and respond to the world of experience (Handwerker, 1998) – is learned and consequently shared. This extent of sharing varies, and consensus analysis allows investigation of the content and distribution (or sharing) of words, concepts, information and knowledge among individuals. The following questions form part of the analytical framework for Consensus Analysis:

- Is there a shared mental model?
- Of what does it comprise (issues, themes)?
- Is there significant disagreement? Are there competing understandings/visions?

[1] Consensus analysis does not use the term 'mental models' but uses concepts that are similar including cultural or knowledge domains which are "organized set of words, concepts, or sentences, all at the same level of contrast, that jointly refer to a single conceptual sphere" (Weller and Romney, 1988).

- If there is a shared mental model, how are different aspects of it interpreted and used among different stakeholders?

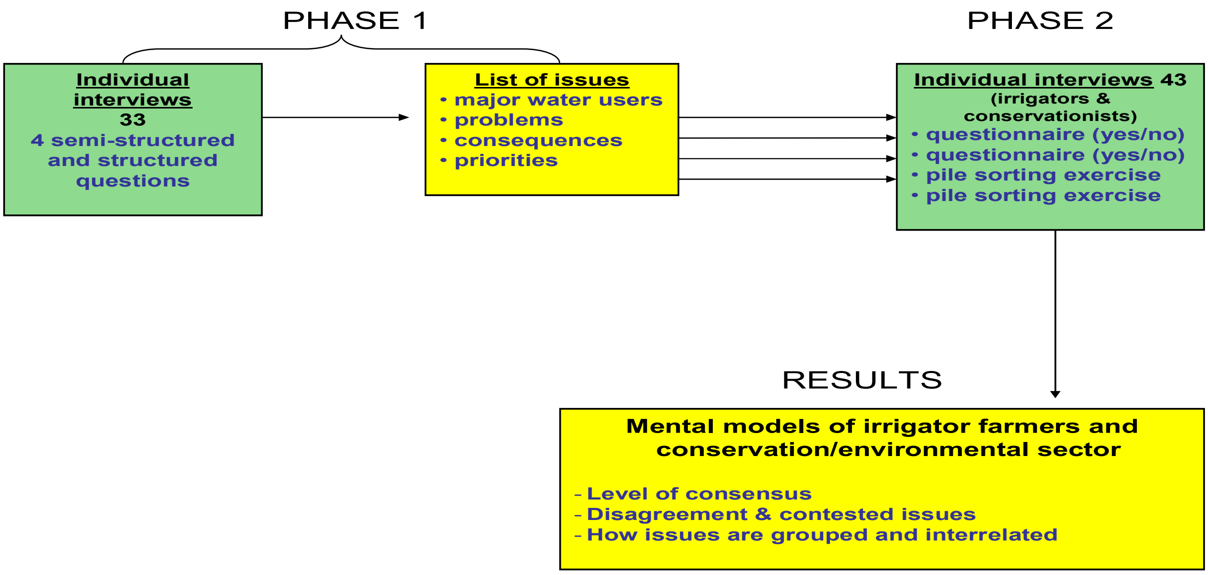


Figure 3. Phases and individual steps in the consensus analysis. The first phase generates a list of issues for each of the specific questions being addressed. Phase 2 takes as inputs these issues and using either questionnaires or pile sorts generates the data that is then analysed.

Consensus analysis typically involves two (or more) phases of fieldwork and data analysis. The phases we carried out for this work are summarised in Figure 3. The first phase generates the lists of issues with which an independent sample of interviewees works in gaining further specific insights in the second phase.

4.1.1. Phase 1 of the Consensus Analysis method

In the first phase, we conducted interviews with 33 individuals. These individuals were identified through purposive and 'snowball' sampling methods. They were affiliated with a diversity of organisations and social groups, including: DWAF regional, Inkomati CMA, SANParks, Irrigation Boards, Mpumalanga Tourism and Parks Agency *Working for Water Project (DWAF)*, Global Forest Products Pty Ltd., consultants, and emergent farmers.

The interview instrument consisted of 12 questions on water resource use and management in the Crocodile Catchment. The interviews were audio-recorded with the interviewee's permission. For the consensus analysis work, we focused on four of these questions. Each question looked at different domain of knowledge regarding water use and management in the catchment:

- major users of water
- causes of problems with current flows
- consequences of the river not flowing
- priorities for future water use.

For the first domain of knowledge – water users – we used a freelisting technique (Weller and Romney, 1988). Each of the 33 people interviewed were asked:

- Who are the major users of water in the Crocodile Catchment?

The remaining three sub-themes required a more open-ended technique, and we asked:

- What is causing the problems with current flows in the Crocodile River?
- What are the consequences of the river not flowing?
- What should be the priorities for future water-use?

Themes emerging from the interviewee responses were coded and for each question, we kept a separate running list of codes, creating new codes when new themes emerged. To eliminate conceptual redundancies, the same codes were used for similar themes or issues. This coding process allowed the answers given in narrative form to be listed in one word or a short phrase. Freelists were generated for all four questions.

Next, these freelists were analysed with *Anthropac* software (Borgatti, 1992). Freelisting makes two assumptions: (1) people tend to list things that they are most familiar with or believe are most important before they list things that are less familiar or less important, and (2) people who know a lot about a subject will list more things than people who know less (therefore, they will have longer freelists) (Quinlan, 2005).

Analysis of freelists in *Anthropac* generates four pieces of information:

- frequency (the number of separate items listed)
- response percentage (the percentage of interviewees who mentioned each item)
- rank (the aggregate average rank for each item)
- salience (a measure based on the frequency and rank of each item; it indicates how much knowledge informants share and how important that knowledge is to them, (Smith, 1993). "It is essentially a weighted average of the (inverse) rank of an item across multiple freelists, where each list is weighted by the number of items in the list" (Borgatti, 1992).

4.1.2. Phase 2 of the Consensus Analysis method

Phase 2 of our work drew on the information generated from the analysis of the freelists collected in Phase 1. A total of 43 people who had not participated in the first phase were selected, also using purposive and 'snowball' sampling. We decided to focus on irrigators (16 interviewees) and 'conservationists' (27 interviewees) as we were interested in knowing if these very different groups shared beliefs or knowledge about water use and management in the Crocodile Catchment. The people we interviewed were members of Irrigation Boards/Water User Associations, the Department of Agriculture and Land Administration (including Directorate of Environmental Affairs), Ecolink (a local environmental NGO) and SANParks. Separate interviews were carried out with each person. They were asked to complete a *yes/no* questionnaire followed by two pile sorting exercises.

<u>Questionnaire:</u> The questionnaire consisted of two sections, one focused on 'major water users' and the other on 'causes of problems with current flows' as generated from Phase 1. Items that had been mentioned more than once were selected for the

questionnaire (for results of the analysis of the freelists, see Tables 1 and 2). Interviewees were first asked to respond to the question 'of the following list of water users in the Crocodile River Catchment, which are major water users?' They had to check 'yes' if they thought a particular water user listed was a major user of water and 'no' if they thought otherwise. They repeated the exercise with the question 'Do these things contribute to problems with current flows in the Crocodile River?'

Pile sorts: After the completion of the questionnaire, each interviewee was asked to participate in two pile sorting exercises, one focused on 'consequences of the Crocodile not flowing' and the other on 'priorities for future water use'. For the pile sorting exercises, the top consequences (those mentioned at least twice) generated from the freelist analysis were written on separate index cards. A separate set of cards was generated for the priorities for future water use that were mentioned at least twice. Thus, two sets of cards were developed. For each set of cards, every card had an identification number written on the back of it. Each time, the cards were thoroughly shuffled before being presented to an interviewee to eliminate the possibility of bias.

Interviewees were first asked to pile sort the 'consequences of the Crocodile River not flowing'. They were given the stack of cards, each containing a single word or phrase, into groups or piles on the basis of similarity. They were instructed that there was no right or wrong way to sort the cards and that they could make as many piles as they wanted, but a minimum of two. After the pile sorting exercise was completed, interviewees were asked to explain what the consequences in each pile represented. We wrote this information down as well as the numbers on the back of each card for each pile that had been created. We repeated the exercise for the cards of priorities, but this time constrained them to exactly three piles: priorities that are highly important, of medium importance, and of low importance

Analysis of questionnaire and pile sort data: Using *Anthropac*, the results of the questionnaire and pile sorting exercises were converted to aggregate proximity matrices (a measure of how often particular items appeared together) and analysed with three methods: (1) consensus analysis (a module in *Anthropac*), (2) non-metric multidimensional scaling (MDS), and (3) cluster analysis.

The consensus analysis module allows one to determine statistically whether there is sufficient agreement among the persons interviewed to suggest that they hold a shared vision, or mental model, regarding a particular issue. MDS and cluster analysis allows one to visualize (see, for example Figure 4) the degree to which people share words, concepts, information or knowledge. These analyses are not restricted to comparing peoples' inputs; they can also be used to see the similarities and differences among the items pile sorted or in the questionnaire (e.g. major waters users, problems, consequences, priorities). In the map produced by MDS, people who are in closer agreement appear closer together; people who have different understanding, or mental models, on the issue appear farther apart. This also applies to items – the more similar in meaning (in the minds of those interviewed) two items are, the closer together they are on the MDS map, and vice versa. Cluster analysis (Johnson's hierarchical clustering module in Anthropac) is another visual technique that is often used in combination with MDS. Instead of mapping people or items on a 2-dimensional (or 3-dimensional, if shown to reduce the stress score) map, cluster analysis produces a schematic diagram of clusters of people (or items) in accordance to their similarity. Cluster analysis is often used to interpret the groupings of people or items in the MDS map.

4.1.3. Data and results

Theme 1: Water users

Analysis of the freelists (Phase 1)

From the first round interviews with 34 people, a wide and diverse range of water users were identified. Table 3 provides a summary of interviewees' perceptions of who are the major water users in the Crocodile Catchment. The information presented in the table was produced by *Anthropac*. It shows that interviewees listed 25 different water users which ranged from diverse social (human) groups to plants and animals.

The most frequently cited water user was 'commercial farmers', who were mentioned by 97 percent (i.e. 32) of the interviewees. Commercial farmers also were perceived as the most salient water users – i. e. interviewees listed them near the top of the list, perceiving them as the 'most important' water users or water users with which they were the most familiar.

Table 3. .Results of analysis of freelists of "major users of water" showing frequency with which interviewees identified users, the relative percentage of interviewees who identified that user, the average ranking of that user and the salience (Smith's S) of the user. (N=34).

ID	USER	FREQUENCY	REL PCT	AVG RANK	Smith's S
1	COMMERCIAL FARMERS	32	97	1.656	0.827
2	INDUSTRIES	14	42	3.429	0.221
3	FORESTRY	12	36	2.75	0.229
4	URBAN AREAS	11	33	3.636	0.176
5	MINING	10	30	2.9	0.182
6	MUNICIPAL AUTHORITIES	9	27	3	0.181
7	DOMESTIC USERS	7	21	3.143	0.107
8	EMERGING FARMERS	7	21	4.143	0.110
9	RURAL POPULATION	6	18	4.167	0.055
10	KRUGER PARK	5	15	4	0.066
11	ECOSYSTEM	4	12	4.5	0.033
12	MOZAMBIQUE	4	12	4.75	0.039
13	RECREATIONAL USERS	3	9	3.667	0.050
14	TOURISM	3	9	1.667	0.080
15	BLACK TOWNSHIPS	2	6	3	0.035
16	HOUSING DEVELOPMENT	2	6	2.5	0.038
17	AQUACULTURE	2	6	1.5	0.057
18	FACTORIES	2	6	3	0.041
19	SHOPS	1	3	5	0.018
20	SCHOOLS	1	3	6	0.015
21	HOSPITALS	1	3	7	0.012
22	GAME FARMERS	1	3	3	0.018
23	SELF-EMPLOYED	1	3	9	0.006
24	PLANTS	1	3	1	0.030
25	ANIMALS	1	3	2	0.025
	Total/Average:	142	4.303		

Analysis of the questionnaire (Phase 2)

The responses to the *yes/no* questionnaire on major water users filled out by 43 people (16 irrigators and 27 'conservationists') were analysed in *Anthropac* with the three methods outlined above: (1) consensus analysis, (2) MDS and (3) cluster analysis. Each of these methods enabled us to assess whether or not there was agreement among irrigators and conservationists, as a whole group and as separate groups, regarding who were the major water users in the Crocodile Catchment. The results of the three analyses indicate that it was not possible to draw any conclusive results regarding whether or not there was consensus (among irrigators and conservationists) regarding the major water users, perhaps because the sample was too small.[2] Conservationists and irrigators did not appear to have different conceptions of the major users (Figure 4) and although the users were perceived to be different we could not detect patterns in the similarities among users or their differences (Figure 5).

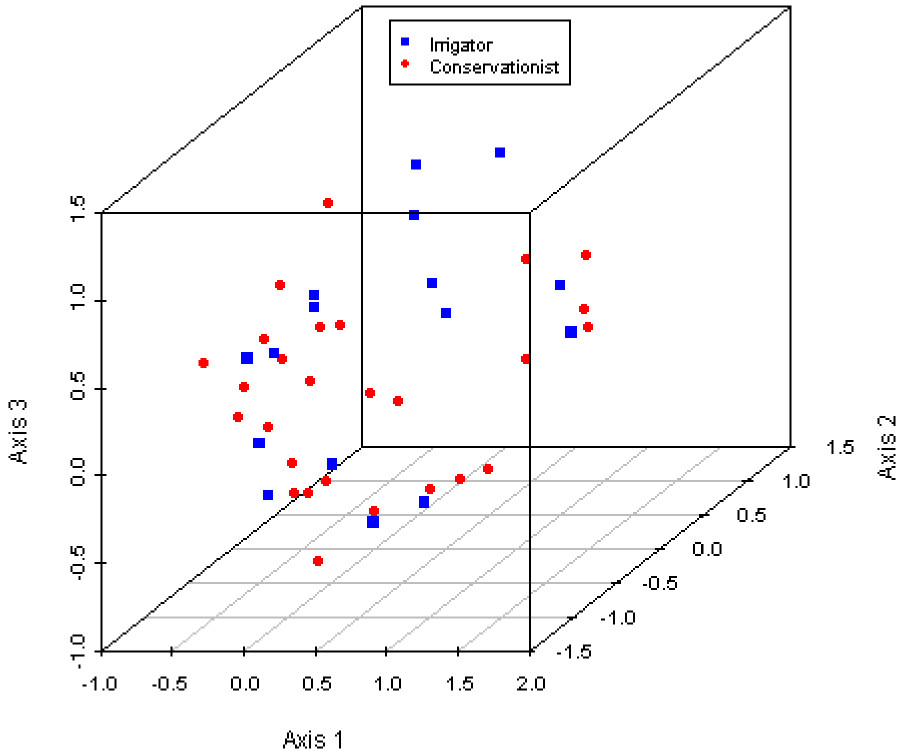


Figure 4. Three dimension plot of the similarities among respondents with respect to their identification of major users of the Crocodile. Plot is the result of Multi-Dimensional-Scaling of similarities. Stress=0.121[3].

[2] The respondent reliability coefficients were below the 0.90 recommended threshold (0.789 for the group as a whole, 0.770 for conservationists, and -0.096 for irrigators) indicating that the results are not stable and would likely not be the same as those obtained in repeated sampling (Romney et al., 1986). This statistical problem may have arisen as a result of an insufficient number of interviews for the freelisting exercise (phase 1). Alternatively, distorted coding, which can occur particularly with complex concepts such as "causes of problems with current flows" and "priorities for future water use", can also account for data analysis problems.

[3] The stress score reflects the degree to which the MDS model represents the data. The lower the score the better the representation. Borgatti 1992 suggests scores of <0.1 are excellent and scores >0.2 are unacceptable.

Although there were similarities among users based on their similarity scores the patterns were not clear; urban and rural groups emerge as a cluster as do environment, international obligations and tourism. However the agricultural and mining / industry sectors were not grouped as closely as one might imagine.

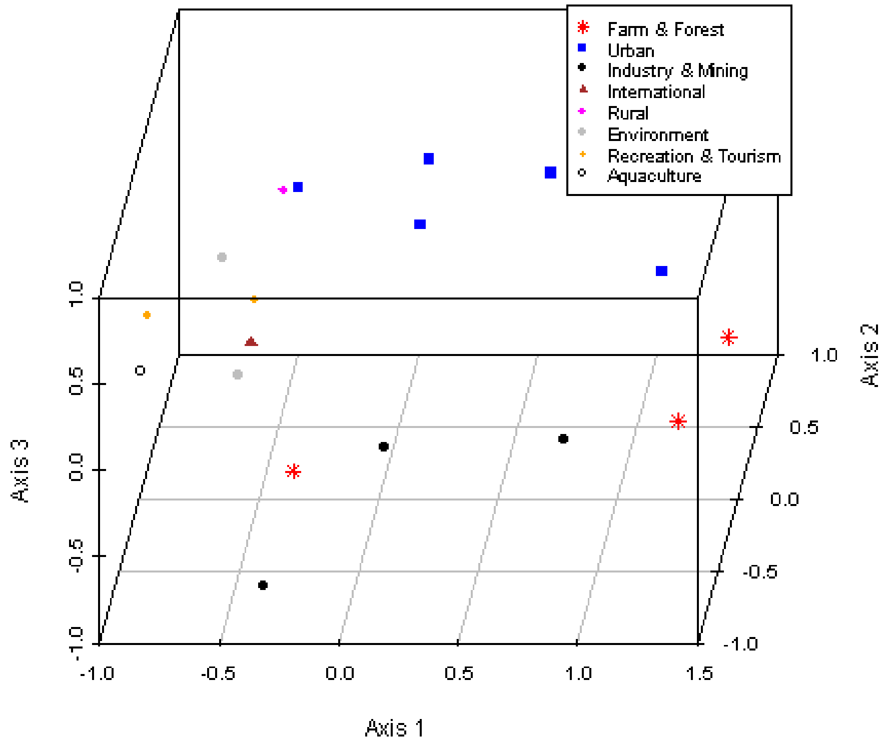


Figure 5. Three dimension plot of the similarities among major users of the Crocodile as identified by respondents. Plot is the result of Multi-Dimensional-Scaling of similarities. Stress=0.082.

Theme 2: Problems with current flows

Analysis of the freelists (Phase 1)

A total of 33 factors responsible for the problems with the current flows in the Crocodile River were mentioned (Table 4). Of these, the most frequently mentioned was 'illegal use of water', mentioned by 32 percent (10 people) of the 43 people interviewed. This was closely followed by low rainfall (25 percent), forest plantations (22 percent), commercial agriculture (22 percent), and Kwena dam (19 percent). If the frequency of times Kwena dam was mentioned was combined with the frequency of mentions of dams in general (16 percent), then dams were mentioned the most frequently (35 percent). However, although dams were most frequently mentioned, they were not perceived as the most important or salient cause of problems with current flows.

Analysis of the questionnaire (Phase 2)

A consensus analysis, MDS, and clustering analysis of the *yes/no* responses to the question 'what are the causes of the problems with current flows in the Crocodile River?' revealed that irrigators and conservationists as groups were not in agreement (see Figure 6; stress score = 0.093) about the underlying factors causing the problems with the current flows in the Crocodile River.[4] There was also no discernable pattern in the similarities of causes (Figure 7).

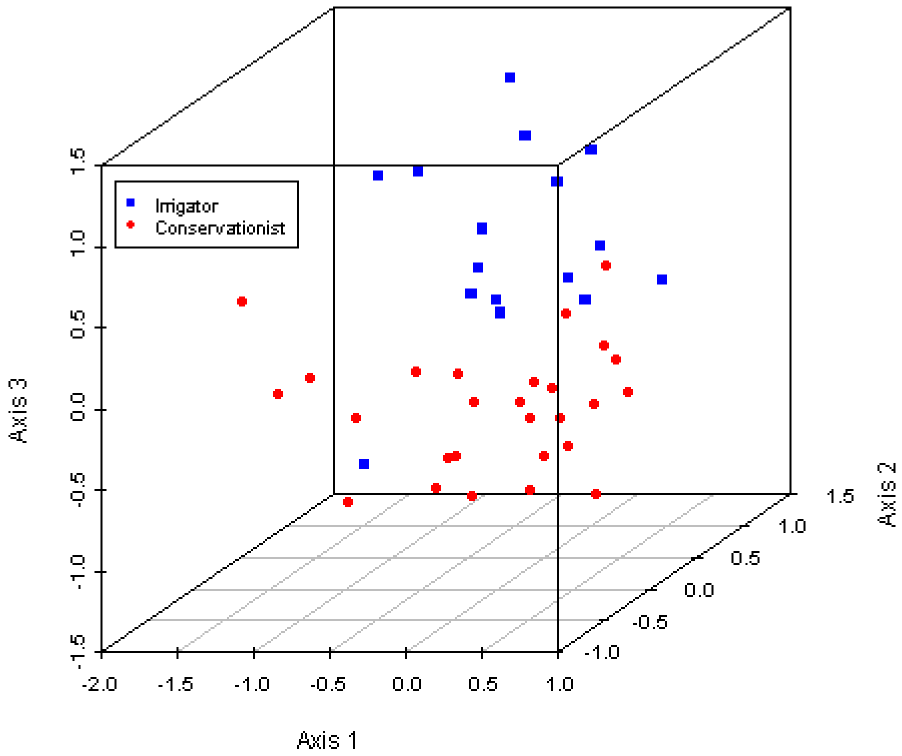


Figure 6. Three dimension plot of the similarities among respondents with respect to their identification of the causes of problems with current flows in the Crocodile River. Plot is the result of Multi-Dimensional-Scaling of similarities. Stress=0.093.

Irrigators and conservationists were in agreement in their identification of some causes but notably disagreed in the identification of others. Stark differences in the frequency with which conservationists and irrigators identified causes due to agriculture as being important were evident with conservationists more likely to see agriculture and irrigators as important problems than were irrigators (Figure 8). Irrigators identified supply side constraints (climate and storage capacity) with a greater frequency than did conservationists. Conservationists identified management issues (poor management from the Kwena Dam, over allocation and management focused on agriculture) with a greater frequency than did irrigators.

[4] The overall group had less than the 2.1:1 ratio between the first and second eigenvalues, and an average knowledge score (shared knowledge of factors causing the problems) of 0.436 or approximately 44% (respondent reliability =0.912). The results for irrigators were inconclusive because of the low respondent reliability coefficient (0.523). The reliability coefficient for conservationists was on the borderline (0.883). As a subgroup, conservationists had an average knowledge score below 0.50 (=0.461) and an almost as high average variability (0.448) suggesting, arguably, that there was no consensus among conservationists regarding the causes of the problems with current flows.

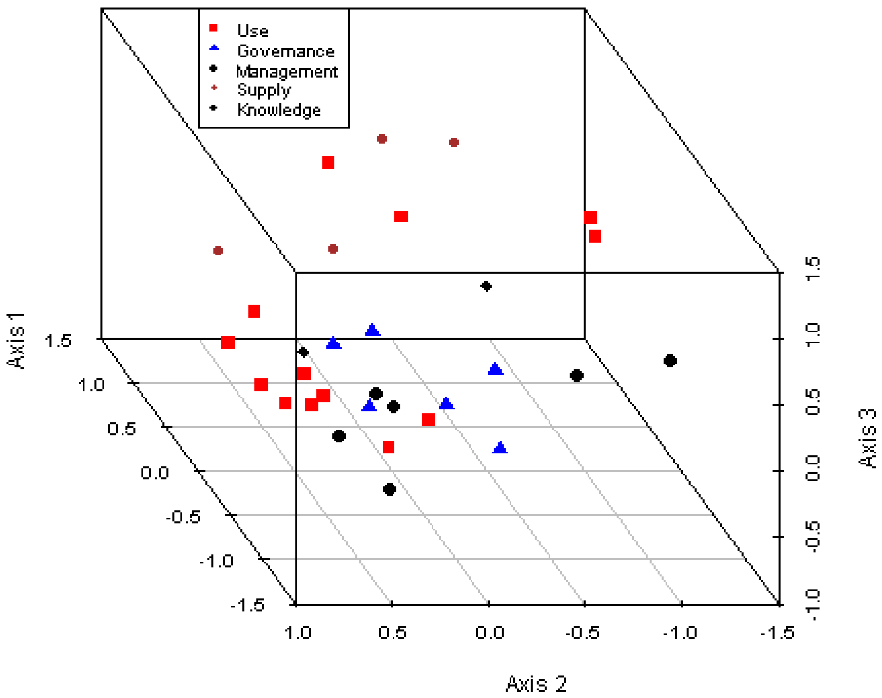


Figure 7. Three dimension plot of the similarities among causes of problems with current flows in the Crocodile River. Plot is the result of Multi-Dimensional-Scaling of similarities. Stress=0.143.

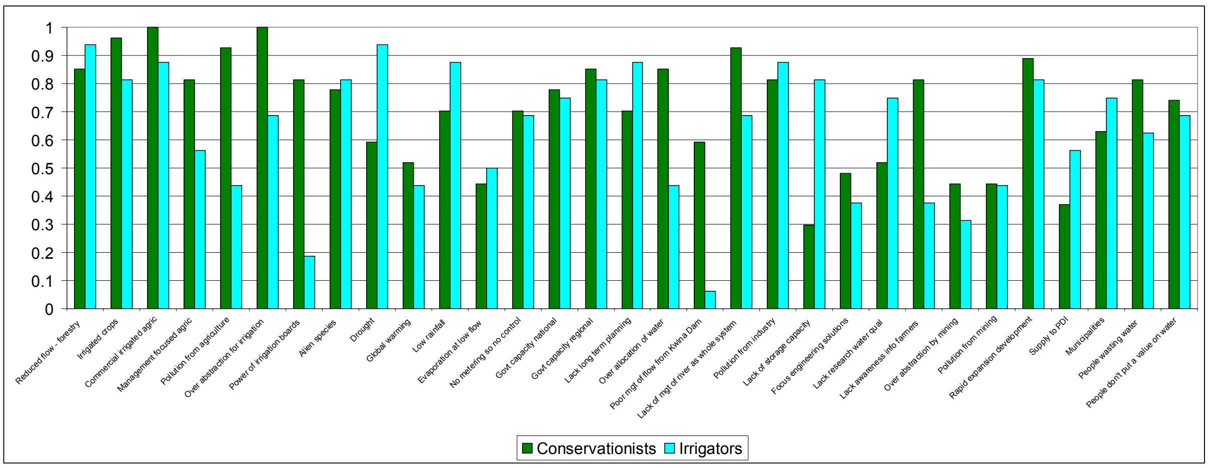


Figure 8. Frequency with which irrigators and conservationists identified each cause of current problems with Crocodile River flows as being important.

Table 4. Results of analysis of freelists of "causes of the problems with current flows in the Crocodile River" showing frequency with which interviewees identified causes, the relative percentage of interviewees who identified that cause, the average ranking of that cause and the salience (Smith's S) of the cause. (N=34).

ID	CAUSE OF PROBLEMS WITH FLOW	FREQUENCY	RESP PCT	AVG RANK	Smith's S
1	ILLEGAL USE	10	31	2.3	0.26
2	LOW RAINFALL	8	25	1.375	0.233
3	FORESTRY	7	22	2.143	0.137
4	COMMERCIAL AGRICULTURE	7	22	2.857	0.125
5	OVER ALLOCATION	7	22	3	0.146
6	KWENA DAM	6	19	2.167	0.153
7	DAMS	5	16	4.2	0.084
8	DEVELOPMENT	5	16	2.6	0.102
9	DROUGHT	5	16	2.4	0.12
10	URBAN AREAS	4	13	4	0.031
11	MANAGEMENT FOCUS	3	9	2	0.069
12	REGIONAL CAPACITY	3	9	5.333	0.039
13	GLOBAL WARMING	3	9	2.333	0.049
14	POLLUTION	3	9	3.667	0.051
15	NATIONAL CAPACITY	3	9	4.333	0.051
16	URBAN GROWTH	3	9	3.333	0.053
17	ALIEN SPECIES	2	6	1	0.063
18	INAPPROPRIATE CROPS	2	6	5.5	0.028
19	MINING POLLUTION	2	6	1	0.063
20	EVAPORATION	2	6	4.5	0.029
21	NO METERING	2	6	2.5	0.038
22	AGRIC POLLUTION	2	6	1.5	0.055
23	WASTAGE OF WATER	2	6	5	0.015
24	AWARENESS	2	6	3.5	0.018
25	LONG TERM PLANNING	2	6	2.5	0.050
26	RESEARCH	1	3	3	0.010
27	OVER ABSTRACTION	1	3	1	0.031
28	IRRIGATION BOARDS	1	3	4	0.021
29	WATER PRICING	1	3	8	0.007
30	ENGINEERING	1	3	6	0.009
31	INDUSTRIAL POLLUTION	1	3	2	0.021
32	GARDEN	1	3	6	0.009
33	PDI SUPPLY	1	3	5	0.006
	Total/Average:	108	3.375		

Theme 3: Consequences of the river not flowing

Analysis of the freelists (Phase I)

A total of 34 different negative impacts were mentioned in response to the question 'what are the consequences of the Crocodile river not flowing?' The consequences mentioned covered a broad range of ecological, social, and economic impacts. The impact on biodiversity was mentioned most frequently, by 30 percent of the people interviewed (see Table 5). It was also perceived as the most salient or important of consequences. This was followed by impact on whole economy (24 percent); on animals (18 percent), and on Mozambicans (18 percent).

Table 5. Results of analysis of freelists of "consequences of the Crocodile river not flowing?" showing frequency with which interviewees identified consequences, the relative percentage of interviewees who identified that consequence, the average ranking of that consequence and the salience (Smith's S) of the consequence. (N=34).

ID	CONSEQUENCES OF CROCODILE NOT FLOWING	FREQUENCY	RESP PCT	AVG RANK	Smith's S
1	BIODIVERSITY	10	30	1.4	0.261
2	WHOLE ECONOMY	8	24	2.625	0.138
3	ANIMALS	6	18	2.333	0.128
4	MOZAMBICANS	6	18	2.167	0.101
5	TOURISM	5	15	3.8	0.075
6	DOMESTIC USERS	5	15	3	0.093
7	EVERYONE	5	15	4.4	0.050
8	ECOSYSTEM	5	15	1.8	0.120
9	FISH	4	12	1.75	0.091
10	DOWNSTREAM	4	12	1.25	0.106
11	COMMERCIAL FARMERS	4	12	4.25	0.060
12	RURAL POPULATION	4	12	3.25	0.061
13	PLANTS	4	12	2.5	0.068
14	LESS WATER	3	9	1	0.091
15	UNEMPLOYMENT	3	9	1.667	0.077
16	KRUGER PARK	3	9	4.333	0.047
17	LESS AGRICULTURE	3	9	2	0.073
18	INDUSTRIES	2	6	1	0.061
19	RIVER	2	6	2	0.040
20	SEDIMENTS	2	6	3.5	0.032
21	INTERNATIONAL	2	6	2.5	0.038
22	DEATH	2	6	1	0.061
23	SOCIAL INSTABILITY	2	6	2.5	0.038
24	WATER RESTRICTIONS	1	3	2	0.027
25	MIGRATION	1	3	3	0.015
26	GROUNDWATER	1	3	6	0.009
27	DAMS	1	3	1	0.030
28	MORALE	1	3	4	0.012
29	EROSION	1	3	3	0.015
30	COMMERCIAL FARMING	1	3	4	0.017
31	LOCAL GOV	1	3	5	0.013
32	PROVINCIAL GOV	1	3	6	0.009
33	INDUSTRY	1	3	7	0.004
34	SANPARKS	1	3	1	0.030
	Total/Average:	105	3.182		

Analysis of pile sorts (Phase 2)

The 43 people who did the pile sorts of the consequences if the Crocodile River stopped flowing generally agreed on (i.e. had high commonality in the measured elements of their mental models) the consequences of the lack of flow in the river.

However the results of the consensus analysis indicated the consensus was not very strong. On average, individual people were in agreement with 65 percent[5] of the elements of the common or group beliefs as to the consequences of flow in the Crocodile River stopping.

The MDS map of the 43 people who participated in the pile sorting exercise of the consequences of the Crocodile River not flowing (Figure 9) suggests reasonable agreement among irrigators and conservationists as to the consequences of the river not flowing. There was a group of irrigators and conservationists who shared, more or less, a mental model of the consequences (i.e. the cluster in the middle of the MDS map in Figure 9).

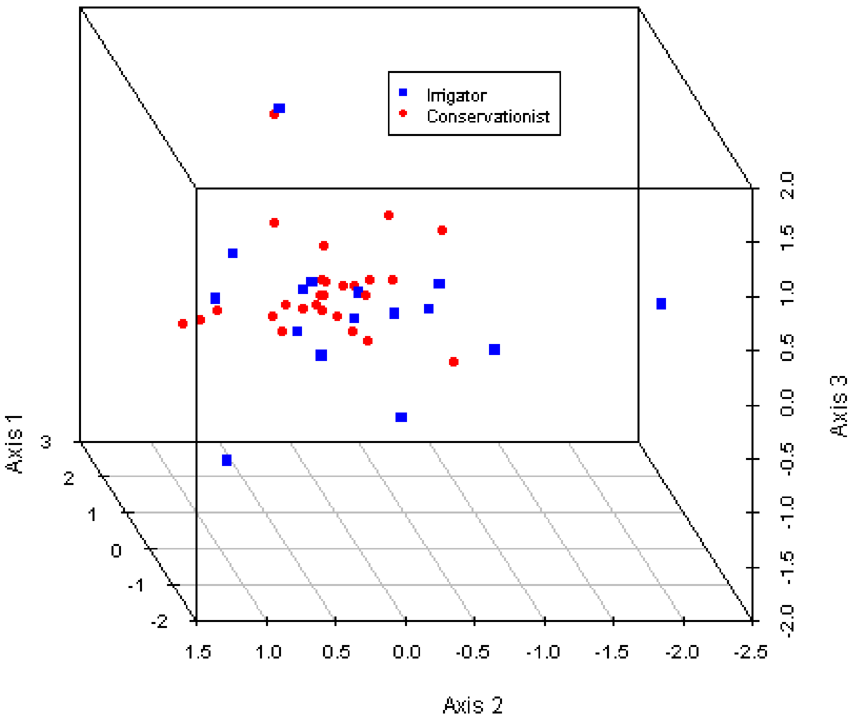


Figure 9. Three dimensional plot of the similarities among conservationists and irrigators as to their perceptions of the consequences of the Crocodile River not flowing. Plot is the result of Multi-Dimensional-Scaling of similarities. Stress=0.132.

The consequences of the Crocodile not flowing were also clearly separable into social, economic and ecological categories (Figure 10).

We also ran MDS and cluster analysis on conservationists and irrigators separately. We found that there was a weak agreement, or mental model, among

[5] Indicated by the average knowledge score of 0.648

conservationists (Figure 11, stress score = 0.128).[6] Most of the conservationists interviewed generally agreed with each other with the exception of two individuals (indicated by numbers 24 and 27 in the MDS map, Figure 111[7]) who had different perspectives from the rest of the group regarding what would happen if the river stopped flowing. Irrigators also seemed to be in consensus regarding the consequences (Figure 12, stress score = 0.122).

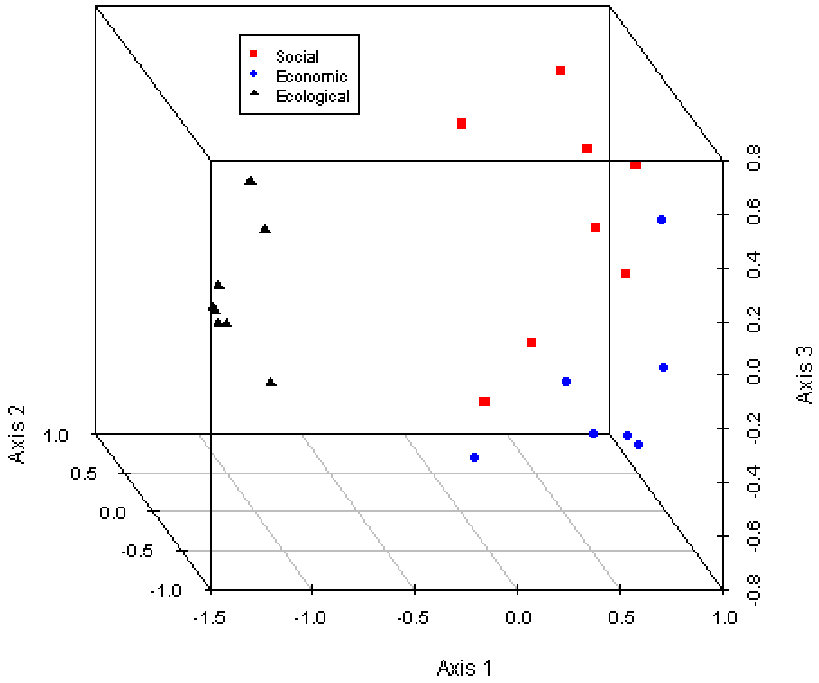


Figure 10. Three dimensional plot of the similarities among consequences of the Crocodile River not flowing. Plot is the result of Multidimensional Scaling of similarities. Stress=0.061.

[6] Respondent reliability coefficient = 0.935; average knowledge score = 0.594 and average variability = 0.395. The ratio of first to second Eigen values of 2.9:1 indicates that there is "weak agreement" (Caulkins 2004).
[7] These individuals had negative knowledge scores in the consensus analysis.

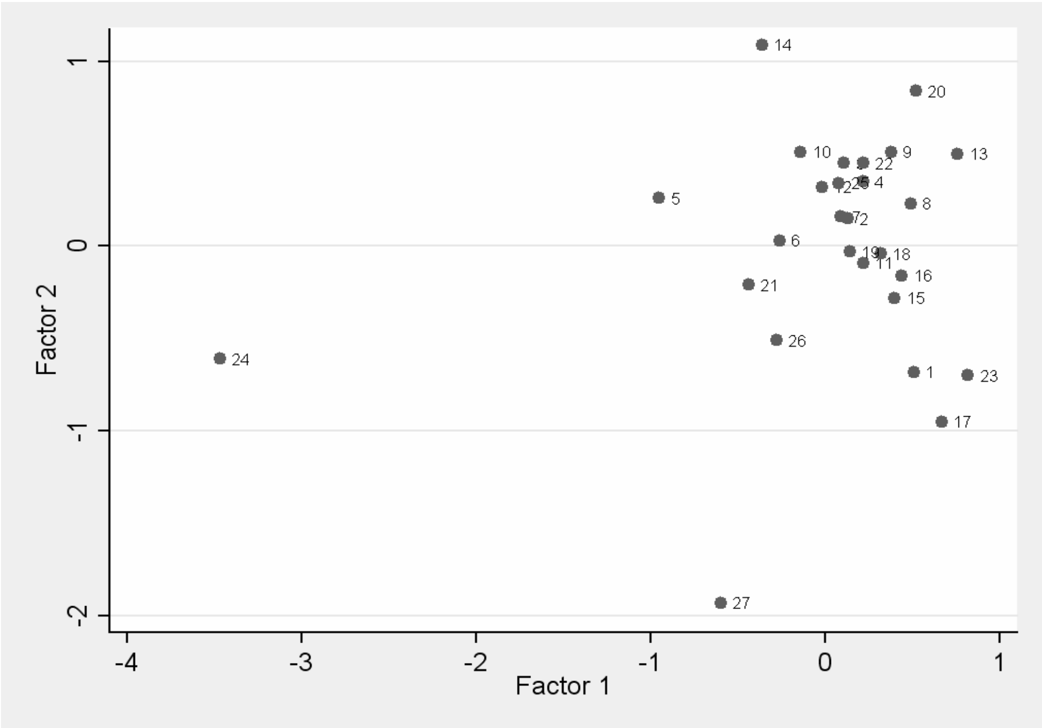


Figure 11. Two-dimensional Multidimensional Scaling (MDS) representation of conservationists according to similarity of pile sorting consequences if the Crocodile River stops flowing.

We also wanted to know if people had pile sorted the consequences into similar piles. Figure 13 shows the MDS representation of the pile sorts of consequences in two dimensions (stress score = 0.100). The consequences circled are those that were found to be grouped together in the cluster analysis (Figure 14). Looking at the horizontal (or x-axis) of the MDS map from left to right, it appears that the consequences clustered on the left side are ecological impacts and, on the right side, socio-economic impacts are grouped together. The vertical or y-axis suggests that the cluster of socio-economic consequences is further broken down into social impacts (top right hand corner) to more economic impacts (bottom left hand corner). There also appears to be a distinction between international social impacts and those that will occur at the catchment level.

Two items – 'less water to us' and 'everyone impacted' – did not group well within the social category. Compared to the other consequences which were very specific, both of these are very broad and potentially vague terms, which may have been open to different interpretations during the pile sorting exercise. Comments from interviewees after the pile sorting exercise about their reasons for piling consequences indicates that people break consequences into these types of categories.

Similar findings were found for irrigators and conservationists separately.[8] In other words, both groups generally pile sorted consequences into ecological and subcategories of socio-economic impacts. The only difference between the two was

[8] Stress scores in two dimensions were 0.090 for irrigators and 0.136 for conservationists.

that irrigators ended to not see 'negative impacts on tourism' as an economic impact but as separate.

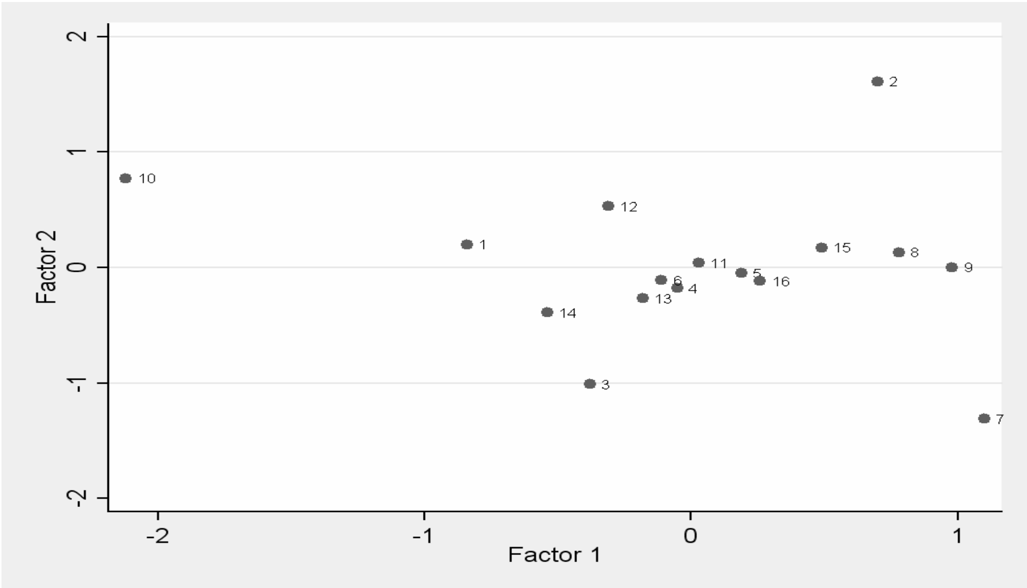
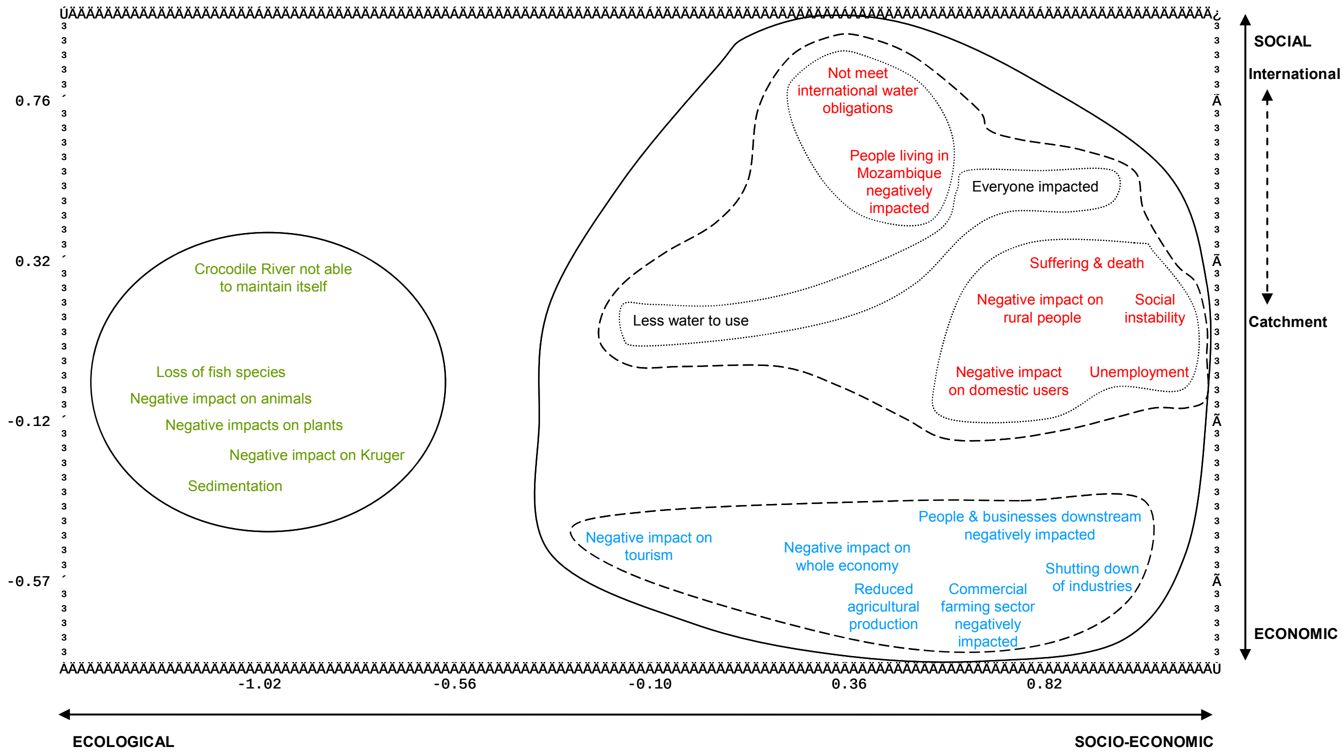


Figure 12. Multidimensional scaling (MDS) representation of irrigators according to similarity of pile sorting consequences if the Crocodile River stops



flowing.
Figure 13. MDS representation of consequences based on how similarly they were perceived by irrigators and conservationists.

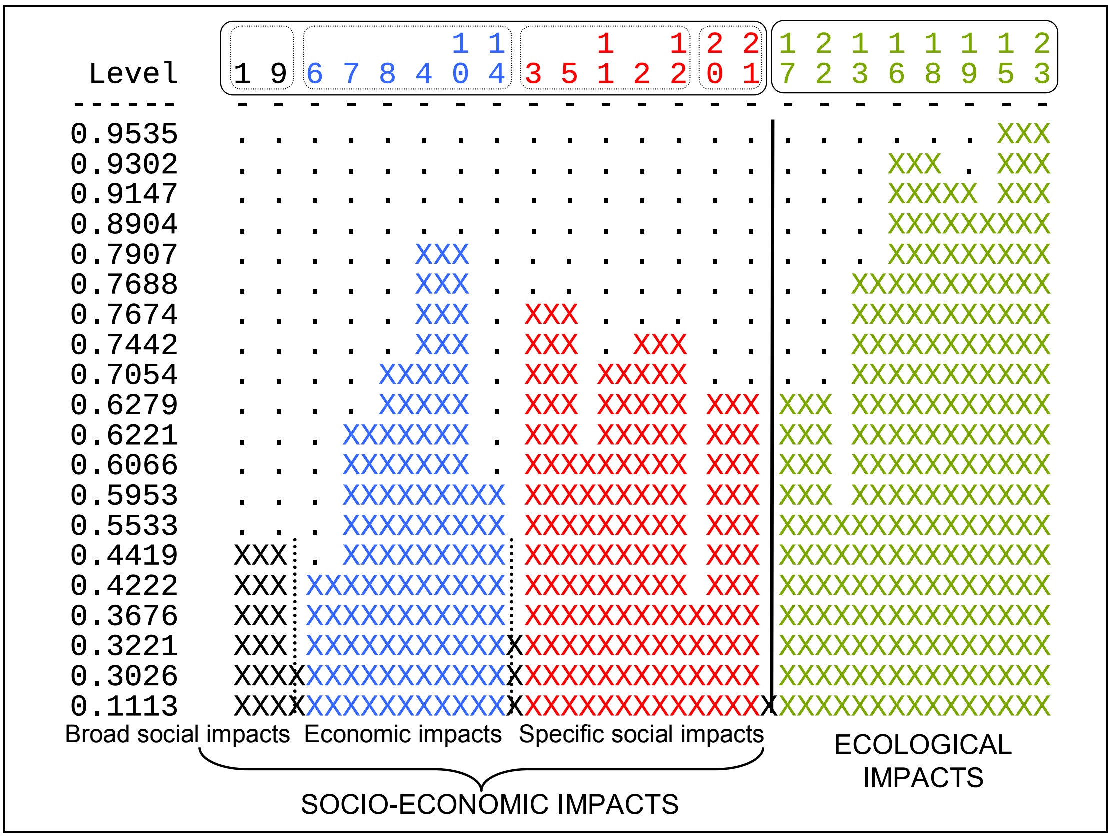


Figure 14. Hierarchical cluster analysis of the consequences of the river stopping flowing. The Level is a measure of the relative distance between concept clusters.

Theme 4: Priorities for future use

Analysis of the freelists (Phase 1)

Over 70 different priorities were listed (the top 40 are presented in Table 6). At the top end, over 40 percent listed basic human needs as a priority for future water use, followed by equity balance mentioned by 34 percent. Water to meet ecological and environmental needs was mentioned by 28 percent.

Table 6. Results of analysis of freelists of "priorities for future water use?" showing frequency with which interviewees identified priorities, the relative percentage of interviewees who identified that priority, the average ranking of that priority and the salience (Smith's S) of the priority. (N=34).

ID	PRIORITIES FOR FUTURE USE	FREQUENCY	RESP PCT	AVG RANK	Smith's S
1	BASIC HUMAN NEEDS	13	41	2.615	0.289
2	EQUITY BALANCE	11	34	4	0.208
3	ECOLOGY AND ENVIRONMENT	9	28	1.667	0.257
4	ECONOMIC DEPENDENCE	6	19	4.833	0.101
5	AGRICULTURE	6	19	4	0.089
6	REALLOCATE FROM AGRICULTURE	6	19	4.5	0.124
7	SHARING	5	16	3.6	0.079
8	INTERNATIONAL OBLIGATIONS	5	16	4.2	0.066
9	POLLUTION	5	16	6	0.068
10	WHOLE SYSTEM	5	16	5.2	0.061
11	CAPACITY	5	16	4.8	0.080
12	INDUSTRY	4	13	6	0.064
13	SUSTAINABLE USE	4	13	2.75	0.086
14	WATER ACT	4	13	1	0.125
15	ENVIRONMENT SUFFERING	4	13	5	0.060
16	EMPLOYMENT	4	13	5.5	0.068
17	MORE CAREFUL UTILISATION	3	9	2.667	0.065
18	BETTER DESIGN AND PLANNING	3	9	7	0.029
19	MORE DAMS	3	9	2	0.084
20	TOWN MUNICIPAL	3	9	3.667	0.067
21	WASTEAGE	3	9	5.333	0.042
22	HUMAN USE	3	9	2.667	0.063
23	COSTS AND BENEFITS	2	6	4.5	0.049
24	ASSESS CURRENT POSITION	2	6	4	0.031
25	DON'T KNOW HOW TO ALLOCATE	2	6	6.5	0.028
26	WATER CONSERVATION	2	6	4	0.044
27	WATER USE EFFICIENCY	2	6	5	0.034
28	MANAGED FOR IRRIGATION	2	6	5.5	0.036
29	GOOD INTENTIONS	2	6	10	0.007
30	CANNOT PRIORITISE	2	6	2.5	0.039
31	ECONOMICS	2	6	3.5	0.046
32	STORE FOR LEAN YEARS	2	6	4	0.040
33	VALUE ADDING	2	6	2	0.052
34	RESERVE	2	6	1.5	0.059
35	INEFFECTIVE GOVERNANCE	2	6	6.5	0.026
36	DEMAND POPULATION	2	6	5.5	0.037
37	DIFFERENT SECTORS	2	6	6	0.026
38	FARMERS STEALING WATER	2	6	8.5	0.017
39	FORESTRY NEGATIVE	2	6	8	0.030
40	MOZAMBIQUE NOT GETTING	2	6	7.5	0.023
41..77	…..	….	….	….	….
	Total/Average (for entire data set of 77 items)	187	5.844		

Analysis of pile sorts (Phase 2)

As in the case of the responses to the questionnaire on water users and causes of current flow problems, it was not possible to draw any definitive conclusions regarding the extent to which irrigators and conservationists (either as a whole group or as separate groups) had shared mental models of priorities for future water use.[9] We also mapped the priorities, using MDS and cluster analysis, to see if irrigators and conservationists had piles sorted them similarly, but these analyses did not enable us to identify any clear patterns (Figure 15). Whilst there appears to be considerable overlap in the views of conservationists and irrigators as to future priorities with the very large list of priorities it was not possible to identify statistically whether or not these were sufficiently similar as to warrant being deemed the same. There was likewise no discernable pattern in the grouping of priorities themselves (Figure 16).

For conservationists, however, the MDS map and cluster analysis results suggest that conservationists distinguished among priorities. They tended to pile sort priorities focused on water management for conservation or sustainability together and water management for human activities in another group.

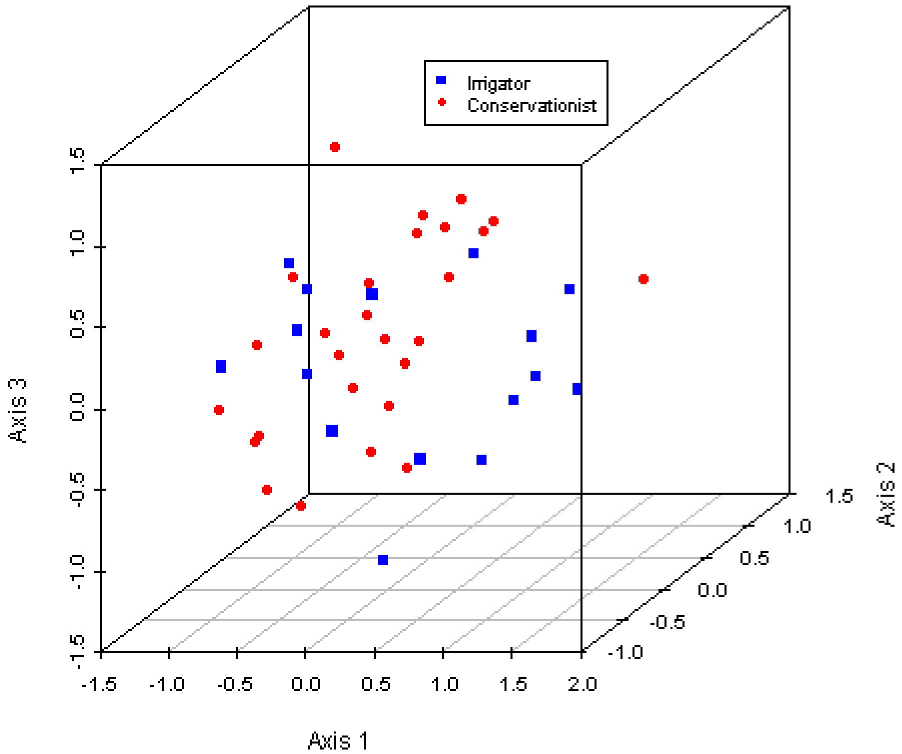


Figure 15. Three dimensional plot of the similarities among irrigators and conservationists views of future priorities for the Crocodile River. Plot is the result of Multidimensional Scaling of similarities. Stress=0.202.

[9] Respondent reliability coefficients were: 0.410 for the group as a whole, -2.895 for irrigators, and -0.159 for conservationists.

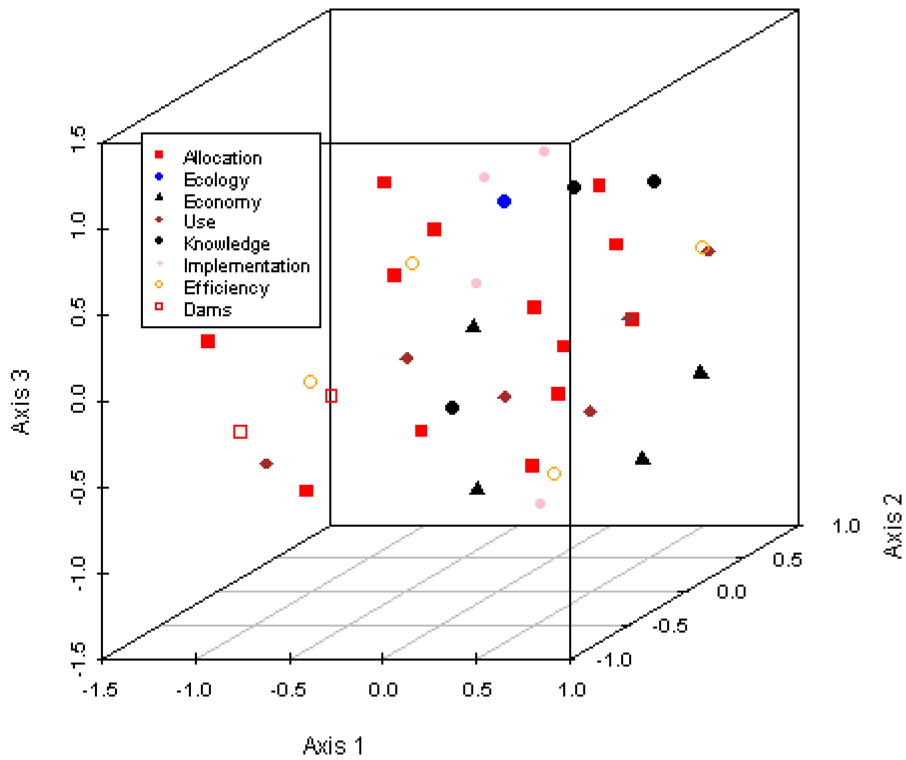


Figure 16. Three dimensional plot of the similarities among future priorities as seen by irrigators and conservationists. Plot is the result of Multidimensional Scaling of similarities. Stress=0.182.

4.1.4. Summary of Consensus Analysis results

The Consensus Analysis focused on comparing the mental models of two groups; conservationists and irrigators with respect to: a) Who the major users of the Crocodile River were; b) What the causes of the current problems with flows in the Crocodile River were; c) What the consequences of the river not flowing would be; and d) What the priorities for future use should be. For each of these factors we looked at the degree of consensus between and within the irrigator and conservationist groups using Consensus Analysis, Multidimensional Scaling (MDS) and clustering. We also used MDS and cluster analysis to identify patterns in the factors or items themselves.

For the major users of the Crocodile River there appeared to be general agreement between conservationists and irrigators although the statistical tests were not unambiguous. Commercial farmers, industries, forestry, urban areas and mining were identified by the majority of respondents as major users.

With regards to the causes of current problems with flows the conservationists and irrigators did not hold the same beliefs or mental models. This is an important difference with implications for how these groups seek to solve the problems (either directly through actions or through lobbying). It would be important to establish a common and accepted understanding of causality that was shared by both groups as a basis for problem solving action.

For the consequences of the Crocodile River not flowing irrigators and conservationists held similar mental models that grouped social, environmental and economic consequences similarly.

For the future priorities of water use the analyses did not yield unambiguous results. Given the lack of consensus around causes this is not surprising.

The differences in mental models of the causes of problems in the flows of the Crocodile River identified through the Consensus Analysis suggest an important area for action research in the future to build the common understanding required for sustained and broadly supported action aimed at solving problems with current flows.

4.2. Method 2: The ARDI method

The use of simulation models in collective decision making for the management of natural resources is one of the characteristics of adaptive management (Holling, 1978; Walters, 1986). However the use of these models to stimulate the participation of stakeholders in the development of management scenarios is much rarer (Costanza and Ruth, 1998; Bousquet et al., 2004). The progressive shift from management plans based on an authoritative or rationalist model towards tools for mediation based on a democratic model (Chauvin, 2002) forms the basis for the emergence of new tools of co-construction and sharing of information such as the ARDI method that was tested during the Crocodile River research process that is the subject of this report.

Following a series of methodological tests implemented on complex case studies or in conflict situations (Etienne, 2006; Levrel et al., 2008; Etienne et al., 2008), a companion modelling approach that accommodates stakeholders in the definition of a land management plans was developed. It proposes to help to imagine a more open, dynamic management, capable of adaptation and anticipation, by gathering the various actors in a partnership, based on correct scientific information and real cultural creativity. Its innovation lies in the work of co-construction of a “conceptual model” of the operation of a territory, based on shared points of view on the current situation and on confronting opinions on probable scenarios of evolution in the years to come.

The approach is based on a mutual comprehension of the key elements of the territory between various stakeholders: structures of management, elected officials, socio-professional, associations, experts and scientists, administrations. This sharing of representations is done by means of a series of collective workshops during which Actors, Resources, Dynamics and Interactions (ARDI) are identified and clarified. This work of co-construction is done within a precise methodological framework leading to the development of scenarios.

As with the Consensus Analysis, the ARDI method in the context of this study takes the outcomes to be representations of elements of human ‘mental models’ that exist at a particular place and point in time. In the case of this work the focus of the co-construction was the socio-ecological system of the Crocodile River Catchment.

The ARDI approach has particular logistical requirements that are important for the successful application of the method. Each meeting must be at least two hours in duration and the participants must remain centred on the task. The ideal is to connect all the workshops corresponding to one specific step over one period not exceeding one month but that can take the shape of a 2½ day workshop, one half-day per week for a month or three separate days over ten days. The workshops are generally led by two people: a facilitator and a scribe.

The first part of the companion modelling approach consists, through the ARDI or similar method, in collectively identifying the principal stakeholders concerned with the tackled question, their management responsibilities, the resources used and the main processes driving changes on these resources. With this intention, the group which takes part in the co-construction of the model must answer the following questions:

- Who are the main stakeholders involved in or whose duty it is to play a decisive part in the management of this territory?
- What are the principal resources of the territory and what key information is needed to guarantee sustainable use of the resources?
- What are the main processes that drive strong changes in resources dynamics?

> ARDI
>
> This technique takes its acronym from its sequence of elicitations:
>
> A = actors (i.e. stakeholders)
>
> R = resources (that stakeholders use, or that in any way drive or influence the outcomes)
>
> D = dynamics (i.e. processes)
>
> I = interactions (i.e. how the elements influence each other – what causes what?)

The individual or group goes through the three questions and elaborates lists for each. To facilitate sharing mental models and representations, the answers to the questions are formalized into easily comprehensible lists of words, with a minimum of coding making it possible to classify the information.

The next step of the ARDI method consists of making a synthesis by stressing the interactions between users and resources. It is a crucial part of the exercise since it will lead to the holistic conceptual model representing interactions related to the tackled question. It is advised to devote more time to this exercise.

After completing these four steps (ARDI) the conceptual model (mental model) is established. Two options arise: a) to work out a proposal for management of a resource based on the conceptual diagram, or b) to use it as a dialog tool. In the first case, the reflection will be focused on the territory and its priorities for implementation or research. In the second case, the reflection will relate to the implementation of a computer model or a role-playing game to help stakeholders to transport themselves into the future and imagine adaptive co-management scenarios. This allows for the collective discussion of how the system might best be managed. The reader may be interested in knowing that companion modelling has been widely applied internationally by the French group who developed it, mainly for mediating conflict around the following issues: irrigation water; the impact of agriculture or forestry; land uses between farmers; organisation of particular product markets; or multiple land use. No companion modelling was performed during this initiative.

Overall, ARDI and companion modelling thus contribute towards people doing the following:

- thinking about how they plan the use and management of their resources
- being explicit about their objectives
- being clear about spatial dimension of their activities
- being transported into possible futures and imagining consequences of decisions
- It is particularly strong on joint buy-in, or sharing, thus allowing people to
- share representations of the structure and dynamics of a system at a locality
- be sensitised to interactions that they may not have previously considered
- understand other stakeholders' perspectives
- negotiate
- allow stakeholders to experience without real risk
- collaborate on future action

4.2.1. The ARDI method in the context of the Crocodile River Catchment

In the context of the process reported here time constraints did not allow the working group to cover all the steps for the companion modelling. However the aim was to test the ARDI framework in the realm of integrated water resources management as set out in the NWA.

Nine participants were selected to, as far as possible, represent the broad range of stakeholders for the drafting of individual mental models and 10 participants formed part of the group involved in the collaboratively constructed mental model. In both individual and group sessions, participants focussed on the following two questions:

- What do **you** think about **water resource** use and management in the Crocodile Catchment?
- What is driving change in the **flow** of the Crocodile River?

Thinking about these, they then went through the four-step ARDI process by answering the following questions:

- What are the main **stakeholders** that interact with the river and its flow?
- What are the main **resources** of the catchment in relation to water flow?
- What are the main **processes** that drive changes in the Crocodile Catchment that affect the river flow?
- How does each stakeholder use the resource and modify the processes?

In the individual ARDI iterations, nine persons were each interviewed for one to two hours, working through the process and background questions above. The Group session took approximately two hours which was unfortunately inadequate to complete the conceptual model entirely. However the aim of the team was to understand the process and procedure and conduct and initial assessment of the method in the context of IWRM in the Crocodile Catchment.

4.2.2. ARDI method results

The ARDI method is less concerned with a conventional quantitative analysis of data than with developing a framework that can be used to interrogate understanding and provide a tool for decision making. We present here, for purposes of interest and discussion, some issues emerging from the raw data for each of the four key areas.

Step 1 analysis: Analysis of the responses to the four key ARDI questions

Key area 1: Stakeholders/actors

Altogether 20 different stakeholders or actors were identified for the Crocodile Catchment. Industry, municipalities and irrigation farmers are most frequently mentioned as key stakeholders, followed by forest companies (Table 7).

Table 7. Frequency with which stakeholders were identified by respondents in the ARDI process.

Stakeholder	No. of times identified
Industry	10
Irrigation farmer	9
Municipalities	9
Forest companies	8
DWAF/CMA	7
Rural community	6
Kruger Park	5
Commercial farmer	4
Tourists	4
Developer	3
Mozambique	3
Conservation bodies	2
Subsistence farmer	2
Tourism operator	2
WUA/IB	2
Brick maker	1
Emerging farmers	1
Land owner	1
NGO	1
Retailer	1

Key area 2: Resources

Twenty six resources were identified altogether. The most commonly identified resources in the catchment were surface water, dams and water-life were most commonly cited as resources in the catchment (Table 8).

Table 8. Frequency with which resources were identified in the Crocodile Catchment.

Resources	Number of times identified
Surface water	8
Dams	6
Water life	5
Irrigation water	3
Riverine life	3
Wetlands	3
Climate	2
Drinking water	2
Sand	2
Scenic beauty	2
Sediments	2
Weirs	2
Agricultural land	1
Alien vegetation	1
Boreholes	1
Domestic water	1
Farmed animals	1
Fish	1
Grass	1
Hydroelectricity	1
Morphology	1
Operating rules	1
Recreation	1
Reed	1
Residential land	1
Vegetables	1

Key area 3: Processes and dynamics

Forty processes were identified as affecting the flow in the Crocodile Catchment with human population increase foremost, then a tie between sediment load, tourism development and developments in crop markets (Table 9).

Table 9. Frequency with which respondents identified the processes operating in the Crocodile Catchment.

Process	Number of times identified
Population increase	7
Crop market	4
Sediment load	4
Tourism development	4
Alien vegetation invasion	3
Chemical modification	3
Drought	3
Stream flow	3
Water rights reallocation	3
Biodiversity laws	2
Climate change	2
Dam construction	2
Forestry development	2
Life support	2
Nutrient leaching	2
Soil erosion	2
Water abstraction	2
Economic development	1
Efficiency of crop irrigation	1
Efficiency of water supply network	1
Fish dynamics	1
Flow regulation	1
Grazing pressure	1
Industry increase	1
Maximization of agricultural profit	1
Overdevelopment	1
Planning for drought	1
Power delegation	1
Property market	1
Property redistribution policy	1
Rain storms	1
Rainfall fluctuations	1
Resource management competency	1
Sewage flow	1
Storage facilities development	1
Stream flow	1
Water demand by PDI	1
Water heating	1
Water purification	1
Evaporation	1

Figure 17 deals with ways stakeholders believed one might back one's own assertions in order to convince other stakeholders of the validity of their own claims. This particular analysis comes from the notes taken by the secretary during the co-construction of the conceptual model. Each argument is developed by the stakeholder to support a particular point of view according to six justification categories mentioned by Boltansky and Thevenot (1999). It was interesting to the group that "science" played such a predominant role – this may relate to the way in which science was used throughout the development of the National Water Act, and simply also be because it is one common denominator in the very heterogeneous society of the Crocodile Catchment.

Processes	Iterations
biodiversity laws	2
climate change	2
forestry development	2
nutrient leaching	2
stream flow	2
water rights reallocation	2
chemical modification	2
drought	3
sediment load	3
tourism development	3
crop market	3
population increase	7

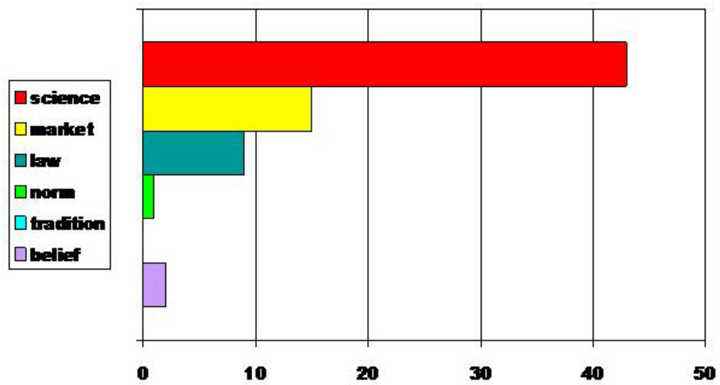


Figure 17. Stakeholders ways of justifying assertions.

Key outcomes of Step 1

The key outcomes of the first step are a series of systems diagrams that participants constructed based on their understanding of the four key areas (Actors, Resources, Dynamics, and Interactions). These visual representations are taken to be elements of the 'mental models' of how a participant understands the system to function. The ultimate aim of this method is for participants from different sectors/groups/institutions to collaboratively construct (co-construct) a visual representation of how the system functions so that they can collectively use the tool to test various management options (through computer modelling, deliberation and negotiation of trade-offs).

The major effort of the research team was to test the process of drafting, firstly, individual mental models and, secondly, a collaborative model for a group of water users and managers. The team saw this as an opportunity to test and learn about such an approach in the complex and dynamic field of water resources management and water law implementation.

Three illustrative ARDI representations resulting from individual interactions with participants are presented (Figure 18). The identities of the participants and their institutions are not indicated for purposes of anonymity. The remaining models differed in many ways but these three have been chosen in an attempt to demonstrate the diversity.

- Utilitarian view (Figure 18) from a commercial-production-agricultural stance in which ecosystem health plays a small indirect role (only via 'non-consumptive users'). The consideration is what the river can provide in terms of flows and storage

- Survivalist view (Figure 19) from a near-subsistence point of view considers what the river can provide, also competition between different types of producers. Broad understanding of what the resource provides and the interactions of groups with it.
- Administrator or consultant (Figure 20). The complexity of the mental model emerges from a concern with the technical processes of allocating water. Highly connected and complex, broad diversity of issues, processes and institutions, sophistication of meaning. Focus on management and institutions.

It is interesting to note how elements of the individual models are influenced by the groups/institutions/ sectors from which they originate. The method however does not establish whether actual practices are influenced by the meanings that people hold.

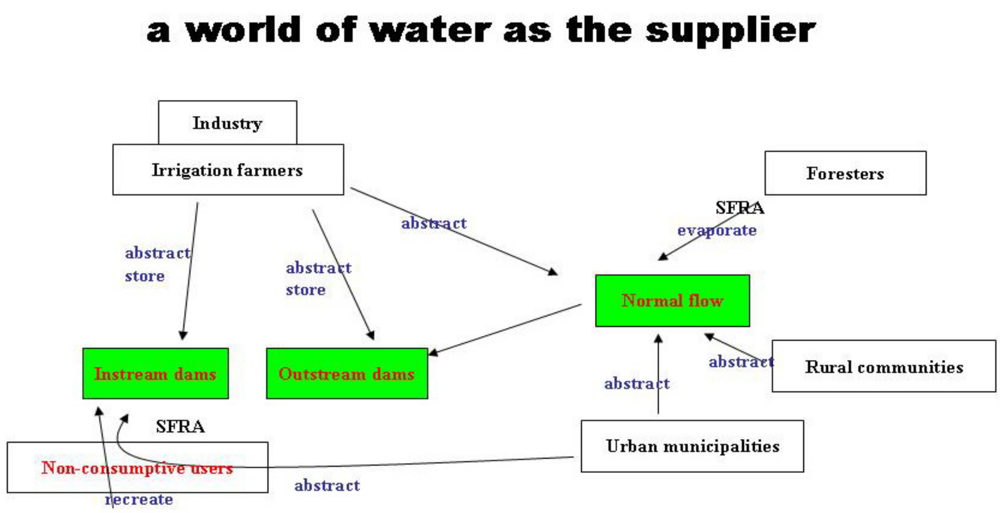


Figure 18. Representation of elements of a commercial agricultural production actor's mental model. The white boxes represent actors, the green boxes resources and the arrows relationships. Red writing means that the participant changed his or her mind during the process

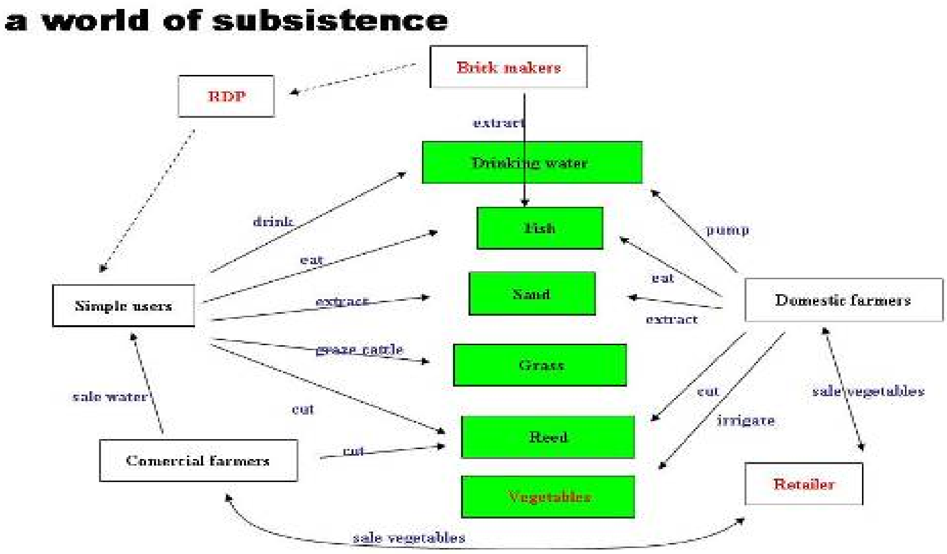


Figure 19. Representation of elements of a near-subsistence actor's mental model. The white boxes represent actors, the green boxes resources and the arrows relationships. Red writing means that the participant changed his or her mind during the process.

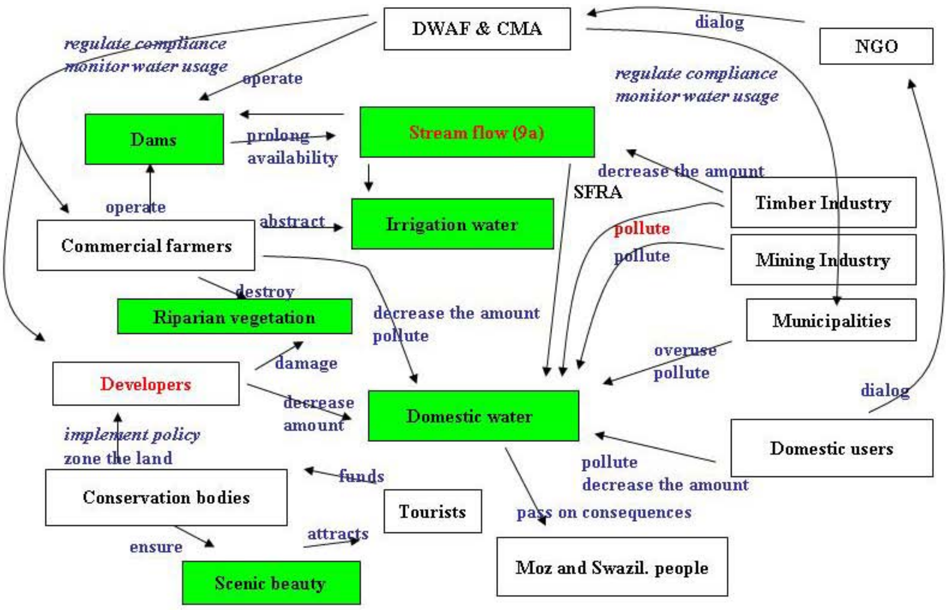


Figure 20. Representation of elements of an administrator or consultant's mental model. The white boxes represent actors, the green boxes resources and the arrows relationships. Red writing means that the participant changed his or her mind during the process.

4.2.3. Group representation

The group mental model was attempted towards the end of the ten-day period and could unfortunately not be completed because of time constraints. A number of logistical lessons were learnt from the collaborative drafting process. The key ones were that the process takes time and that participants need to be well briefed on what the process involves. The process as arranged proved to be over-demanding; nevertheless it was valuable for the research team members to see how such a session was run in practice.

The incomplete group model is depicted in Figure 21. It is interesting to note that elements of individual mental models are present in the group mental model to varying degrees. Whether this is a product of power dynamics, skewed water allocations, socio-political forces etc warrants further analysis.

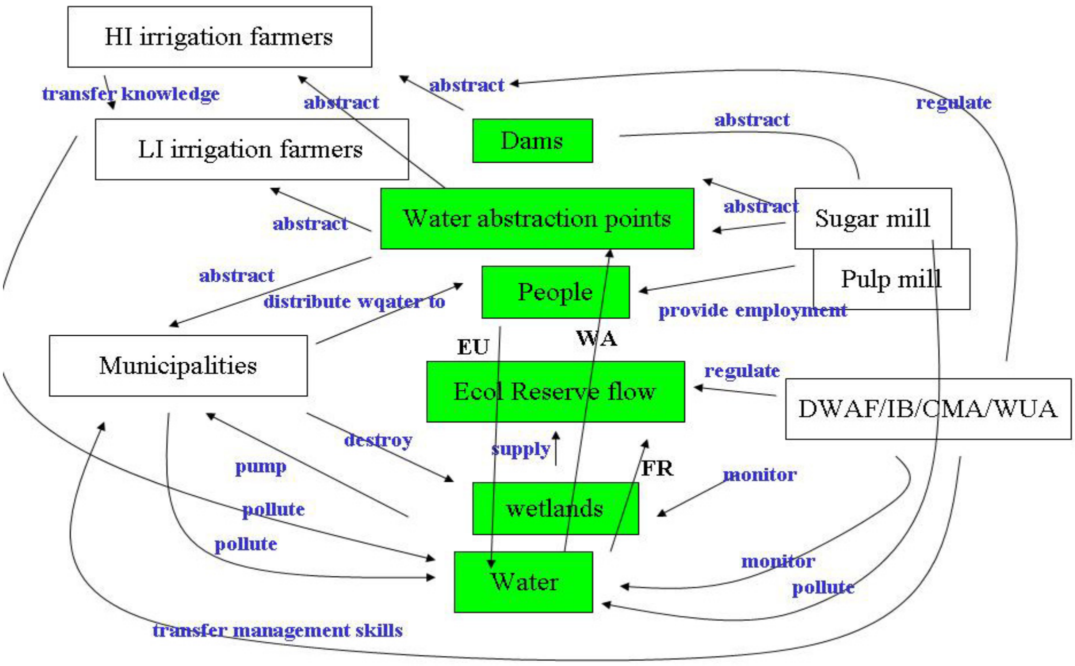


Figure 21. Provisional (incomplete) representation of elements of the group mental model. The group comprised actors who had been involved with the development of individual models as well as additional people from the same sectors. The white boxes represent actors, green boxes resources and the arrows relationships. The bold acronyms locate the key processes (WA for water abstraction, EU for eutrophication, FR for flow regime). HI and LI represent high intensity and low intensity.

Step 2: ARDI method and computer modelling

The second step of the ARDI method is aimed at using the systems diagrams that participant construct to generate models that show how management decisions will affect the resource over a series of iterations (say 5, 10 and 15 years). The research team was unable to perform the second step of the ARDI method in any detail. A preliminary computer simulation was prepared and run for the two feedback sessions to demonstrate how changes to land uses would affect the river flow over a number of interactions.

5. Evaluation of the methodologies against the objectives

5.1. General comments on the two methods

In the following section we evaluate the two methods from a general perspective and in relation to the principles of the National Water Act, specifically that of sustainability (i.e. the Ecological Reserve). Comparisons of the methods must be made in the context of the project as well as the design purpose of the methods.

The suite of analytical methods associated with Consensus Analysis were designed to explore the degree of similarity of concepts (whether objects, relationships or dynamics) in a domain across a group of individuals believed to hold some knowledge or beliefs of that domain. CA is therefore a descriptive tool set or one that can be used to derive explanations of observed social interactions. The ARDI method was designed to build consensus. ARDI is more of an action research tool designed to build a common understanding among members of a group. The two methods therefore have quite different purposes and we might therefore expect them to have strengths and weaknesses associated with their purpose. One might for example ask whether the representations generated through the ARDI process emerged from the process – this may be more about espoused theories than theories in use in the sense of Argyris and Schon (1978). Whilst we suspect that the Consensus Analysis method would generate elements of more deeply held beliefs or theories in use we do not have evidence to support this expectation.

Both methods provide opportunities to represent the way that both individuals and groups understand aspects of how water resources are used, engaged with and managed. Whilst the CA method relies on selecting specific questions and the responses to these questions, ARDI focuses on four key aspects of water resource use, management and interaction. Although the methods are different in procedure they rely heavily on the use of language for the articulation of the mental model. This means that in areas such as the Crocodile Catchment - with a diversity of languages - there is a need for participants to express themselves in their mother language. The CA method can be used to prepare mental models that can be compared within and across institutions, organizations, and groups. This is useful for determining the level of consensus that exists regarding a particular issue. ARDI on the other hand, seeks to use understandings of the current situation to develop a future consensus or vision. The strengths and challenges of both methods are summarised in Table 10.

There were significant logistical challenges in running the two methods in parallel. The value of running both methods in parallel needs to be questioned in future applications.

These challenges included:

- Having to 'share' the available interview candidates between the two methods in the most sensible way. Consensus analysis may require quite large samples for the two stages. The actual pool of people or the total population in some sectors in the Crocodile River was quite small. Thus having to split this population across two methods reduced the available sample for the CA approach.

- Differing sampling requirements of the two methods placed additional demands on the team. In the case of consensus analysis the same people should not be sampled in the second step as were interviewed in the first step. In the ARDI second step of group model building the same individuals should be present.
- Because of the length of each "interview" in the ARDI method fewer people could be interviewed thus the sample sizes, in the first or individual steps, would be smaller. This can be corrected for in the second or group modelling stage.

Table 10. Strengths and challenges of CA and ARDI as tools to understand mental models.

Consensus Analysis	ARDI
Strengths	
•Enables rigorous quantitative analysis •Can elicit without influencing mental models •Useful to identify all aspects of mental models (objects, relationships, behaviours, valence, characteristics) •Facilitates identification of bridging issues and potential conflict areas	•Allows a diversity of understandings to be articulated in a non-judgmental way •Provides a visual representation of how system is constituted and functions •Provides an opportunity for various stakeholder groups to grasp the diversity of understanding •Useful for stakeholders to understand the consequences and the effects on the system of a particular management decision through companion modelling exercise •Useful to develop a shared vision for management of a resource
Challenges	
Preparation for fieldwork •Significant knowledge of and relationships with stakeholders required •Engagement and preparation with stakeholders required •Ensure careful wording of questions (one question per mental model) *Interview processes (phases 1 and 2)* •Lengthy individual interviews with many people •Time consuming to record and transcribe interviews •Needs time to reflect and prepare between stages •The need to sample adequately, i.e. sampling sufficiently in phase 1 until either 'saturation of ideas' i.e. no new issues appear, or identification of a core set of items that people seem to agree on. *Data analysis process* •Requires significant technical skill and time *Communication of data results* • Complex outputs require careful explanation	*Preparation for discussion sessions and drafting systems diagrams* •A basic level of familiarity with stakeholders and context is required to select participants *Discussion sessions* •Lengthy individual and group discussion sessions to elicit mental model of system •Facilitator and recorder require skills •Participant needs to be at ease and not concerned about providing 'correct' answers •Individual interviews can be stressful for some •Participant needs to understand the context of the process *Data analysis process* •Time required to process responses into visual format *Communication of data results* •Complex outputs require careful explanation

5.2. Utility of the methods for water resources management

An important question was the usefulness of the methods to identify and represent elements of the mental models of individuals or groups in relation to the structure and dynamics of the interactions between people and the Crocodile River system, in the context of compliance with the provisions of the Water Act.

The following criteria were used by the team to evaluate the methods with respect to water use and management:

- Did they reveal issues related to sustainability?
- Did they help understand how people view the Reserve as a tool?
- Did they help us understand perceptions of why there is non-compliance?
- What are the possibilities for feasibility and replication? (Considering cost, stakeholder fatigue; language, literacy, diversity, comprehensiveness, values)
- How representative are the processes?
- How inclusive are they?

The criteria were used to assess if the methods assisted with (a) understanding peoples' mental models of sustainability and (b) more specifically, if we could explore factors that enable or constrain compliance with the legislation that is designed to achieve sustainability in South Africa, namely the Reserve. We also comment on issues of feasibility.

5.2.1. On sustainability and the Reserve

In the case of CA, the team did not ask explicitly about either sustainability or the Reserve but rather explored mental models associated with users, causes of problems with current river flows, the consequences of no-flow, and priorities for future use. Because the approach was not implemented to explicitly explore mental models associated with sustainability or the Reserve evaluations against these criteria are somewhat problematic. Never the less we can use the data from the CA to explore issues of sustainability if we assume a set of factors or conditions that would enhance sustainability are met:

1. There is consensus among stakeholders as to the goals, objectives and values for managing the set of resources or the system and the consensus view is of a socially, economically and ecologically sustainable system;
2. There is consensus among stakeholders as to the current state of the system relative to the goals or objectives;
3. There is consensus among stakeholders as to the causes of failure to achieve goals or objectives;
4. There is consensus among stakeholders as to the actions that need to be taken to address the major causes of failure to achieve goals or objectives and these actions are taken;
5. There is consensus among stakeholders on the need for effective monitoring and evaluation to establish the effectiveness of the actions taken to achieve the stated goals and where needed there is consensus among stakeholders on corrective actions to take.

This model of sustainability assumes that cause-effect relationships are knowable and repeatable. The proposed model advocates a consensual approach which is consistent with the Water Act. It assumes that whilst a degree of disagreement is important to maintain the vitality of the system where conflictual differences persist, these may inhibit the achievement of sustainability.

We did not directly use CA to establish whether or not there was a consensus set of goals, objectives or values associated with the Crocodile Catchment. However the lack of consensus around future priorities for use suggests (but is not conclusive) that there was not a consensus goal or set of objectives for the Crocodile Catchment among the stakeholders that took part in this research. In future applications of the method in this context it would be important to establish the goals or objectives of each group and to identify the degree of consensus among groups as a first priority.

We did not directly attempt to establish the degree of consensus around the current state of the system in relation to goals. Rather it was assumed there were problems and the questioning sought to identify causes of problems rather than the extent to which there were problems.

The CA did enable us to identify a lack of consensus as to the causes of current problems with flow. The lack of consensus here suggests a reduced likelihood of sustainable use. It would be important for the CMA to achieve consensus among stakeholders as to causes to enhance the likelihood of sustainably achieving goals. In particular CA enabled us to identify specific patterns of causal attribution among stakeholder groups (e.g. Figure 11). These could form the basis of a process for developing, through ARDI type modelling or evidence based analyses, consensus as to causality.

We did not directly explore consensus around the actions believed likely to achieve desired outcomes. However, the lack of consensus around causes and future use suggests consensus around the means needed to achieve the (unclear) goals would be unlikely.

Thus although not directly addressed the CA approach did provide insight into sustainability issues if one accepts as valid the stated model of sustainability and its assumptions.

With regard to the Reserve the CA results did provide clear insights; there was not a general agreement that ecosystems were an important user of the water in the Crocodile Catchment. There was however, general agreement on the negative impacts on ecosystems of the river not flowing. There was not a general agreement on the need to take actions to address the Reserve in the future although issues associated with allocation were commonly noted and do suggest that resolving allocation problems are high on the list of stakeholders' priorities. Thus although not directly addressed by the CA method the approach did provide insights into issues associated with the Reserve. These preliminary analyses suggest that relative to other uses the Reserve is a lower priority for many or it is perhaps not well understood. These insights provide useful messages for those developing the catchment management strategy for the Crocodile; was the fact that stakeholders did not perceive ecosystems as important users due to a lack of understanding or due to a lower value placed on ecosystems relative to other users? The former is a problem more likely to be amenable to resolution than is the latter.

Many of the ARDI assessment's systems diagrams provided insight into sustainability through showing how stakeholders and resources interact. Drivers of the system, as understood by different stakeholders, become clear, as does the way in which they understand the system to function. As with the CA, the ARDI method provided a spectrum of systems diagrams for a number of different sectors/stakeholder groups.

By conducting an analysis of the diagrams, a sense of what drives water management choices might be obtained.

The over arching aim of ARDI is to provide a tool that will help different stakeholder groups work collaboratively towards more sustainable management choices. Time constrains prevented the team from completing the companion modelling activity. ARDI indicated that in general people were familiar with the Reserve as a tool, but individual detailed understanding was often limited. Occasionally, an understanding of non-compliance with the Reserve was tangentially elucidated, but it would not seem that the ARDI technique (used as it was in this study) is a good immediate way of understanding this. Although it was (and could potentially be very) representative and inclusive, the levels of input and collaboration needed on the parts of all parties would have to be carefully weighed up if use of the method were to be mainstreamed.

5.2.2. On non-compliance with the law

The questions posed by the CA team did not directly address compliance with the law. However, as with the discussion of the previous criteria we can use the results of the CA to infer some elements of understanding of compliance.

For the purpose of this discussion we assume that compliance with the law takes as given that people are aware of the law and what compliance means. We expect that voluntary compliance would be greater where the following were true; a) there is consensus that the rule or law is meaningful, appropriate and non-discriminatory; b) there is consensus that compliance with the rule or law yields greater individual or social benefits than does non-compliance; c) there is consensus that those not in compliance will be identified and made to comply.

Both the CA and ARDI methods identified non-compliance as an important issue for stakeholders in the catchment. For example, the most commonly identified reason for problems with the flow of the Crocodile River - as perceived by stakeholders during the CA activity- was 'illegal use'. However, given the lack of consensus across conservationists and irrigators as to the causes of problems with flows the CA results suggest that compliance may be low; if the rule or law does not address the major causes then it is unlikely to be perceived as meaningful, appropriate and non-discriminatory.

Because the mental models that were explored as part of the CA were not those directly related to compliance we are unable to explore which elements of stakeholder mental models were most strongly associated with non-compliance. For example the actual meaning of 'illegal' was not clarified by the method nor was it located spatially or temporally. 'Illegal' could refer to unlicensed use, non-compliance with conditions specified in licenses, or disregard for the Reserve. The extent of the perceived problem was also not discussed. Thus additional work would be required to understand these important details. A similar lack of detail specifically on issues of compliance is also evident with ARDI.

In many ways, CA could be seen as a screening technique to, for instance, define specific thematic areas that water management needs to address within the catchment. What is valuable is that both methods highlight the nature and extent to which stakeholders perceive problems relating to WRM in the catchment. This information is useful in engaging water managers and broader stakeholder groups in subsequent stages of collaborative work as it provides a basis from which to tackle problems.

5.2.3. On feasibility, representativeness and inclusivity

Firstly, we realized that it was going to be taxing to set up almost 100 carefully-considered interviewees (stratified into categories, and non-overlapping as far as was possible) for a practical schedule over two weeks. It required goodwill in a South African society where 'workshop fatigue' is now a reality of democratic processes. Ultimately the goodwill of the newly formed CMA and 'neutrality' of the overseas group did a lot to promote interest and participation in the research. However there are limits to the involvement that stakeholders can afford, and these need to be carefully considered. It seems that there is potential to sensibly link future initiatives to requirements for drafting the Catchment Management Strategy.

Both methods accommodate high levels of representation and inclusivity and are therefore in accordance with participatory water resources management as required by the NWA. They both generate a sense of involvement and 'buy-in' in that they draw information and engagement from a broad spectrum of stakeholders. However, the demands of the methods for time and funds need to be carefully considered. The CA method, for example, requires that sampling be conducted within institutions 'until no new ideas surface from the sampling'. This exhaustive sampling can be time consuming and costly especially if it needs to cover a large sample of stakeholders as is the case with water users. The ARDI method is less exhaustive but requires that there is adequate representation from all major water use sectors before a collaborative systems diagram can be developed. Inadequate representation can lead to a skewed view of the system and the misidentification of important system drivers. The results of the consensus analysis (e.g. Figure 11) provide strong evidence for the need for great care in selecting and hence using the results of particular representatives from a stakeholder group; some representatives of the group may have strongly divergent views that are not representative of the group. It strikes us as being important to conduct careful stakeholder analyses and CA before embarking on the ARDI process of consensus building. This has bearing on the companion modelling as a tool for decision making that forms subsequent phases of the technique.

The debriefing meetings held after the fieldwork (one in Skukuza with about 25 attendees and one in Pretoria with about 40 attendees) to present initial experiences and findings proved very useful. Also, further detailed contact was made by two South African team members during a visit to Australia for an environmental flows meeting in September 2007, with the Australian component of the team. This contact and other wider electronic discussions have contributed to ideas around a possible way forward.

5.3. Potential applications for IWRM in South Africa

Although the team set out to test the application of the two methods within the specific context of sustainability and compliance with environmental flows in the Crocodile Catchment, the opportunity arose from the work to reflect on their wider application. Clearly in the multiple-stakeholder arena called for by IWRM under the

NWA it would be valuable to employ tools that set out to understand how, why and where differences in conceptual understanding, language use, meaning and practices might arise. This is especially important where stakeholders are expected to collaboratively set priorities for management of water on a catchment scale. Understanding the spectrum of mental models that exist regarding the functioning of the catchment provides decision-makers with an opportunity to publicly clarify perspectives and positions and so better understand why it is that certain groups make particular decisions. The assumption here is that the more stakeholders hold in common understanding the resource the more likely they are to reach consensus regarding its management.

Understanding the different orientations can be valuable in elucidating options for sustainability. For example, mental models within particular sectors might be driven by technological interventions rather than ecological principles. Such understanding provides water management with the opportunity to deliberate how the two can be reconciled through collaboration and consensus reaching. In the case of the ARDI method, the co-construction of a shared mental model is a way of getting 'buy-in' from stakeholders as it represents involvement in the early stages of negotiating the meaning and value that water resources hold for a particular catchment.

The generation of a shared mental model for the catchment based on principles allows stakeholders to test (through computer modelling) the effects of particular management choices on the resource. In this way different stakeholder groups can negotiate the best possible configuration of management options for the catchment. These management options can then be used as the basis for developing the Catchment Management Strategy (CMS) as required by the NWA. The framework for the development of a CMS is provided in Figure 222. This indicates that the CMS comprises four parts: a situation assessment and vision-setting exercise (Part a), and three groups of strategies, including water resource management sub-strategies (Part B), facilitating sub-strategies (Part C), and integrating sub-strategies (Part D).

Part A provides the foundation on which the strategies are developed and it is in this component that both ARDI and CA would prove particularly useful, particularly given their emphasis on stakeholder involvement. Furthermore, their use for the development of the various sub-strategies could also be considered. The vision is based on an understanding of the current situation (the situation assessment) and serves as the pillar that supports the strategic direction for IWRM. We suggest that the main opportunities for employing the two methods reside within the situation description and assessment (CA method), and for vision-setting (ARDI method). Indeed, ARDI has been widely used for vision-setting and future planning in natural resources management (www.commod.org).

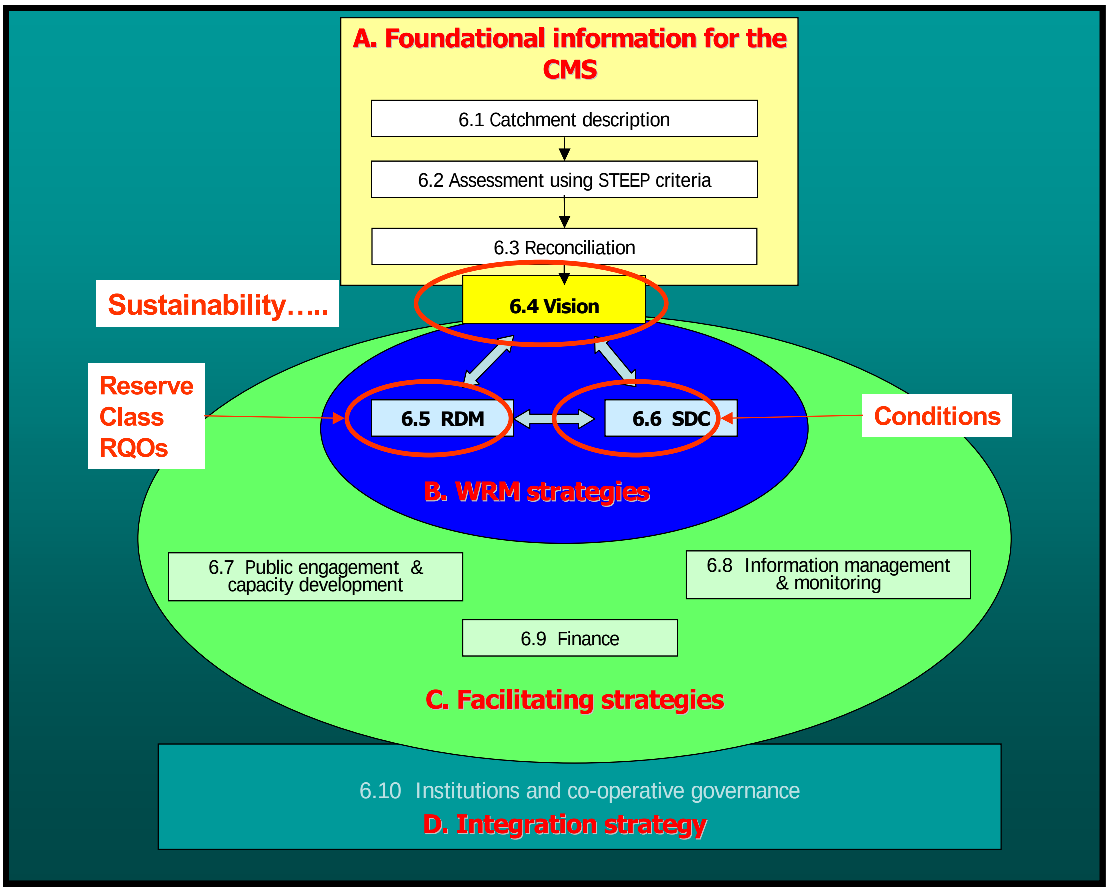


Figure 22. Framework for a Catchment Management Strategy (Pollard et al., 2007)[10]

The use of the Consensus Analysis method to understand where there is consensus or divergence on the current situation regarding aspects of water resources in the catchment. It may also be valuable in helping decide who to invite to a visioning exercise, so that a good spread of mental models was represented. ARDI on the other hand is more suited to setting a vision and then simulating different management options (or scenarios) by means of computer modelling for particular configurations of the vision. It is clear that ARDI or ARDI-like process could act as a useful way to obtain agreement around visions for a catchment, though there will no doubt be other contending methods. Such methods can support the co-development of, and sharing by, stakeholders who are unequally empowered.

As mentioned, both of the water resource management sub-strategies (resource-directed measures (RDM), and source-directed controls (SDC), there are important requirements for compliance. Thus tools such as CA and ARDI could also be considered for the development of the water resources sub-strategies.

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[10] Note that issues of sustainability are likely to feature as part of the Vision, RDM and SDC. The development of this suite of water resources management strategies requires multiple stakeholder engagement. The intended outcome is a collection of strategic plans that represent a 'win-win' situation that is arrived at through consensus. [RDM= Resource Directed measures, SDC= Source Directed Controls, RQO = Resource Quality Objectives, WRM = water resource management, STEEP = Social, Technological, Environmental, Economic, Political]

The strong emphasis on stakeholder involvement of both methods is and important strength since through the involvement of people in such processes, individuals and organizations develop a greater stake in IWRM and expand their knowledge base and capacity. In discussions at the Pretoria feedback meeting, negotiation theory was raised, and in particular the difference between handling interested and affected parties. Inter-departmental and inter-scale differences can further confound the above. In South Africa there are still likely to be big differences between urban and rural mental models, with a disconnect in the minds of many city dwellers between water supply and water sources. Consequently, there can be significant barriers to accepting and internalizing new information. As became evident in many mental models, enforcement alone cannot be relied upon and therefore motivation and buy-in are crucial.

Though the delegates to the debriefing meetings accepted that the team had partly described mental models at that time, the question (also clearly recognized by the team) came up repeatedly as to how *persistent* these models are, and how they might change over time. In fact, in a transforming environment such as the water sector it should be expected that mental models expand and transform as individuals and organizations develop the capacity to implement within a new legislative environment. Tracking changes in mental models could provide an important measure of transformation in the water sector. There was also a feeling that too much emphasis on prevailing mental models might lead to 'logjam' because the various existing beliefs/demands might be incompatible. Instead, the question was asked whether a spirit of 'future-building' would not help align mental models. This is where the application of mental models for the visioning process described above is useful. To a large extent, the ARDI technique focuses on the future in a subtle and non-threatening way.

There exists considerable potential for interlinking mental models study into adaptive management processes and studies. Specifically the CA might be useful for tracking changes in understanding within institutions and so provide a measure of responsiveness to the need for changing knowledge and practices.

A thought-provoking critique of the team's work centred on what was different or new. It seemed that there was considerable hope that these methods had probed deeper than previous understanding – and this in spite of the Crocodile Catchment being one of the most studied systems in South Africa. In addition to the other shortcomings of the techniques that have already been discussed, it was noted that neither method elucidates power relations nor how these affect the actions and practices of institutions. Finally, issues of resources and finances will have to be factored into the broad application of the techniques so as to derive a clear picture of the costs and benefits. Nonetheless, we suggest that both methods - in their current or in a modified form – offer potential valuable application in the field of IWRM field in South Africa.

Lastly it may be useful to identify a process that would contribute to the development of CMS and that built on the results of this work. We see four processes that could contribute to the development of sustainable CMS and are aligned with the framework of Figure 22:

Step A

1. Stakeholder analysis: Identify major stakeholder groups and power relationships using social network analysis.
2. Consensus analysis of key questions related to:
    a. The social, economic and ecological sustainability of water use;
    b. The major determinants of the social, economic and ecological sustainability in water use;
    c. Actions (for each key stakeholder group) that are deemed most likely to bring about socially, economically and ecologically sustainable use.
3. Participatory modelling: Explore action, outcome relationships using ARDI like techniques to identify pathways to sustainability and thence to identify broadly acceptable vision.

Step B and C

4. Monitoring and learning to support progress to goals: Bayesian Belief Network (BBN) modelling to support ongoing monitoring and evaluation of key factors determining social, economic and ecological sustainability as well as progress towards goals.

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