An adaptable, multi-disciplinary water resource management framework for the uMngeni River Basin

Report to the

WATER RESEARCH COMMISSION

Compiled by

Steve Mitchell, Duncan Hay & Charles Breen

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Obtainable from:

Water Research Commission
Private Bag X03
Gezina 0031

orders@wrc.org.za or download from www.wrc.org.za

This report emanates from a project titled *Development and pilot testing of a multi-disciplinary water resource management framework, following a socio-ecological systems approach at a catchment (or basin) level, using existing knowledge and identifying knowledge gaps, particularly on ecosystem adaptation to climate change* (WRC Report No. K8/1021).

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Executive Summary

We all need water to survive but for many a water resource provides other benefits. For some it may be recreation and for others a necessary input for production or manufacturing. Because uses are varied and users are widely separated spatially, economically and socially within a river basin we live our daily lives unaware of the needs of others and how the benefits are shared. We are also unaware of the consequences of how our choices and actions affect others; we are not conscious of the reality that rivers are shared resources. Because of this there are growing calls for a more inclusive and participative approach to governance of water resources. Achieving this will require a society that is informed, sensitive to, and appreciative of how the state of the water resource and social and economic wellbeing are linked – how 'river health' and 'social and economic health' determine each other. This project is a first step toward developing an approach for preparing a 'state of the river basin report' in which river health and societal wellbeing are linked with the intention of promoting wider appreciation for why, where and how each one of us should act so that we progress toward a more equitable and sustainable future. It is an input to the following projects that are due to start shortly:

- Demonstration of how healthy ecological infrastructure can be utilized to secure water for the benefit of society and the green economy through a programmatic research approach base on selected landscapes (University of KwaZulu-Natal, funded by the WRC)
- Investing in ecological infrastructure to enhance water security in the uMngeni River Catchment (South African National Biodiversity Institute funded by the South African Green Trust)
- Improving Water Quality Security: Towards a New Paradigm (International Water Security Network and Monash South Africa, funded by Lloyd's Register Educational Trust).

The uncertainties of global environmental change and the fast changing socio-economic conditions provide major challenges for water management. At the same time management of natural resources, water resources in particular, is undergoing a paradigm shift from practices that have been developed and implemented by technical experts to one in which stakeholder knowledge is respected and has influence in policy and management decision making; a shift toward collaborative governance. This is particularly necessary under conditions of scarcity when sharing benefits becomes stressful, even life threatening. Collaborative governance is also considered more appropriate for integrated and adaptive management needed to cope with the complexity of social-ecological systems (SES). The goal is to maintain the resilience of SESs while at the same time ensuring that the systems are robust so that they retain integrity even while changing. The social learning transformative processes underlying successful collaborative governance connect stakeholders in flexible networks that facilitate development of appreciation for the different meanings people attach to the resource. This growth in understanding provides the foundation of trust that is necessary for collaboration when sharing access to scarce resources.

Because the supply of and need for ecosystem services is so varied across river basins and can change quickly, our understanding of who benefits or expects to benefit from the water resource and in what ways, is generally incomplete. Allocative decisions are made without

fully appreciating the needs and expectations of users and commonly have unanticipated consequences that are undesirable; decisions around the reallocation of rights to benefits can compromise some users, particularly the powerless, who may have established rights gained through either prior use, or law.

The resilience of a river basin SES is reflected in the 'health' of both the ecological and the social sub-systems and particularly in the health of the social linkages – the participative and social learning processes. Being able to identify and understand the determinants of system health provides insight into where management can intervene effectively and efficiently and particularly in contexts characterised by rich and poor, empowered and powerless, with empathy. This project developed a prototype framework that helps integrate the needs of users into a structured decision-making process for water resource management. It is based on the following understanding of water resource management:

- Management is an inclusive, transformative process in which participants are sensitised to changing needs and collaborate to achieve equitable sharing of the benefits deriving from aquatic resources that can be sustained in the long term.

The framework addresses the need to:

- Facilitate social learning and accountability for river basin management amongst basin stakeholders
- Guide the establishment of a methodology for determining the state (health) of the river basin social-ecological system
- Provide a structured decision process for making trade-offs between users;
- Provide a comprehensive audit trail of accountability for decisions and actions taken;
- Provide advice on how to make relevant research products more accessible to basin management.
- Provide a description of the training needed to use the proposed framework.

The uMngeni was chosen as the case study basin. Although it covers only 0.36% of South Africa's surface area, it houses approximately 9% of South Africa's population and generates an estimated 9% of South Africa's GDP. There are a number of government and non-government initiatives directed toward evolving a new approach to managing the uMngeni water resource and the landscapes that impact on it. Currently there is no shared framework that provides a means of focusing and integrating the various initiatives. Of the frameworks reviewed for this study, each had limitations. These were addressed by developing a composite from a number of frameworks and associated processes. The overall framework is the minimalist representation of social-ecological systems described by Anderies and colleagues (Anderies et al., 2004). Responses to a number of questions are used to inform the components of the Anderies framework in the report and in part through the following frameworks (see Figure 8 in the report):

- State or Health of a system
- Well-being and livelihoods
- Robustness in SESs
- Ecosystem services
- Common pool resources

- Strategic adaptive management
- Benefit sharing
- Treehouse model

In addition to identifying the main components and linkages within the river basin SES, the preparation of the State of the Basin Report is designed support a chain of custody to ensure an auditable trail of accountabilities. It will also identify gaps in knowledge and understanding that need to be filled and capacity development needs.

The high-level structure of a prototype State of the River Basin Report is provided. The form that this report takes will depend on the structure of the SES in the river basin under consideration, but it will be guided by the findings of the implementation of the framework. A selection of readily available indicators is provided.

Acronyms

CoC	Chain of Custody
CSIR	Council for Scientific and Industrial Research
DWA(F)	Department of Water Affairs (and Forestry)
FEPA	Freshwater Ecosystem Priority Areas
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
IBT	Inter Basin Transfer
ISP	Internal strategic perspective of water management areas by DWA
IWRM	Integrated water resource management
MSC	Marine Stewardship Council
NFEPA	National Freshwater Ecosystem Priority Area
NGO	Non-Government Organisation
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
PEFC	Programme for the Endorsement of Forest Certification
SANBI	South African National Biodiversity Institute
SES	Social ecological system
WESSA	The Wildlife and Environment Society of South Africa
WMA	Water Management Area

Glossary of Terms

Adaptive management is a decision-making style, used especially in natural resource management, which acknowledges and deals with complexity (see its definition below) and uncertainty by processes of probing and testing, designed to support ongoing learning. It is characterised by feedbacks influencing action in a continuing way (adapted from Biggs and Rogers, 2003)

Benefits are measured by ecosystem services, defined as the aspects of ecosystems that are utilized by people to produce human well-being (Fisher et al., 2008).

Chain of Custody. 'The movement and location of physical evidence from the time it is obtained until the time it is presented in court' (Free Dictionary, The, undated).

Collective Action is the involvement of a group of people that voluntarily engages some kind of coordinated action based on their shared interests, experiences and expectations. (Meinzen-Dick et al., 2004).

Common pool resources are those from which it is difficult to exclude potential users (*excludability*) and where use of the resources by a potential user reduces availability for other users (*subtractability*). (Ostrom et al., 1999; Berkes, 1989; Burger et al., 2001)

Common property refers to a set of rights and obligations whereby a group of individuals collectively governs use of a resource by its members (Burger et al., 2001; Fernandez-Gimenez, 2002).

Community Based Natural Resources Management (CBNRM) in southern Africa is a variant of community based conservation approach, which is based on the premise that conservation and development goals can be achieved, where local residents have a role in the decision making about natural resources (Adams and Hulme, 2001; Jones and Murphree, 2004; Fabricius et al., 2004).

Complex system: "Levin (1999) suggests that any system which shows the following three attributes will show complex behaviour: diversity of components; interactions between these components (especially local ones); and any selection process, such as that posed through for instance, natural selection or a stock market. A complex system can be distinguished from a simple or complicated one, by a number of attributes including non-linearity, uncertainty, emergence, multiple scales and cross-scale effects, self-organisation and feedback loops.

Complexity: There are several ways to approach defining complexity conceptually and technically (colloquially, complexity has a looser meaning). A very concise philosophical definition is the following (it is seriously recommended that it be read <u>in combination with</u> the description below, of a *complex system*): *Complexity is the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its [important] properties. It requires that we find distinctly different ways of interacting with systems. Distinctly different in the sense that when we make successful models, the* formal

systems needed to describe each distinct aspect are not derivable from each other (Mickulecky, 2007).

Ecological infrastructure – A concept which is coming to the fore which has not received attention as yet is that of **ecological infrastructure**. It was greeted with a certain degree of suspicion when it was first put forward. However, as we begin to understand it as the 'generator' of ecosystem services so is acceptance growing. Also, it appears that people outside the environmental/ecological domain can relate to it quite well.

Ecosystem services are the aspects of ecosystems (including ecosystem organisation or structure as well as process and/or functions) that are utilized by people to produce human well-being (MA, 2005)

Efficiency: Economic efficiency exists when resources are allocated so that no activity can be increased without cutting back on some other activity (Nicholson, 2005).

Equity: In economics, equity is the capital of a firm, after deducting any liabilities to outsiders other than shareholders, who are typically the legal owners of the firm's equity (The Economist, 2011). It can also relate to the concept of fairness in economics, particularly as to taxation or welfare economics. More specifically it may refer to equal life chances regardless of identity, to provide all citizens with a basic minimum of income/goods/services or to increase funds and commitment for redistribution (Wikipedia 2011).

Governance is concerned with creating the conditions for ordered rule and collective action (Stoker, 1998). It is ultimately about who decides and how. It denotes "the interactions among structures, processes and traditions that determine how power is exercised, how decisions are taken on issues of public concern, and how citizens or other stakeholders have their say" (Graham *et al*., 2003). Governance encompasses policies, institutions, processes and power.

Institutions are the "prescriptions that humans use to organize all forms of repetitive and structured interactions" (Ostrom, 2005: 3). They denote the rules and norms used by individuals in delimiting the "mays, musts, and must nots" of any situation. While some of these rules are formal, many rules-in-use lack formal status.

Millennium Ecosystem Assessment Framework (MA) provides a sound and well-established framework for the assessment of ecosystem services and the benefits to human well-being. The MA established the concept of ecosystem services as an essential model for linking the functioning of ecosystems to human welfare benefits (MA, 2003).

Property rights can be defined as "the claims, entitlements and related obligations among people regarding the use and disposition of a scarce resource" (Furubotn and Pejovich, 1972).

Public infrastructure combines two forms of human-made capital, physical and social. Physical capital includes any engineered works, such as dikes, irrigation canals, etc. Social capital includes the rules actually used by those governing, managing, and using the system

and those factors that reduce the transaction costs associated with the monitoring and enforcement of these rules (Anderies et al., 2004).

Public infrastructure providers are the entities or people mandated to provide the physical and social capital which make up the public infrastructure (Anderies et al., 2004).

Resilience. The concept of resilience measures the amount of change or disruption that is required to transform the maintenance of a system from one set of mutually reinforcing processes and structures to a different set of processes and structures (Anderies et al., 2004).

Risk or ecosystem service risk is the function of the likelihood and consequence of the hazards posed by a particular management scenario to which the ecosystem service is exposed (Ginsburg et al., 2010)

Robustness. The concept of robustness is well developed in engineering, where it refers to the maintenance of system performance either when subjected to external, unpredictable perturbations, or when there is uncertainty about the values of internal design parameters (Anderies et al., 2004).

Social-ecological system (taken as equivalent to socio-ecological system, which is said more easily): A social-ecological system is a linked system of people and nature. (Roux et al., 2009). See also the definitions and description of complexity and of a complex system above. Or, a socio-ecological system can be defined as people, their natural and human-made resources and the relationships among them (Anderies et al., 2004).

A **Stakeholder** is a person, group, organization, member or system who affects or can be affected by an organization's actions (Wikipedia).

1. Project purpose

The overall objective of this project is to develop a prototype multidisciplinary strategic planning and adaptive management framework for river basin governance that will be tested on the uMngeni River Basin.

The framework should:

- Facilitate social learning and accountability for river basin management amongst basin stakeholders
- Guide the establishment of a methodology for determining the state (health) of the river basin social-ecological system
- Provide a structured decision process for making trade-offs between users;
- Provide a comprehensive audit trail of accountability for decisions and actions taken;
- Provide advice on how to make relevant research products more accessible to basin management.
- Provide a description of the training needed to use the proposed framework.

2. Introduction

In 2012 a group of adventurous 'water resource advocates' from the Dusi-uMngeni Conservation Trust (DUCT) walked the length of the uMngeni River (SA Geographical Naming Commission, 2010) from its source to the sea, a distance of about 250km. The purpose of their walk was to profile and bring attention to various water resource management issues they encountered along the way. At Nagle Dam in the Valley-of-a-Thousand-Hills they discovered that the dam's sluice-gates were closed and, as a consequence, there was little flow in the river downstream of the dam. Not only was this compromising the ecological integrity of the river system but rural residents downstream were deprived of their established rights to the benefits from the water and its flow. Why were the sluice gates closed? Was it because the decision makers were not aware of the rights and needs of people living along the river between Nagle Dam and the junction of the uMngeni and Msunduzi Rivers? The dam is part of a water storage system designed to provide an assured supply of water supply to eThekwini Municipality (Durban and surrounds). So, in their efforts to secure the rights of one group of people the decision makers compromised the rights of another group (Hay et al., 2013).

The experience illustrates two very important principles: The first is that every use of the water resource reduces its availability. This is known as subtractability. The second is that because everyone needs water it is difficult to exclude people from its benefits. This is known as excludability. Because the water resource is characterised by these two principles it should be managed as a common pool resource, one in which society is enabled to actively participate in decision making.

This is one example of many that illustrate where we find ourselves – the uncertainties of global change and fast changing socio-economic conditions are challenging traditional approaches to water resource management and encouraging appreciation for social-ecological complexity (Pahl-Wostl, 2007). Coping with this complexity requires that management of natural resources, water resources in particular, undergoes a paradigm shift from management practices that have been developed and implemented by technical experts to collaborative governance involving stakeholders whose rights to access the benefits are defined and acknowledged. Collaborative governance is better suited to integrated and adaptive management that is required for optimising equity and efficiency in complex social-ecological systems (SES) in which supply and demand are so variable in time and space. Empowering resource users and holding them accountable for policy and practice as infrastructure providers (see Figure 3) enables informal institutions (decentralised) to support the formal (centralised) institutions of government.

In past times when the benefits of access to the resource easily met demand, competition among users was minimal and order in resource use could be achieved through a centralised governance regime. This is no longer the case because demands and uses have increased and become more varied and so we have to also rely on self-regulation within and among resource user sectors to give effect to formal institutions of governance. We have to expect and have confidence that for example, agriculture or manufacturing or municipalities and even individuals will impose self-regulation for the benefit of society. By promoting order and accountability in society social-ecological systems they become more robust (less responsive to whims), and resilient (able to change while retaining integrity). The social

learning processes underlying successful collaborative governance connect stakeholders in flexible networks that allow development of shared understanding, empathy and the capacity and trust needed to discover equitable solutions and for self-regulation in support of those solutions.

Because water connects everyone in a river basin the wellbeing of the each individual and the population as a whole reflects how the benefits of a water resource are sustained, equitably allocated and managed: the state of the social system mirrors the state of the water resource and *vice versa.* So, a river basin provides a logical approach to bounding a SES and the state (health) of the rivers that drain the basin informs us of the 'health' of the system as a whole. How can we measure and manage the 'health' of a social-ecological system? A healthy river basin is one in which participative governance leads to a sharing the benefits of the resources in an optimal and equitable manner, and to living within the capacity of the system to deliver those benefits. Healthy river basins increase resilience and robustness of the SES enabling it to cope with shocks from internal and external influences.

3. Some lessons from recent history

There are many practical lessons we can draw from previous experience that are pertinent for this study:

- Encourage self-organisation. Parsons (2007:407) has suggested that “if a system is to make a significant change from its status quo, the changes are likely to come from creative self-organizing rather than from planned change” giving emphasis to the importance of research being designed to promote self-organisation. Creative self-organization is necessary for participative governance and adaptive management
- Develop an appropriate property rights regime and give attention to the sharing of benefits. Hay et al. (2013), Nkhata et al. (2012a and b) and Nkhata et al. (2009) illustrate the centrality of property rights and benefit sharing for self-organisation in the use of common pool resources
- Encourage and sustain collective identity. Mosimane et al. (2013) illustrate the importance of collective identity for collective action in management of common pool resources
- Use participative research methods. Backeberg (2010) and Blignaut and Sibande (2008) show how important this is for the design and uptake of research.
- Engage social learning. In order to achieve the requisite depth of understanding one has to commit to a long-term interactive, social learning process. A programme of ten to fifteen year duration may be required for behavioural change to become internalised and self-sustaining. It is important to appreciate that stakeholders have different value systems; that there might be many different and competing perspectives and they are legitimate and ‘right’; that outcomes of various management interventions are usually uncertain, and there is often insufficient factual information to guide decision making (Ravetz and Funtowicz, 2008).
- Integrate vertically. The formal institutions of government provide the context for informal institutions that arise when participative governance is encouraged. The informal institutions provide self-regulation at scales that are generally not achievable by government
- Understand how capacity constrains progress. Backeberg (2010) has illustrated this for rainwater harvesting and Wigboldus et al. (2010) provide insight into how capacity development should be understood. Some important questions are: Is the context supportive of change? Do people have the requisite assets and skills? What motivates the desire for change?
- Develop focus that reflects context. Miller and Shinn (2005:181) encourage researchers to ‘reverse the temporal sequence of their activities, first conducting studies in which external validity (i.e. understanding community context) is their utmost concern and then conducting studies that privilege concern about internal validity’.
- Be reluctant to simplify. Water resource management is complex and it is necessary to embrace and incorporate this into whatever is being designed. Weick and Sutcliffe (2007) show how being reluctant to simplify makes us willing

to test our assumptions about the system; it prepares us for the unexpected. Learn from the powerless. If one is able to respond directly to the needs of people, particularly the developmental needs of poor people, one is far more likely to achieve success in addressing one's own needs. It is necessary to sublimate one's own agenda and respond rather to what stakeholders think is important.

- Harness communities for management. Strongly informed by the concept and practice of Community Based Natural Resource Management (CBNRM; Breen, 2013), is the notion that it is people on the ground whose day-to-day activities affect the resources who are, in effect, the managers.
- Understand management is a way of conducting research and learning. While trawling through many papers and discussing numerous concepts, models and frameworks was necessary and valuable, the most valuable experience was gained in the field, engaging with stakeholders and supporting processes. Real-life is the best laboratory in which to learn.

4. The uMngeni River Basin – a snapshot

(Much of the information in this section is extracted from a presentation compiled by Riaz Jogiat of the uMgungundlovu District Municipality. His contribution is acknowledged with gratitude.)

The uMngeni River Basin encompasses an area of 4 416 km^2 (0.36% of South Africa) and the river is 255 km in length from its source at uMngeni Vlei (elevation 1830 m) to its mouth at Durban. It has several tributaries of which the most important is the Msunduzi River, with its source in Vulindlela and passing directly through Pietermaritzburg, the provincial capital of KwaZulu-Natal. Because of an inter-basin transfer from the upper Mooi River to the uMngeni the two basins are regularly referred to as the Greater-uMngeni River Basin (Figure 1).

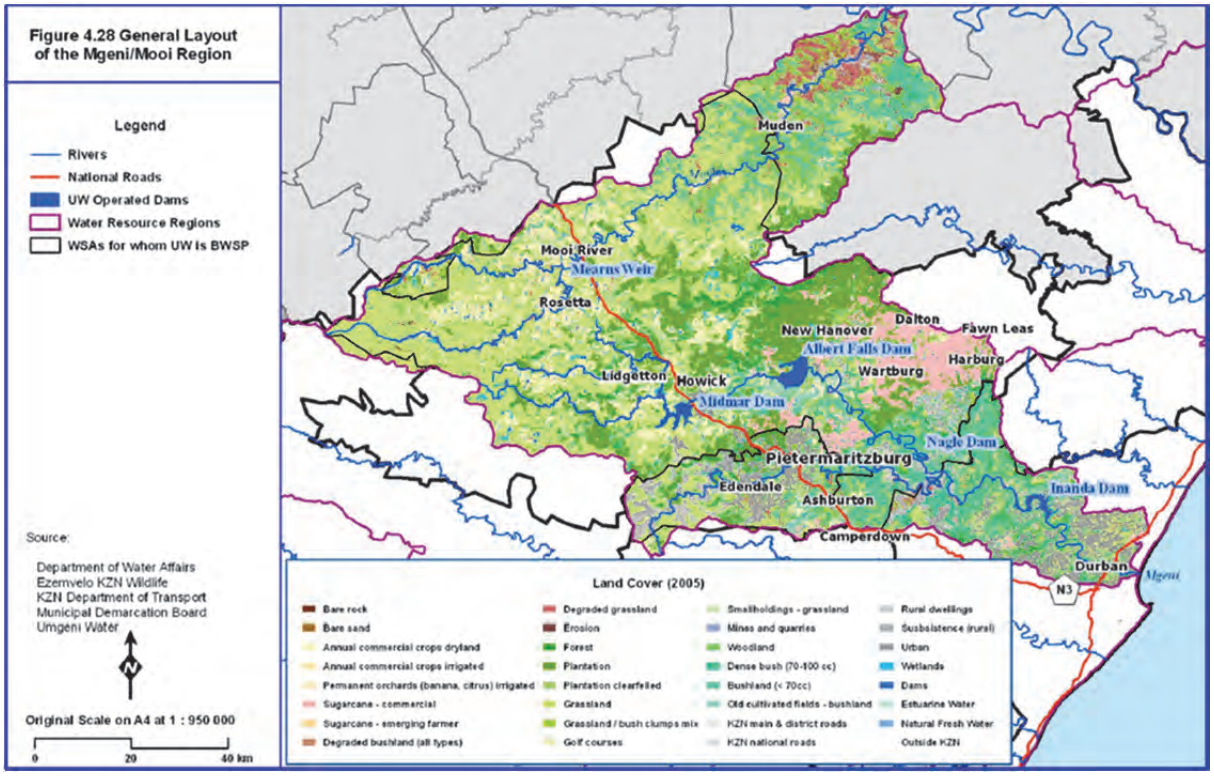

Figure 1. The uMngeni and Mooi River Basins

Two municipalities constitute the major portion of the river basin – eThekwini Metropolitan Municipality towards the coast with a population of about 3.45 million people and, inland, the uMgungundlovu District Municipality with a population just over 1 million. The great majority of these people, rich and poor are entirely dependent on the water resources of the river basin for their well-being. The uMvoti to uMzimkulu Water Management Area, in which the uMngeni River Basin falls, contributes approximately 11.5% to national GDP, with an estimated 80% of this coming from the Durban – Pietermaritzburg hub. So, the river basin is of significant socio-economic importance locally, regionally and nationally.

Census data for the uMgungundlovu Municipality from 2011 allows us to define the socio-economic character of the river basin fairly well. Average annual household income is about

R 90 000 per annum – most people are not rich but they live above absolute poverty levels. There are, however, large disparities between rich and poor. There is a very strong urbanisation trend where rural municipalities reflect declining populations and urban municipalities reflect rapidly increasing populations. Nearly 10% of the population have no access to piped water and only 42% have water piped into their homes. Linked to this, 42% of the population have flush toilets in their home. 86% of households have access to electricity and household refuse collection is to less than 50% of homes. In urban settlements where there is no or irregular collection of refuse river systems are regularly used as a disposal system. 30% of residents are unemployed. Government and Agriculture are the lead employment sectors.

Environmentally, 40-50% of the uMgungundlovu Municipality's landscape has been transformed from the natural condition, primarily for urban residential and industrial use, and large-scale commercial agriculture, primarily sugar cane, timber, beef and dairy. The region is a climate-change hotspot with predictions that rainfall and temperatures will increase in both winter and summer seasons. Violent storm events will increase in magnitude and frequency and with this, so will flood events. Water quality is declining throughout the river-basin driven primarily by poor sanitation infrastructure, inappropriate land-use (especially overgrazing), agriculturally based organic inflows and industrial waste. Infestations of alien invasive plant species are increasing, especially in riverine habitats, despite significant investment in clearing and habitat restoration.

Institutionally (in a water resource governance and management context), as mentioned previously, The uMngeni River Basin falls within the uMvoti to uMzimkulu Water Management Area which in turn falls under the jurisdiction of what is loosely referred to as the KZN Catchment Management Agency. This is currently being established. Within the uMngeni River Basin there are four Catchment Management Forums (CMFs) which cover the entire basin. At a more local level are several water user associations and irrigation boards. The irrigation boards are in the process of being converted into water user associations.

Initiatives that address directly and indirectly water resource governance and management in the uMngeni River Basin are many and varied. This is not a comprehensive list rather it indicates level of governance-related activity.

- The CMA process being led by the Department of Water Affairs (DWA)
- Major infrastructure development, particularly Spring Grove Dam and its inter-basin transfer, and sewage works and reticulation upgrades/expansions
- Detailed water reconciliation studies and scenario planning led by DWA.
- Detailed hydrological and climate change research by UKZN and partners
- River health research and monitoring by numerous organisations
- Conservation stewardship programmes in the upper-basin being led by WWF and Ezemvelo-KZN-Wildlife
- Wetlands conservation and management being led by Mondi Wetlands Programme, WESSA and others
- Water quality research by UKZN and DUT
- Practical alien invasive clearing and natural system restoration led by DUCT
- A variety of educational programmes being led primarily by WESSA and UKZN

- Water pollution and sanitation systems research by UKZN and DUT
- Fairly detailed water quality monitoring, primarily by Umgeni Water
- Various spatial development frameworks and strategic environmental assessments of the municipalities
- Various citizen/community-based initiatives aimed at establishing conservancies, improving water quality, reducing pollution, improving land-use practices, giving residents a voice and other advocacy-based activities
- An Ecological Infrastructure Partnership being led by eThekwini Municipality and the South African National Biodiversity Institute (SANBI) aimed at restoring and maintaining ecological infrastructure in the basin so as to enhance water security
- Mainstreaming biodiversity into land use regulation and management at the municipal scale – an advanced proposal to GEF being led by SANBI and uMgungundlovu Municipality.
- A climate change adaptation programme – advanced proposal being led by uMgungundlovu District Municipality

5. What are the water resource management issues?

(Sections 4 and 5 are extracted, for the most part, from a report compiled on the WRC Wat Indaba hosted by UKZN and DUT in February 2013.)

Commencing in June 2012 a process was initiated to establish the key management issues in the uMngeni River Basin. This consisted primarily of engaging with a broad range of stakeholders in the uMngeni River Basin and canvassing their views about the major issues that stakeholders face. In many instances these were unscripted open-ended conversations. This process culminated in a "Wat-Indaba" in February 2013 hosted by the University of KwaZulu-Natal, Durban University of Technology and Water Research Commission. This was, essentially, a knowledge sharing session and comprised a number of presentations by key basin stakeholders.

Participants were primarily executives and/or senior management form the following organisations:

- The KZN Planning Commission
- Department of Water Affairs (Regional Office)
- Water Research Commission
- Umgeni Water
- uMgungundlovu District Municipality
- eThekwini Municipality
- Greennetwork
- Dusi-uMngeni Conservation Trust (DUCT)
- Wildlife and Environment Society of South Africa (WESSA)
- Pietermaritzburg Chamber of Business (PCB)
- Durban Chamber of Commerce and Industry
- Upper-uMngeni Catchment Management Forum
- The Msunduzi Catchment Management Forum
- Msunduzi Innovation and Development Institute (MIDI)
- GeaSphere KZN
- The DWA led Catchment Management Agency process
- The National Water Resource Strategy process
- The International Water Governance Conference

Arising out of these conversations, presentations and engagements what appear to be the emerging issues and themes?

Opportunity and competitive advantage

- The alignment of the well-watered uMngeni River Basin with the most important socio-economic development axis in KZN is a major opportunity and provides the province with a competitive advantage. We are an economic gateway to South Africa and the rest of sub-Saharan Africa.

State

- The state of the uMngeni River Basin reflects the state of society within the basin. (The river basin is a social-ecological system in which society, the economy and the natural resources are dynamically connected. Changes on one inevitably result in changes in the other.) In order to improve the state of the system we need to improve our behaviour towards it and towards each other.
- The Basin is under significant pressure from multiple demands and uses. This is affecting social and economic development opportunities, human health and ecological integrity. Specific issues include:
    - Reduced water quality caused primarily by inadequate sanitation systems, unregulated industrial pollution, and organic run-off from agricultural land
    - Reduced water quantity caused by massive losses, wastage, insufficient commitment to demand side management (water conservation and rainwater harvesting) and under-pricing
    - Loss of ecological infrastructure and associated production potential caused by, among others, the destruction of groundcover and subsequent erosion caused primarily by grazing pressure, and inappropriately designed infrastructure development, and unregulated sand-winning
    - Reduced biodiversity through land transformation, alien invasive plant infestation, water abstraction and pollution.
- The state of the river basin as a social-ecological system is largely unmeasured and unmonitored. The real costs of choices made are unknown. This makes it difficult to identify, plan, and monitor specific interventions and evaluate progress.

Governance and management

There is need to:

- Integrate governance and management of the uMngeni River Basin horizontally (within government and across the basin) and vertically from government down to resource users.
- Develop a property rights regime so that the resource rights and users are unambiguous
- Define the roles and responsibilities of various authorities and public entities so that they are easily and clearly understood
- Establish processes of governance that enable participation, learning and self-regulation need to be designed and operationalised
- Develop leadership, management and regulatory capacity to sustain momentum. There is concern that the CMA process is taking too long and keeps changing so that it may not serve the desired purpose for the Basin
- Make regulatory enforcement work. There is little to no regulatory enforcement taking place.
- Draw business and industry into participatory governance and require them to assess and report on performance
- Determine the ‘Reserve’ so that confidence in water resource allocation can be improved.

Knowledge and information

- There are significant bodies of knowledge and information about the Basin but it needs to be synthesised and reported on in ways that promote participation in governance
- Social learning has not been prioritised, so much this knowledge and information is not readily known, understandable or accessible to managers and stakeholders
- There is no shared information platform and process that can be used to inform governance and management.

Skills, capacity and education

- Leadership, management and technical capacity and skills in most sectors are inadequate to deal with the issues
- There is insufficient focus on water resource education in schools and amongst adults

Infrastructure, services and finance

- There are significant backlogs in the development of water supply and sanitation infrastructure and services
- There is insufficient maintenance of existing infrastructure
- Financing systems for infrastructure development and payment systems for services are unsustainable
- Policy and practice is not sufficiently supportive of participative governance and management.

6. Frameworks and models that might help us analyse these issues.

"…… essentially, all models are wrong but some are useful." (Box and Draper, 1987)

(Some of this section is drawn in large part from Hay D, Breen C and Kotze D (2012). The contribution of Kotze is acknowledged with gratitude.)

If we agree that the unit of governance and management is a river basin then how do we analyse the river basin in such a way that the results contribute to better management? In short, what do we need to know and how should we be guided to advance participative governance and management? While each stakeholder may know how the state of the resource affects personal or enterprise wellbeing, few if any have the holistic picture that is necessary to understand how their use determines wellbeing of others and how our efforts to achieve wellbeing determine the state of the resource. Stakeholders need to have both deeper (vertically integrated) and broader (horizontally integrated) understanding of the interactions between the state of the resource and the social and economic wellbeing of the inhabitants of the basin if they are to be empowered for participative governance. To gain this understanding we need to develop representations of how the system is structured and operates: models or frameworks that will direct data gathering, interpretation and allow us to test assumptions. The frameworks and associated protocols are some of the assets that are required for governance and management but participants also have to be motivated and have the necessary capabilities to participate effectively. Motivation is personal and depends on individual circumstances but it can be fostered by creating operating contexts that make it easier and more rewarding to participate. Participants become motivated when they feel their participation is valued and they are given responsibilities and held accountable. This is why giving attention to property rights is so important for management of common pool resources. Three necessary steps to achieve this are:

- Design and establish an institutional structure and functions dedicated to support for participatory governance
- Create a governance context that encourages self-organisation. Establish a property rights regime that acknowledges the common pool nature of water resources, allocates rights and responsibilities and enables self-regulation
- Develop frameworks and associated protocols and processes that facilitate social learning vertically and horizontally

First we need to be able to determine the state or health of the system, and what are the major drivers that contribute to this state. But in order to do that we also need to understand what the system is. We need to understand what people require to achieve well-being and what the system contributes to achieving this well-being. We have to understand how people access and share the benefits and finally we need to be able to establish an adaptive management system to accommodate learning, different value systems and perspectives, rights of access, restitution and decisions around trade-offs.

No single framework or model can achieve all this. We need to draw on a number of frameworks and processes that we might use in different circumstances. Those we suggest address:

- The state or health of the system
- Well-being and livelihoods
- River basin as a complex social-ecological system
- River basin as a supplier of ecosystem services
- Water resources in a river basin as common pool resources subject to common property theory
- Adaptive governance and management
- How we share the benefits that aquatic ecosystem services supply

6.1 Establishing the state or the health of the system

Figure 2 broadly illustrates the relationship between the state of the socio-economy and the health or state of the river basin.

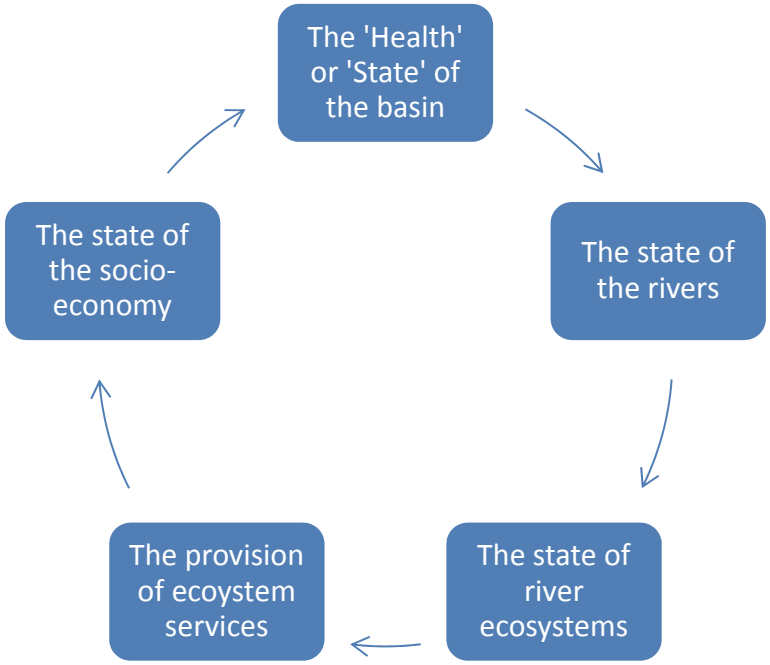

Figure 2. The relationship between the state of the socio-economy within a river basin and the health or state of the rivers in the basin.

Knowing the 'current health' of the basin is not sufficient to direct management toward sustainability, that requires us to connect river health to the determinants of health in a manner that allows the understanding of their ability to continue to deliver the ecosystem services on which society depends. So, if the 'health' of a river basin SES is to be managed,

it is necessary to be able to trace the causal links between what is happening in the basin and the implications these have for river health and human health in its broadest sense. When we are able to do this we can report on the state of the river basin, share information in an open and transparent manner and identify and prioritise interventions that will leverage desired change. But, identifying and being aware of the causes of and interventions required for remedial action are not sufficient to bring about the required behavioural change. Because every one of us affects the state of rivers either indirectly or directly, we must understand rivers to be shared or common pool resources with a value and impact on well-being of the society and economy.

We are all custodians of river health. When we understand rivers as common pool resources we appreciate the importance of instituting a property rights regime that enables collective accountability and management of river health and, through that, to also address the health of the river basin social-ecological system. This understanding suggests three compelling directions for research:

- If we accept the common pool nature of water resources, how should we establish an appropriate governance regime?
- What models or frameworks can we use to connect river health with the determinants of river health in ways that enable us to identify and prioritise interventions? As shown in Figure 2 the river ecosystems provide ecosystem services that sustain the socio-economy in a basin while at the same time the socio-economy affects the health of the rivers in the basin and so the stream of ecosystem services delivered to the socio-economy.
- How should we report on the state of the river basin in ways that are transparent and encourage learning and accountability?

The research undertaken in this consultancy seeks to develop a format for a State of the River Basin Report which will empower stakeholders in the river basin to assess the state of the basin and to appreciate how they are affected. Based on the framework for assessing the robustness developed by Anderies et al. (2004) ('the Anderies Framework'), it will guide stakeholders through the process, enabling them to identify areas of river basin governance and management requiring attention.

This framework, which is applicable to river basin scale, enables us to connect the social, economic and ecological sub-systems in ways that facilitate social learning, accountability and co-management that is both strategic and adaptive. Increasingly, socio-economic wellbeing of the country is being affected by both the availability of water and the state of our water resources. In the Water for Growth and Development (2009) strategy, the Department of Water Affairs expresses concern about the declining quality of the country's water resources. Society is unable to exist without access to an adequate supply of freshwater that is fit for use and development depends on there being sufficient water to provide for the needs of the proposed development (National Development Plan, 2011). However, because we usually have an incomplete understanding of those who benefit from the water resource and in what ways, decisions around water use are commonly made without taking account of the needs and expectations of all users. The result of such decisions are likely to

compromise some while benefitting others and in extreme cases may be unsustainable, particularly in a situation where a river basin is approaching or has reached the limit of its ability to provide the required water and is over-exploited. DWA has demonstrated this in many of its reconciliation studies. As indicated, development is heavily reliant on the nature and extent of the benefits that are derived from the water resource and these benefits are threatened by, for example, pollution, climate change, alien and invasive vegetation species. A green economy which takes the value and limitations of ecosystems into account is more likely to deliver sustainability.

The framework and associated processes is designed to empower stakeholders by enabling stakeholders to monitor selected conditions within the basin at intervals and compare the current results with previous results. This would take the form of a State of the River Basin report.

The South African government is committed to Integrated Water Resource Management (IWRM) (NWRS 1, 2004; Water for Growth and Development strategy, 2009) and the basis for this is the recognition of the interdependence of different sources, uses and users of the benefits derived from water resources. The following two examples of this interdependence are taken from Frost and Sullivan (2010). For instance, if the rivers in the Kruger National Park were to become totally degraded, it is estimated that this would result in a loss of tourism revenue of 30% for the Park. And the Dusi Canoe Marathon is worth annually an estimated R30,000,000 in equipment and accommodation and R100,000,000 in marketing costs, but this activity is under constant threat from the health risks caused by poor water quality (Frost and Sullivan, 2010).

Information is required by government, communities, businesses, and individuals to enable basin stakeholders both to make better choices as well as to use the tools and processes to measure the success in managing the SES. To achieve this, a framework was developed (detailed below, see Figure 3 and following) to form the basis of a State of the River Basin Report. This report is designed to provide structure to the monitoring of the implementation of IWRM in the basin. Underpinning the primary framework, where required, are other frameworks that may be used to represent an SES and shape the synthesis of research as recommended by Breen et al. (Biggs and Rogers, 2003; Pollard and du Toit, 2007; Rogers, 2009: Breen et al., 2011; Breen et al., 2012; Hampton and Parker, 2011). In addition to the Anderies framework, other frameworks recommended by Breen et al. (2011) to assist the process of social learning are the Millennium Assessment (MA, 2005) and Walker et al. (2002). These bound the SES in ways that permit stakeholders to examine and understand the system network with its many feed-forward and feed-back linkages.

If this framework is to be institutionalised as part of the suite of DWA reporting instruments it will need to be compatible with current departmental initiatives.

IWRM, as prescribed by the National Water Act (1998), should incorporate a strategic approach to water resources, other biodiversity assets, all beneficiaries (direct and indirect) of aquatic ecosystem services and public and private infrastructure and their custodians beyond water resources infrastructure. It can only successfully be implemented at a basin-wide level, through collective effort of water resource managers and other biodiversity

resource managers (Breen et al., 2011). Successful implementation of IWRM requires that society accepts this interrelatedness of water uses and users. The implementation of IWRM, thus, requires that society use a single set of rules (institutions) for their decision-making.

DWA has ways of measuring the water resource quantity and fitness for use. What is needed is a complimentary process which will enable society as a whole to evaluate the achievement of goals surrounding the maintenance of SES resource robustness so as to ensure that the benefits which can be derived from aquatic resources and the equitable and optimal distribution of these are not compromised. To this end a prototype format for the State of the River Basin Report is developed which will enable river basin managers to record, and so manage, the way with which society interacts with the resource. In addition, the Chain of Custody for river basin management is clarified. This Chain of Custody outlines the responsibilities and accountabilities of the various river basin stakeholders in maintaining the preferred state of the resource. The Chain of Custody, combined with Strategic Adaptive Management, provides an audit trail for monitoring and evaluation by keeping account of decisions and actions taken and the outcomes of these.

6.2 A river basin as a complex social-ecological system

Social-ecological systems have been defined variously as *people, their natural and human-made resources and the relationships among them* (Anderies et al., 2004); *linked systems of people and nature* (Roux et al., 2009) or *"…. a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context."* (Glaser et al., 2008). While it is generally agreed that these systems are 'real things', Jahn et al. (2008) advance an additional view. *"It is yet also possible to understand social-ecological systems as models of knowledge about real-world phenomena."*

Complexity, adaptive systems and social-ecological systems go hand-in-hand in the academic literature. What is meant by complexity? Manson (2001) provides us with the key attributes:

- A complex system is defined more in terms of the relationships between constituent parts than the parts themselves.
- The internal organisation of a complex system is not an amorphous mass but rather a multitude of discrete but linked subsystems and subsystems of subsystems.
- A complex system owes its existence to the environment – anything outside the system's boundary.
- However, a complex system is not entirely beholden to its environment. It is able to shape, react and anticipate.
- A complex system has emergent qualities through which its capacity is greater than the sum of its constituent parts
- It is able to change and evolve through self-organisation and dissipation

The final attribute would indicate that a complex system is, by its very nature, an adaptive system. An adaptive system is one which can respond to changes in the external

environment and or changes in the relationships between the constituent parts of the system – it is a self-organizing system that retains integrity while changing.

Whatever systems we use or develop need to take into account the social-ecological systems internal organisation; the relationship and interactions between the internal and external environment; its adaptive, reactive and anticipatory nature, and those qualities that support emergence.

A recently completed Water Research Commission project developed an approach to support estuary-based economic empowerment (Bowd et al., 2012). Following the comparative analysis of a number of frameworks, that of Anderies and others (2004) was chosen as the conceptual basis for the process (Figure 3).

We have found the Anderies et al. (2004) framework particularly useful because it directs us to engage the system as a whole rather than choosing among the ecological, economic and social dimensions. It also encourages us to engage in defining in a systematic way not just the components but also the relationship between the components. Below are a series of questions derived from the framework which allow us to understand much better how the system functions and to identify gaps in our knowledge of the system.

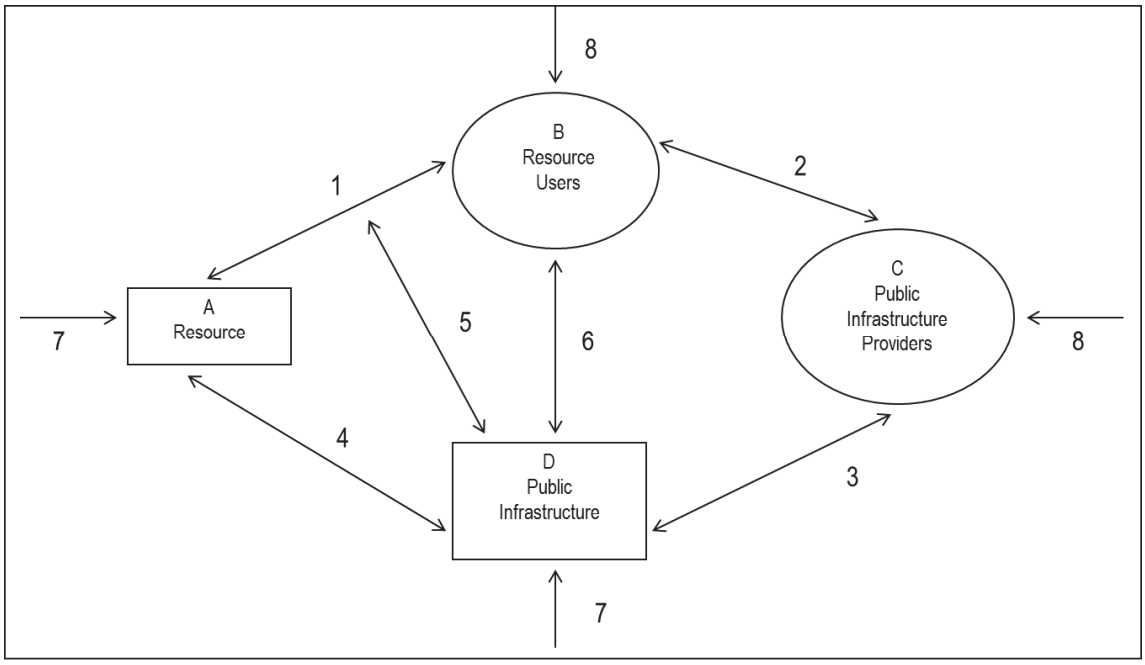

Figure 3. A Framework illustrating a social-ecological system as conceptualised by Anderies et al. (2004).

Description of the components for the Anderies et al. (2004) framework:

The arrows indicating the relationships between the entities of the framework are bi-directional, which takes account of the feedback from the interactions between the components of the framework.

In Table 1 we explain the components involved in social ecological systems and in Table 2 the links between the entities.

Table 1. The entities involved in social ecological systems (from Anderies et al., 2004)

Entities	Examples	Potential problems
A. Resource	Water source Fishery	Uncertainty Complexity / Uncertainty
B. Resource users	Farmers using irrigation Fishers harvesting form inshore fishery	Stealing water, getting a free ride on maintenance Overharvesting
C. Public infrastructure providers	Executive and council of local users. association Government bureau	Internal conflict or indecision about which policies to adopt Information loss
D. Public infrastructure (Physical)	Engineering works	Wear out over time
D. Public infrastructure (Social – institutional rules)	laws, conventions etc.	Memory loss over time, deliberate cheating
External environment	Weather, economy, political system	Sudden changes as well as slow changes that are not noticed.

Table 2. The links between the entities of a social-ecological system (from Anderies et al., 2004)

Link	Examples	Potential Problems
(1) Between resource and resource users	Availability of water at time of need/availability of fish	Too much or too little water / too many uneconomic fish – too many valued fish
(2) Between users and public infrastructure providers	Voting for providers Contributing resources Recommending policies Monitoring performance of providers	Indeterminacy / lack of participation Free riding Rent seeking Lack of information/free riding
(3) Between public infrastructure providers and public infrastructure	Building initial structure Regular maintenance Monitoring and enforcing rules	Overcapitalization or undercapitalization Shirking disrupting temporal and spatial patterns of resource use Cost / corruption
(4) Between public infrastructure and resource	Impact of infrastructure on the resource level	Ineffective

Link	Examples	Potential Problems
(5) Between public infrastructure and resource dynamics	Impact of infrastructure on the feedback structure of the resource – harvest dynamics	Ineffective, unintended consequences
(6) Between resource users and public infrastructure	Coproduction of infrastructure itself, maintenance of works, monitoring and sanctioning	No incentives / free riding
(7) External forces on resource and infrastructure	Severe weather, earthquake, landslide, new roads	Forces a change of state in the resource and destroys infrastructure
(8) External forces on social actors	Major changes in political system, migration, commodity prices, and regulation	Conflict, uncertainty, migration, greatly increased demand

Questions to the components informing the Anderies framework.

The resource

- What is the resource defined in terms of services?
- What does it comprise? (What are its key biophysical features?)
- How big is it?
- How does it connect to other resources?
- What is its history and its significance to people living at or around it?
- Are there any obvious trends (focus on the resource)

The users

- Who makes use of the aquatic ecosystem services?
- Where are they from?
- What is the state (or states) of well-being of people using these services, how does the particular use affect the state, and are there any obvious trends?

The public infrastructure providers

- Who is responsible for governing the system?
- What government departments, systems of traditional leadership and other agencies are involved?
- Who makes the rules or laws that dictate how people use the river basin?
- Who supplies the infrastructure, services and equipment that allow the use of the river basin?

The public infrastructure

- What are the rules, conventions and norms that govern use?
- Are there formal rights of access that govern use?
- What infrastructure and services are in place to support use of the wetland?

The relationship between the users and the resource (Arrow 1)

- Who is using the resource?
- What is being used and what is it being used for? (What ecosystem services are being supplied by the system?)
- How important are the uses? (What is the contribution of various ecosystem services to the well-being of people in and beyond the system and at what scale?) (What proportion of household income is coming from the services?)
- How are the various uses changing over time and what is causing these changes?
- How are the various uses organised and allocated to people? (What property rights regime is in place for each ecosystem service?)
- How does one use of the system affect another use or other uses of the system? (Are there conflicting or contradictory property rights regimes in place?)
- How are the uses of the system affecting its health? (What is the impact of use on the ecosystem?)
- Are there potential uses that have been thought of that would benefit people but are not being used?
- What is the trajectory of change? (rapid, slow, gradual, erratic, large spatial scale, small spatial scale)
- How would these potential uses benefit people?

The relationship between users and public infrastructure providers (Arrow 2)

- How are rules of use made?
- How is infrastructure and service delivery planned and implemented?
- How are decisions recorded and circulated?
- Do the users play a role in making decisions? If so, how does this happen?
- Does the system work?
- What are the problems that are encountered?
- How might these problems be solved?

The relationship between public infrastructure providers and public infrastructure (Arrow 3)

- How do the governors make the rules?
- How do the service providers plan the infrastructure and service delivery?
- Are rules monitored and regulated? If so, how?
- How does maintenance of infrastructure and services take place?

The relationship between public infrastructure and the resource (Arrow 4)

- What impact are the rules having on resource levels/condition?
- What impact are the physical infrastructure and services having on resource levels/condition?

The relationship between public infrastructure, and the resource and the users (Arrow 5)

- Do the users think that the rules of use are fair?

- Do the users think that the infrastructure and services are adequate?
- Are the users involved in making the rules, and managing and governing the system?
- Are the users involved in developing and maintaining infrastructure and services?

The impact of external driving forces on any component or any relationship within the system (Arrows 7 and 8)

- What are external forces impacting on the system?
- How are they impacting on the system?
- How are they affecting people's well-being?

In addition to the above list of questions, the components of the Anderies Framework are also informed by the Millennium Assessment (MA, 2005), the framework of sustainable livelihoods developed by DFiD (1999), Common Pool Resources (Nkhata et al., 2012) and the Treehouse model (McCool et al., 2013).

6.3 The river basin as a supplier of ecosystem services

The concept of an ecosystem service based approach to natural resource management was the central to the Millennium Ecosystem Assessment (MA, 2005). It is still in its infancy. To quote Fish (2011) *"….natural and social scientists are still a long way from appreciating fully the practical needs and consequences of thinking about the natural world in this way."* However, despite arguments about what constitutes an ecosystem service and how we might measure it, the concept is helpful because it relates easily to the way in which people interpret their use of resources.

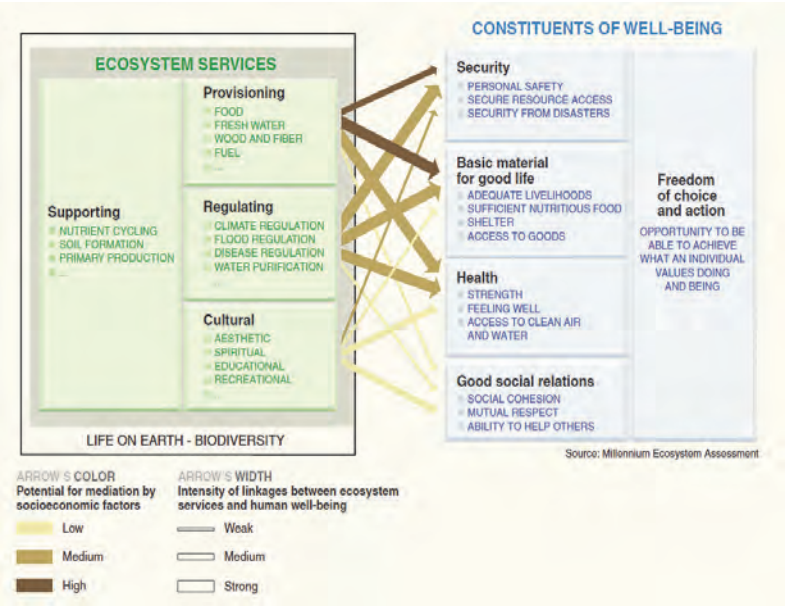

Figure 4. The relationship between ecosystem services and well-being as conceptualised in the Millennium Ecosystem Assessment (MA, 2005)

The framework, illustrated above (Figure 4), is useful in that it attempts to explicitly link ecosystem services to the various constituents of well-being. However, the starting point in this framework is the ecosystem service supply, not well-being. To quote Fish (2011) again "*Advocates of the ecosystem services framework need to develop a more elaborate understanding of how a rich and variegated term such as 'well-being' maps back onto the services that nature provides."* He likens existing efforts to attempting to start a business without analysing the demand (or need). We remain preoccupied with service supply not service demand.

6.4 The river basin as a supplier of well-being and livelihoods

"*After all, life satisfaction is neither a direct, verifiable experience nor a known personal fact like one's address or age. It is a global retrospective judgment, which in most cases is constructed only when asked and is determined in part by the respondent's current mood and memory, and by the immediate context."* (Kahneman and Krueger, 2006).

Ultimately we govern and manage a river basin so that it can contribute, on a sustainable basis to our well-being. But what constitutes wellbeing. It is notoriously difficult to define and measure but these attributes, drawn from a number of sources (NEF, 2011; MA, 2005), give us a fairly good idea of what wellbeing is all about:

- The freedom of choice and action
- The fulfilment of fundamental needs
- A sense of individual vitality
- The ability to undertake activities that are meaningful, engaging, and which make people feel competent and autonomous
- A stock of inner resources to help people cope when things go wrong and be resilient to changes beyond their immediate control
- A sense of supportive relationships and connectedness with others.
- The dynamic process that gives people a sense of how their lives are going, through the interaction between their circumstances, activities and psychological resources

The New Economics Foundation (NEF, 2011) proposes five steps to achieving well-being – 'connect', 'be active', 'take notice', 'keep learning' and 'give'. The primary constituents of well-being include health, nutrition, safety and protection, material possessions, education/learning, identity, social relations, and creativity. What ultimately constitutes overall well-being is unique to each individual and unique to different groups of individuals.

Amongst materially poor people there is a strong positive correlation between income levels and well-being. As income grows so does the correlation weaken to the point that, amongst materially affluent people, there appears to little or no correlation.

The concept and assessment of livelihoods gained traction in the late 90s and early 2000s through work conducted for and on behalf of DfID (British Government's Department for International Development). "*A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or*

enhance its capabilities and assets both now and in the future, while not undermining the natural resource base." (DfID 1999).

While the concept of livelihood is more narrowly defined than that of well-being, it is apparent that they are complimentary – in achieving livelihood options one achieves many of the constituents of well-being. An important advance in the development of the livelihoods concept was the recognition that cash (financial capital) was only one constituent of a basket of capital (or assets) that were required to fulfil livelihoods objectives. The narrower definition of livelihood also lent itself to a fairly objective framework for analysis that is illustrated below (Figure 5).

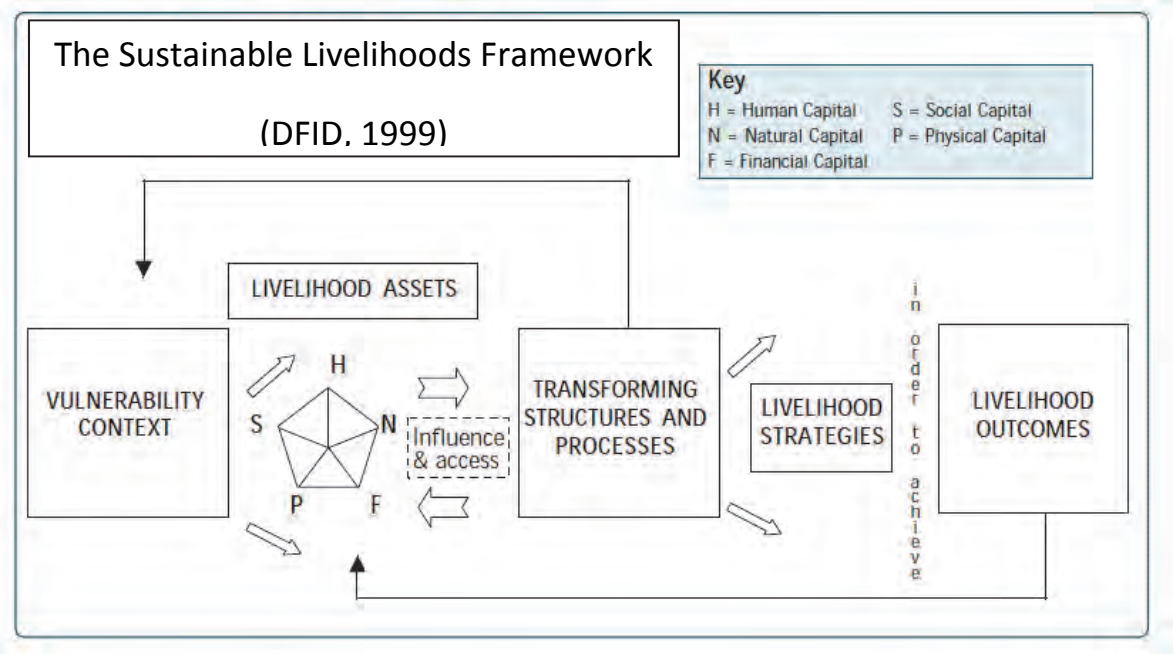

Figure 5. The Sustainable Livelihoods Framework (DfID 1999).

Both the concept of well-being and the livelihoods framework are useful in guiding our thinking and our analysis, primarily because they force us to think far beyond the material. While the economic value of the aquatic ecosystem services in the basin are self-evident, their value is much more than that. They have significant spiritual, cultural, ecological, social and recreational values which need to be factored into decision making on the allocation of benefits from these services.

6.5 Water resources in river basins as common pool resources

The existence of legal pluralism was explored by Pollard and Cousins (2008) who examined the community-based governance of freshwater resources. The situation in South Africa is that there is not a single water resource governance system. The water resource is formally governed through legislation on the water, although this is more complicated in the case of wetlands as wetlands fall under both the water and terrestrial legislation. In communal areas they found that people used a mix of traditional rules and norms with the statutory legislation. They compared this situation with that existing in Zambia, Zimbabwe and Mozambique and

found a similar mix of traditional rules and norms and statutory legislation to exist in these countries. They also found that in areas where the statutory legislation was less effective people tended to use traditional systems.

Nkhata et al. (2012), drawing on, amongst others, the seminal work of Ostrom and colleagues, reviewed the international research experience of property rights and aquatic ecosystem service management. To summarise two general points: first, many aquatic systems can be considered common-pool resources – the exclusion of users is difficult and each user has the potential to subtract from the welfare of others. Second, common-pool resources lend themselves to effective governance through the implementation of appropriate common property rights regimes.

Specifically, Nkhata et al. (2012) demonstrated that property rights regimes regulate and coordinate the allocation and sharing of benefits that accrue from ecosystem services; that clearly defined property rights build 'social capital' for the common good; that secure property rights provide incentives for investment in the management of the resource; and finally, that secure property rights result in improved resilience of the social-ecological system.

Delving a little deeper into property rights: should an individual or a group of people wish to access, withdraw, manage or alienate (sell) ecosystem services that accrue from a natural system they require a property right. A property right is an '*enforceable authority to undertake particular actions in specific domains*'.

At a technical level, property rights are categorised into five regime types (Coelho et al., 2009):

- Private property – individuals have the right to undertake socially acceptable use of the resource and exclude other users
- State property – individuals have rules of access to a resource determined by a management agency
- Common property – a group of clearly defined co-owners has access to the resource and can exclude non-members. The co-owners have both the rights and responsibilities of management
- Open-access property – no defined group of users is set and the benefit stream from the resource is available to everyone.
- "Anti-Commons" property – a regime in which multiple owners hold effective rights of exclusion over a scarce resource resulting in, effectively, a stalemate where nobody benefits.

Building on this understanding it is evident that for a group of individuals to benefit from aquatic ecosystem services they require rights of access to these services. Some key questions include:

- What specific rights do specific users have and what are these levels of rights (see Table 6.3)?
- To what ecosystem service does the right relate – is it water for drinking or for irrigating crops?
- Are there variations in these rights in space and time?

Schlager and Ostrom (1996) disaggregated rights and positions (Table 6.3) and so provided a framework for analysing rights within the context of a social-ecological system.

Table 3. Bundles of Rights Associated with Positions (Schlager and Ostrom, 1996)

Bundle of Rights?	Owner	Proprietor	Claimant	Authorised user	Authorised entrant
Access	X	X	X	X	X
Withdrawal	X	X	X	X	
Management	X	X	X	X	
Exclusion	X	X			
Alienation	X				

So, different individuals or groups might have different bundles of rights for different ecosystem services within different property rights regimes that might vary both in time and space. Understanding this will be critical in allocation of resources in the river basin. The general view is that these rights are poorly understood and have been eroded – by both omission and commission – they are not granted, not acknowledged and not honoured.

6.6 Strategic Adaptive Management

The theory and practice of strategic adaptive management (SAM) as it relates to freshwater resources is detailed in McLoughlin et al. (2011) and Kingsford and Biggs (2012). To highlight key aspects:

- It is designed to engage complex social-ecological systems where there are high levels of uncertainty
- It is a learning-by-doing approach with ongoing negotiation, learning, iteration and adaptation
- It facilitates social learning taking into account both social and ecological dimensions of a system
- It focuses on achieving consensus through cooperation
- It recognises that while knowledge and understanding will always be incomplete, action is required

So, if we recognise river basins as complex social-ecological systems it is inevitable that we should use an adaptive management – a ‘management by experiment’ – approach in support of both social and ecological well-being.

SAM supports the realisation of our proposition. It is, in effect, a rigorous process followed by stakeholders to:

- Achieve a common vision about a river basin social-ecological system
- Establish the desired state
- Set and implement operational objectives
- Monitor, review and refine

Importantly, it engages the detail of what, how, when, who and how much, as illustrated by Figure 6.

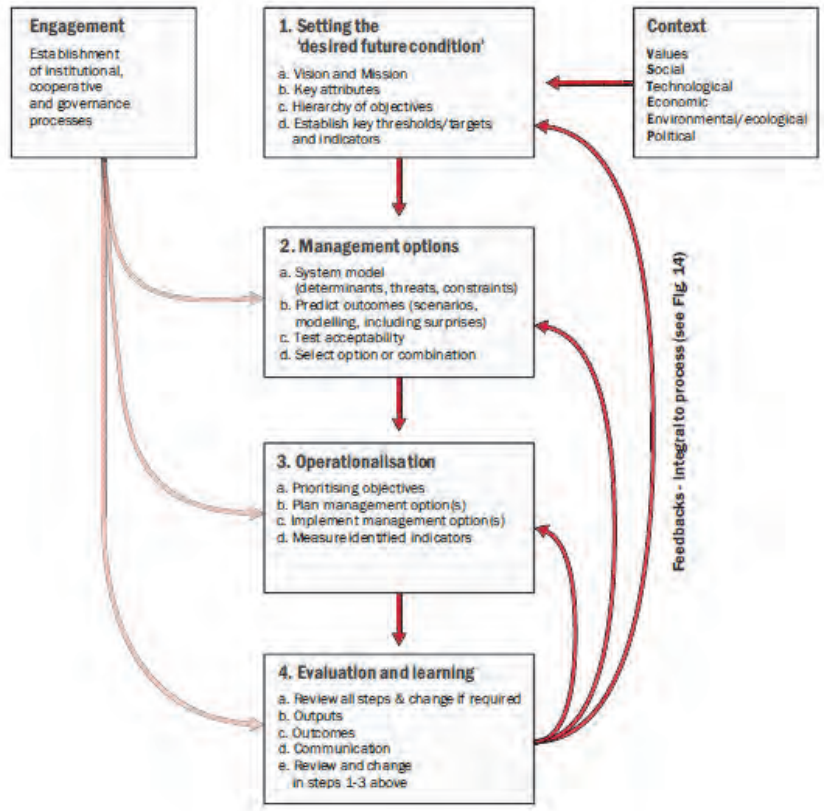

Figure 6. A generic strategic adaptive management framework (extracted from Kingsford and Biggs 2012)

6.7 Benefit sharing

The South African Department of Water Affairs logo “Some for all forever” reflects an intention for equitable sharing of the benefits from access to and use of the services deriving from aquatic ecosystems. The term ‘benefit’ generally implies an advantage or gain from something and so we may consider a benefit as something that promotes well-being. But, because what each of us needs to improve wellbeing may be quite different, individuals and groups value aquatic ecosystem services differently and we can readily appreciate that sharing issues will continue to form the core basis of debates about the governance and management of the use of these services. Given that the supply of and demand for aquatic

ecosystems services are so variable in time and space (Koch et al., 2009), there are widely differing opinions on how to respond to the complexity surrounding benefit sharing arrangements. Complexity in turn is fuelled by heightened uncertainty about the likely consequences for wellbeing of both collective and individual choices. As demands for access to and use of aquatic ecosystem services become more diverse and grow, relative scarcity will increase, fostering competitive rather than cooperative behaviours necessary for sustainable and equitable allocation of the associated benefits.

It is increasingly appreciated that because the majority of benefits derived from aquatic ecosystem services are accessed collectively, they should be governed as common pool resources. A governance system that provides an acceptable degree of security of access to ecosystem services is necessary for fostering sustainable use because investment (effort, finances etc.) is usually required to realize the benefits of these services.

In such complex contexts, governing and managing the use of the benefits of aquatic ecosystem services is not simply a matter of setting a utility function and selecting the alternative leading to the preferred set of consequences. On the contrary, it requires a systemic framing of key determinant variables which define the effectiveness, efficiency, equity and sustainability of benefit sharing arrangements. Knowledge about benefit sharing must be scientifically reliable and evolve to remain contextually relevant.

6.8 The Treehouse Model

During 2000-2009 researchers and conservationists met regularly at the ‘Tree-house’ in the Kruger National Park (unfortunately, the ‘Tree-house’ burnt down). The purpose of these meetings was to design and implement a research programme focusing on the governance and management of protected areas. A model or framework that emerged became known as the ‘Treehouse Model’ (Figure 7). It has been adapted for various applications but its fundamental design, when we link it to the issues described in the next section are likely to be highly relevant to the uMngeni River Basin.

In this process the Treehouse Model (McCool et al., 2013) is focused on knowledge, where it resides, how it may be accessed and how it may be employed. Some examples of questions aimed at directing the thinking when using the Treehouse model are listed below. The aim of the Treehouse model is to increase the resilience of the river basin social-ecological system through the application of relevant knowledge and the building of the capacity necessary to apply the knowledge.

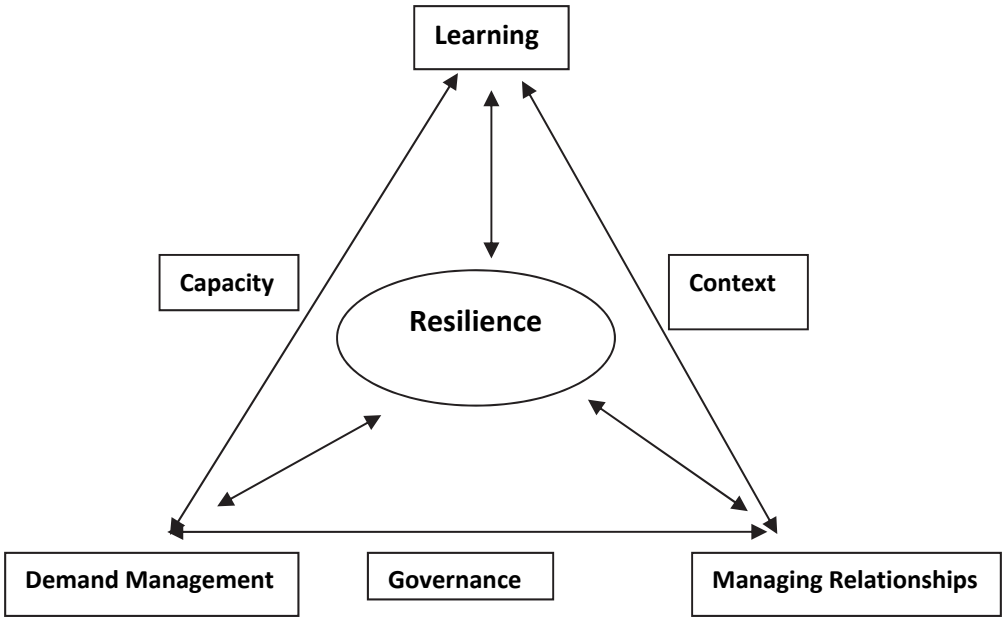

Figure 7. Treehouse Model (McCool et al., 2013)

Demand management

- What knowledge is needed to tackle the identified need(s)?
- Does this knowledge exist?
- If the knowledge exists, where is it housed?
- What is needed to access the knowledge?
- If the knowledge does not exist, what is the priority of developing it?

Managing relationships

- What is the relationship between the source and the end-user of the knowledge?
- Is the pathway for knowledge transfer clear?

Learning

- Who holds the knowledge?
- Can the knowledge be accessed?
- What new knowledge is needed?
- Does the platform exist for basin stakeholders to learn together about river basin governance?

Governance

- What institutions exist to enable the use of existing and new knowledge
- Are these sufficient?

Capacity

- Does the capacity exist for the interpretation and use of existing knowledge?
- Does the capacity exist for the generation of new knowledge as identified through this process?

- Does the capacity exist for the application of the knowledge that is needed?
- What training is needed to address the gaps identified in this process?

Context

- Is the context clearly understood?

6.9 Some concluding thoughts on models, frameworks and concepts

We use models to portray how we currently understand the structure and functioning of an SES. Inevitably they are simplifications of what is more complex than we envision. Because the system is always changing so too must our models. Despite our uncertainty models help us organise our thinking and learn about complexity. Of the various models, frameworks and theories described above none are 'good' or 'bad'. Also, no single model, framework or concept can service all our needs. We require a 'toolbox' full of them. Each one or a combination is relevant in a particular context and/or for a particular purpose:

- The 'State of the System' framework provides us with foundation that underpins the others.
- The concepts of well-being and livelihoods allow us to focus on what we are ultimately striving for and to differentiate its various components.
- The livelihoods framework helps us understand the components of and the drivers for improving livelihoods.
- The concept of a social-ecological system forces us to link society and nature, and the 'Anderies' Framework helps us understand this system, the relationships between its various constituents and what questions we might use to interrogate it.
- The Millennium Ecosystem Assessment assists us in understanding the concept of ecosystem services and how they act as mediators of human well-being.
- The concept of water resources as common pool resources that require governance and management through a common property rights regime, the notion of bundles of rights with varying types of access provide a firm foundation for establishing rights of access to water resources. This is strengthened through the concept of benefit sharing.
- At the level of management, Strategic Adaptive Management (SAM) provides us with a practical way of incorporating complexity, and learning by doing and reflecting on what we have done.
- Finally, the Treehouse Model provides us with a framework that might be useful in conceptualising and implementing a water-resource focused research programme.

A concept which is coming to the fore and has not received attention as yet is that of **ecological infrastructure**. It was greeted with a certain degree of suspicion when it was first put forward, probably in the same way as the concept of ecosystem services was about ten years ago. However, as we begin to understand it as the 'generator' of ecosystem services so is acceptance growing. Also, it appears that people outside the environmental/ecological domain can relate to it quite well. With the establishment of the Ecological Infrastructure

Partnership for the uMngeni River Basin it is likely to enjoy considerable prominence going forward.

7. The multi-disciplinary water resource management framework

A multi-disciplinary water resource management framework which follows a socio-ecological systems approach at a basin level needs to integrate people, knowledge and competence from a wide spectrum of society and as such, no single framework of those reviewed will suffice to deliver the required integration. The framework process proposed here is a composite of frameworks and associated processes which has guided the various aspects of the initiative currently underway in the uMngeni Basin, each of which addresses components of the full picture. Figure 8 indicates how the frameworks may work together to develop an integrated understanding of the river basin social ecological system.

No two river basins are the same and so the framework provides a guide as to how to understand any particular river basin. The inclusion or exclusion of components, such as the one or more of the range of questions to be answered when populating the Anderies framework, is left to the discretion of the team working through the framework for the river basin under consideration.

7.1 Employment of the framework

The framework of Anderies et al. (2004), designed to analyse the robustness of a social-ecological system, is used as the integrator of inputs. The inputs themselves are derived from other frameworks and processes, the use of each of which is covered in the report. In addition to this, The Treehouse model reminds readers that resilience is determined by, among others, relationships among resource users, their expectations of benefits demand for resources and how they learn about the system. It is designed to encourage learning by enriching contextual understanding. At the level of management, Strategic Adaptive Management (SAM) provides us with a practical way of incorporating complexity, and learning by doing and reflecting on what we have done. The SAM process provides for keeping records of all decisions and monitoring results in a structured way. An extension of this record-keeping, as described below, also provides for the Chain of Custody of the decisions taken to ensure that an audit trail is available.

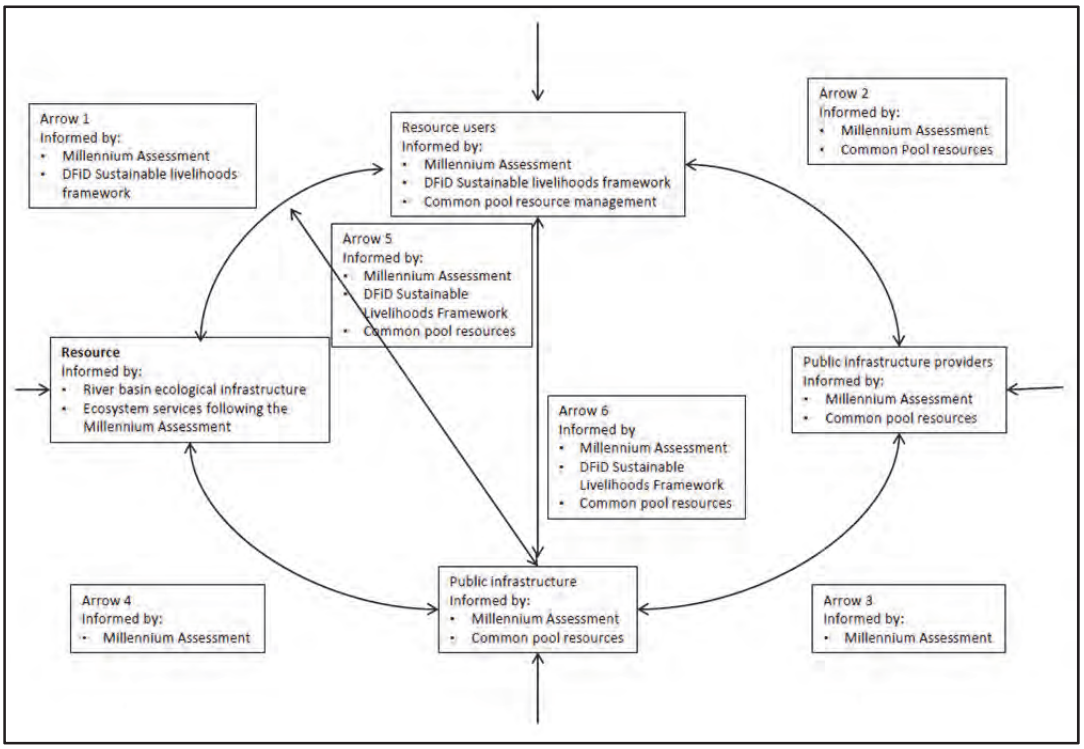

Figure 8. The Anderies Framework showing which other frameworks inform the various components of the main framework.

Methodology

To populate the Anderies Framework the questions in the document should be answered as appropriate. The other frameworks described in the document will give guidance in the specific situations to which they are relevant and should be used to ensure that nothing is left out.

The populated Anderies framework will provide the description of the social ecological system. This will inform the development of two further parts of the framework.

- The first is to provide the basis for input into the Treehouse model. One output from the Treehouse model will be the social learning that needs to occur, another will be ways in which research products may be managed in order for them to be accessible to river basin managers.

- The second is to develop a strategic adaptive management framework with indicators appropriate for the basin under consideration. Strategic adaptive management requires that a record be kept of all decisions so that they may be revisited at intervals to ensure that they are achieving what they were designed to achieve. These feedback loops allow for the adjustment of the vision, aims and methods where necessary to achieve the desired state.

This record-keeping will be taken further through the identification of departmental positions / people who are responsible for making and executing the decisions and interventions that are indicated through the strategic adaptive management (SAM) process to enable effective management of all aspects of the river basin governance and management.

> **NOTE:** Where possible, the responsibilities / accountabilities assigned to the various actors in the river basin who have been identified through the SAM process should be included as KPIs (key performance indicators) in the individuals' performance agreements. In this way the person will be empowered to fulfil the responsibility / accountability that has been assigned to him / her.

8. The State of the River Basin Report

The detail in the State of the River Basin Report will be guided by findings of the framework, but should address the following:

- **The definition and state of the resource:** The state of the resource should be assessed from the point of view of the stream of ecosystem services provided by the river basin. It should address the condition of the ecological infrastructure in the basin, highlighting any changes which have occurred since the previous reporting period. From this will follow an assessment of the changes in the stream of ecosystem services from which the socio-economy benefits.
- **The resource users:** The resource users should be identified. Their needs and the relationships between them should be assessed, taking into account any limitations imposed by the resource (such as availability or quality). The relationship of the resource users to the resource should be evaluated. Needs for capacity building should be noted and addressed. Any changes to the resource users or their requirements should be highlighted. All decisions taken should be recorded, together with the accountabilities of the people and the decisions should be gauged to assess how well they are achieving the intent of the decision.
- **The public infrastructure providers:** Amongst the points to be assessed are 'how effectively are basin stakeholders able to make input into the river basin management'.
- **Public infrastructure:** The roles of both the institutional and the physical infrastructure in guiding the management of the river basin should be considered. Are they contributing to the robustness of the SES? Are they providing the basis for effective management of the water (common pool) resource? Where changes need to be made, these should be planned.

8.1 Selection of indicators

All monitoring should be done within the framework of Strategic Adaptive Management (SAM). An early step in the SAM process is the setting of the preferred state. Achievable goals are defined through the process of defining the objectives hierarchy (Rogers and Bestbier, 1997) and once this has been done, indicators should be selected to enable the progress towards achieving the desired state to be monitored.

The function of an indicator is to provide an efficient and effective means of measuring the condition of a system and so, over time, providing a means to assess change to the system. Indicators need to be selected to measure the systems of interest to the particular river basin, but some indicators which measure factors of general concern are given below.

The River Health Programme: The River Health Programme provides a cost-effective means of monitoring the state of the water resource (*sensu* National Water Act), providing the opportunity to identify both long-term trends as well as accidental spills and other short term changes.

Ecological infrastructure: Monitoring key aspects of the biodiversity will provide insight into the state of, and changes to, the ecological infrastructure.

Non-Revenue Water (NRW): NRW provides insight into the state of the municipal infrastructure as well as the effort that municipalities put into managing their infrastructure. Municipalities are required to report on NRW although some of the smaller municipalities do not have the capacity to do so.

Water Quality – Point sources: The Green Drop System implemented by the Department of Water Affairs in 2009 has gathered considerable momentum and now provides a reliable measure of the effectiveness of the treatment of the urban wastewater discharged into the environment. It does not cover the concentrations or loads of nutrients discharged which is of crucial importance particularly to inland systems.

Human Health: What is the level of incidence of water-borne diseases, specifically gastro-intestinal diseases in infants?

Governance: How effectively is society participating in water resource governance and management?

9. How do we take this forward?

In the midst of complexity a few things are abundantly clear. The uMngeni River Basin is the cradle that sustains its residents. It is where we live, where we work and where we play. The water flowing through it sustains us physically, emotionally and spiritually, and it sustains our businesses, our farms and forests, and our natural systems. It is the lifeblood of our society and our economy – it is a social issue, a political issue, an economic issue and an ecological issue. As we grow and develop so does the demand for water resources – we use more and we pollute more. As the resource becomes scarcer so does its allocation – some, for all, forever – becomes more difficult and more complex. And when we add in possible climate change impacts, the complexity increases further.

We all recognise that the governance and management of the uMngeni River Basin – its people and its resources – is a shared responsibility involving government, business and society. We know we cannot do it alone. We also know that, for very selfish reasons, we have to get it right. Getting it wrong will compromise our individual and collective well-being. It will also impact directly on the developmental trajectory of our country and our province. Getting it right improves our collective well-being and provides KZN with a competitive economic advantage in a country regularly short of water.

- Finally we know full well that we are currently getting it wrong. Governance and management efforts at the scale of the river basin are ineffectual. We know enough about the state of the system to know that it is in decline. Fundamental change is required. We need to build and sustain a more enabling context for participative governance and develop within society and government the necessary motivation and capabilities. So, what should we be doing as researchers?
- Grow our knowledge base in institutional and technical areas in support of effective governance and management of the river basin
- Build the capacity of our current and future generation of river basin leaders, managers, practitioners and researchers
- Act as a catalyst for collective and coordinated action

A partnership with UKZN and DUT as leads is a logical starting point. Both are recognised leaders in knowledge generation in support of water resource management. There is considerable depth in disciplines required to support water resource management. These range from filtration technology to law. In addition, we are currently educating and training the leadership cadre of tomorrow and we can mobilise partners from numerous sectors. In short, together with our numerous partners we can deliver ‘source-to-sea’ solutions for many situations.

What might guide our thinking in the design of this partnership?

- It is a partnership programme focused on participative learning and improving our knowledge about water resource governance, management and technical issues at the scale of the river basin.
- It is an integrated study dealing with the river basin as a social-ecological system
- It is demand or needs driven – regulators, managers, planners and users will be instrumental in identifying the key research areas

- It is a mechanism to provide existing research capacity with direction and focus, and to contextualise current and past research
- It is a vehicle to build new leadership, management and research capacity through post-graduate training and experiential learning

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Annexure 1: Chain of custody

The Chain of Custody (CoC) is originally a legal term referring to the handling of evidence to be used in a criminal or civil court proceedings. The term is defined by the Free Dictionary (Undated) as '*The movement and location of physical evidence from the time it is obtained until the time it is presented in court*'. The process requires strict documentation ('paper trail') of the handling and storage of evidence in order to be certain that it reaches the court in its 'original' state and that it has not been tampered with in any way. The evidence may take any form, including digital. The full CoC for legal purposes has three overarching requirements:-

1. Testimony that the piece of evidence is what it is supposed to be
2. Testimony of the continuous possession of the piece of evidence from when it was first collected to when it was presented in court and
3. Testimony by each person who handled the piece of evidence for whatever reason that the evidence remained in the same condition when passing through the CoC.

The concept of a CoC has been adopted by certain natural resource-based industries to enable consumers to recognise and support good practice.

World-wide, the forestry industry has a number of certification processes to provide suppliers and end users of forestry products with the assurance that the products are from sustainably managed forests. Globally, the two largest umbrella certification programmes are the Programme for the Endorsement of Forest Certification (PEFC, 2013) and the Forest Stewardship Council (FSC, 2013). The PEFC is an international non-profit NGO which promotes sustainable forest management through independent certification. It requires adherence to eight core international labour organisation conventions and it is the choice of small forest owners. The FSC is a not-for-profit multi-stakeholder organisation established to promote responsible management of the world's forests. Through their CoCs both organisations provide assurance to the end users of the wood and products that the timber originates from sustainably-managed forests.

The Marine Stewardship Council (MSC, 2011) provides a similar service to sustainable fishing, where the CoC is designed to follow the fish from the ocean to the consumer, ensuring that no non-CoC products are included in what the consumer purchases. In the case of the PEFC, FSC and MSC, the product bears the label that assures potential purchasers of its compliance with the standards set by the organisation.

Chain of Custody for River Basin Management

The State of the River Basin Report will outline how a CoC for the management of river basins may be implemented through developing an understanding of, and then structuring, the process in River Basin Management. In order to ensure that all involved understand their individual responsibilities and accountabilities the CoC needs to address the following three components:

Custodianship

River basin management depends on a network of collaborating custodians, some of whom are in the framework provided by formal organisations, others not. But each of these entities is a custodian of part of the overall river basin governance system. The accountabilities are both vertical and horizontal within the overall framework. The framework structure needs to be adaptable to accommodate both the systems in different river basins as well as changes that may occur over time.

Of what do you have custody?

In the case of river basin governance, this would probably be information of various types or an asset such as a wetland or man-made structure.

Sanction

Once the custody is clear and has been accepted by the various custodians then official sanction can be given to certain people / entities for the activities for which they are responsible.

Annexure 2: Notes on accessing research products

For the purpose of this section research products have been divided into 3 categories, as follows:-

- Existing research products
- Research currently on-going
- Research to be undertaken in the future

Existing research products: There is a lot of existing research which may not be readily accessible to basin stakeholders who are not specialists in the topics of the research. In order to make these accessible it may be necessary for a subject matter expert who understands what is needed from the research product to extract the relevant knowledge and present it in a way that is accessible to the basin stakeholders.

Research currently on-going: If the research initiative is already on-going when the river basin governance initiative is started then there should be effective communication between basin stakeholders and researchers, and basin stakeholders should be encouraged to make input into the ongoing research to ensure that the product will address the need of the basin stakeholders.

Research to be undertaken in the future: Research that is being planned should involve the basin stakeholders from the beginning of the needs identification process and take account of their identified needs. There should be regular communication between the basin stakeholders and researchers through the course of the research to ensure that the basin stakeholders are *au fait* with the research product as it is being developed.