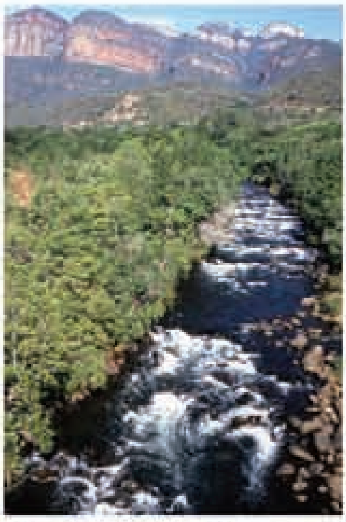
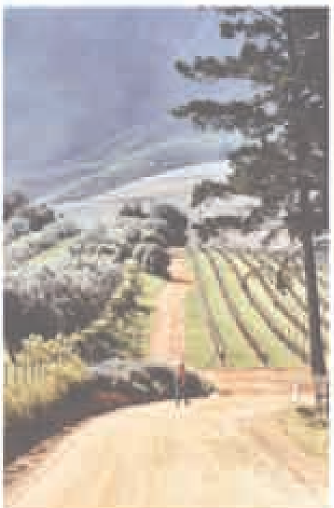
DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

Socio-economic guidelines for the 7-step classification procedure - February 2007



1st Edition

Chief Directorate
Resource Directed Measures

Volume 3

water & forestry

Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

THE DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

First Edition: February 2007
Volume 3

Socio-Economic Guidelines for the 7 – Step Classification Procedure

Chief Directorate: Resource Directed Measures

Technical Guidelines for
DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

First Edition

Department: Water Affairs and Forestry

Development of the Water Resource Classification System (WRCS)
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Preface

The Water Resource Classification System (WRCS) was established in response to the South African National Water Act of 1998. The WRCS is a set of guidelines and procedures that, when applied to a specific catchment, will ultimately assist in the process of maintaining a balance between protecting our national water resources and using them to meet economic and social goals. The procedures are to be applied as part of a consultative ‘Classification Process’, the final outcome of which is a decision about the set of desired characteristics for each of the water resources in a given catchment.

The Classification Process sets a ‘Class’, which defines objectives for every significant water resource—watercourse, surface water, estuary, or aquifer. There are three classes, ranging from the minimally used to the heavily used. These objectives describe the desired condition of these resources and the extent to which they can be utilised.

The Classification Process is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use. A key component of classification is therefore the ongoing process of evaluating options with stakeholders in which the economic, social and ecological trade-offs will be clarified and decided upon.

Volumes 1 to 5 of these reports build on an earlier version of the classification system and meet the terms of reference as set out in the inception report (DWAF, 2005a). The development of the new system was completed in twelve months using the Olifants/Doring catchment as a ‘proof of concept’ catchment. The Olifants/Doring system was chosen for two reasons: 1) A recent Reserve determination study had provided much of the required information. 2) Most of the WRCS project team had been involved in the determination study.

It was initially planned that once the draft WRCS had been developed, it would be tested, refined and possibly streamlined using two other, more complex catchments (such as Thukela and Incomati). This turned out not to be possible. The description of the classification procedure has therefore been left as generic as possible so that future applications of the WRCS can build on and improve the procedures and guidelines presented in these volumes.

The classification system regulations will be developed from these volumes.

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ACRONYMS

ASGISA	Accelerated and Shared Growth-South Africa
BHN	Basic Human Needs (Reserve)
CAPS	Cape Area Panel Study
CMS	Catchment Management Strategy
Cons.	(Freshwater) Conservation (target)
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of South Africa
DMA	District Management Area
DME	Department of Minerals and Energy
DoH	Department of Health
DWAF	Department: Water Affairs and Forestry
EA	Enumerator Area
EC	Electrical Conductivity
EGSAs	Ecosystem Goods, Services and Attributes
EIS	Economic Information System
ELU	Existing Lawful Use
ESBC	Ecologically Sustainable Base Configuration (scenario)
EWRs	Ecological Water Requirements
GDP	Gross Domestic Product
GGP	Gross Geographic Product
GNP	Gross National Product
HDI	Human Development Index
HEP	Hydro Electrical Power
I&AP	Interested and Affected Parties
IES	Incomes and Expenditure Surveys
IPCC	International Panel on Climate Change
ISP	Internal Strategic Perspective
IUAs	Integrated Units of Analysis
IWRM	Integrated Water Resource Management
LM	Local Municipality
LR	Leaching Requirement
MAP	Mean Annual Precipitation
MC	Management Class
MRC	Medical Research Council
NDSD	National Department of Social Development
NWA	National Water Act
NWRS	National Water Resource Strategy
OECD	Organisation for Economic Co-operation and Development
OHS	October Household Survey
PES	Present Ecological Status
PSLSD	Project for Statistics on Living Standards and Development
PSU	Prime Sampling Unit
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
SADHS	South Africa Demographic and Health Survey
SAL	Small Area Survey
SALDRU	Southern Africa Labour Development Research Unit
SAM	Social Accounting Matrix
SFRA	Stream Flow Reduction Activity
TC	Test Catchment

TDS	Total Dissolved Salts
TEV	Total Economic Value
UNDP	United Nations Development Programme
WMA	Water Management Area
WRCS	Water Resource Classification System
WRSA	Water Resource Situation Assessment
WSAM	Water Resources Situation Assessment Model
WUA	Water User Associations

1 INTRODUCTION

The WRCS is required by the National Water Act (NWA) (No. 36 of 1998), and consists of a set of guidelines and procedures for determining the different classes of water resources (Chapter 3, Part 1, Section 12). Desired characteristics of the resource are represented by a Management Class (MC) which outlines the attributes required of different water resources by the resource custodian (Department: Water Affairs and Forestry (DWAF)) and by society.

The WRCS will be used in a consultative process (i.e. the Classification Process) to classify the water resources within a geographic region in order to facilitate finding a balance between protection and use of the water resources. The actual process of *applying* the WRCS procedures described in this volume to a catchment is called the Classification Process i.e. establishing the MC. The economic, social and ecological implications of choosing a MC need to be established and communicated to all Interested and Affected Parties (I&AP) during the Classification Process.

The outcome of the Classification Process will be the setting of the MC, Reserve and Resource Quality Objectives (RQOs) by the Minister or delegated authority for every significant water resource (watercourse, surface water, estuary, or aquifer) under consideration. This will be binding on all authorities or institutions when exercising any power, or performing any duty under the NWA. This MC, which will range from Minimally to Heavily used (Table 1.1), essentially describes the desired condition of the resource, and concomitantly, the degree to which it can be utilised. In other words, the MC of a resource sets the boundaries for the volume, distribution and quality of the Reserve and RQOs, and therefore informs the determination of the allocatable portion of a water resource for use. This has considerable economic, social and ecological implications.

Table 1.1 Proposed water resource classes

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

1.1 Objectives of this report

This report presents the socio-economic guidelines for undertaking Steps 1 to 5 of the classification procedure (see Section 1.2) through a ‘proof of concept’ application to the Olifants/Doring catchment (Test Catchment 1 (TC 1)). The context to the WRCS, the definition of the classes and description of the overall classification procedure is presented in Volume 1 of this series (Dollar *et al.*, 2007). The guidelines for the ecological and decision analysis components of the classification procedure and their application to the Olifants/Doring catchment are presented in Volumes 2 (Brown *et al.*, 2007) and 4 (Joubert *et al.*, 2007) respectively.

1.2 7-step classification procedure

A 7-step procedure to recommending the MC of a resource (the outcome of the Classification Process) is proposed (Figure 1.1). The seven steps which may be embedded in other DWAF processes are:

Step 1: Delineate the units of analysis and describe the status quo of the water resources:-

a. Describe the present-day socio-economic status of the catchment;
b. Divide the catchment into socio-economic zones;
c. Identify a network of significant resources, describe the water resource infrastructure and identify the water user allocations;
d. Define a network of significant resources and establish the biophysical and allocation nodes.
e. Describe communities and their wellbeing;
f. Describe and value the use of water;
g. Describe and value the use of aquatic ecosystems;
h. Define the Integrated Units of Analysis (IUA);
i. Develop and/or adjust the socio-economic framework and the decision-analysis framework; and
j. Describe the present-day community wellbeing within each Integrated Unit of Analysis.

Step 2: Link the value and condition of the water resource:-

a. Select the ecosystem values to be considered based on ecological and economic data;
b. Describe the relationships that determine how economic value and social wellbeing are influenced by the ecosystem characteristics and the sectoral use of water; and
c. Define the scoring system for evaluating scenarios.

Step 3: Quantify the Ecological Water Requirements and changes in non-water quality Ecosystem Goods, Services and Attributes:-

a. Identify the nodes to which Resource Directed Measures data can be extrapolated and make the extrapolation;
b. Develop rule curves, summary tables and modified time series for all nodes for all ecological categories; and
c. Quantify the changes in relevant ecosystem components, functions and attributes for each ecological category for each node.

Step 4: Determine an Ecologically Sustainable Base Configuration scenario and establish the starter configuration scenarios:-

a. Determine an Ecologically Sustainable Base Configuration (ESBC) scenario that meets feasibility criteria for water quantity, water quality and ecological needs;
b. Incorporate the planning scenarios (future use, equity considerations and existing lawful use); and
c. Establish the Resource Directed Measures configuration scenarios.

Step 5: Evaluate scenarios within the Integrated Water Resource Management (IWRM) process:-

Steps 5 and 6 form part of the 'Larger Process' where the economic, social and ecological trade-offs will be made. Trade-offs will also need to be made between Existing Lawful Use (ELU) and equity considerations. Emerging from this 'Larger Process' will be the recommended MC, Reserve and RQOs, CMS, allocation schedule, modelling system and the monitoring, auditing and compliance strategy. A number of key questions will need to be addressed in this 'Larger Process'. These include:

- at what level will the trade-offs be negotiated?
- in what institutional setting will they be negotiated?
- what types of scenarios will inform the process of negotiation?; and
- since the recommended MC, Reserve, RQOs, CMS and allocation schedule will impact on specific groups of people in different ways, what processes will guide decisions about who benefits and who pays the social and economic cost?

These key questions should be framed (and assessed) in the context of equity, efficiency and sustainability as required by the NWA, and by the core objectives of the present government which are, amongst others, to halve poverty and unemployment by 2014, to reduce the regulatory burden on small and medium businesses, and to eliminate the second economy[1]. Step 5 should therefore contribute to meeting government's objective of '…reduce(ing) inequality and virtually eliminating poverty'.[2] To address these objectives and to fit within the larger DWAF institutional context, Classification Procedure Step 5 needs to include the following sub-steps:

a. Run a yield model for the Ecologically Sustainable Base Configuration scenario and other scenarios and adjust the scenarios if necessary;
b. Assess the water quality implications (fitness for use) for all users;
c. Report on the IUA-scale ecological condition and aggregate impacts for each preliminary scenario;
d. Value the changes in aquatic ecosystems and water yield;
e. Describe the macro-economic and social implications of different catchment configuration scenarios;
f. Evaluate the overall implications at an Integrated Unit of Analysis-level and a regional-level; and
g. Select a subset of scenarios for stakeholder evaluation.

Step 6: Evaluate the scenarios with stakeholders:-

a. Stakeholders evaluate scenarios and agree on a short-list; and
b. Recommend classes for the Integrated Units of Analysis.

Step 7: Gazette the class configuration:-

a. Populate the Integrated Water Resource Management summary template and present to the Minister or his/her delegated authority;
b. Decision by the Minister or his/her delegated authority on the Integrated Unit of Analysis classes, nested ecological category configurations, Reserve(s), allocation schedule(s) and the Catchment Management Strategy;
c. Set the resource quality objectives;
d. Gazette Integrated Unit of Analysis classes, nested ecological category configurations, Reserve(s) and resource quality objectives; and
e. Develop a plan of action for implementation of the recommended scenario which must include a monitoring programme.

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[1] www.info.gov.za/issues/asgisa/.
[2] www.info.gov.za/issues/asgisa/.

1.3 Structure of this report

The report is structured and aligned with the classification procedure presented in Figure 1.1. The guidelines and procedures for the socio-economic components of each of the 7 steps are presented, together with an example of application of the guidelines and procedures to the ‘proof of concept’ catchment, the Olifants/Doring.

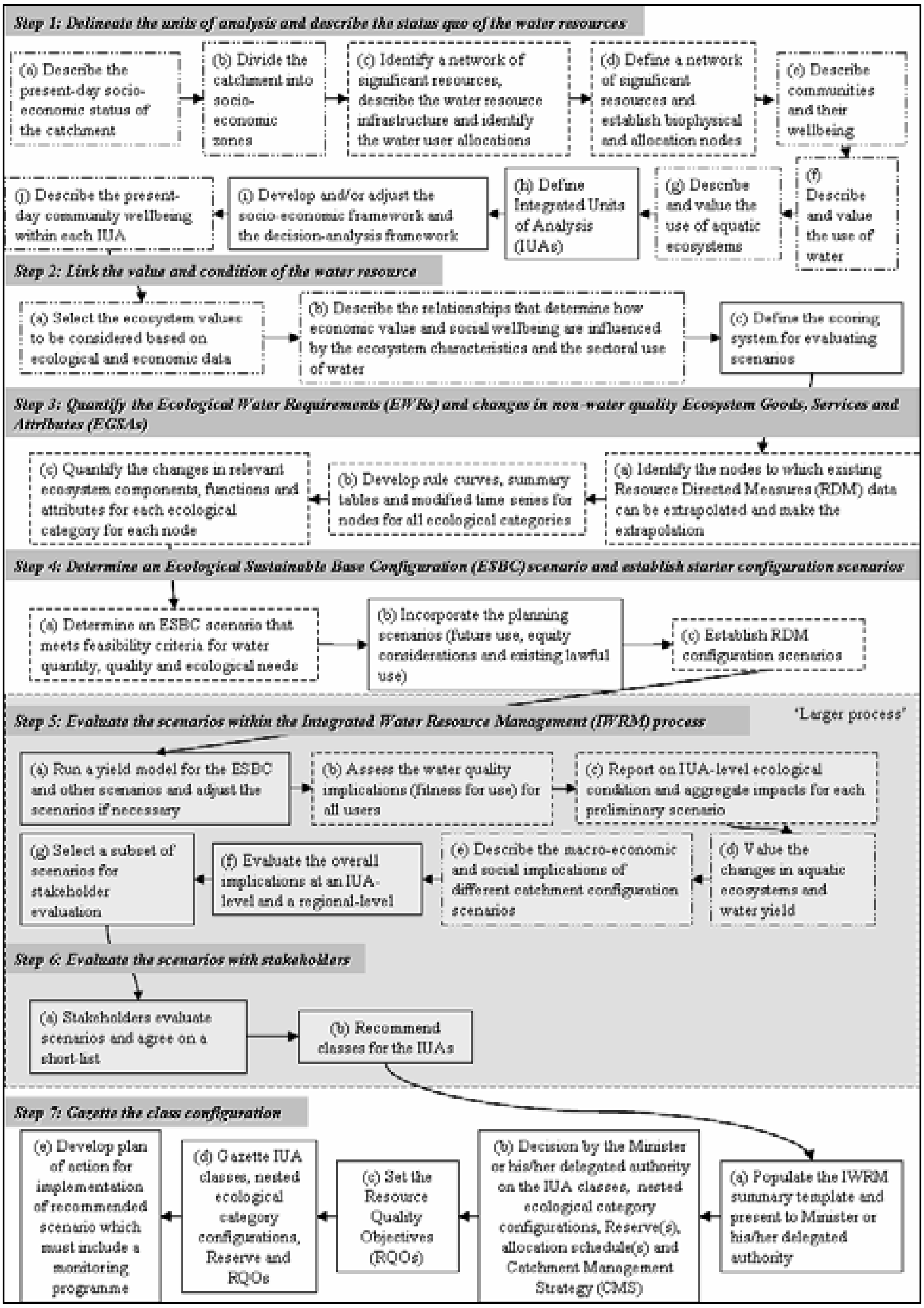

Figure 1.1 Proposed 7-step classification procedure (note that Steps 5 and 6 form part of the ‘Larger Process’)

2 SOCIO-ECONOMIC CONCEPTUAL FRAMEWORK FOR THE CLASSIFICATION PROCEDURE

In contrast to the ecological component (see Brown *et al.*, 2007) of the WRCS, which can draw on over 10 years of Reserve experience, the socio-economic component breaks new ground, and can only draw on a limited number of studies to aid its development. For this reason, before presenting the socio-economic guidelines for the 7-step classification procedure, it is necessary to highlight a number of concepts, methods and measures (e.g. Ecosystem Goods, Services and Attributes (EGSAs), the measurement of economic value and the measures of economic implications and social wellbeing) that provide the context for the 7-step procedure.

2.1 Integrating economic and social goals into the management class

The NWA calls for the efficient, equitable and sustainable use of the nation's water resources. These economic, social and ecological goals respectively, are embodied in DWAF's official motto, '*ensuring some, for all, for ever, together*'. The economic goal of efficiency relates to maximising economic returns from water resources, or achieving the maximum net benefit. The social goal of equity seeks to allocate and distribute the costs and benefits of utilising the resource fairly, while the ecological goal of sustainability seeks to promote the use of resources in a way that meets the needs of current generations, but does not compromise the economic opportunities and social wellbeing of future generations. These goals are also consistent with government's Accelerated and Shared Growth-South Africa (ASGISA)[3] strategy that takes the position that without interventions targeted at reducing South Africa's historical inequalities, growth is unsustainable. In the context of Integrated Water Resource Management (IWRM), this involves allocating water for historic redress as a legal imperative, and contributing to eliminating the second economy.

To assess the economic prosperity and social wellbeing implications of different catchment configuration scenarios, the socio-economic component of the classification procedure should make provision for assessing the target catchment's current socio-economic status and the potential economic and social wellbeing implications of different options (scenarios). These implications may be considered at various scales.

It is also important to point that that whereas the ecological descriptions will be relative to a pre-development condition, the baseline for the socio-economic implications is the present. In many cases it is difficult to describe a current value, but it will be feasible to estimate a loss or gain in value under different scenarios. Thus the current situation can only be described in quantitative terms as far as is feasible or practical, and changes in value will be estimated for different scenarios.

2.2 The concepts of ecosystem goods, services and attributes and types of value

Ecological systems provide services that are critical to the functioning of the earth's life-support system (Costanza *et al.,* 1997). They contribute both directly and indirectly to human welfare, and therefore have economic value. Indeed the earth's ecosystem services have been estimated to be worth in the order of US$33 trillion per annum (Costanza *et al.,* 1997). Because these services are not fully traded in commercial markets, however, they are often given very little weight in policy decisions, and the ecosystems which generate them are taken for granted. It is thus important to estimate the economic values associated with aquatic and other water-dependent ecosystems, and consequently, to estimate how these values would change if these systems were to be altered in any way, for example by changes in class.

[3] www.info.gov.za/issues/asgisa/

In ecological-economics parlance, natural systems represent the ‘natural capital’ that, together with man-made capital and human capital, produce goods and services that are consumed by households in the economy. Ecological-economics recognizes the important contribution made by ecosystems both in supplying raw materials and in absorbing wastes associated with economic production, as well as the earth’s limited capacity for economic growth. Following the publication of Costanza *et al.*’s (1997) article in *Nature,* ecosystem functions have been catapulted into the public arena, repackaged as valuable ‘goods and services’.

The classification of ecosystem characteristics in terms of economic commodities (goods and services) may be thought of as follows (Table 2-1). Goods are the tangible products provided by ecosystems, such as timber, and services encompass benefits such as those associated with ecosystem functioning, for example, water purification. Natural systems also have attributes, such as biological diversity and scenic beauty, which contribute to their potential, such as ecotourism value, or sense of place, adding to overall quality of life. Most authors mention ecosystem goods and services or ecosystem services (goods being implicit), but for the WRCS, attributes will be considered explicitly, as this valuable aspect of ecosystems may otherwise be forgotten.

Table 2-1 A comparison of ecological and economic characteristics of ecosystems (adapted from Aylward and Barbier, 1992)

System characteristics	Ecosystem characteristics	Economic characteristics
Stocks	Structural components	Goods
Flows	Environmental functions	Services
Organization	Biological and cultural diversity	Attributes

The value of ecosystem goods and services is often described in terms of the resource-economics concept of Total Economic Value (TEV) of biodiversity, a framework that has been devised to simplify the description and measurement of value (Figure 2.1).

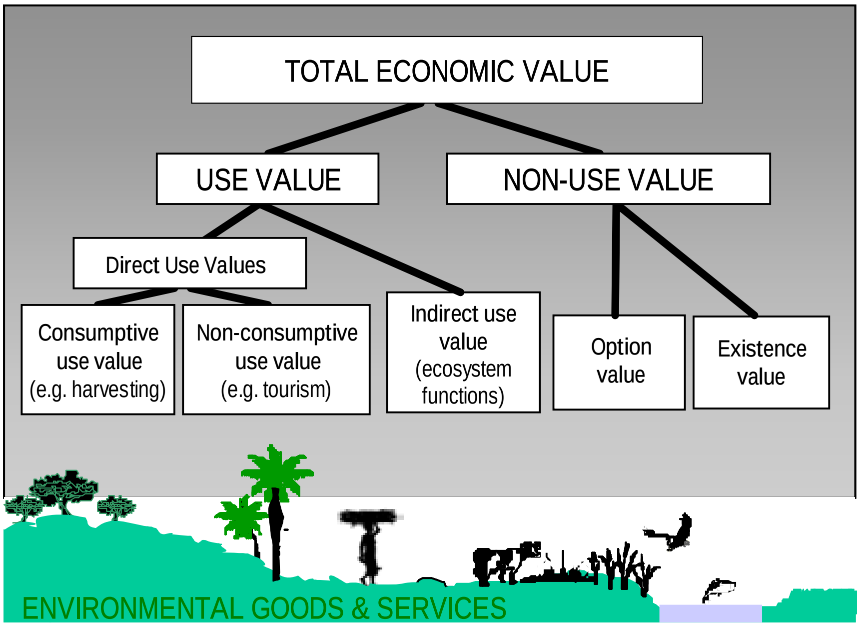

Figure 2.1 Total Economic Value (after Turpie *et al.*, 1999)

The way in which biodiversity, EGSAs, and the components of TEV are linked is depicted in Figure 2.2 (Turpie, 2004). The structural components and organization of biodiversity, akin to the popular interpretation of biodiversity, underpins ecosystem functioning. In particular, it is thought to play an important role in determining the resilience of ecosystems, or their capacity to withstand major perturbations, by ensuring the continuity of ecosystem functioning (or provision of ecosystem services) over a range of environmental conditions (Holling *et al.*, 1995).

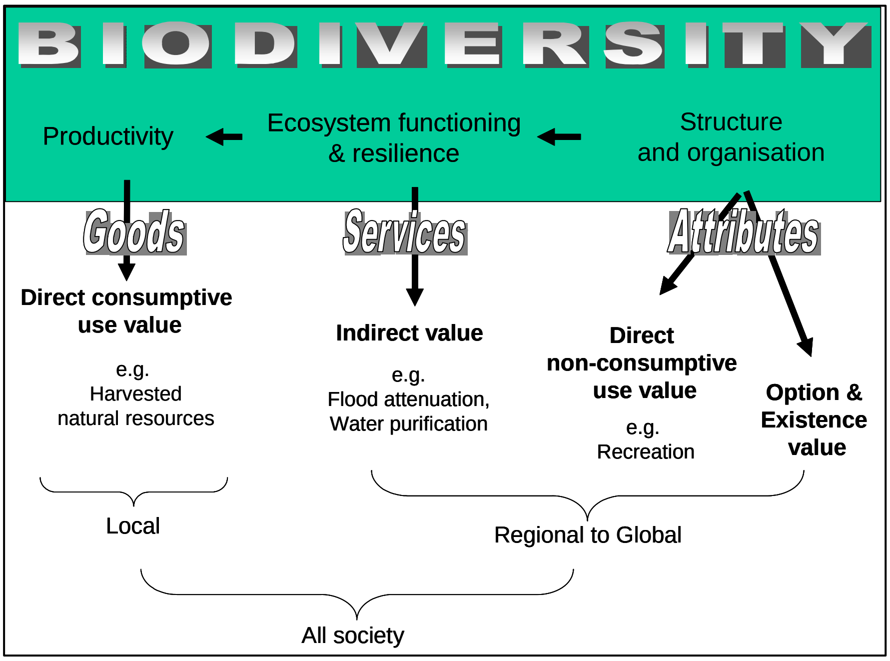

Figure 2.2 Relationships between biodiversity, goods services and attributes, and elements of Total Economic Value (after Turpie, 2004)

While certain species have more important roles than others under one set of environmental conditions, others become important when those circumstances change. The loss of species is thought to undermine the buffering role played by ecological redundancy (Perrings *et al.,* 2000). Indeed, the maintenance of structural diversity and organization within ecosystems (these characteristics are used as indicators of 'ecosystem health') is important for the maintenance and stability of primary production, which ultimately gives rise to the direct consumptive use value of ecosystems (Figure 2.2). These are the values derived from local activities such as livestock grazing or resource harvesting. However, ecosystem functioning is also important in that it contributes to economic processes at a broader scale. Water regulation and purification, and carbon sequestration are processes which provide value at a broad scale. In addition, genetic diversity and organization contribute non-consumptive use value in the form of recreational and tourism value as well as option and existence value. Option value is a measure of potential future use of biodiversity. For example, most cultivated crops contain genetic material that is recently incorporated from related wild species (Perrings *et al.,* 2000). Existence value is a measure of the satisfaction that people gain from the simple knowledge of the fact of certain aspects of biodiversity. The alteration of catchment hydrology changes the structural make-up of its aquatic and water-dependent ecosystems, their genetic diversity and organization of biodiversity, effectively altering the foundations of these ecosystems. In so doing, ecosystem functioning and resilience, and ecosystem productivity are affected. Different class configurations can thus have implications for all the values described above. While the changes in hydrology on biodiversity has been the subject of considerable research, the full implications of these influences are not generally understood, even in concept, by many policy- and decision-makers.

Total economic value encompasses all the measures that affect human welfare. Nevertheless, it is currently only those values that are relatively tangible (direct and indirect use values, akin to goods and services) that carry any weight in the political arena.

2.3 Spatial and scale issues

Ecosystem services have different meanings at different spatial scales. For example, at a local scale, the maintenance of ecosystem productivity might be seen as an ecosystem service provided to farmers and pastoralists. However, the same land might produce other services, such as carbon sequestration, that are consumed by other actors in society. The time scales of these perspectives are also considerably different.

The degree to which a service is directly associated with a particular catchment will also differ. For example, water supply and regulation may be seen as a service in itself to consumers of water. However, those benefiting from the ecosystem goods and services provided by downstream aquatic ecosystems are also indirect beneficiaries of this service.

2.4 Goods, services and attributes of aquatic ecosystems

The main types of EGSAs that would be associated with aquatic ecosystems are listed in Table 2-2. These EGSAs are discussed in more detail below, providing lists of different types of EGSAs within each category. Probable importance of each of these in the Olifants/Doring catchment is indicated in parentheses.

2.4.1 Water

Water is fundamental to survival, but can be broken down into various socio-economic uses. When dealing with EGSAs, water is only considered in terms of its *in-situ* use, since water extracted from the ecosystem will be considered separately. Thus, water as an EGSA, would include the following use values:

2.4.1.1 Food and medicine

Many aquatic and groundwater-dependent ecosystems provide foods and medicines which are used by surrounding communities living in the area, or harvested commercially. These are of particular importance to poor communities, especially those in communal land areas, but are also important for rural settlements and farm workers on privately owned lands. These include fish, shellfish, bait species, food and medicinal plants and salt.

2.4.1.2 Raw materials

As with food and medicines, aquatic and groundwater-dependent ecosystems provide raw materials which are used by surrounding communities living in the area, or harvested commercially. These include, but are not limited to, grass for thatching, crafts and fencing, sedges for mats and crafts, reeds for mats, fences and building, timber and poles from riparian and mangrove forests, firewood, sand, pebbles, clay, and minerals.

Table 2-2 Ecosystem goods, services and attributes of aquatic and water-dependent ecosystems, adapted from Costanza *et al.* (1997)

	EGSAs	Ecosystem functions	Examples
Goods	**Water**		Provision of water for subsistence use
	Food, medicines	Ecosystem production	Production of fish and food plants, medicinal plants
	Raw materials	Ecosystem production	Production of craftwork materials, construction materials and fodder
Services	**Gas regulation**	Regulation of chemical composition of the atmosphere	Carbon sequestration, oxygen and ozone production
	Climate regulation	Regulation of temperatures, precipitation at local levels	Urban heat amelioration, wind generation
	Disturbance regulation	Regulation of episodic and large environmental fluctuations on ecosystem functioning	Flood control, drought recovery, refuges from pollution events
	Water regulation	Regulation of water flow	Provision of dry season flows for agricultural, industrial and household use (spatially and temporally)
	Erosion control and sediment retention	Retention of soil and fertility within an ecosystem	Prevention of soil loss by vegetation cover, and capture of soil in wetlands, added agricultural (crop and grazing) output in wetlands/floodplains
	Nutrient cycling	Storage, recycling, capture and processing of nutrients	Nitrogen fixation, nitrogen cycling through food chains
	Waste treatment	Recovery of nutrients, removal and breakdown of excess nutrients	Breaking down of waste, detoxifying pollution; dilution and transport of pollutants
	Ecological regulation	Regulation of pest and disease vector populations	Regulation of malaria, bilharzia, liver fluke, black fly, invasive plants, etc.
	Refugia	Habitat for resident and migratory populations	Critical habitat for migratory fish and birds, important habitats for species
	Nursery areas	Nursery habitat for species that complete their lifecycle elsewhere	Critical breeding habitat, Nurseries for marine fish
	Export of materials and nutrients	Export of materials and nutrients to other ecosystems	Export of nutrients to marine ecosystems
Attributes	**Genetic resources**	Unique biological materials and products	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species
	Structure and composition of biological communities	Species diversity and habitats providing opportunities for recreational and cultural activities	Tourism and recreation
			Cultural, educational, spiritual and scientific values
		Amenity	Riparian trees providing shade for livestock and people

2.4.2 Carbon sequestration

Carbon sequestration is probably the only significant gas regulation function that could be derived from aquatic and groundwater-dependent ecosystems.

Carbon is taken up by plants in the growth process and stored in above and below-ground plant biomass. In addition, litter production and other processes lead to the accumulation of carbon in soil. The amount stored in plant biomass is a relatively constant function of total mass, but the rate of carbon uptake from the atmosphere depends on the growth rate of these plants. The amount stored in soils differs according to vegetation cover and land use.

The sequestration of carbon is an important service which offsets the damage caused by increasing atmospheric carbon and resultant global climate change. It has been conservatively estimated that climate change in South Africa will carry a cost of about 1 to 2% of Gross Domestic Product (GDP) by 2050 (possibly up to 6%), due to changes in ecosystem productivity, ecotourism opportunities, disease vectors, agricultural production and due to infrastructural damage, amongst other effects (Turpie *et al.,* 2004a). The estimated damages are equivalent to about R80 per tonne of carbon emitted; taking into account the fact that carbon contributes about 60% of total greenhouse gas emissions in South Africa (Scholes and van der Merwe 1995; Rowlands, 1996). The sequestration of carbon by ecosystems thus has a positive economic value.

While it is relatively straightforward to determine the standing stock of carbon in a landscape, estimating the rate of carbon sequestration is a more complex issue. This is related to the rate of carbon storage, but also to how permanently the carbon is stored. A vegetation type or land cover type can only be considered as a permanent sink for carbon if it remains sequestered for at least 20 years (IPCC/OECD, 1994). In terms of carbon trading, only the restoration of long-lived indigenous trees is considered valid. Nevertheless, faster growing vegetation may result in high levels of soil carbon sequestration, even if biomass carbon is not stored for long. In general the savanna and thicket biomes have a higher rate of carbon sequestration than other biomes (Driver *et al.*, 2004).

Carbon is taken up in all natural and agricultural plant growth at various rates. However, it is only in the forestry plantations that carbon is potentially sequestered permanently. These crops end up as products such as furniture or paper, where carbon remains sequestered, rather than, for example, firewood, the burning of which would release carbon back into the atmosphere. Tree plantations sequester biomass carbon at a rate of about 3 tonnes per ha per year, whereas grasslands and annual crops cannot be considered to sequester biomass carbon to any significant degree (Turpie *et al.*, 2003). Whether the actual rate of this accumulation differs under different land uses is however unknown.

It is likely that aquatic ecosystems are largely carbon-neutral in an undisturbed state. The main issue to be considered is the sequestration or loss of carbon that would result from a change in vegetation biomass as a result of changes in class. This could be significant in the short term if there were, for example, a loss of a large area of mangroves.

2.4.3 Climate regulation

Regulation of local climate is a service which is often associated with forests, especially large-scale tropical rainforests. Aquatic and water-dependent ecosystems are unlikely to influence local climate to any significant degree.

2.4.4 Disturbance regulation

Disturbance regulation is usually associated with wetlands, such as floodplain wetlands and coastal mangrove areas. Floodplain wetlands can ameliorate the potential impacts of flood events by ameliorating flood peaks and lengthening the flood period. Coastal mangroves are considered to provide important protection to coastal areas from potential storm damage. Both of these types of habitats are maintained to some extent by freshwater flows. Wetlands (more seepage wetlands than floodplain wetlands) within the higher altitudes of a catchment may ameliorate downstream flooding to some extent, thus providing a service to downstream farmers and settlements.

2.4.5 Water regulation and recharge

Some high altitude wetlands intercept precipitation during the wet season, so that it infiltrates into the ground. This water is then released gradually through the rest of the year, thereby helping to maintain base flows during the dry months. These base flows are critical to aquatic ecosystem health, as well as to rural populations that are directly reliant on rivers or springs for agriculture, domestic use and livestock watering. Other wetlands recharge aquifers, contributing to groundwater elsewhere.

The effects of water regulation on downstream aquatic ecosystem health would be accounted for in terms of the outputs of goods and services of those systems. Impacts on flow for run-of-river users or for yield of downstream dams would be an important function to value in terms of water yield and its associated production. Nevertheless, this function of aquatic ecosystems is complex and not well understood.

2.4.6 Sediment retention

Floodplain areas capture sediments and nutrients from rivers which enriches the agricultural potential of these areas. The additional productivity of these agricultural areas compared to upland field areas can be attributed to the flow-related deposits. This is more important in the more mesic dryland agricultural areas of the country.

The capture of sediments in wetlands, floodplains and riparian vegetation can also be a cost-saving service which is provided by conservation of these ecosystems. In addition to maintaining the natural sediment dynamics of aquatic ecosystems (which is accounted for in terms of the value of goods and services provided by the systems as a whole), they trap sediments created by upstream erosion. Sediment transport that might otherwise occur due to ecosystem degradation, would incur costs associated with increased turbidity of aquatic systems, siltation of aquatic habitats and siltation of water supply infrastructure and monitoring weirs. Higher silt loads in rivers and estuaries may decrease light penetration and thus primary productivity, which in turn affects fisheries. Silt deposition within rivers, wetlands and estuaries decreases habitat and hence biodiversity in these systems. Siltation of dams and weirs reduces their capacity and lifespan, incurring costs through increased maintenance and/or augmentation schemes.

2.4.7 Waste treatment

Aquatic systems can play an important role in the absorption and breakdown of organic and inorganic pollutants. Organic pollutants, such as nitrates and phosphates, and inorganic pollutants, such as heavy metals, are diluted, taken up by plants, trapped along with sediments or broken down within aquatic systems. Waste treatment services obviously only occur downstream of where wastes are generated. This service is related to the health of downstream aquatic ecosystems, which is in turn related to the in-stream flow. Waste treatment services are of value wherever downstream water and ecosystem services occur that would be impacted by a loss of water quality.

A number of studies have been carried out on this function in natural and created aquatic habitats (e.g. Peltier *et al.*, 2003, Batty *et al.*, 2005; Thullen *et al.*, 2005). From these studies, it appears that several variables determine the degree to which wastes are removed in a system, and there may be no simple formulae that can be applied locally or generally. Waste uptake does not only occur within aquatic ecosystems, but also occurs during the drainage process, as waste water runs through various habitats *en route* to streams and rivers. Numerous studies in the Northern Hemisphere have shown that a large proportion of the nitrate in subsurface flows moving towards streams was removed from the water as it passed through riparian areas. The waste treatment service is also dependent on the form in which waste occurs. For example, phosphorous is less easily absorbed when it is in dissolved form (Peterjohn and Correl, 1984), and is most efficiently removed from water when it is attached to sediment, which is then trapped in riparian zones or wetlands. All of these studies give varying estimates of the amounts of nitrates and phosphates removed by riparian and wetland areas, and data tend to be reported as the percentage change in concentration. Removal rates obviously depend on starting concentrations.

In South Africa there are data on the capacity of artificial wetlands to treat wastewater (e.g. one ha wetland can treat about 272 m^3 of wastewater per day – Rogers *et al.*, 1985), but little data exists on natural systems, which are generally less efficient (A. Batchelor, pers. comm.). Accuracy of estimation of the value of the wastewater treatment by aquatic habitats will depend on finding out absolute rates (e.g. g of N per year) of waste removal.

The environmental impact of pollutants depends on their concentration within a system, rather than on absolute quantities. In South Africa, there are guidelines, or standards, which describe the concentrations above which pollutants become toxic, or have a noticeable environmental impact (DWAF, 1996). In other words, waste water has to be treated to the extent that these guidelines are met. The aquatic habitat is able to assimilate the amount of waste generated up to these threshold levels. If aquatic habitats are degraded or in-stream flow is reduced, then the capacity of the environment to absorb wastes will be reduced, and producers of waste water have to incur additional costs to meet environmental standards.

The cost savings generated by the environment’s assimilation capacity represent the value of this ecosystem service. The damage incurred by downstream users (e.g. loss of productivity) as a result of deterioration of water quality is an external cost of the polluting activity that occurs when the assimilation capacity of the ecosystem has been exceeded. These external costs (ultimately associated with water use) should also be valued, but should be incorporated into the outputs associated with water use, rather than the value of aquatic ecosystems.

2.4.8 Ecological regulation

Some ecosystems support organisms that help to keep pests under control. While this may be true of some aquatic ecosystems (e.g. fish that eat disease vectors), another important aspect is that aquatic ecosystem degradation can improve conditions for certain pests (e.g. reduction in flows leading to stagnant water ideal for mosquitoes and bilharzia, or invasive plants such as water hyacinth). Changes in flow might also affect the abundance or range of alien invasive fish species. While this service is often called ‘biological control’, for the purposes of this project, it is called ecological regulation.

The proliferation of pests, disease or invasive organisms has impacts on biodiversity and ecosystem health, and hence the output of ecological goods and services, and also on human and livestock health. In many cases considerable expenditure is made to control these organisms to prevent such damages. This expenditure can be seen as a proxy for the potential damages if left uncontrolled. Alternatively, if no management measures are taken, the cost of these impacts are measured in terms of the change in value of aquatic ecosystems, plus the impacts on human and livestock productivity. In most cases, some combination of these effects can be seen, and both types of costs (management and damages) should be estimated.

2.4.9 Refugia, nursery function and exports to other ecosystems

Catchments can contain important refuges for populations of species that are rare and/or valuable. For example, a wetland might provide a dry-season refuge for animals that provide an ecotourism resource beyond the wetland during the rest of the year, such as around the Okavango Delta, Botswana.

Estuaries act as nursery areas for many marine invertebrates and fishes that return to the sea. Freshwater outputs also carry nutrients and sediment that affect habitat and productivity in the adjacent inshore marine areas, contributing to productivity and to maintenance of beaches (DWAF, 2004b). Maintenance of estuarine habitats ensures the provision of nursery areas which sustain a variety of fisheries both commercial, subsistence and recreational (Lamberth and Turpie, 2003).

2.4.10 Genetic resources

Aquatic and groundwater dependent ecosystems may contain genetic material which is of value for food crops, medicines, etc. While recognised as a highly important service, it is impossible to quantify how these genetic resources may be of use in the future. It is assumed that the Freshwater Conservation targets (Brown *et al.*, 2007) and sustainability minima (in terms of flows) (Brown *et al.*, 2007) for the catchment areas will ensure the representivity and maintenance of genetic diversity.

2.4.11 Tourism and recreational value

The aquatic and groundwater dependent ecosystem biodiversity of a catchment contributes to the tourism and recreational value of the region. Biodiversity may contribute to these values due to high diversity, rare or unusual species or habitats, the availability of populations for recreational hunting or fishing, and its contribution to scenic beauty.

Trout fishing is a valuable recreational activity in many catchments, but is based on alien fish species and largely relies on the damming of streams. Bass fishing occurs largely in dams. While not based on indigenous fauna, these activities do provide significant value. Dam fishing is not dependent on in-stream flow and need not be considered. However, changes in the value of in-stream fishing under different scenarios should be considered.

2.4.12 Amenity

Riparian trees may provide valuable shade for livestock and people.

2.4.13 Cultural, spiritual and educational value

The cultural value of catchments includes their contribution to education, scientific knowledge and the spiritual wellbeing of South Africans. Although one could possibly quantify the amount of use of the area by educational groups, scientists, etc., it would never be possible to quantify the true contribution that this makes to society. For example, the educational experience afforded by the area might influence the way in which new generations treat their environments far from this area. This value will not be estimated in monetary terms, but should form part of the qualitative assessment of how natural capital contributes to community wellbeing in the area.

2.5 Measurement of economic value

There are many ways in which the values of EGSAs can be expressed. These values ultimately have to be presented in the same ‘currency’ as values associated with water use, in order to be comparable and allow trade-offs. Thus it is recommended that all values be expressed in terms that are compatible with standard national accounting procedures. This involves understanding the contributions of both water and aquatic EGSAs to sectoral turnover, and in turn, computing the impacts of any changes in this turnover on the regional economy.

It was necessary to consider what types of economic activities would need to be considered that would potentially be affected by changes in class and ecosystem health. These are identified and classified in the following section. Following this, the treatment of non-sectoral values is discussed, and the types of measures that will be derived as the outputs are outlined.

2.5.1 Typology of sectoral users of water and aquatic ecosystems

2.5.1.1 Water users currently recognised by the National Water Resource Strategy

Water users were defined by DWAF during the development of the first edition of the National Water Resources Strategy (NWRS) (DWAF, 2002a) (Table 2-3). This breakdown of user categories has been widely used subsequently and is unlikely to change in the short- to medium-term. A description of each category is given below. Note that in this list, users are grouped both in terms of sectors (e.g. industrial) and communities (e.g. primary social needs).

2.5.1.2 Economic sectors considered in macro-economic analysis

For the purposes of national accounting and macro-economic analysis, the economy is generally broken down into standard set of sectors (Table 2-4).

Table 2-3 Water users defined by DWAF (2002a)

User type	**Explanation**
Basic Human Needs Reserve	The quantity required for Basic Human Needs (BHN) Reserve is not defined in the NWA, but has been set through DWAF policy documents at 25 l/person/day. It is generally only necessary to allow for this amount where communities are abstracting their water requirements directly from a river. In the case of supply to urban areas, the Reserve is included in the amount supplied; the implication being that if supplies are reduced during a drought, it will never be reduced to below the BHN of 25 l/person/day.
Ecological Reserve	This is the amount reserved for aquatic ecosystems
International requirements	International requirements are those stipulated in agreements with neighbouring countries.
Primary social needs	The NWRS uses the term 'Rural' in all their water use tables, but this covers more than just rural domestic use. The definition given in Addendum 8 of the Water Management Area (WMA) report (DWAF, 2003) is water for social needs, such as poverty eradication, primary domestic needs and uses that contribute to maintaining social stability. The implication of this is that water for subsistence farming is seen as a very high priority and is often included in the NWRS estimates of Rural water use.
Strategic requirements	Strategic water use refers exclusively to water used in the power generation process, typically the cooling of South Africa's many coal-powered stations. This does not include water for hydropower since this is a non-consumptive use.
Industrial use	The term 'Industrial Use' in the NWRS generally refers to industries which are not supplied via the urban reticulation system and typically include large industrial users such as Sasol. Small industries supplied by Municipalities are typically subjected to the same priority of supply as the urban users who share the same water supply reticulation system.
Urban use	This comprises water used by households in towns and cities and hence includes water for garden irrigation, fire fighting, hospitals, offices, light industry, etc.
Irrigation	This includes all water used to irrigate commercial crops.
Forestry	Forestry does not use the 'surface water resource' *per se* but intercepts rainfall and increases evapotranspiration, hence reducing river flow and the water available to other users. Once a forest has been planted, its water use cannot be controlled or restricted as can other users, and in this context it can be seen as the highest priority use in that it uses water even before it gets to the river. Water use by forestry is difficult to quantify because it impacts on different users in different ways. Its location in the catchment relative to dams and other uses also influences the impact of forestry on other water users.
Dryland sugarcane	The impact of dryland sugarcane is essentially the same as forestry, the difference being that forestry has been declared a Stream Flow Reduction Activity (SFRA), while dryland sugarcane has not. The implication of this is that a license is required from DWAF to establish a commercial forest, while there is currently no such limitation of the planting of dryland sugarcane. DWAF are in the process of declaring dryland sugarcane a SFRA.

Table 2-4 Economic sectors (after DWAF, 2001a)

Sector	**Description**
Agriculture, fishing and forestry ('Agriculture')	Includes agriculture, hunting and related services, comprising the following activities: • growing of crops; • market gardening; • horticulture; • mixed farming; • production of organic fertiliser; • forestry; • logging and related services; • fishing; and • operation of fish hatcheries and fish farms.
Mining and quarrying	Includes, *inter alia*: • mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore etc.); • extraction of crude petroleum and natural gas; • service activities incidental to oil and gas extraction; • stone quarrying; • clay and sand pits; and • mining of diamonds and other minerals.
Manufacturing	Includes, *inter alia*: • the manufacturing of food products, beverages and tobacco products; • production, processing and preserving of meat, fish, fruit, vegetables, oils, fats; • dairy products and grain mill products; • textile and clothing; • spinning and weaving; • tanning and dressing of leather; • footwear; • wood and wood products; • paper and paper products; • printing and publishing; • petroleum products; • nuclear fuel; and • manufacture of chemical substances.
Electricity, water and gas	These are utilities. This sector includes: • supply of electricity, gas and hot water; • the production, collection and distribution of electricity; • the manufacture of gas and distribution of gaseous fuels through mains; • supply of steam and hot water; and • collection, purification and distribution of water.
Construction	This sector includes: • site preparation; • building of complete constructions or parts thereof; • civil engineering; • building installation; • building completion; and • renting of construction or demolition equipment.

Sector	Description
Wholesale and retail trade, hotels and restaurants (‘Trade’)	This includes: • wholesale and commission trade; • retail trade; • repair of personal household goods; • sale, maintenance and repair of motor vehicles and motor cycles; and • hotels, restaurants, bars, canteens, camping sties and other short-stay accommodation.
Transport, storage and communication (‘Transport’)	Includes, *inter alia*: • land transport; • railway transport; • water transport; • transport via pipelines; • air transport; • activities of travel agencies; • post and telecommunications; • courier activities; and • storage.
Finance, real estate and business services	This includes: • financial intermediation; • insurance and pension funding; • real estate activities; • renting of transport equipment; • computer and related activities; • research and development; • legal, accounting, book-keeping and auditing activities; • architectural, engineering and other technical activities; and • business activities not classified elsewhere.
Government and social services (‘Community services’)	Includes, *inter alia*: • public administration and defence; • social and related community services (education, medical, welfare and religious organisations); • recreational and cultural services; and • personal and household services.
Other	Includes, *inter alia*: • private households; • extraterritorial organisations; and • representatives of foreign governments and other activities not adequately defined.

2.5.1.3 Typology of sectoral use of water and aquatic ecosystems

The main purpose of this typology is to expand the list of sectoral activities considered in water resource decision-making to include users of aquatic ecosystems as well as conventional water use sectors, and to identify the users (see Section 6) that will be considered in the economic (sectoral) analysis as opposed to those groupings that will be considered in the social analysis (see Section 7).

The user categories identified by the NWRS (Table 2-3) include some that would not be treated as sectors in a macro-economic analysis; some that form sub-sectors of the major economic sectors, and exclude some additional sectors or sub-sectors that probably also need to be considered in the classification procedure. The latter are not consumptive users of water, and are described in more detail below.

The BHN and water for Primary social needs are important for consideration in the social analysis (see Section 10), but are not included under sectoral outputs.

The ecological Reserve is not considered as a sector, but the EGSAs resulting from the ecological Reserve are considered in terms of the contribution to sectoral production, described below.

Although hydropower is not considered as a water user in the NWRS (DWAF, 2002a) because its use is not consumptive, it may have to be considered as a water user sector in the classification procedure. This is because hydropower may have to be traded-off against other uses if it involves tying up water, e.g. upstream users cannot consume this water. It also impacts on the ecological health of the downstream aquatic ecosystems.

There are also several sectors that would not be recognised as water users but that have aquatic EGSAs as an input. These include the fisheries, tourism, real estate and transport sectors.

Freshwater, estuarine and marine fisheries are affected by the ecological Reserve. For example, an estuary may act as a nursery area for a marine fishery, and the productivity of the nursery area may depend on the flow of freshwater into the estuary (Drinkwater, 1986).

Tourism is impacted by the health of natural systems, including aquatic ecosystems. For example, tourism in Kruger National Park would be negatively affected by a reduction in river quality (Turpie and Joubert, 2001).

Real estate prices are influenced by the quality of the surrounding environment, including the presence and health of aquatic ecosystems. Property values associated with aquatic ecosystems are particularly high. Thus a change in the quality of these systems has the potential to have a measurable impact on the real estate sector (Kulshreshtha and Gillies, 1993; Van Zyl and Leiman, 2001).

Aquatic ecosystems can provide valuable transport routes, such as the River Rhine in Europe. This is not typically the case in South Africa, and is therefore excluded.

It is thus recommended that the notion of water users be modified for the sectoral analysis in the classification procedure to water and aquatic ecosystem users. These users can be defined in terms of economic activities or at the sectoral level, but would typically be defined at the activity level. The economic activities and sectors that rely on water and/or aquatic ecosystems are listed in Table 2-5.

Table 2-5 Economic activities and sectors that could be considered as water and aquatic ecosystem users in the classification procedure

<table>
<tr><th>Economic activity</th><th>Sub-sector</th><th>Sector</th></tr>
<tr><td>Irrigation agriculture</td><td rowspan="3">Agriculture</td><td rowspan="5">Agriculture, fisheries and forestry</td></tr>
<tr><td>Dryland sugarcane</td></tr>
<tr><td>Livestock</td></tr>
<tr><td>Plantation forestry</td><td>Forestry</td></tr>
<tr><td>Commercial fisheries</td><td>Fisheries</td></tr>
<tr><td>Mining (split by type – gold, coal etc.)</td><td></td><td>Mining</td></tr>
<tr><td>Urban industry</td><td rowspan="2"></td><td rowspan="2">Manufacturing</td></tr>
<tr><td>Non-urban industry (‘industrial use’)</td></tr>
<tr><td>Hydropower</td><td rowspan="2">Electricity</td><td rowspan="3">Electricity, water and gas</td></tr>
<tr><td>Coal power</td></tr>
<tr><td>Urban domestic use</td><td>Water</td></tr>
<tr><td>Tourism and recreation</td><td>Tourism/Hospitality</td><td>Trade</td></tr>
<tr><td>Real estate</td><td>Real estate</td><td>Financial</td></tr>
</table>

2.5.1.4 Typology in terms of relationships with aquatic resources

Each of the aforementioned sectoral activities interacts with aquatic resources in one or more ways, and can be broadly grouped into:

(i) **Aquatic ecosystem-dependent activities**: those that use aquatic EGSAs, often activities that would benefit from improved health of these ecosystems. For example, tourism and real estate activities benefit from healthy and attractive systems.

(ii) **Activities that impact on aquatic ecosystems**: those that impact on flow and water quality, often with a negative impact on ecosystem health. For example mining requires water abstraction and generates pollutants.

However, the second category can be further subdivided into three categories, depending on the nature of these impacts:

a) **Water-consuming and polluting activities:** these are activities that tend to rely on abstraction and consumption of water and which yield polluted return flows.

b) **Streamflow-reducing activities:** these are non-irrigated agricultural activities that intercept sufficient precipitation and/or runoff to have a measurable negative impact on streamflow downstream.

c) **Flow-changing activities:** hydropower generation is the best example of such an activity, as it is neither consumptive nor polluting in the conventional sense. It is, however, important to note that the water reserved for hydropower is precluded from other upstream uses, and that downstream aquatic ecosystems may be negatively impacted by altered flows and water quality (e.g. temperature).

A proposed typology of sectoral activities based on the relationships with aquatic ecosystems is provided in Table 2-6.

Table 2-6 Typology of economic activities in terms of their relationships with water and aquatic EGSAs

Activity type	Economic activity	Relationship to water and EGSAs			
		Depends on EGSAs	**Water use**	**Changes stream-flow**	**Pollution load**
Type 1. Water consuming and polluting	Irrigation agriculture		X		X
	Livestock		X		X
	Mining		X		X
	Urban industry		X		X
	Non-urban industry		X		X
	Coal power		X		X
	Domestic use		X		X
Type 2. Streamflow reducing	Plantation forestry			X	
	Dryland sugarcane			X	
Type 3. Flow changing	Hydropower		X	X	#
Type 4. Aquatic ecosystem dependent	Floodplain agriculture*	X			
	Commercial fishing	X			
	Tourism	X			
	Real estate	X			

while not polluting in the conventional sense, not that there is temperature pollution.
* This includes livestock production which is enhanced by increased grazing potential of wetland areas, or by direct access to rivers.

The way in which this typology could be used is that the output of the different economic activities could be measured and estimated under different scenarios of aquatic ecosystem condition at the catchment scale. This would allow an estimate of the overall implications of each scenario on the economy. The way in which values are estimated may differ for each of the different types of activities (e.g. in terms of relationships with water availability versus ecosystem quality), but the types of measures of outputs would be the same in order to facilitate overall comparison at the sectoral level. In terms of measuring outputs, for example all may be considered in terms of their contribution to national income within a national accounting framework.

2.5.2 Measures of economic impact

Changes in sectoral outputs due to changes in class configuration scenarios (Brown *et al.*, 2007) can be measured in terms of impacts on several macro-economic variables. These are described as follows:

2.5.2.1 Contribution to Gross Geographic Product (GGP)

The impact on GGP reflects the magnitude of the annual value added to the South African economy. Value added consists of three aspects, namely:

- remuneration of employees;
- gross operating surplus; and
- Net indirect taxes

2.5.2.2 Job creation (i.e. the impact on labour requirements)

Labour, together with capital and entrepreneurship form the primary production factors required for economic production. In South Africa there is vast unemployment and poverty, and the creation of employment is therefore of paramount importance.

2.5.2.3 Capital formation

For an economy to operate investment is needed. Capital, together with labour and entrepreneurship form the basic production factors needed for production in the economy. The effectiveness and efficiency with which these factors are combined will determine the overall level of productivity of the production process. The latter in turn will depend on a whole array of factors, of which the appropriate technology and skills content of the labour force are two important elements.

2.5.2.4 Household income and income distribution

This is measured as the impact on low-income, poor households and the total income to all households. Reduction of poverty and inequality has been a central concern of South Africa's government since 1994. Low household income has been specifically used in this study to indicate the impact that a sector has on the reduction of poverty.

In order to estimate these impacts, it is first necessary to estimate the change in turnover for each type of water and aquatic ecosystem user. Following this, the impacts are generated using a Social Accounting Matrix (SAM). The measures that can be used are summarised in Figure 2.3.

2.5.3 Non-sectoral values of EGSAs

Not all EGSAs provide value that can or should be expressed in terms of sectoral turnover. This includes certain ecosystem services that are better expressed in terms of costs avoided or incurred (if the service is degraded), and not in terms of impact on turnover, thus generating additional information in the summary of economic impacts (Figure 2.3).

Non-use (option and existence) and intangible use values (e.g. educational, scientific and spiritual value) can be valued using labour-intensive survey-based methods, but for the classification procedure will be considered in terms of their contribution to human wellbeing through a scoring system only (see Joubert *et al.*, 2007).

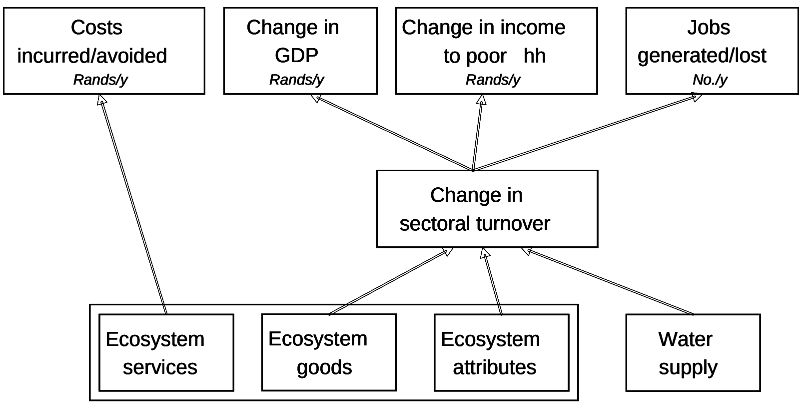

Figure 2.3 Measures of economic value (top boxes) to be derived from ecosystem and water use

2.6 Measurement of societal wellbeing

In order to evaluate the implications of alternative catchment configuration scenarios (Brown *et al.*, 2007) in the Classification Process, community types within each targeted catchment need to be described in terms of their current wellbeing. Wellbeing is linked to poverty and vulnerability, and these concepts are discussed in detail below. A process will need to be developed to predict and describe how the wellbeing of affected communities changes under different scenarios. Community wellbeing is linked to economic (sectoral) output (which determines employment and income), but is also influenced directly by ecosystem health (which affects livelihoods, health and income). Moreover, the description of community wellbeing facilitates consideration of poor communities in decision-making processes.

This is consistent with the South African constitution, the NWA and government's Accelerated and Shared Growth-South Africa (ASGISA)[4] that require interventions targeted at reducing South Africa's historical inequities and halving poverty and unemployment by 2014, and thus forms a critical component of the classification procedure.

2.6.1 Concepts and measures of poverty, vulnerability and wellbeing

Wellbeing is a synonym of 'welfare', and can be defined as the state of being healthy, happy or prosperous. Although a potentially complex notion, community wellbeing can thus be simply considered as the state of income, health and happiness of a community.

Poverty is most simply defined as the state of having little or no money and few or no material possessions. Poverty is thus a state that reduces people's wellbeing.

Vulnerability of a community can be defined as its susceptibility to stressors or changes and is determined by the combined strength of its physical, social, financial, human and natural capital assets. A community that has a weak asset base would be particularly vulnerable. Poverty and vulnerability are related in that a poor community is likely to have a weak asset base.

Vulnerability tends to be defined with respect to a minimum level of livelihood (Sinha and Lipton, 2000), and is linked to ideas of defencelessness or what Chambers (1989) notes as a 'lack of means to mitigate or cope without incurring losses'. For Davies (1996), vulnerability is a balance between the sensitivity and resilience of a livelihood system. Poor communities are therefore likely to be more vulnerable to shock and 'the plight of vulnerable groups is part of standard poverty analysis' (Hoogeveen *et al.*, 2003).

If a person is deprived of the basic necessities of life that person is vulnerable. Nations, communities, households and individuals can be vulnerable. Baulch and Hoddinott (2000) notes, 'households with greater endowments and greater returns will tend to be less vulnerable to shocks … …vulnerability to shocks is intimately linked to poverty'. Vulnerability assessments focus on the dynamic nature of poverty and the reasons for its persistence. Poverty is one of the main factors leading to vulnerability - poor households are less able to absorb shocks – such as loss of physical, social, financial, natural or human capital because they have lower asset bases in all these areas. The poor are less able to guarantee safety from risks to their assets. Poor households are typically more exposed to risk and also less protected from it.

A community's level of vulnerability would determine the degree of impact that changes in class would have on community wellbeing under different scenarios. For example the same change might have a bigger impact on wellbeing for a more vulnerable community.

2.6.2 The sustainable livelihood framework

The United Nations' Sustainable Livelihood Framework emphasises the relationships of people to their environment and makes the linkages between the natural environment, poverty and human development explicit.

Community wellbeing is influenced by the state of each of the following types of capital:

[4] www.info.gov.za/issues/asgisa/

- social capital – resilience of community measured in terms of access to networks and strength of associational life. This includes the concept of ‘voice’ and involvement in decision-making;
- physical capital – bricks and mortar; includes livestock and capital investment in farm (infrastructure);
- financial capital – cash flows, includes savings, investments;
- human capital – measured in terms of skills, education levels, *a priori* learning that helps an individual to achieve his/her potential or capabilities; and
- natural capital – access to natural resources such as wild foods and building materials.

Thus it is important to realise that changes in aquatic ecosystems, which constitute part of natural capital, should ideally be seen in the context of all the elements that contribute to societal wellbeing.

2.6.3 Existing measures of wellbeing

During the 1950s and 1960s poor countries recorded impressive growth rates. This, however, did not translate into improved living standards, and it became clear that conventional economic measures (such as Gross National Product (GNP) per capita) were inadequate as indicators of societal wellbeing. This led to a focus on the development of indices with which to measure wellbeing at various scales (Dasgupta, 1993; Clark, 2003).

The United Nations compiled the Human Development Index (HDI), a composite measure of poverty that includes measures of life expectancy, income, education, access to clean drinking water and ‘voice’. The HDI was initially made up of 5 weighted components:

1. The percentage of people expected to die before the age of forty.
2. The percentage of adults who are illiterate.
3. The percentage of people with access to health services.
4. The percentage of people with access to safe water.
5. The percentage of children under five who are malnourished.

Aspects of human wellbeing that are excluded from the index due to lack of data or measurement difficulties are political freedom, ability to participate in decision-making, personal security, ability to participate in the life of the community and threats to sustainability and intergenerational equity (UNDP, 1997). These have been captured in a small way in a revised HDI which now includes a measure of ‘voice’. Conventional wisdom therefore is that poverty is clearly broader than a lack of income because it is deprivation across many dimensions (Sen, 1999; UNDP, 2000; Narayan *et al.*, 2000; World Bank, 2000), and it is now widely accepted that because poverty is multi-dimensional (Hulme and Shepherd, 2003), the index for measuring poverty needs to be a composite.

More recently the Australians have identified nine areas that contribute to social wellbeing and for which statistics are being generated: population, family and community, health, education and training, work, economic resources, housing, crime and justice, and culture and leisure[5].

2.6.3.1 List of available datasets

Appendix A provides an overview of available datasets that could be used to provide an indication of levels of wellbeing among affected communities in the Classification Process. A summary of the available data sets in the public domain is presented in Table 2-7.

[5] http://www.abs.gov.au/AUSSTATS accessed 8 May 2006

Table 2-7 Available datasets

Name of Survey	Spatial scale	Year(s)	Sample size
Afrobarometer	National	2000, 2002	1 200
*Census Data	National	1996, 2001	
*Demographic and Health Surveys	National	1987, 1998	
General Household Surveys	National	2002, 2003	
HSRC National Surveys	National	1998, 1999	
Income and Expenditure Survey	National	1995, 2000	
Labour Force Survey	National	Feb. + Sep. 2000 - 3 March 2004	
*October Household Surveys	National	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001	16 000 to 30 000
National HIV and Syphilis sero-Prevalence Survey	National	2000	16 607
*Project for Statistics on Living Standards and Development	National	1993	8 500
South African Integrated Family Survey 2000	Langeberg	2000	2 020
Survey of Time Use (StatsSA)	National	2000	
Victims of Crime Survey (StatsSA)	National	1998	

* relevant to the Olifants/Doring catchment

2.6.3.2 Synopsis of available data for describing wellbeing

Based on the review of existing information (Appendix A), existing measures that could be used to describe wellbeing are listed in Table 2-8. However, not all of these measures are available at the appropriate scale.

Table 2-8 Available socio-economic measures that would be potentially useful in an index of wellbeing, their scale of availability, and thus feasibility for use

Measure	Scale of availability	Suitability
Household income	Sub-Place scale, or Enumerator Area*	High
Rate of employment	Sub-Place scale, or Enumerator Area	High
Health	Provincial or District level, and (by arrangement) at magisterial level	Medium
Water supply (main source)	Sub-Place scale, or Enumerator Area, but no data on household water quality or assurance of supply – strongly correlates with race and annual household income	High
Sanitation (type of toilet)	Sub-Place scale, or Enumerator Area	High
% female-headed households	Sub-Place scale, or Enumerator Area	High
Dependency ratio[6]	Available at the provincial level, household size, education and income closely correlate	Low
Education of household head	Sub-Place scale, or Enumerator Area	High
Stability of community	Not available at the provincial or magisterial levels	Low

*Enumerator Area data are only available by arrangement, but aggregated as agreed.

2.6.4 Index of social wellbeing

The most effective indices will be those that are generic enough to be applied to a wide range of settings (Luers *et al.*, 2003). The more complex the indicator, the less likely it is to

[6] Dependency ratio: ratio of (potentially) economically active population to the retired population and children under 16 years of age. Aged dependency ratio is the ratio of the economically active to the retired population

be valid, and this can affect the overall reliability of the index. The question of scale requires some consideration. The higher the spatial resolution, the more reliable the information. In other words, if one were able to provide a composite index at a small spatial scale, this would provide high confidence data. In evaluating scenarios using an index, the temporal effects of change are also an important consideration (Luers *et al.*, 2003). For example, inundation of communal lands may have negative impacts on a community in the short-term, but could provide an important fishery resource in the longer-term. In other words, in gauging the impacts of the external stressor, one needs to consider whether there are likely differences over time and whether a vulnerable community is able to develop mechanisms of resilience to the stressor over time.

After a review of possible options and consideration of suitable available data, it was originally proposed to create an Index of Community Wellbeing that comprised an assessment of the five types of capital available to different communities, based on a sustainable livelihood framework approach. However, it proved difficult to align the scores describing the status quo with those describing changes in wellbeing under different scenarios.

Thus a simpler index is proposed, which concentrates on the three main elements of wellbeing: health, wealth and happiness (Figure 2.4). Prosperity or wealth is indicated by a simple measure of the proportion of households that are non-poor. The poverty line varies according to household size, for example varying from about R18 500 for a family of five to about R30 000 for a family of 8 (Schwabe, 2004). Based on the income categories available in the census, it is recommended that non-poor households are conservatively defined as those wih an income of at least R38 400 per household per annum.

It should be accepted that cash income and subsistence income are substitutes, and that the two should be valued together to ascertain household wealth. The baseline value should be calculated on the basis of reported income plus the value of aquatic ecosystem resources harvested by households for own consumption. Jobs are also an indicator of prosperity, but give more information on the distribution of income. Health will reflect the proportion of households that are entirely healthy at any one time. Happiness is probably related to prosperity and health, but for the purposes of classification will primarily reflect the utility derived from aquatic ecosystems. This utility accounts for the intangible use and non-use values associated with these systems.

The weighting of the three components is discussed elsewhere (see Volume 4; Joubert *et al.*, 2007). Weighting should reflect the relative contribution of each component of the index to wellbeing, and not the degree of accuracy of the data for each component. Weightings should ideally be agreed in a workshop process involving professional sociologists or social geographers, and be verified with stakeholders. The wellbeing index would be at its most robust when all values have been allocated from reliable sources and weights are considered appropriate.

The index is designed for making use of available data at a desktop-level, but there is opportunity to increase the accuracy of measures through primary data collection. In all cases, the level of confidence of the component scores should be described based on data reliability. In some cases, where assumptions are made based on anecdotal evidence or 'common sense' the value would be less reliable or valid than in cases where primary data are available.

In addition to the wellbeing index it would be useful to provide an accompanying description of the communities in terms of a livelihood framework, as this will give additional sense of the vulnerability of these communities. This description can be quantitative in terms of indicators of certain types of capital for which data exist, or qualitative, where only descriptive accounts may exist. This is described in Volume 4 (Joubert *et al.*, 2007)

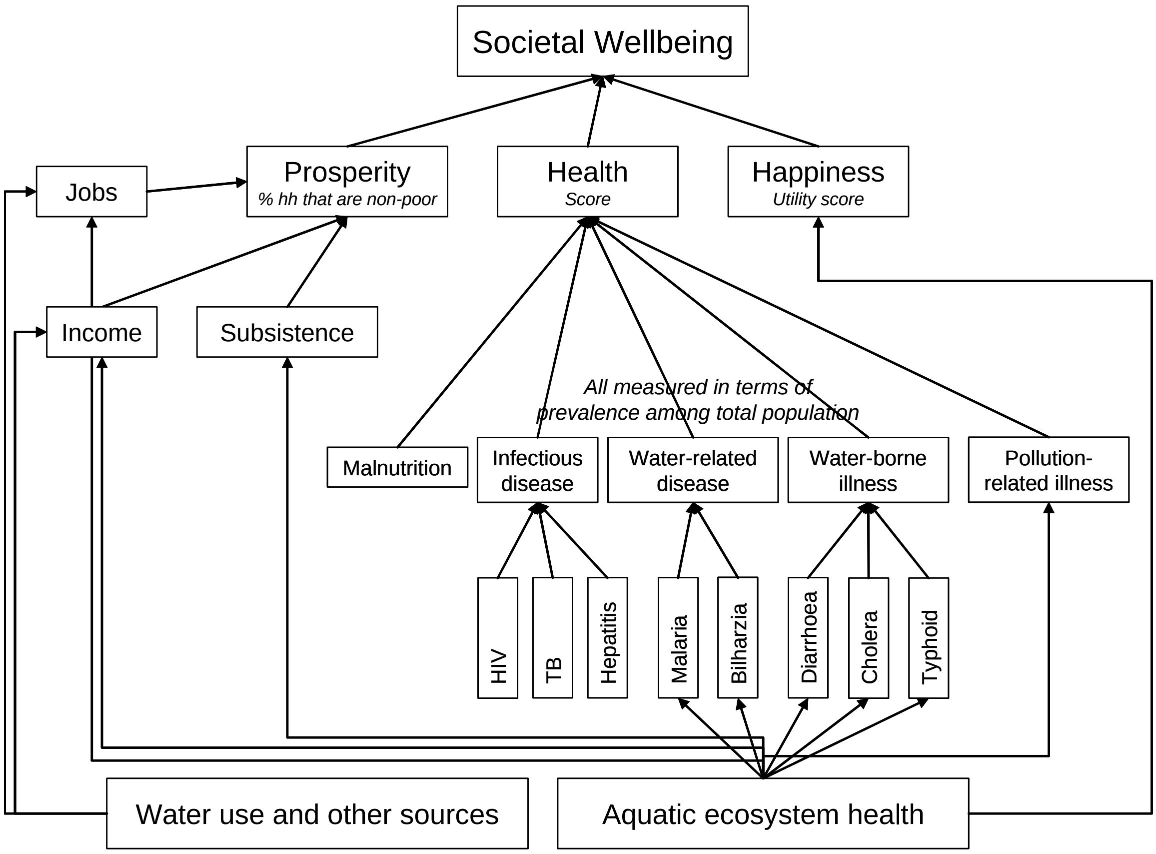

Figure 2.4 Proposed structure for measuring social wellbeing

2.7 Remaining structure of this report

The remainder of this report is structured and aligned with the classification procedure presented in Figure 1.1. The guidelines and procedures for the socio-economic components of each of the 7-steps are presented, together with an example of application of the guidelines and procedures to the 'proof of concept' catchment, the Olifants/Doring. Steps that require input from the decision-analysis component, but are not the exclusive domains of the decision-analysis component are highlighted in *italics* (Table 2-9).

Table 2-9 Summary of the socio-economic components of the 7-step classification procedure

Step	Description	Section
1a	Describe the present-day socio-economic status of the catchment	3
1b	Divide the catchment into socio-economic zones	4
1e	Describe communities and their wellbeing	5
1f	Describe and value the use of water	6
1g	Describe and value the use of aquatic ecosystems	7
1h	*Define the Integrated Units of Analysis (IUA)*	*8*
1i	*Develop and/or adjust the socio-economic framework and the decision-analysis framework*	*9*
1j	Describe the present-day community wellbeing within each IUA	10
2a	Select the ecosystem values to be considered based on ecological and economic data	11
2b	Describe the relationships that determine how economic value and social wellbeing are influenced by ecosystem characteristics and the sectoral use of water	12
5d	Value the changes in aquatic ecosystems and water yield	13
5e	Describe the macro-economic and social implications of different catchment configuration scenarios	14

3 DESCRIBE THE PRESENT-DAY SOCIO-ECONOMIC STATUS OF THE CATCHMENT (STEP 1A)

3.1 Introduction and rationale

The aim of this sub-step is to describe the *present-day socio-economic status of the target catchment*. This requires a description of the population; land use and economy of the catchment which is required for Step 1b where the catchment will be divided into socio-economic zones (see Section 4).

3.2 Procedure

Population density figures can be obtained from the quaternary catchment-level data provided by Water Resources Situation Assessment Model (WSAM) (DWAF, 2001b) or from national census data. Catchment land use can be described on the basis of the best available GIS coverage, in conjunction with available reports on the area, such as DWAF's Internal Strategic Perspectives (ISP) developed for each Water Management Area (WMA).

The economy can described in terms of the relative contribution of different sectors and how this composition compares to the rest of the country. This can be done using data provided in the Economic Information System (DWAF 2004c) and Statistics South Africa, as well as from recently published data from documents such as ISPs.

3.3 Example: Olifants/Doring catchment

3.3.1 Introduction

The Olifants/Doring catchment lies within the Olifants/Doorn WMA. Much of the data available for the area is provided for the WMA as a whole, but wherever possible, the data have been extracted for the Olifants/Doring catchment.

3.3.2 Population

The Olifants/Doorn WMA is the least populous WMA in the country, with about 0.25% of the national population (DWAF, 2002b). About two thirds of the population is concentrated in the south-western part, in the Koue Bokkeveld, the Olifants River Valley and the Sandveld (outside of the Olifants/Doring catchment), corresponding with the areas of most economic activity. Only 30% of the population live in the arid areas of the Doring River catchment, the catchments of the northern tributaries of the Olifants River, and the Namaqualand coastal catchments (though these areas account for 80% of the WMA) (DWAF, 2002b). Thus the majority of the area is very sparsely populated (Figure 3.1), with the result that more than half of the population of the WMA is classified as urban[7], despite the strongly agricultural base of the economy. Due to HIV/AIDS and urbanisation trends, a general decline is expected in the population of the area, particularly in the rural population (DWAF, 2003).

Various estimates have been made of the 1995 population of the WMA. These range from 104 000 people based on estimated population per quaternary catchment (DWAF, 2001b; 2002b), to 113 000 people (DWAF, 2003), to 267 000 based on the population of all the municipalities in the WMA (DWAF, 2004a). The population of the Olifants/Doring catchment, based on quaternary catchment estimates, is approximately 83 200 people.

The urban population is based mainly in Vredendal (Matzikama Local Municipality (LM)) and Calvinia (Hantam LM), as well as Citrusdal, Clanwilliam, Vanrhynsdorp, Nieuwoudtville, Loeriesfontein, Ebenhaesar, Wuppertal and other small settlements. Based on analysis of the municipal populations (DWAF, 2004a), the population is predominantly Coloured (77%), with 20% White and 3% African. More than 90% of the population are Afrikaans speaking, and relatively few (3.9%) have tertiary education. Nine percent of the population are without sanitation.

3.3.3 Land use

Due to the low rainfall over much of the area, the catchment is not suitable for dryland farming on a large scale. More than 90% of the land is untransformed, with these lands being utilised for conservation, tourism and low intensity grazing for livestock (DWAF, 2002b), thus mostly retaining its indigenous vegetation cover (Figure 3.2). There are about 11 780 large stock (mainly cattle), 336 000 small stock (sheep and goats) and 10 930 pigs in the Olifants/Doring catchment (DWAF 2002b, based on 1994 livestock census).

The tourism industry is expanding and supporting economic development in the area. It is based mainly on the unique rugged landscape of the Cedarberg, the wide arid plains of ‘Bushmanland’ and the spring displays of wildflowers throughout the region. Coastal resorts and relatively pristine rivers are also attractions. The Olifants estuary remains largely undeveloped as a tourist attraction.

[7] Note that DWAF (2002b) defined functional urban areas (although populations in many of these had been defined as rural in the census).

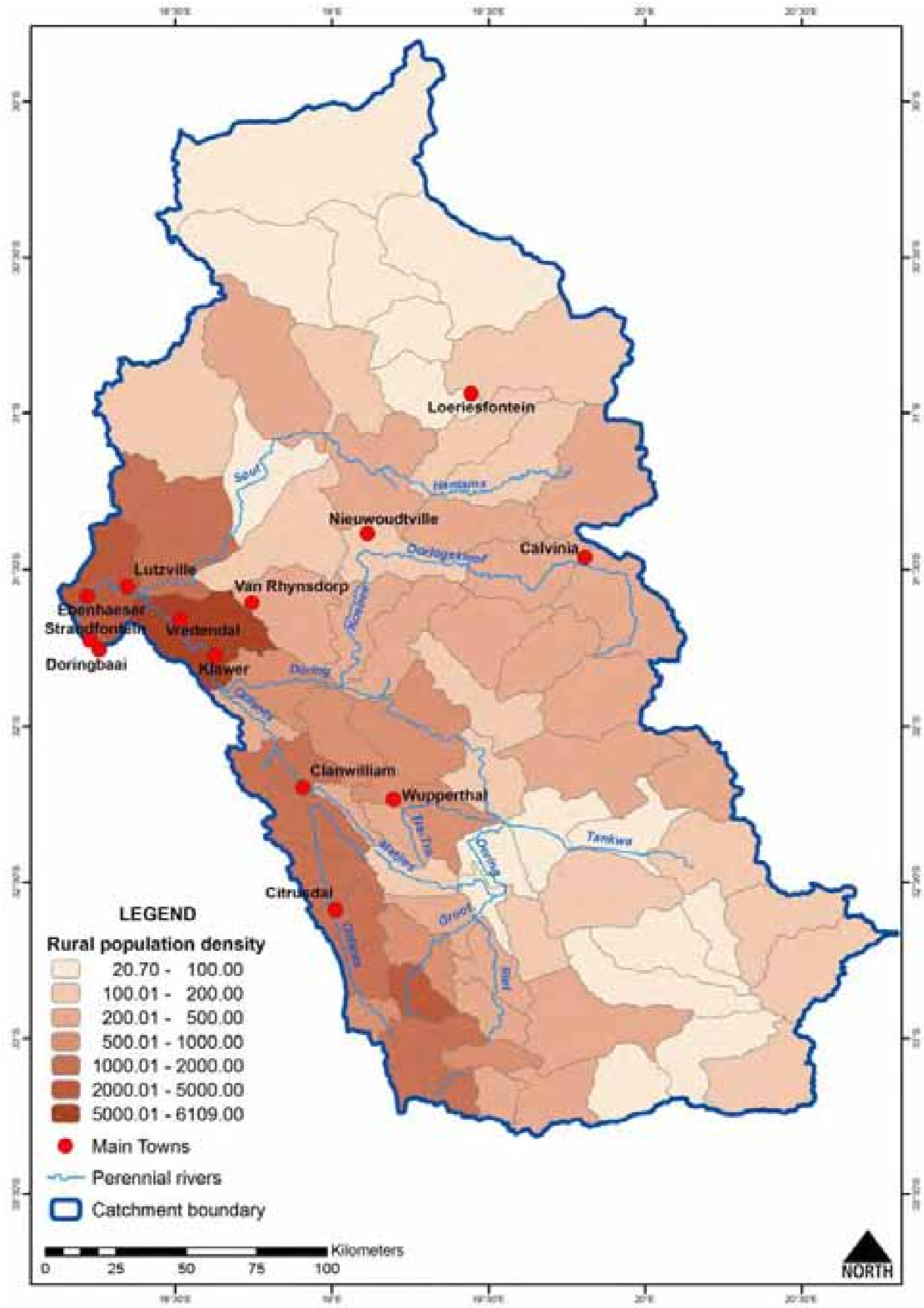

Figure 3.1 Rural population densities (based on the 1996 census) in the quaternary catchments within the Olifants/Doring catchment

Up to 4% of the WMA (219 000 ha) is used for dryland farming, although this would be expected to vary from year to year, depending on rainfall. Dryland crops are mainly wheat and rooibos tea. The total area under dryland crops is unknown, but is likely to be much lower than the estimate of 219 000 ha based on satellite images (CSIR, 1996). It is probably closer to 100 000 ha for the whole WMA (DWAF, 2002b). There is no sugar grown in the catchment area.

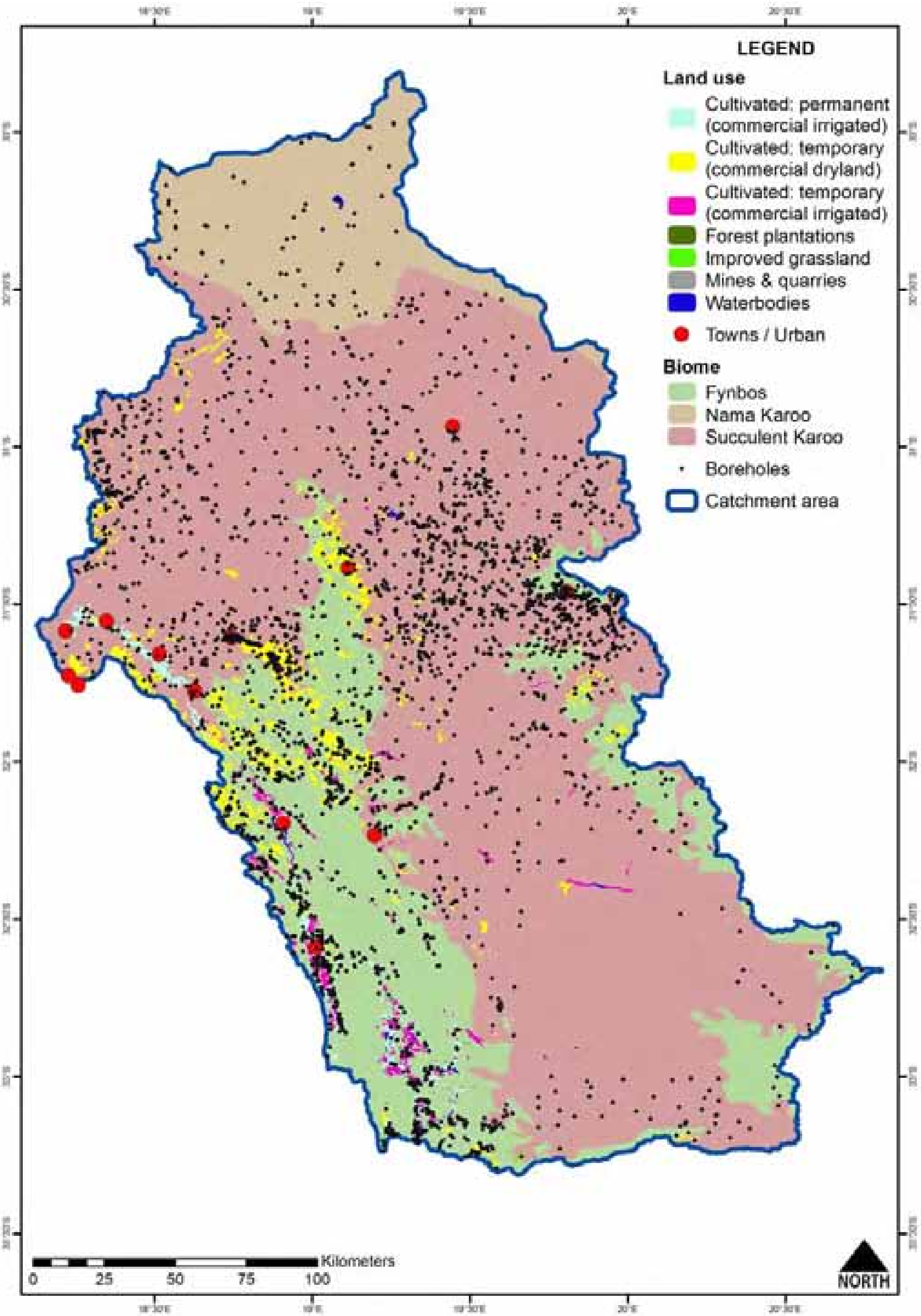

Figure 3.2 Vegetation and land use of the Olifants/Doring catchment

Irrigation agriculture is well developed in the WMA, and new areas for irrigation have been investigated. Irrigated crops, including citrus, deciduous fruits, grapes and potatoes (mainly in the Sandveld), are grown on a large scale in the south-western parts of the WMA (DWAF, 2002b). Estimates of the area of irrigated crops vary. DWAF (2002b) estimated that a total area of 46 700 ha was under irrigation in the WMA, of which an average of about 40 000 ha are harvested because much of the area is only used in years of plentiful water supply. Of the total area under irrigation, some 33 700 ha is in the Olifants/Doring catchments (DWAF, 2002b) (Table 3-1). DWAF (2003) estimated that about 32 400 hectares are under irrigation in the WMA, including private schemes and the Olifants Government Water Scheme. DWAF (2004a) estimated a total irrigated area of 28 600 ha (Table 3-2), and the ISP (DWAF 2005b) estimates a total area of 49 700 ha under irrigation.

Table 3-1 Land use 1995 (after DWAF, 2002b)

Area (km^2)	Irrigation	Dryland crops	Affore-station	Nature reserves	Urban	Total area
Total in Doring catchment	116	860	2	560	6	24 042
Total in Olifants catchment	221	720	8	509	17	23 549
Total	337	1 580	10	1 069	23	49 066

Table 3-2 Areas under irrigation (after DWAF, 2004a)

Area	Ha under irrigation	Main crops
Koue Bokkeveld	9 000	Deciduous fruit
Witzenberg and Bo-boskloof	2 700	Deciduous fruit
Citrusdal	5 400	Citrus and wine grapes
Vredendal	11 500	Wine and table grapes

Irrigated agriculture is found mainly within the Western Cape portion of the catchment (97%), along the Olifants River and in the southern elevated areas of the basin (the Koue Bokkeveld) (Table 3-1 and Table 3-2), with about a quarter to a third of the irrigated area occurring in the Doring catchment. In the Doring catchment, cultivation tends to be confined to hilltops and the flatter areas next to major tributaries, and at Elansvlei, Bos River and Doringbos along the Doring River. There is comparatively little suitable area for cultivation along the Doring River. Potential for further irrigation in the WMA has been identified as 134 500 ha, of which 42 300 ha is in the Doring River catchment (DWAF, 2003).

There are a total of 997 ha of tree plantations in the high-rainfall, mountainous parts of the catchment. These are located at the headwaters of the Olifants River (380 ha of pine), in the Cederberg (385 ha) and on the mountain slopes fringing the Koue Bokkeveld (232 ha of pine).

Mining is relatively limited, and includes gypsum mining, a saltworks near the estuary mouth, sand and diamond mining. Apart from the Namakwa Sands heavy minerals mine on the north-western coast of the WMA, mining operations are small and mainly comprise quarrying or dredging marine diamonds (DWAF, 2002b).

Urban areas are small and only cover about 31 km^2 (DWAF, 2005b).

3.3.4 Overview of the economy

Because economic statistics are collected at the district level, they do not correspond with catchment boundaries, and estimates of the contribution of the catchment are therefore approximates. The Olifants/Doorn WMA has been estimated to contribute under 0.5% of the national economic output, and less than 1% of formal employment, making it the smallest contribution of any WMA in the country (DWAF, 2001a; DWAF, 2003). Nevertheless, it had the highest growth rate of any WMA between 1988 and 1997, of just under 4% (DWAF, 2001a). Based on the percentage area of each magisterial district lying within the WMA, Vredendal, Ceres and Clanwilliam Magisterial Districts have been estimated to contribute about 75% of the economic output in the Olifants/Doorn WMA (DWAF, 2001a). The agricultural sector was estimated to contribute as much as 43% of the economic output of the WMA in 1994 (Schlemmer *et al.*, 2001, DWAF 2005b). The WMA contributed almost 3% of the agricultural output of the national economy, and 1.5% of trade output, with most other sectors contributing less than 0.3% (DWAF, 2001a). In 1994, 75.5% of the labour force was formally employed, 16.4% was informally employed and 8.1% was unemployed (DWAF, 2001a).[8] This is much lower than the national unemployment figure of 29.3% (Schlemmer *et al.*, 2001; DWAF, 2005b).

The economic characteristics of the Olifants/Doring catchment are similar to the WMA. An analysis of more recent data at the catchment level suggests that agriculture contributed at least 36% to total output in 2001 (Figure 3.3). This is in stark contrast to the national agricultural contribution of 3.4% to the economy. The proportional significance of this sector is thus about ten times higher than in the national economy.

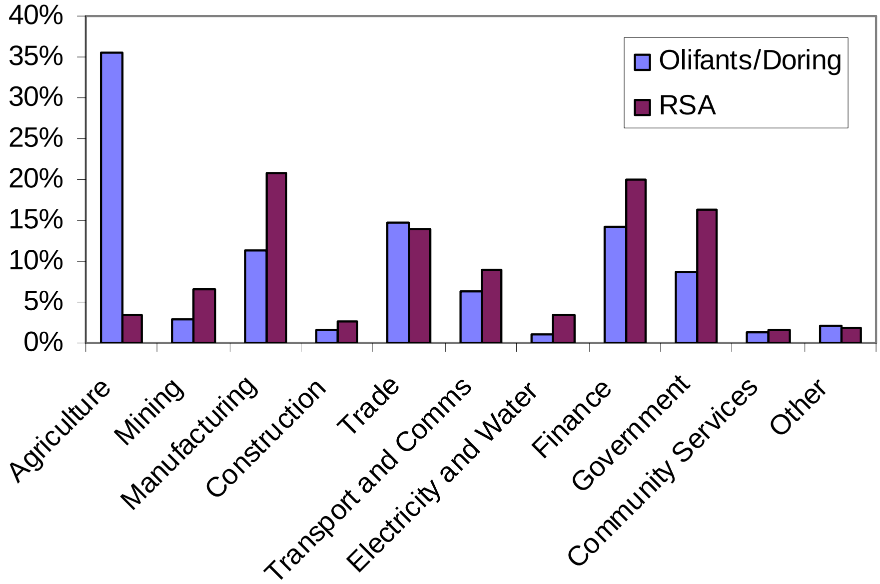

Figure 3.3 Proportional contribution by sector to the Olifants/Doring catchment and national economy (after EIS, 2004)

The importance of the agricultural sector is attributed to the high value products cultivated in the area as well as the low level of activity in other sectors. The sector is relatively stable due to the diversity of products produced. The agricultural sector includes production of wine and table grapes, oranges, potatoes and tomatoes, rooibos tea, fresh fruit, dried fruit, wheat and fisheries (DWAF, 2002b). Expansion is limited by the availability of water for irrigation. Growth in this sector will require improved water use efficiency and further value adding through increased processing.

Trade, which includes much of the tourism 'sector', contributes some 15% to the economy of the catchment, and is the second-most important activity. This sector mainly comprises wholesale in wine, fruit, wheat and other agricultural products, as well as tourism and trade services to the local community. Tourism has been identified as the sector 'with the greatest anticipated growth between 2000 and 2025' (DWAF, 2001a).

The manufacturing sector (11.3%) is based mainly on food and beverage processing activities, particularly in Vredendal, as well as on steel and minerals.

The mining sector is small, centred mainly on the Namakwa Sands mine north of the Olifants River mouth, where titanium slag and other minerals are mined.

[8] Formally employed includes employers, employees or self-employed who are registered tax-payers. Informally employed includes employers, employees or self-employed in unregistered economic activities. Unemployed includes those actively looking for work but not in any type of formal or informal employment.

The Olifants/Doorn WMA is considered to have a comparative advantage[9] in Electricity, Mining and Agriculture, with location quotients[10] of 4.0, 2.8 and 1.4, respectively (DWAF, 2002b). The Olifants/Doring is the only catchment in South Africa where rooibos tea is produced, with over 300 commercial and 200 smaller growers.

4 DIVIDE THE CATCHMENT INTO SOCIO-ECONOMIC ZONES (STEP 1B)

4.1 Introduction and rationale

Alternative configurations of aquatic ecosystem condition need to be understood in terms of their implications for societal wellbeing as well as their implications for economic prosperity (see Section 14). Societal wellbeing needs to be considered at a broad scale to include any members of society that are potentially impacted by a change in class. It also needs to be considered for those members of society that are most vulnerable, especially in the light of the national priorities for redress and poverty alleviation. The most practical way to deal with this problem is to delineate society as a whole into relatively homogenous communities that might be affected in different ways. It is proposed to do this by delineating socio-economic zones and describing the communities within them.

4.2 Procedure for delineation of socio-economic zones

Communities could be defined in a simple, straightforward way that can be represented spatially and in such a way that any individual could identify his/her community and be able to identify with it. The delineation of communities has to be done in such a way as to reflect relationships to water and aquatic resources. It is thus proposed to first define socio-economic zones in terms of land use, tenure and types of aquatic ecosystems as a first cut, before defining communities within each of these zones. Socio-economic zones have been described before in the context of water management in South Africa, for example in the ISPs. However, the way in which this has been done has not been defined or standardised. Nevertheless, it would be inadvisable to put strict rules in place as to how this should be done, since circumstances differ widely around the country.

Factors that should be taken into consideration when delineating socio-economic zones include the following:

- land tenure: communities on communal lands tend to have different social set-ups, tend to be poorer and tend to have more direct relationships with water and ecosystem goods than people on private lands, thus this should normally be the first layer considered in dividing an area into zones;
- predominant land use: this provides an idea of the degree and type of dependence on water by rural communities;
- aquatic ecosystems and rainfall patterns, which adds depth to the understanding of the above two layers regarding likely use of water and aquatic resources; and
- any other pertinent variables that appear to create a pattern. It is important to include this because there are numerous other variables that may have important localised influences, and it would be negligent to ignore these. For example, it might be useful to isolate a particular recreational node or fishing community for which there is a particular relationship with an ecosystem.

[9] Comparative advantage of a region means that it has a more competitive production function for a specific product or service than other regions in the economy.

[10] A location quotient is a measure of comparative advantage which compares a sector's share in gross geographic product (regional output) with its percentage share in the national economy. A value >1 indicates comparative advantage.

Once the areas are identified, the actual boundaries are delimited using quaternary catchment boundaries, which are at a sufficiently fine scale to approximate socio-economic zonal boundaries. This facilitates the integration of ecological and socio-economic aspects in the classification procedure, especially the delineation of Integrated Units of Analysis (IUAs) (Brown *et al.*, 2007).

4.3 Example: Olifants/Doring catchment

Based on considerations of land tenure and land use within the study area, the Olifants/Doring catchment was divided into relatively homogenous socio-economic zones, as follows (Figure 4.1):

1. Koue Bokkeveld:
   High altitude irrigation farming area, characterised by relatively high winter rainfall and use of numerous farm-dams for irrigation.

2. Doring Rangelands:
   Relatively mountainous area characterised by conservation and livestock farming and low population density.

3. Knersvlakte:
   This is an arid area characterised by very low population density and extensive rangelands as the main land use.

4. Upper Olifants:
   Irrigation farming area along the Olifants River valley, with major urban areas.

5. Olifants/Doring dryland farming:
   This area is characterised by a relatively high proportion of land under dryland farming, but with livestock still an important activity.

6. Lower Olifants:
   Irrigation farming area along the lower Olifants river valley and floodplain down to the estuary, with several small urban areas.

7. Estuary
   Communal land area comprising the poor fisher-farming community of Ebenhaesar. This is identified as an important target area in terms of resource-poor irrigation farmers. This area falls within the previous area and is associated with the Olifants estuary.

These socio-economic zones form the basis for the description of the communities of the study area (see Section 4).

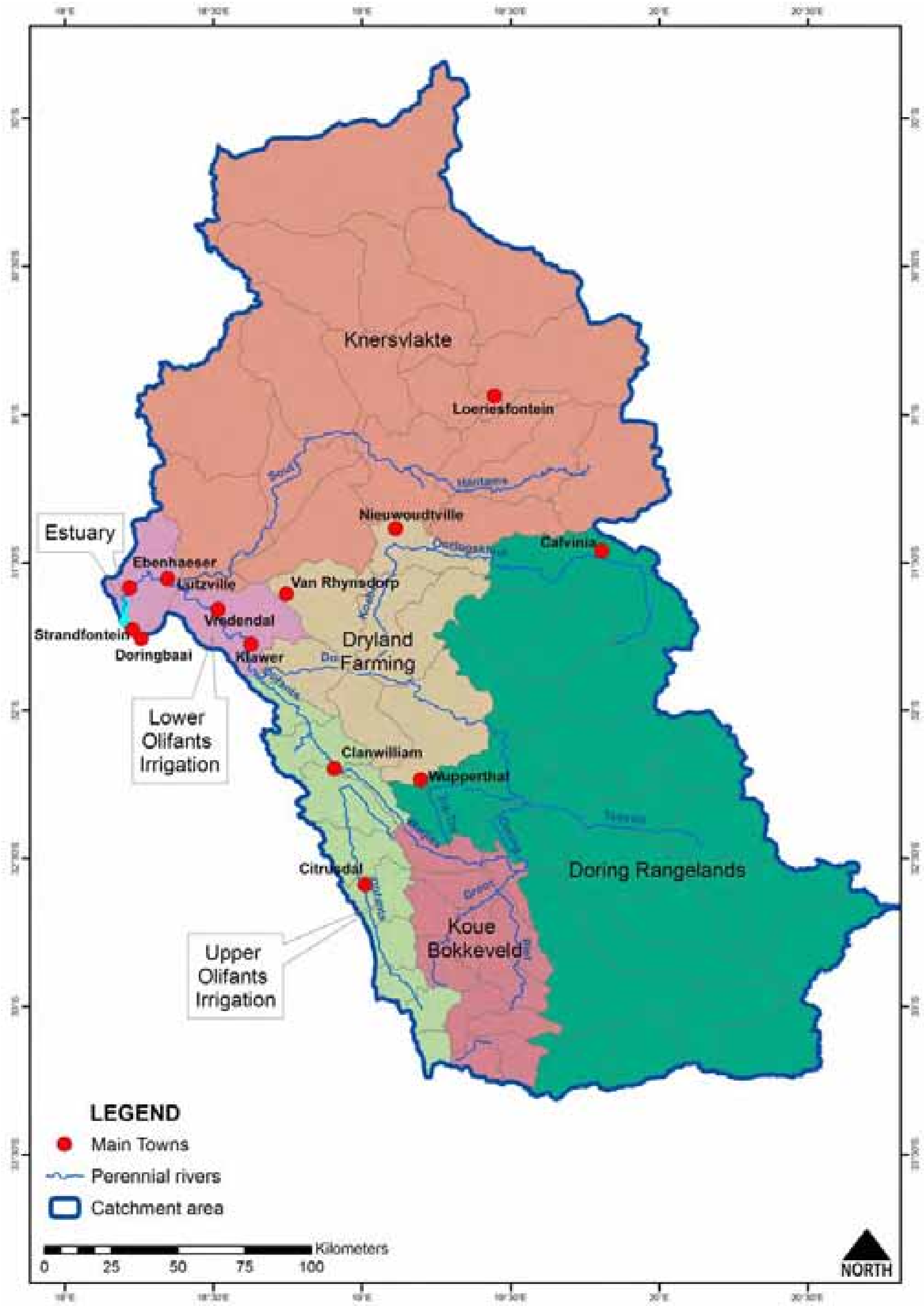

Figure 4.1 Socio-economic zones identified for the Olifants/Doring catchment, showing the quaternary catchments included in each zone

5 DESCRIBE COMMUNITIES AND THEIR WELLBEING (STEP 1E)

5.1 Introduction and rationale

The purpose of this step is to estimate the current wellbeing of the communities within each of the zones that were identified in Step 1b (see Section 4). This will be used as the basis against which potential changes in wellbeing will be measured for each catchment configuration scenario (see Joubert *et al.*, 2007). This step involves a description of various aspects of each community that will give a sense of the levels of financial, physical, human, social and natural capital assets available to those communities, as well as the construction of an index of wellbeing based on information on income, use of natural resources, health and the status of the aquatic environments in each zone. The way in which the measures described here are combined to calculate an overall index of societal wellbeing is described in Joubert *et al.* (2007).

5.2 Procedure

5.2.1 Summarise population data

Population data for each of the zones can be obtained from the quaternary catchment-level data collated by DWAF in the WSAM.

5.2.2 Describe community characteristics

Household characteristics within each zone will largely be described on the basis of census data. Since it is not possible to obtain census data at the same geographic resolution as the quaternary catchments and hence socio economic zones, it is necessary to first establish which census Sub-place areas fall within each zone, and what proportion of each falls within the zone. Census data are then collated from those Sub-places, and weighted according to their contribution to the population of each zone. The following characteristics of each zone are described on the basis of census data:

5.2.2.1 Household income category

Households are divided into categories of poor and non-poor and subcategories are defined within these categories (Table 5-1). In addition to household income, percentage employment should also be reported.

Table 5-1 Recommended income categories, based on income categories in the census data

Category	Definition	Annual household income in Rands
Poor	Very poor	No income – 9 600
	Poor	9 601 – 38 400
Non-poor	Tolerable	38 401 – 76 800
	Comfortable	76 801 – 153 600
	Wealthy	153 600 and above

5.2.2.2 Services and infrastructure

Three indicators could be used to describe levels of services and infrastructure available to communities: access to water, sanitation and security of tenure. These in turn provide an indication of the physical capital assets that communities have.

Access to water may vary in reliability as an indicator of physical capital. Piped water in the home does not necessarily make a community more or less able to cope with shocks if the shocks impact directly on the infrastructure, allocation or pricing of water, or if assurance of supply is compromised because households are unable to pay for the water. The indicator of toilets is more reliable as a measure because it is unequivocal that if a household has no toilet or uses a bucket, that household is deprived of physical capital. Tenure is also an important indicator, as an individual who owns and has fully paid for his/her dwelling is less vulnerable than a person who occupies a dwelling rent free. Although the short-term gains – of not paying rent – are obvious, the long-term vulnerability of occupying a dwelling rent free, gives an entitlement to the owner of that dwelling that compromises the wellbeing (over time) of members of the household.

5.2.2.3 Education

A description of the education levels obtained within a community provide an indication of the level of human capital in each zone.

5.2.2.4 Community cohesion and organisational skills

Social capital is reflected, in part, by the degree to which communities are organised. This is a critical component in estimating the resilience and coping mechanisms of communities. Among other things, social capital could be indicated by the existence of Water User Associations (WUA) and water-related stakeholder committees. However, the existence of these organisations does not necessarily indicate the frequency or quality of meetings, nor does the existence of these institutions reflect the degree of 'voice'. In other words, it is possible that these forums are dominated by elites and that the claims of some are amplified whilst the claims of others are muted (Goldin, 2005). It also does not indicate the horizontal or vertical connections between user groups. In other words, the existence of a commercial farmers association does not necessarily mean that the skills (or financial assets) in this unit would benefit a small-scale farmer's association in the same area. Nevertheless, a description of community organisation in relation to water-related issues would probably provide a reasonable means of comparison across spatial units in a given catchment.

5.2.2.5 Relationships with water and aquatic resources

This reflects the importance of natural capital to a community. One cannot assume because a household is located in an area where there are abundant resources that could be harvested that the individual household members are afforded the right to harness these products by the land owner. Similarly, even if there are fishery activities, it may not be correct to assume that the proceeds are evenly distributed across households or that there is an assurance of supply over time.

5.2.3 Calculate prosperity score

The percentage non-poor households in each socio-economic zone are calculated using income data.

5.2.4 Calculate human health score

There are numerous measures of aspects of human health. The challenge is to use a simple set of measures that provide an indication of the overall health of a community. This will need to be used as the baseline against which to assess changes in health due to changes class (which may impact on, for example, the abundance of aquatic pests and pathogens due to changes in water quality). Four groups of health indicators are recommended (i.e. malnutrition, infectious diseases, waterborne diseases and water-quality related diseases – see Table 5-2) with a set of available measures selected for each group. For the baseline description of health, measures should be taken at the highest level of resolution available, which is often at the provincial or district municipality level.

As noted above, health data are not generally available at a high level of resolution. Thus the baseline situation will be described at the best available level of resolution, and as this is often at a district municipality or provincial scale, many of these measures will be used across several or all of the socio-economic zones in a catchment. Table 5-2 presents the suggested measures.

Table 5-2 Measures of health recommended for the health score

Disease	Measure
Malnourishment	% of under fives that are malnourished x proportion of under fives in population
HIV	% of total population afflicted
TB	
Hepatitis	
Malaria	no cases as a % of population
Bilharzia	
Diarrhoea	% of under fives that are malnourished x proportion of under fives in population
Cholera	% of total population afflicted
Typhoid	
Skin irritations	No data for baseline, but considered in scenarios

The health score very roughly describes the burden of disease in each socio-economic zone, approximating the percentage of people afflicted by major diseases. Note that this is incomplete, and the burden of disease should ideally consider a lot more information, but the values to be assessed in the scenarios will be relative to this.

These values are aggregated into prevalence of four categories of disease (Figure 5.1). It is proposed to add the prevalences to provide the best idea of overall level of each of these disease groups. However, this addition could be weighted according to a measure of the seriousness of each disease, such as the probability of dying (e.g. using published case fatality rates).

5.2.5 Calculate utility score

The utility score is intended to be a proxy measure for the level of satisfaction or happiness derived from aquatic ecosystems. This utility is a combination of intangible use values such as spiritual and educational value, and non-use values, such as existence and bequest value. It is assumed that utility is a function of rarity and abundance of components of biodiversity, which in turn are related to the health and conservation importance of that system. Thus it is assumed that utility is a function of the health of these ecosystems.

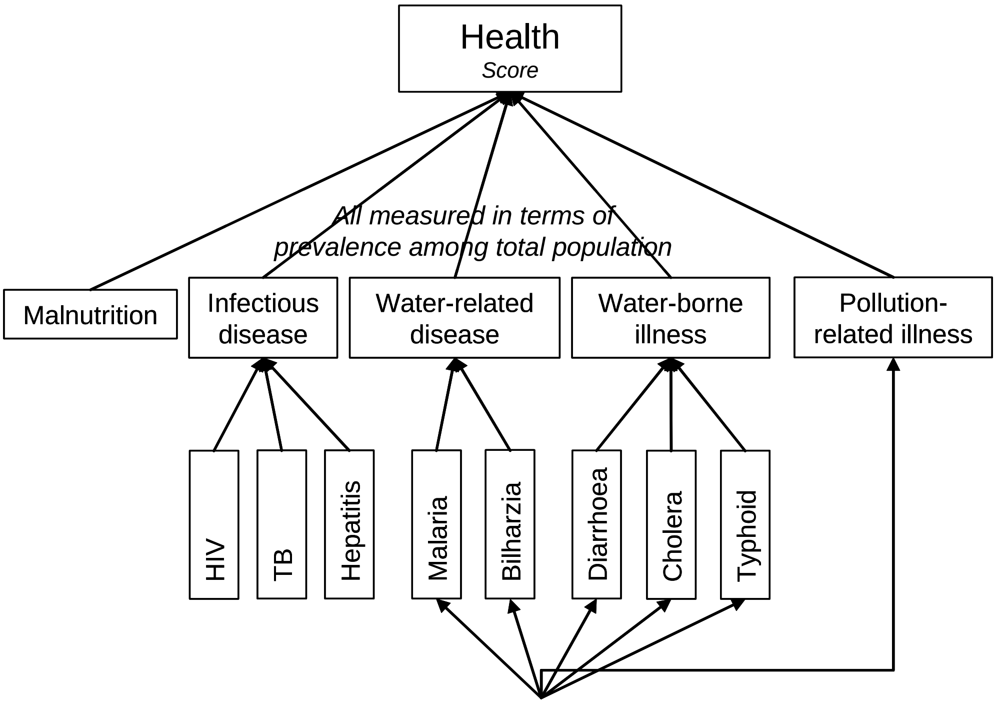

Figure 5.1 Construction of the health score

The relationship between utility and ecosystem health is not well understood. Turpie *et al.* (2005) demonstrated a negative relationship between level of development and existence value of estuaries. However, no study has investigated the relationship between existence value and ecosystem health *per se*. Thus a hypothetical relationship that can be used until further research is conducted has been developed.

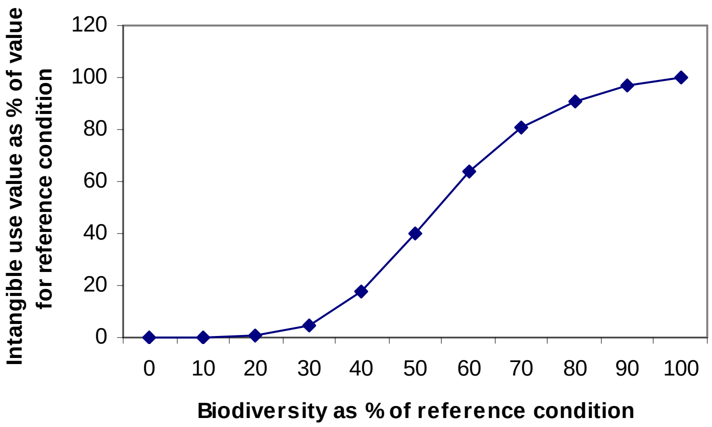

Figure 5.2 Utility as a function of ecosystem health, in terms of percentage resemblance to the pre-development condition

It is assumed that an ecosystem in a pre-development condition would have an existence value score of 100. This score is expected to remain high if the ecosystem is degraded slightly, but below some threshold point, utility would be expected to drop of rapidly with decreasing health.

5.3 Example: Olifants/Doring catchment

The estimated population of the Olifants/Doring catchment is 83 200 people with approximately 50% of the population defined as urban, living in the small towns and villages in the catchment (Table 5-3). More than half of the population is concentrated in the lower and upper Olifants River zones (about 29 000 and 19 000 people, respectively). The dryland farming zone, Doring Rangelands and Koue Bokkeveld zones each have about 9000 – 11 000 inhabitants, the Knersvlakte is very sparsely populated (<5000) and about 3500 people live in the vicinity of the estuary. The characteristics of these populations were described on the basis of Census 2001 data, for which Sub-place level data were adjusted on the basis of percentage area falling within each zone. Estimates of the rural and urban proportions thus differ slightly from the quarternary-based estimates.

Table 5-3 Estimated population of the Olifants/Doring catchment by socio-economic zone (Estuary zone is included within the Lower Olifants) (DWAF, 2001b)

	Koue Bokkeveld	Doring Rangelands	Knersvlakte	Upper Olifants	Dryland Farming	Lower Olifants	Grand total
Urban population	411	7 150	1 900	8 150	4 850	18 950	41 411
Rural population	9 292	4 092	2 952	10 722	4 611	10 126	41 796
Total	**9 703**	**11 242**	**4 852**	**18 872**	**9 461**	**29 076**	**83 207**

There is reportedly a decreasing rural population because of a lack of economic stimulants, migration of young people and because of the impact of HIV/AIDS (DWAF, 2005b). The northern and eastern parts of the catchment are characterised by the highest levels of unemployment, a sparse population, poor infrastructure and high poverty levels (DWAF, 2005b).

The characteristics of the populations of each zone are presented in Table 5-4 and are derived from the 2001 Census data. Sub-place level data were adjusted on the basis of percentage area falling within each zone.

Table 5-4 Summary of population characteristics for each zone. All are % households except education, which is % individuals.

	Koue Bokkeveld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary
% rural	94	57	57	53	61	33	100
% poor	85	82	84	77	84	73	71
% with Matric education	9	13	13	17	15	18	23
% without flush toilets	15	32	55	28	23	16	17
% in rent-free housing	84	40	33	38	41	33	0

Poverty levels are extremely high throughout the catchment, with more than 70% of households earning less than R38 500 per year in all areas. The eastern parts of the catchment, which are more sparsely populated, are characterised by high levels of poverty (over 80%). About 10% of the labour force are unemployed, which is lower than the national average, and about 2% of the employed are seasonal labourers. There is also a strong immigration of seasonal workers during the harvest and planting seasons.

Education levels are low throughout, being higher in the Lower and Upper Olifants zones and highest in Ebenhaesar. Very few (about 4%) are educated beyond matric, and those are mainly white. Educated young people tend to leave the area.

The majority of households have flush toilets, but significant proportions of households still rely on chemical or pit latrines or have no sanitation. Sanitation conditions are worst in the Knersvlakte area, but are relatively good in the main irrigation zones (Koue Bokkeveld, Lower Olifants) and around the estuary.

Security of tenure is fairly low generally, with more than a third of households occupying rent-free dwellings (e.g. labourer cottages) in most zones, and as many as 84% in the Koue Bokkeveld. There is no rent-free occupation in the estuary (Ebenhaesar) zone, which is a communal land area.

Community cohesion and organisational skills reflect the “social capital” within communities, and are indicated to some extent by the extent to which communities have developed forums, committees and associations such as Water User Associations (WUAs). Communities in most of the zones are relatively well organised in respect of water, with several WUAs, irrigation boards and committees, apart from the arid Knersvlakte zone.

The communities of the different zones have different relationships with water and aquatic resources. The Koue Bokkeveld, Upper and Lower Olifants zones are important irrigation areas where economic activity and income is highly dependent on water supply. Other zones rely extensively on groundwater. The Lower Olifants zone is also interesting in that there is some saaidam agriculture. Tourism-related activities occur in all the zones which depend to a certain extent on aquatic systems (e.g. hiking, scenic, fishing, rafting, birdwatching). Direct dependence on aquatic ecosystem resources is negligible, except in the case of the estuary, where up to 200 households in the Ebenhaesar community are involved in a gill net fishery.

6 DESCRIBE AND VALUE THE USE OF WATER (STEP 1F)

6.1 Introduction and rationale

This objective of this sub-step is to describe the way in which water is used currently, and to estimate the value generated by that use. However, since multiple sectors may be involved, it makes sense to rationalise the valuation of water users to only those sectors or activities that might be affected by changes in water availability under the different catchment configuration scenarios (see Brown *et al.*, 2007). Thus at this stage there will need to be some input from the broader planning process within DWAF.

6.1.1 Description of economic (sectoral) outputs

As for the aquatic ecosystems (see Section 7), it will be necessary to describe the present status of the catchment-related economy and the impacts of different catchment configuration scenarios on the economy. This will entail describing the sectoral uses of water and aquatic EGSAs within the above typology, and quantifying their contribution to the economy (e.g. turnover, contribution to regional income, employment). The status quo and changes in this contribution could be estimated for the different catchment configuration scenarios with the help of rule-based models and an economic model such as a Social Accounting Matrix (SAM). The measures and models that could be used are described in more detail in Turpie *et al.* (2006).

6.2 Procedure

All of the descriptions presented in this sub-step are at the scale of the socio-economic zone (see Section 4.

6.2.1 Description of water supply to users

Production outputs are the gross income or turnover of each user activity. The primary inputs required to estimate changes in turnover of water users are:

- the volume of water allocated to the various water users in each sub-system; and
- the level of water assurance given to each water user in each sub-system.

Water assurance is the guarantee given by DWAF to individual water users in respect of the amount of time that water will be available to them, expressed as a percentage. Levels of assurance for each water user have to be taken into account (see section on water demand schedules below).

Currently, each water user has an existing water allocation and water assurance guarantee. Assessment of the current situation should incorporate ‘normal changes’ in future water usage patterns, i.e. normal economic and demographic growth, normal price changes, etc. As such, the current situation is a reflection of future water usage with its associated economic impacts, excluding changes resulting from water re-allocation decisions (i.e. the ‘without intervention’ scenario).

6.2.2 Inputs required on user sectors

Table 6-1 lists the data inputs required for each category of water user (see Section 6 for a description of the recommended users). These inputs are derived from the current situation and are assumed not to change under the different catchment configuration scenarios. Thus no additional adjustments need to be made to determine the economic and socio-economic impacts resulting from a re-allocation of water.

Table 6-1 Inputs required for user sectors for changes in economic value

Water Users	Data required
Agriculture	Number of hectares Water usage per hectare [m^3] Annual production (e.g. tonnes per hectare) Annual production value (Gross income) [Rands] Labour requirements per hectare [Numbers] Annual capital requirements per hectare [Rands] Water Production Elasticities [%]
Commercial Forestry	Number of hectares Water usage per hectare [m^3] Tonnes per hectare Annual production value (Gross income) [Rands] Labour requirements per hectare [Numbers] Annual capital requirements per hectare [Rands]
Domestic Households	Total population [Numbers] Water use per person per annum [m^3] Current economic value of water Current cost of supply of water [R/kl] Direct labour multipliers [Numbers] Direct capital multipliers [R million]
Industry and Power	Current water usage [$10^6 m^3$] Current GDP [R million] Direct labour multipliers [Numbers] Direct capital multipliers [R million]
Fisheries	Current production value [R million] Current cost of water Direct labour multipliers [Numbers] Direct capital multipliers [R millions]
Tourism	Number of tourist days Spending per tourist day [Rand per tourist per day] Direct labour multipliers [Numbers] Direct capital multipliers [R millions]
Real estate	Turnover in property sales attributed to aquatic environment (R per year) Direct labour multipliers [Numbers] Direct capital multipliers [R millions]

6.3 Example: Olifants/Doring catchment

6.3.1 Introduction

Water use in the Olifants/Doring catchment is described by Mallory *et al.* (2006). A summary is presented here. The irrigation agriculture sector is by far the largest water use sector with estimated requirements of about 96% of the total requirements within the catchment, although estimates of the actual amount of water used vary (Table 6-2, Table 6-3). Thus the remainder of this section will consider only agricultural water use, assuming that this will be only sector that will be significantly affected under different scenarios.

Table 6-2 Water volume requirements (in million m³/a, for the year 2000) at 1:50 year assurance for different areas within the Olifants/Doorn WMA (after DWAF, 2004a; DWAF, 2005b)

Sub-area	Quaternary catchments	Irrigation	Urban (1)	Rural (1)	Mining and bulk industry (2)	Afforestation (3)	Total local requirements	Transfers out	Grand Total
Upper Olifants	E10A - E10G	100	1	1	0	1	103	94 (4)	197
Koue Bokkeveld	E21A - E2	65	0	1	0	0	66	0	66
Doring	E22, E23, E24A-M, E40A-D	13	1	1	0	0	15	0	15
Knersvlakte	E31A-H, E32, E33A-F, F60	3	0	1	3	0	7	0	7
Lower Olifants	E10H-K, E33F-E33H	140	3	1	0	0	144	4 (5)	148
Sandveld		35	2	1	0	0	38	0	38
Total for WMA		**356**	**7**	**6**	**3**	**1**	**373**	**0**	**373**

(1) Includes component of the Reserve for BHN at 25 l/c/d.
(2) Mining and bulk industrial water uses, which are not part of urban systems.
(3) Quantities given refer to impact on yield only.
(4) Transfers out of the Upper Olifants of 94 million m^3/a for downstream irrigation, mainly via the Lower Olifants River canal.
(5) Transfers out of the Lower Olifants of 4 million m^3/a consist of a transfer of 2.5 million m^3/a to meet the Namakwa Sands mining requirement, and 0.4 million m^3/a to northern Sandveld urban use. The rest is provision for losses.

Table 6-3 Annual supply of water to different sectors for each of the socio-economic zones of the study area, in $10^6 m^3$ per annum, estimated for this study (after Mallory *et al.*, 2006)

Socio-economic zone	Coalpower	Industry	Mining	Rural	Urban	Irrigation	Stream flow reducing activities
Koue Bokkeveld	0	0	0	0.64	0.12	106.1	0
Upper Olifants	0	0	2.91	0.67	3.36	152.77	0
Doring Rangelands	0	0	0	0.69	0.72	44.49	0
OD dryland farming	0	0	0	0.26	0.12	35.92	0
Lower Olifants + Estuary	0	0	0	0.51	0	115	0
Knersvlakte	0	0.72	0	0.53	0.6	28.68	0
TOTAL	**0**	**0.72**	**2.91**	**3.30**	**4.92**	**482.96**	**0**

6.3.2 Agricultural water use

Table 6-4 provides a summary of the conditions that influence irrigation farming. Estimates of irrigated crop area vary, as well as DWAF (2001b) estimates of irrigation crop area. Based on DWAF (2002b) and WSAM data (DWAF, 2001b), it is estimated that about 33 000 ha are harvested annually in the study area on average (Table 6-5). While the area of fields is considerably larger, some of this is irrigated only in years when sufficient water is available. Grapes and deciduous fruits are the most important irrigated crops (Table 6-5). Assurance of supply is low for Lucerne, medium for vegetables and high for the remaining irrigation crops.

The nature of irrigation practices varies throughout the catchment. Upstream of the Doring River confluence, the **upper Olifants Valley** is intensively cultivated with about 10 670 ha under irrigation. Most of this is under citrus trees, with a smaller area of deciduous fruit orchards. Drip irrigation is widely used in the orchards. Upstream of the Clanwilliam Dam, irrigation water is either stored in farm dams or is pumped from the river. Downstream of the dam, water is supplied by canal from the dam. Most of the land developed for irrigation is irrigated every year because of the crop type (orchards) and the reasonably reliable water supply (DWAF, 2002b).

At the head of the Doring catchment, the **Koue Bokkeveld** area is extensively cultivated with about 9000 ha under irrigation (DWAF, 2004a), mainly for deciduous fruit and some vegetables. Irrigation is mainly from farm dams. The orchards are generally under drip irrigation, while the vegetables are under sprinklers (DWAF, 2002b).

The **Doring rangelands** area is dry, and about 1000ha of mainly lucerne, pasture and vegetables are irrigated, much of this with water imported from the Breede River Basin via the Inverdoorn Canal (DWAF, 2002b).

The **Knersvlakte** area receives some summer rain as well as winter rainfall. Less than 350 ha of mainly lucerne and pasture is irrigated from farm dams and the privately owned Oudebaaskraal Dam (DWAF, 2002b).

In the **Olifants-Doring dryland farming** area, most irrigation occurs in the western portion, which has winter rainfall. About 1800 ha are irrigated. Most of this is lucerne and pasture, apart from the up to 300 ha of vegetables in the Brandewyn River valley (DWAF, 2002b). There are several farm dams in the headwaters of the Oorlogskloof river and tributaries which irrigate a relatively constant area of about 460 ha of mainly lucerne and pasture (DWAF, 2002b).

Downstream of the Olifants – Doring confluence, the **lower Olifants** valley has about 11 200 ha of land irrigated from canals from the Bulshoek Barrage using mostly water released from the Clanwilliam Dam. The main crops are grapes (wine, table and raisins), deciduous fruits and vegetables. As a result of some double cropping of vegetables, the area harvested is about 11 500 ha on average (DWAF, 2002b). In addition, about 270 ha of land (mostly lucerne) around the upper Sout and Vars Rivers is irrigated using the "saaidam" method. This involves abstracting floodwater for irrigation via a series of parallel bunds almost at right angles to the river. These divert floodwater onto the lands both to wet the lands and to deposit the rich silt in the water as fertilizer. This method is not possible in the lower reaches of these rivers due to salinisation.

Table 6-4 Water-related characteristics of the socio-economic zones, based on quaternary catchment-level data (DWAF, 2001b)

Data	Doring Rangelands	Knersvlakte	Koue Bokkeveld	Lower Olifants Irrigation	Olifants/Doring Dryland farming	Upper Olifants Irrigation	Total
Area (km^2)	16 398	18 797	3 072	1 613	6 533	2 653	49 066
Average Mean Annual Precipitation (MAP) (mm/a)	209	147	425	160	269	535	273
Predicted no. of boreholes	47	0	82	0	1	37	167
Water supply (10^6m^3)							
Major dam	2.46	2.25	-	3.98	3.64	0.85	13.18
Minor dams	2.26	-	-	-	5.58	126.10	133.94
Water requirement (10^6m^3)							
Strategic Bulk On-site	23 582	11 266	10 336	3 634	10 160	9 294	68 272
Irrigation	10.74	9.11	103.88	104.05	48.87	130.59	407.24
Irrigation area (km^2)							
High category	4.56	0.80	51.61	105.81	3.18	98.55	264.51
Medium category	26.99	5.71	100.50	-	26.69	32.83	192.72
Low category	0.53	0.97	-	-	12.87	-	14.37
Area dryland crops (km^2)	20.75	15.80	22.65	183.55	70.70	37.66	351.11
No. Large Stock Units	281 056	121 303	242 576	726 900	236 528	471 810	2 080 172

Table 6-5 Estimated irrigated crop area (km^2) in each socio-economic zone in 1995 based on a combination of quaternary catchment-level data (DWAF, 2001b) and estimated average harvested area (after DWAF, 2002b)

Socio-economic zone	Deciduous fruit	Grapes	Citrus	Pasture/Lucerne	Other vegetables	Other crops	Total harvested in average year
Upper Olifants	10.7	-	74.0	-	19.0	3.0	106.7
Doring Rangelands	-	-	0.6	4.3	5.5	0.3	10.7
Koue Bokkeveld	70.0	-	-	-	16.0	-	86.0
Olifants/Doring Dryland	-	1.7	0.4	2.9	9.7	3.2	17.8
Knersvlakte				1.5	1.8	-	3.4
Lower Olifants	2.0	102.0					104.0
Total	**82.7**	**103.7**	**75**	**8.7**	**52**	**6.5**	**328.6**

6.3.3 Irrigation agriculture turnover

Turnover from irrigation agriculture was estimated based on the area of each category of crops in each zone (Table 6-6). Total turnover from irrigation agriculture is very roughly estimated to be in the order of R2 billion per annum, based on farm turnover data and expert opinion (Table 6-7). Note that this is for ‘proof of concept’ only. Ideally, better turnover data should be sourced through specialist studies if data are not readily available.

Table 6-6 Turnover and employment for typical farms in the irrigation-farming sector (A. Laubscher, Stellenbosch University, *in litt.)*

Type of crop	Location	Typical farm size (ha)	Turnover R/ha	Employment		
				Manage-ment staff	Permanent labourers	Seasonal labourers
Citrus	Citrusdal and Clanwilliam	70	R60 000	2	11	70 for 5 months
Wine grapes (plus vegetables)	Melkboom, Klawer, Vredendal, Lutzville	75	R40 000	2	12	40 for 3 months
Table grapes	Melkboom, Klawer, Vredendal	25	R160 000	2	16	60 for 4 months

Table 6-7 Rough estimate of turnover and employment irrigation farming in each zone, based on Table 6-6 and rough assumptions of turnover for medium and low value crops (all values in Rands).

Descriptor	Doring Range-lands	Kners-vlakte	Koue Bokke-veld	Lower Olifants Irrigation	Olifants/ Doring Dryland Farming	Upper Olifants Irrigation	TOTAL
Estimated average turnover per ha:							
High value crops	60 000	40 385	60 000	40 385	43 810	60 000	
Medium value crops	30 000	30 000	30 000	30 000	30 000	30 000	
Low value crops	12 500	12 500	12 500	12 500	12 500	12 500	
Total turnover (R millions)	109	22	611	427	110	690	1 969
Management jobs	3 482	689	19 523	13 650	3 517	22 035	62 896
Labour	113 534	22 472	636 625	445 114	114 676	718 531	2 050 952

7 DESCRIBE AND VALUE THE USE OF AQUATIC ECOSYSTEMS (STEP 1G)

7.1 Introduction

This objective of this sub-step is to describe the way in which aquatic ecosystems are currently used, and to estimate the value generated by that use. This provides the current or baseline value against which the catchment configuration scenarios (see Brown *et al.*, 2007) will be evaluated. While all EGSAs should identified and described (in qualitative terms at least), a baseline value can often only be estimated for some of these as the information required is often not available without investing in a costly survey. The latter is true for most ecosystem services, where it is usually easier to measure the impact of change than to try and compute a baseline value to one input of a multiple input production processes. Some aquatic ecosystem goods and services have a direct or indirect influence on production and can thus be valued in terms of sectoral outputs, while others are better valued in terms of costs savings or incurred.

A range of methods are usually applied to the valuation of ecosystem goods, services and attributes. These include relatively straightforward methods of quantifying direct consumptive use, replacement cost or cost avoided methods for the valuation of ecosystem services, revealed preference methods for the measurement of recreational and aesthetic values (e.g. travel cost method, hedonic pricing method) and stated preference methods (e.g. contingent valuation) for the measurement of existence value. In the Classification Process, it is unlikely that the resources will be available to carry out many of these valuation methods. Thus in most cases the valuation will rely on existing information and simple assumptions about how values relate to ecosystem condition.

7.2 Procedure

There is a wealth of literature on the ecosystem goods and services provided by aquatic ecosystems. The list of goods, services and attributes and associated values provided in this study can act as an initial checklist in identifying those that are likely to be relevant for the catchment in question. This process will require some investigative work, most of which can be done through brief consultations with relevant specialists and key informants that are familiar with the catchment, if information is not readily available in the literature.

Following their identification, the goods, services and attributes and their associated values are systematically dealt with. For each, it will be necessary to identify data requirements, and to search for existing information on these requirements.

7.3 Example: Olifants/Doring catchment

7.3.1 Introduction

A preliminary assessment suggests that several EGSAs are of medium to high significance in the Olifants/Doring catchment (Table 7-1). The following is an overview of all the values, providing information on the goods, services, attributes and their values wherever possible, or giving reasons why they are not valued.

Table 7-1 A list of ecosystem goods, services and attributes and associated values, and a preliminary assessment of their probable significance in the Olifants/Doring catchment, based on readily-available existing information and expert opinion

EGSAs	Description of value	Component	Probable significance
Water	Subsistence use of water		Low
Food, medicines and grazing	Subsistence or commercial use of fish and food plants; medicinal plants	Riparian and instream vegetation	Negligible
		Invertebrates	None
		Fish	High (estuary)
		Birds	Negligible/None
Raw materials	Use of craftwork materials, fuel wood, construction materials and fodder	Reeds, sedges, timber, poles, firewood, grazing	Low/negligible

EGSAs	Description of value	Component	Probable significance
Gas regulation	Carbon sequestration		Negligible/None
Disturbance regulation	Flood control		Unknown, probably important
Water regulation (in terms of sponge)	Absorption of wet season flows and provision of dry season flows for agricultural, industrial and household use (spatially and temporally)		Unknown, possibly Medium
Erosion control and sediment retention	Prevention of siltation of water infrastructure		Low
	Added agricultural output in floodplains		Low except possibly an input into the 'saaidam' agricultural system in the Doring catchment
Waste treatment	Breaking down of waste, detoxifying pollution; dilution and transport of pollutants		High
	External costs of overloading (not an ecosystem service *per se*, but will be accounted for as reduction in water use value)		High
Amenity	Riparian trees providing shade for livestock and people		Low/Negligible
Ecological regulation	Regulation of malaria, bilharzia, liver fluke, black fly, invasive plants, etc.	Human diseases	None
		Livestock pests and pathogens	Low
		Invasive aquatic/riparian plants	Low
Refugia, nursery value and export of materials and nutrients	Critical habitat for migratory fish and birds, important habitats for species		Negligible/None
	Critical breeding habitat, nurseries for marine fish		High
	Export of nutrients to marine ecosystems		Negligible/None
Structure and composition of biological communities	Tourism and recreation	Dam-based fishing and other water-sports	High
		Freshwater fly fishing	Low/Medium
		Freshwater coarse fishing in rivers (bass, etc.)	Low
		Estuary angling	Low/Medium
		River rafting/canoeing	Medium
		Aquatic attractions – Niewoudtville waterfall	Low/Medium
		Hiking, 4x4 trails, wilderness usage (rivers add value)	Unknown, possibly Medium
	Cultural, educational, spiritual and scientific values of ecosystems	Unknown	Unknown, probably Low
Genetic resources	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species		Unknown

7.3.2 Water for basic human needs

Based on the census data on the communities of the different socio-economic zones (see Section 3), it would appear that very few people in the Olifants/Doring catchment depend on collecting water from rivers or boreholes for their domestic water supplies, with the vast majority having piped water to their dwellings.

7.3.3 Estuarine fisheries

There is some use of fish resources, mainly in the estuary, by the Ebenhaesar Community, and also reportedly in the rivers by poorer members of the community (Lamberth, 2005). There is no information on the latter activity.

There are approximately 1 200 gill-netters operating in estuaries in South Africa (Lamberth and Turpie, 2003). On the West Coast, legal gill-netting only takes place in the Olifants estuary, having been discontinued on the Berg River. On the Berg River estuary, there were 120 gill-net permit holders, plus about 100 illegal operators, and annual effort was about 13 230 net days of legal effort plus at least 4 000 net days of illegal effort (Hutchings and Lamberth, 1999). The Rietvlei/Diep system is fished by about 10 to 12 poachers (Lamberth, 2000).

There are 45 gill-net permit holders in the Olifants estuary, and an estimated additional 10 to 30 people operating without permits (Sowman *et al.*, 1997). Annual effort is about 15 300 net days/year (Lamberth, 2005).

The Olifants gill-net fishery targets harders *Liza richardsoni*. Mean annual landings of harders by the fishery are in the region of 100 t with a further 5 to 20 t of by-catch species such as elf *Pomatomus saltatrix* and silver kob, *Argyrosomus inodorus* (Hutchings and Lamberth, 2003). The annual tonnage from the Olifants Estuary comprises 1 to 2 % of the national catch by the inshore beach-seine and gill-net fisheries (Lamberth *et al.*, 1997). The nets used are restricted to 45 m in length and a minimum mesh size of 48 mm. All the fishers use rowing boats; the use of motors being frowned upon either because the fishers cannot afford them or due to the perception that they scare the fish. Fishing is seasonal, being confined mostly to summer (October to April) during low flows. Although abundance and/or catchability of harders may be lower in the winter months, making fishing not worthwhile, any attempt at setting nets is usually impeded by waterborne debris.

Sixty percent of the fisher households rely on fishing for 25 to 50% of their summer income, whereas for the remaining 40%, fishing comprises 75% of household income (Sowman *et al.*, 1997). A large part of the catch is consumed with more than 50% of households eating fish every day.

The low flow experienced during 2004 saw the fishery active throughout the winter months. However, despite the overall increase in effort throughout the year, total catch was 100 to 120 tonnes, similar to the annual average. This suggests that catches were spread out over a longer period and that catch per unit effort declined with the increase in effort. Consequently, it appears that recruitment is low, fishing mortality high and the 45 operators are above the sustainable effort maximum, with most fish entering the system being caught. While decreased flows are likely to lead to decreased catches, prolonged high flows or floods in winter may also result in extreme hardship for the families reliant on fishing for a livelihood.

The economic value of the fishery was considered in terms of the value of landed catches by small-scale fishers (this includes the value of fish consumed as well as sold), and turnover generated by commercial fishers.

Only the commercial income and recreational expenditure values contribute to standard measures of national income (e.g. GDP), although subsistence income should also be considered as value added to the economy.

The total value of fisheries within South African estuaries is estimated to be about R656 million per year (2005 rands; based on Lamberth and Turpie, 2003). This is based on an estimated total annual catch of 2 482 tons. Ninety-nine percent of this value (nearly R652 million) is the value of recreational angling, while net and traditional fisheries together make up the remaining 1% of value. Based on estimated catches of the gill-net fishery and the national average value per kg (Lamberth and Turpie, 2003), the fishery in the Olifants estuary is estimated to be worth about R491 400 to R629 600 per annum (2005 rands). This value is pertinent to the Estuary socio-economic zone only.

7.3.4 Other food and raw materials

There is no recorded use of other foods or building materials (e.g. reeds) gathered from the aquatic ecosystems in the study area. This is not surprising because of the population make-up and the lack of traditional dwellings in the catchment.

There is commercial harvesting of sand in the Olifants/Doring Dryland socio-economic zone by a single operator under permit from the Department of Mineral Affairs and Energy (J. Briers, DME, pers. comm.). This operator extracted 5 482 m^3 of sand during the last financial year, generating a gross income of about R35 600 (J.D. Stemmet, sand miner, pers. comm.). It is likely that the availability of sand in the Doring River will be affected by the construction of an impoundment on that system, but it is not possible to estimate the degree to which sand availability would change from the results generated in the Reserve study (C. Brown, EWR specialist, pers. comm.), or whether the sand mining operation would be affected.

There has also been diamond mining and prospecting in the Olifants River mouth region during the past 50 years or so. The mining concessions either side of the mouth probably have an impact on water quality and mouth dynamics.

7.3.5 Carbon sequestration

Carbon sequestration is measured in terms of the net storage or loss of carbon that takes place as a result of a long-term increase or decrease in biomass. It is assumed that the aquatic ecosystems considered in this study are carbon neutral (biomass is neither being increased or decreased at present), and that the catchment configuration scenarios would not have a significant impact on this balance.

7.3.6 Flow regulation, flood control, soil retention and erosion control

Wetlands in the upper catchment might have an important flow regulation function, in that they absorb flows during wet periods and release them during dry periods, hence maintaining dry season flows, when water is in demand. These wetlands may also be important for soil retention. However, these functions have not been investigated and the type of study required would be beyond the scope of this project.

It is, however, important to note that were a dam to be built on the Doring River (which currently has a high silt load), it could lead to significant scouring of the river downstream, which could result in bank erosion leading to loss of valuable agricultural lands. Land suitable for viticulture in the Vredendal-Lutzville area sells for about R80 000/ha (noble white cultivars) or R105 000/ha (noble red cultivars) on average, or about R16 000/ha for land suitable for irrigated vegetable production (Standard Bank Agricultural Advisory Unit, pers comm.).

7.3.7 Waste absorption

Waste absorption is likely to be an important ecological service provided by the aquatic ecosystems of the study area, particularly in that agricultural return flows are diluted and assimilated by the system. The value of this function is usually estimated in terms of the cost savings of treating the water before it is released. However, the quantity of pollutants released into the system was unknown. It is important to note that the value of the system is only measured in terms of the amount assimilated by the system. This capacity could be reduced under certain circumstances, resulting in decreased water quality downstream and exacerbating the negative impacts on downstream users that would already be caused by increased pollution loads due to agricultural expansion.

7.3.8 Refuge areas and nutrient export

Refuge areas are areas that help to maintain populations in a broader area. For example, wetlands within relatively arid areas may play an important seasonal role in the maintenance of wild herbivores that are utilised in tourism operations well beyond the wetland. This is probably not important in the study area apart from for fish. In the rivers, some of the smaller tributaries have become important as refuge areas for endemic fish, although their ability to repopulate the rest of the river system is low at present (see discussion below). In the estuary, some inshore marine fish populations may utilise the estuary as a warmer refuge during upwelling events (Lamberth, 2005). The extent of this function in its contribution to marine populations is, however, unknown.

The export of sediments and nutrients to the marine zone is an important function of some river systems. For example, the prawn fisheries of KwaZulu-Natal depend on such exports (DWAF, 2004b). However, this function is far more important on the east coast, which is relatively nutrient-poor, than on the West Coast, where the outputs of estuaries do not compete with the nutrients supplied by the Atlantic upwelling systems (Turpie and Clark, 2006). Sediment exports could be important, however, but there is no information on this.

7.3.9 Nursery value

7.3.9.1 Introduction

Nursery areas are areas that are used as breeding habitat for populations that reside elsewhere. The nursery function of the Olifants estuary is considered to be significant, in that many marine species caught in the surrounding marine fisheries are dependent on estuaries as nursery areas (Lamberth and Turpie, 2003). This value is described in more detail below.

Estuaries provide nursery areas and habitat for numerous species of fishes which are exploited by recreational and commercial harvesting in the inshore marine environment. Different species are dependent on estuaries to different degrees for stages of their development and growth. On the West Coast, the Olifants estuary is thought to be particularly important as a nursery area since it is one of only four permanently open systems, and it accounts for 23% of the estuarine area on the West Coast (Turpie *et al.*, 2004b).

This assessment is based on existing literature describing estuarine and coastal fisheries and their values, as well as the nursery value of estuaries. The basic biology and ecology of estuarine fishes is described in Lamberth (2005).

7.3.9.2 West Coast fisheries, participation and effort

There are about 431 000 recreational fishers and well over 21 000 commercial fishers active in the inshore marine environment in South Africa. Beach seine and gill net fisheries on the West Coast are likely to be the fisheries that are most affected by changes in the Olifants estuary. The commercial line fishery, recreational shore angling and recreational boat angling fisheries could also be affected to a small extent.

7.3.9.2.1 Commercial gill-net and beach seine netting

Gill-net fisheries on the West Coast target harders and St Joseph sharks *Calorhynchus capensis*, as well as species on the 'bait list' such as maasbanker *Trachurus trachurus*. All gill-net permits issued for the marine environment are on the West Coast, from Yzerfontein northwards (approximately 118 permits), apart from occasional experimental fisheries elsewhere. In addition, illegal gill-netting occurs throughout the South African coastline, though mostly on the west and south coasts. There are an estimated 268 illegal gill-nets on the West Coast, 60 on the south coast, and 120 on the KwaZulu-Natal coast.

Some 28 of the 60 beach seine permits in the country are held on the West Coast.

There are approximately 2 700 people who derive some sort of income in the legal inshore net fisheries along the west and south coasts, with a total effort of approximately 32 000 net-days per year.

7.3.9.2.2 Commercial boat-based linefishing

There are approximately 18 533 commercial line fishers operating from 2 581 registered boats in South Africa, for 380 800 boat-days per year (Lamberth and Turpie, 2003). Some 9 000 of these are the West Coast (Brouwer *et al.,* 1997; Sauer *et al.,* 1997), though at least half of these may have become recreational line fishers since the number of licences were reduced in 2003.

7.3.9.2.3 Recreational shore angling

There are an estimated 412 000 regular shore anglers in South Africa (McGrath *et al.,* 1997), 26 000 of whom are on the West Coast (Brouwer *et al.,* 1997; Sauer *et al.,* 1997). The majority of anglers come from the upper two quintiles of income earners in South Africa (McGrath *et al.*, 1997).

7.3.9.2.4 Recreational boat angling

There are an estimated 12 054 recreational boat anglers, operating from 3 444 boats (McGrath *et al.,* 1997), on 92 988 boat-days per year. Some 210 of these are on the West Coast (Brouwer *et al.,* 1997; Sauer *et al.,* 1997). However, in many cases, the distinction between commercial and recreational boat fishermen is blurred, ranging from purely recreational fishers to those selling some catches to finance boating expenses or to supplement an existing income, to those who fish on a permanent commercial basis. The situation has changed since the allocation of fishing rights began in 2001, with many part-time fishers being removed from the fishery.

7.3.9.3 Inshore marine catches

The total inshore marine catch in South Africa is estimated to be 28 107 tonnes per year (Lamberth and Turpie, 2003). Of this 60% is made up by the commercial line fish sector and 23% by the commercial net fishery, the remainder being made up of recreational fisheries. Inshore fishery catches on the West Coast account for about 15 000 tonnes, and make up 53% of the total catch. In contrast to the rest of the country, these catches are predominantly commercial, whereas recreational catches are more important than commercial catches in the rest of the country.

7.3.9.4 Utilised species, their distribution and dependence on estuaries

Of the approximately 160 species that occur in South African estuaries, about 80 species are utilised in coastal fisheries. Some 19 of these species occur in the estuaries of the West Coast region. Of these, 8, 9 and 2 species fall into categories II, III and IV, respectively (none in I or V), in terms of their dependence on estuaries (Whitfield, 1994, Table 7.2). Of particular importance are the Category II species, for which management of estuaries plays a crucial role in inshore fisheries.

Table 7.2 The five major categories and subcategories of fishes that utilise southern African estuaries (Whitfield, 1994)

Category	Description
I	Estuarine species that breed in southern African estuaries. Ia. Resident species that have not been recorded spawning in marine or freshwater environments. Ib. Resident species that also have marine or freshwater breeding populations.
II	Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. IIa. Juveniles dependent on estuaries as nursery areas. IIb. Juveniles occur mainly in estuaries, but are also found at sea. IIc. Juveniles occur in estuaries but are usually more abundant at sea.
III	Marine species that occur in estuaries in small numbers but are not dependent on these systems.
IV	Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This category includes some species that may breed in both freshwater and estuarine systems.
V	Catadromous species that use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions. Va. Obligate catadromous species that require a freshwater phase in their development. Vb. Facultative catadromous species which do not require a freshwater phase in their development

The catches of estuarine-associated fish species differ from west to east around the coast, following biogeographical changes from the Cool Temperate region on the West Coast through to the Subtropical region north of the Mbashe River in the Eastern Cape. Numbers of estuarine species in catches increase from west to east around the South African coast. Within regions, species composition of catches within estuaries also differs between estuaries of different types and sizes, with greater species richness associated with larger and permanently open estuaries such as the Olifants (Lamberth and Turpie, 2003).

7.3.9.5 Estuary-associated species in marine catches

Numerous estuary-associated species have been recorded in all types of inshore marine fisheries. The contribution of different categories of estuary-associated species to inshore marine fisheries on the West Coast is summarised in Table 7-3. Category IIa species (e.g. white steenbras), which are entirely dependent on estuaries, generally make up a relatively small percentage of catches, ranging from 0.5% of recreational boat and spear fishing catches to 1.05% of commercial net catches. Historically, prior to stock collapse, Category IIa species (white steenbras and dusky kob) made up a substantial part of catches. The proportion of Category IIb species in catches is generally lower than of category IIa species, but Category IIc species are highly important in the commercial net fisheries and recreational shore fishery (Table 7-3). The Category IIc species are dominated by harders in the commercial net fisheries. The main species in these fisheries are shown in Table 7-4.

Table 7-3 Percentage contribution of different categories of estuarine-associated fish to the inshore marine fisheries on the West Coast. All percentages in terms of biomass except recreational shore angling, in terms of numbers (after Lamberth and Turpie, 2003)

Fishery type	Estuary-dependence category*				
	IIa	IIb	IIc	III	Total
Recreational shore	0.51	0.17	41.26	13.81	55.75
Recreational boat	0.02	<0.01	0.80	0.10	0.92
Recreational spear	0.05		0.09	0.09	0.23
Commercial boat	0.09	<0.01	0.80	0.10	0.91
Seine and gill-net	1.05	0.04	80.86	1.10	83.06

*IIa Juveniles depend on estuaries; IIb juveniles occur mainly in estuaries; IIc juveniles occur in estuaries; III Marine species that occur in but not dependent on estuaries.

Table 7-4 Contribution of the main estuary associated species to West Coast fisheries (% catch) (after Lamberth and Turpie, 2003)

Fish	Category	Commercial Gill/seine	Commercial boat	Recreational shore	Recreational boat
Harders	IIc	79	0.1	9.5	0.1
Elf	IIc	1	0.1	0.1	0.1
Strepie	IIc	0.1	0.1	0.3	0.1
Dassie	IIc	0.1	0.1	1	0.1
White Steenbras	IIa	0.1	0.1	0.5	0.1

7.3.9.6 Estuarine contribution to inshore marine fishery values

The total value of inshore marine fisheries in South Africa is about R3.64 billion per year (2005 Rands, of which about R647 million is attributable to West Coast fisheries (based on Lamberth and Turpie 2003; Table 7-5). Approximately 53% of the West Coast value is the value of the recreational fisheries, the remainder being commercial value.

Estuarine fish make up about 25% of the value of the gill- and seine-net fisheries and 0.3% of the value of the commercial boat fisheries on the West Coast, or about 8% of the overall value of West Coast inshore marine fisheries (Table 7-5). However, not all of these fish are equally dependent on estuaries. Category IIa species are entirely dependent on estuaries to complete their life cycles. Because the juveniles of Category IIb species are largely confined to estuaries, their level of dependence on estuaries was considered to be very high, and was estimated as 90%. The overall numbers of Category IIc species, whose juveniles mainly occur in marine environments, are augmented by the presence of estuarine habitat areas. Estuarine areas comprise about 30% of the juvenile habitat available to these species, and those juveniles using estuaries are frequently in better condition than those in marine habitats (De Decker and Bennett, 1985). It is thus estimated that 30% of the marine catches of Category IIc species can be attributed to estuarine export. Thus in calculating the contribution of the different types of species to fishery values, estuaries are assumed to account for 100%, 90%, and 30% of the value of category IIa, IIb and IIc species, respectively. Category III species are not included in this value.

Table 7-5 Percentage contribution of estuarine-associated fishes to the total value of the inshore marine fishing sectors on the West Coast, the total annual values of the fisheries, the amount and percentage of total which is comprised of estuary-associated species, and the contribution of estuaries to total fishery values (2005 rands) (after Lamberth and Turpie, 2003)

Fishery type	% Estuary-associated category				Total value	Estuary fish contribution		Value due to estuaries	
	IIa	IIb	IIc	III	R million	R million	%	R million	%
Recreational shore	0.60	0.03	18.05	2.24	160.53	33.59	20.92	9.7	6
Recreational boat	0.00	0.00	0.39	0.01	170.18	0.68	0.41	0.2	0.1
Recreational spear	0.12		0.06	0.12	11	0.03	0.3	0.02	0.1
Commercial boat	0.04	0.00	0.78	0.05	286.87	2.52	0.88	0.8	0.3
Seine- and gill-net	3.89	0.02	72.90	1.86	18.1	14.23	78.67	4.66	25.8
TOTAL					**646.68**	**51.05**	**7.9**	**15.38**	**2.4**

Thus, adjusting values according to the level of contribution that estuaries make to the catches of species of different categories, the estimated contribution from estuaries to inshore marine fisheries on the West Coast is 2.4% of the total value, or about R15.4 million per year (2005 rands, Table 7-5). The contribution on the West Coast is somewhat smaller than the 21% of total value for the country as a whole. The latter estimate is the value that would be lost if estuaries were ‘removed’ from the coastline.

7.3.9.7 Nursery value of the Olifants estuary

The portion of the West Coast inshore fishery value that is due to estuaries (R15.4 million) is the nursery value of estuaries on the West Coast. How much of this comes from the different estuaries is unknown, and depends on several factors such as estuary size and mouth status, as well as geographical location. The Olifants estuary makes up about 23% of the estuary area on the West Coast (not including the upper Berg estuary floodplain which is largely a freshwater habitat). This is a conservative estimate because the Olifants and Berg estuaries probably contribute more than the Orange, due to the location of the fisheries. Thus a conservative estimate of the nursery value of the Olifants estuary is some R3.45 million per year (2005 rands; Table 7-6).

Table 7-6 Annual values of fisheries that benefit from the Olifants estuary, and the total value attributed to the estuary

Fishery	Fishers	Total value (millions)	Value from Olifants estuary (millions)
West Coast gill and seine	321 gill + 84 seine (+ crew)	R18.1	R1.07
West Coast commercial boat	9 000	R286.87	R0.18
West Coast recreational shore and boat	210	R341.71	R2.28
Total nursery value of Olifants estuary fish			**R3.45**

7.3.10 Genetic resources

Genetic resources are valuable in many systems, but probably least valuable in freshwater and estuarine systems, where most species are extremely widespread. There are also few species that have widespread commercial potential (e.g. for agriculture or horticulture). Nevertheless, there are endemic species, and there is a possibility that these may become useful. It is not possible to determine this value.

7.3.11 Tourism and recreational value

7.3.11.1 General overview of tourism in the study area

The Olifants/Doring catchment has become an increasingly popular tourist destination for South Africans and overseas tourists. Much of the appeal lies in the natural features of the area, particularly the mountainous areas which provide opportunities for peaceful getaways or adventure holidays involving a variety of aquatic and non-aquatic outdoor activities. The Cederberg Wilderness Area is well known for its rugged beauty; features rare species such as the elephant's foot plant and the snow protea, and has the best examples of San rock art in the Western Cape. The Namaqualand flower displays are possibly one of the biggest attractions to the area during early spring and several tour operators offer tours to view flowers. Aquatic ecosystem-based activities in the area include river rafting, canoe trails (near Citrusdal), fly fishing, coarse fishing, and estuarine angling, as well as viewing the Nieuwoudtville Falls, a 100 metre high natural feature on the Doring River.

Accommodation facilities in the catchment range from extremely isolated and rustic camping facilities to self catering chalets and luxury guesthouses either in towns or in the middle of wilderness areas. Due to the hot, dry climate during the summer months, most of the out-of-town accommodation facilities and many of the hiking trails are located within short distances of streams and natural swimming holes.

The towns in the catchment offer their own attractions (e.g. wine cellars, rooibos tea and veldskoen shoe factories, historical monuments), as well as using natural attractions (including river- and dam-based activities) within their vicinity as a large part of their marketing strategy.

Unlike most large estuaries in South Africa, there is no major urban settlement around the mouth of the Olifants estuary, apart from the tiny village of Papendorp. There is a guesthouse at Papendorp, and at Ebenhaesar, about 10 km up the estuary, locals have established a guest house and camping area. The nearest resort town is Strandfontein, situated on the coast just south of the estuary. Visitors to this area fish in the estuary as well as off the coast.

7.3.11.2 River Rafting and kayaking

During late winter and early spring, depending on amount of rain and snow-melt, the Doring River offers some challenging white water rafting. Four rafting companies offer white water rafting from Klawer. Mainly one or two day trips are available although shorter trips are offered, often through other companies as part of a tour which includes flower viewing and hiking. Most of the trips take place on the stretch of the Doring River above the confluence near Klawer between the end of June and September, with each company running between 15 and 20 trips over the season. Some companies offer rafting from Clanwilliam as well (The River Rafters staff pers. com.). Some of the accommodation establishments in the Olifants/Doring catchment, such as Oudrif guest farm, offer guests use of canoes for paddling on nearby rivers, streams or dams. Total turnover from river rafting is estimated to be in the region of R1 million per annum.

7.3.11.3 Freshwater angling

Invasive alien species were introduced to the Olifants River between 1920 and 1940 in order to ‘improve the fishing’. Introducing these species had significant implications for small and large indigenous cyprinid species. In particular, wherever the smallmouth bass occurred after introduction, the smaller redfin minnows were eliminated and larger cyprinids suffered from poor recruitment. The indigenous fishes have been further impacted by the expansion of agricultural development in the Olifants catchment and the small and large dams in the system, particularly the Bulshoek and Clanwilliam dams, which prevent upstream spawning, and the loss of water quantity and quality due to abstraction (Impson, 2004). In the Doring River, indigenous species now occur in very low numbers, while alien invasive species such as bass and bluegills are abundant (Impson, 1999).

Fresh water angling is an important attraction to the Olifants/Doring catchment, and both locals and tourists visit the area specifically for fishing. Freshwater angling takes place at sites throughout the catchment, and some accommodation enterprises offer fishing in their farm dams and smaller streams running through their properties. All fresh water fishing can only be done with a permit, regulated by Cape Nature Conservation who sell licences directly, but also indirectly through some tourism bureaus. Freshwater anglers are encouraged to catch and kill alien species such as bass, bluegill and carp but fishing for yellowfish and sawfin has to be practiced on a catch-and-release basis.

Freshwater fishing comprises coarse fishing for the exotic species (bass, bluegill and carp) throughout much of the catchment, but mostly in the dams (small or large), and flyfishing for indigenous species, such as Clanwilliam yellowfish and Clanwilliam sawfin, mostly in the smaller stream in the upper parts of the catchment. Rainbow trout have been introduced into dams in the headwaters of the Doring River in the Kouebokkeveld, as the highlands are cool enough even in summer for trout. The trout are kept in dams that are almost entirely syndicate/privately owned and are therefore not generally accessed by the public, and fly-fishing for trout is therefore a very small industry. Brown trout are found in the Olifants gorge.

The recreational fishery is dominated by the exotic fishery, and is mainly for black bass in Clanwilliam Dam, and to a lesser extent in Bulshoek Dam. The section of the Olifants River near Citrusdal and the Clanwilliam Dam is also popular mainly for catching black bass. The Clanwilliam Dam and other bass fishing areas are used for fishing throughout the year but are especially busy during the flower season (August to September) and over the December/January holidays (Marthinus September, Clanwilliam Dam Resort, pers. com). The town of Clanwilliam hosts no less than three Bass ‘classics’ and two provincial tournaments, with each event hosting at least 100 participants over a weekend, and many of these staying longer. In addition, most of the Cape Bass clubs will hold at least one club outing on the Clanwilliam Dam (S. Kulenkampff, South African Federation of Artificial Lure and Fly Fishing Association and South African Bass Anglers Association *in litt*.). These outings would result in considerable expenditure in the area. Indeed, one of the biggest obstacles to conservation and control of exotic species is the high value of the bass, carp and trout fisheries, especially bass in the Olifants/Doring, where annual expenditure is probably in the millions.

In comparison, fly-fishing for indigenous species is a relatively specialised hobby. Even though this is becoming a more popular sport among fly-fishermen (as opposed to trout-fishing elsewhere), opportunities for fishing for yellowfish and sawfin are relatively small, due to bass having virtually eliminated them from most of the catchment. Where bass exist, indigenous fish are outcompeted and only occur in very small numbers, which are too low to support recreational angling for those species. The value of indigenous fly-fishing is probably about 10 to 20% that of bass-fishing (D. Impson, Cape Nature, pers. comm.), and is probably fairly small compared with the value of fly-fishing in other parts of the country (Turpie *et al.*, 2004c).

7.3.11.4 The Olifants estuary recreational fishery

A total of 67 000 recreational anglers and 5 700 cast netters are estimated to use estuaries in South Africa. On the West Coast, recreational angling in estuaries is limited, primarily due to lack of suitable angling fish, with an estimated effort of up to 4 400 angler days per year in total (equivalent to about 147 anglers). All the effort is currently recreational, although about 14% of these anglers admit to selling part of their catch (Lamberth, 1996). Cast nets are used regularly by about 95 recreational shore anglers in West Coast estuaries, almost exclusively targeting harders, with a total effort of about 2 837 angler days per year.

The Olifants estuary line-fishery comprises recreational shore-angling and limited recreational boat fishing. The boats used range from small dinghies to ski-boats of 6 m in length. On the Olifants, the bulk of the effort is from shore angling and boat use is minimal. Based on angler densities on the adjacent shorelines and angler and boat counts in the Berg and Olifants estuaries, there may be up to 0.12 anglers per km of estuary or a maximum of 4 400 angler-days per year expended in West Coast estuaries from the Berg River northwards (Lamberth and Turpie, 2003). The gear used ranges from hand lines to fishing rods of various shapes and sizes, including fly-rods.

Recreational anglers catch an estimated 14 to 20 tonnes of marine line-fish in estuaries on the West Coast annually, 1 to 2 tonnes (8 %) from the Olifants estuary. Recreational anglers catch a further 0.1 tonnes of harders using cast-nets as well as a small but unknown quantity of freshwater fish, mostly the introduced species such as Mozambique tilapia *Oreochromis mossambicus* and smallmouth bass *Micropterus dolomieu*. The bulk of the Olifants Estuary linefish catch is made within 500 m of the mouth and comprises silver kob, Angolan kob *Argyrosomus coronus*, white steenbras *Lithognatus lithognathus*, West Coast steenbras *L. aureti* and elf. Of these, the stocks of silver kob and white steenbras are collapsed and those of elf and West Coast steenbras are overexploited. Estuarine fish stocks cannot be considered as discrete and in isolation from the marine environment. The current status of estuarine stocks is largely a reflection of the nationwide decline that has occurred for most line-fish species.

The economic value of the recreational fishery was considered in terms of the expenditure on fishing by recreational fishers (= income to subsidiary industries such as accommodation and fuel). While the commercial and traditional fisheries are forms of generating cash or subsistence income, and are largely valued in terms of the market value of their catches, the value of recreational angling does not lie mainly in the market value of the fish caught. Recreational anglers value the sport and experience, and expend considerable sums on this activity, largely irrespective of their catch returns (McGrath *et al.,* 1997). The value attributed to this fishery is mostly in terms of gains to subsidiary industries that benefit from angler expenditure (McGrath *et al.,* 1997). Based on regional estimates of recreational value, the fishery is estimated to be worth between R561 600 and R1 259 200.

7.3.12 Summary

A summary of the values of aquatic ecosystem goods, services and attributes in the Olifants/Doring catchment is provided in Table 7-7.

Table 7-7 Summary of the values of aquatic ecosystem goods, services and attributes in the Olifants/Doring catchment

	EGSAs	Description	Value	Socio-economic zone
Goods	**Water**	Negligible use for basic human needs	Not valued	N/A
	Food, medicines and grazing	Subsistence estuarine fishery at Ebenhaesar	R0.5 – 0.6 million / annum	Estuary
	Raw materials	Sand mining near Klawer	R35 000 / annum	Olifants/Doring Dryland
Services	**Gas regulation**	Carbon sequestration assumed to be negligible	Could not be valued	All
	Disturbance regulation	Flood attenuation possibly important but unknown	Could not be valued	Mainly Koue Bokkeveld
	Water regulation	Timing of flows probably regulated by upper catchment aquatic systems, but not been studied	Could not be valued	Mainly Koue Bokkeveld
	Erosion control and sediment retention	Downstream erosion likely if Doring River dammed; effect unquantified	Not valued, losses could be >R100 000 per ha	Olifants/Doring Dryland, Lower Olifants
	Waste treatment	Several sources of pollution benefit from the carrying capacity of the system; load capacity and actual loads unknown	Not valued, estimation of impacts under different scenarios would require further study	All
	Nursery areas	Olifants estuary provides important nursery area for West Coast fisheries	Value R3.45 million in contribution to commercial and recreational fisheries	Estuary
Attributes	**Genetic resources**	There are some unique biological materials and products that may have future potential value	Unlikely to affected by scenarios, cannot be valued	All
	Structure and composition of biological communities	There is extensive recreational and tourism use of the catchment, with several activities being water based, though generally on a fairly small scale	Estuary fisheries R0.6 – 1.3 million per annum Freshwater fishery values unknown but probably significant	Estuary All

8 DEFINE THE INTEGRATED UNITS OF ANALYSIS (STEP 1H)

See Volume 2 (Brown *et al.*, 2007).

9 DEVELOP AND/OR ADJUST THE SOCIO-ECONOMIC FRAMEWORK AND THE DECISION-ANALYSIS FRAMEWORK (STEP 1I)

9.1 Introduction

This objective of this sub-step is to either develop a new *socio-economic valuation framework* (see Volume 3; Joubert *et al.*, 2007 for a discussion on the decision-analysis framework component of this step) *that links changes in yield and ecosystem characteristics to socio-economic values*, or to apply or adjust the socio-economic framework recommended in this report (i.e. Section 2). This decision will depend on the specific characteristics of the targeted catchment, and/or the preference of DWAF and/or the team appointed for the Classification Process. Which ever of the two options is chosen (i.e. develop a new framework or adapt or apply the framework presented in Section 2), the framework must predict changes in socio-economic values with changes in yield and ecosystem characteristics for different catchment configuration scenarios. The current framework (Figure 9.1) incorporates two sets of parameters:

- a configuration of ecosystem health categories among the water resources of the catchment with their associated flow regime; and
- a utilizable yield of water.

These two sets of parameters are generally inversely related, with increased aquatic ecosystem health requiring a reduction in utilizable yield. The yield, which is described in terms of the characteristics of water supplied to water users, influences the output of water user sectors. The catchment configuration scenarios also influence the output of EGSAs, from which a number of values are derived. Some of these values influence sectoral outputs and others are measured in terms of costs avoided or incurred. Sectoral outputs are then translated into measures of economic impact using a SAM, or a related input-output tool (see Section 14). Societal wellbeing is influenced by sectoral production, and also directly by ecosystem uses.

Flow regulation in terms of ecosystem influence on the timing of flows should be internalised in the ecosystem component, but will be too difficult to do in reality.

9.2 Procedure

The procedure for applying Step 1i in the Classification Process will need to be developed as and when catchments are classified.

9.3 Example: Olifants/Doring catchment

The socio-economic framework developed for the ‘proof of concept’ catchment is presented in Section 2, while the conceptual diagram indicating the information pathways is presented in Figure 9.1.

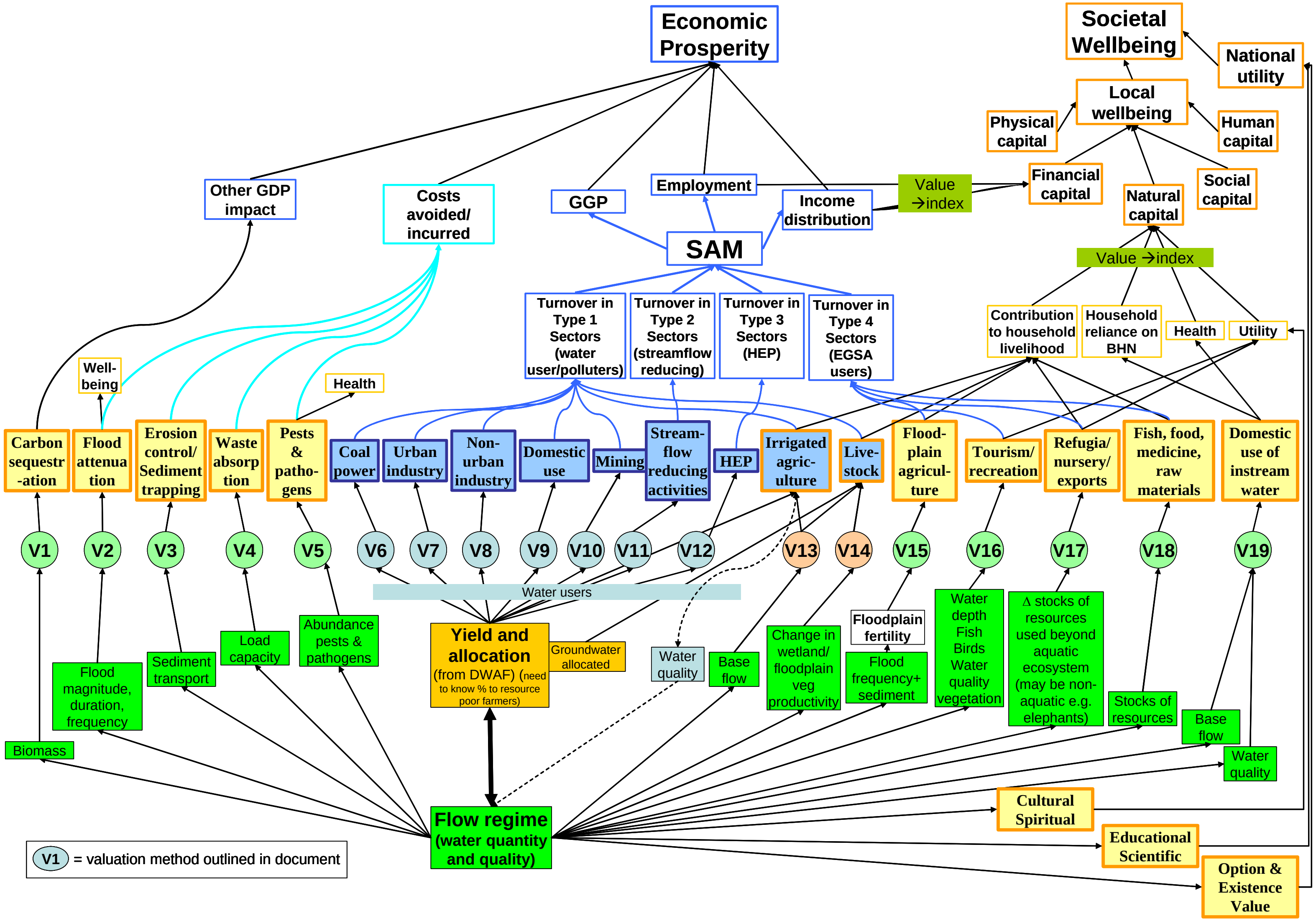

Figure 9.1 Information pathways for the proposed socio-economic valuation framework for the 'proof of concept' catchment

10 DESCRIBE THE PRESENT-DAY COMMUNITY WELLBEING WITHIN EACH IUA (STEP 1J)

10.1 Introduction

This objective of this sub-step is to describe *the present-day community wellbeing within each IUA*. (defined in Step 1h – see Section 8) using the index developed in Step 1e (see Section 5). This is to ensure that the ecological and socio-economic implications of different catchment configuration scenarios and reported at the same scale.

10.2 Procedure

This step involves collating the income data collected for Step 1e and sourcing the relevant health data for the catchment. The level of resolution of the health data will depend on the degree to which the zonal boundaries and catchment boundaries correspond with scales of available data. These data are then used to calculate the community wellbeing index, the procedure for which is described in more detail in Volume 4.

10.3 Example: Olifants/Doring catchment

Health data were obtained at a district or provincial level from the District Health Information System Database. The data were not available at sufficient resolution to be able to distinguish the health situation in different zones. Thus the same health scores were applied to all zones in the catchment. The input data for prosperity and human health measures are summarised for each of the socio-economic zone in Table 10-1.

Table 10-1 Measures for each IUA of various criteria that form inputs into the index of social wellbeing and health measures. Health measures are % individuals in the population.

Descriptor	**Koue Bokkeveld**	**Doring Rangelands**	**Knersvlakte**	**Upper Olifants**	**Dryland farming**	**Lower Olifants**	**Estuary**
Prosperity							
% non-poor households	17	19	16	21	16.5	30	22.5
% employed	93	88	69	86	82	74	53
Health*							
Malnourishment	3.3	3.3	3.3	3.3	3.3	3.3	3.3
HIV	10.7	10.7	10.7	10.7	10.7	10.7	10.7
TB	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hepatitis							No data
Malaria	0	0	0	0	0	0	0
Bilharzia	0	0	0	0	0	0	0
Diarrhoea	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Cholera	1	1	1	1	1	1	1
Typhoid				No data			
Skin irritations				No data			

*Source: District Health Information System Database. National Department of Health

11 SELECT THE ECOSYSTEM VALUES TO BE CONSIDERED BASED ON ECOLOGICAL AND ECONOMIC DATA (STEP 2A)

11.1 Introduction and rationale

During the classification procedure, it is unlikely that a comprehensive valuation of all aspects of water and aquatic ecosystems would be feasible because of financial, time and data constraints. Thus it will be necessary to rationalise those values on which to concentrate efforts for the scenario analysis in Steps 5 and 6 (see Joubert *et al.*, 2007; Volume 4).

11.2 Procedure

Rationalisation could be on the basis of the following criteria:

- current value or change in value likely to be significant;
- sufficient ecological data available to estimate changes in value; and
- sufficient socio-economic data available to estimate changes in value.

The last two are open to interpretation in terms of the quality of data that are sufficient to make a reasonable estimate. As a guideline, a rough estimate is better than no estimate, since it can always be challenged by stakeholders if necessary. In the end, it is ultimately the order of magnitude of the values that counts, rather than the accuracy of the number.

The following procedure could be adopted:

- All possible EGSAs of the ecosystem are tabulated, together with the following information:
  - description of value;
  - probable significance in the catchment;
  - data requirements from the ecological component;
  - possibility of being able to obtain relevant ecological data;
  - other data required (social, agronomic etc.); and
  - possibility of being able to obtain other relevant data

Following this, the types of value which are not desirable or feasible should be eliminated with justification.

11.3 Example: Olifants Doring/catchment

For the 'proof of concept' catchment, the Olifants/Doring, the following ecosystems were considered based on the information collected in Step 1 of the classification procedure:

Water
- household use: Very low; most of the population has piped water;
- watering cattle: Very low; most farmers will rely on boreholes and farm dams; and
- *in-situ* washing: Very low or none; poor communities are adjacent to saline reaches.

Food and medicine
- fish: High; the Ebenhaesar-Papendorp community relies to some extent on estuarine fishing; recreational fishing; farmers and farm workers fish in the middle reaches;
- shellfish: Negligible or none;
- bait species: Low; by recreational fishers, incorporated in recreational fishing value;

- food and medicinal plants: Negligible or none; and
- salt: yes, but not influenced by instream flow

Raw materials

- grass for thatching, crafts, fences: Negligible or none;
- sedges for mats, crafts: Negligible or none;
- reeds for mats, fences and ceilings: Negligible or none;
- timber and poles from riparian or mangrove forests: Negligible or none;
- firewood: Negligible or none;
- sand/pebbles: Negligible or none; only in small quantities;
- clay: Negligible or none; and
- minerals: Negligible or none.

Carbon sequestration

- overall, this impact is likely to be small, particularly in semi to semi-arid catchments such as the Olifants/Doring: Low; in plantation forests only.

Climate regulation

- aquatic and water-dependent ecosystems are unlikely to influence local climate to any significant degree.

Disturbance regulation

Wetlands within the higher altitudes of the catchment may ameliorate downstream flooding to some extent, thus providing a service to downstream farmers and settlements, though probably fairly small

- flood attenuation: Low; wetlands and riparian vegetation; and
- coastal protection: None.

Water regulation and recharge

No research has been carried out on this function in the Olifants/Doring catchment, and little if any, has been carried out elsewhere in South Africa.

- water regulation: *Presumed* Low, possibly significant in the Koue Bokkeveld; and
- aquifer recharge: *Presumed* Low.

Sediment retention

- enhanced agricultural production: None; and
- prevention of siltation of dams: unknown, probably Low.

Waste treatment

The value of water treatment is based on the load that can be absorbed without damage to the ecosystem.

- waste treatment: Medium; polluted return flows may be diluted and some wastes assimilated before reaching the estuary, providing slightly better water quality to downstream users.

Ecological regulation

The Olifants/Doring catchment is outside of the range of the main water related diseases, but black fly does occur in the area. The area is not a stronghold for invasive aquatic plants. Thus this value is likely to be small.

- control of pests and pathogens: None; and
- control of alien invasives: Low.

Refugia, export and nursery functions

In the case of the Olifants/Doring catchment, this type of relationship with aquatic ecosystems is unknown. It is thought, however, that the estuary may act as a refuge for marine fish during upwelling events, due to the difference in temperature (S. Lamberth, DEAT: MCM, pers. comm.). However, this is merely a hypothesis, and no data are available. However, nursery freshwater flows from the Olifants/Doring catchment have a significant influence on the productivity of West Coast fisheries.

- refugia: Low; but estuary may have measurable value;
- nursery function: Medium; makes a measurable contribution to marine fisheries; and
- export of nutrients and sediment: Unknown impact.

Tourism and recreation

In the Olifants/Doring catchment, aquatic ecosystems provide opportunities for river rafting, canoeing, fly fishing and estuary angling, as well as fishing for exotic species (mainly bass). Bass fishing is mostly in dams, however, although some takes place in the rivers of the lower catchment. In addition to water sports, many of the other activities (e.g. hiking) in the catchment benefit from the use of rivers.

- biodiversity attractions: Medium.

Amenity

This could be important in arid and semi-arid catchments such as the Olifants/Doring. It is however, particularly difficult to attach a value to this kind of service.

- shade trees: unknown, but could be important in places.

11.3.1 Rapid assessment of data requirements and availability

A summary of the data requirements for estimation of aquatic ecosystem-based values (EGSAs) is provided in Table 11-1 together with an assessment of their importance and feasibility for measurement in the Olifants/Doring catchment.

11.3.2 Summary and prioritisation of values to be considered

Rationalisation of the values to be used in the scenario analysis are summarised in Table 11-2.

Table 11-1 The data requirements for valuation of aquatic ecosystem-based values, and importance and feasibility for the Olifants/Doring catchment

EGSAs	Description of value	Component	Probable significance	Data requirements from the ecological component	Possibility of being able to obtain relevant ecological data	Other data required (social, agronomic etc.)	Possibility of being able to obtain relevant data (other)
Water	Subsistence use of water		Low	Change in volume and quality	Possible	Household dependence on instream water (% households)	All
Food, medicines and grazing	Subsistence or commercial use of fish and food plants; medicinal plants	Riparian and instream vegetation	Negligible	Proportional change in availability and abundance of key species, grouped in terms of use and response to changes in flow	Possible	Household use of resources	No data
		Invertebrates	None				No data
		Fish	High (estuary)				Good data from Ebenhaeser
		Birds	Negligible/None				No data
Raw materials	Use of craftwork materials, fuel wood, construction materials and fodder	Reeds, sedges, timber, poles, firewood, grazing	Low/negligible	Proportional change in availability and abundance of key species, grouped in terms of use and response to change in flow	Possible	Household use of resources	No data
Gas regulation	Carbon sequestration		Negligible/None	Change in vegetation biomass	Not possible	Literature (value/tonne)	Good data
Disturbance regulation	Flood control		Unknown, probably important	Assessment of change in flood risk due to degradation of aquatic ecosystems (e.g. wetlands)	Not possible (only qualitative indication)	Value of infrastructure, fields at risk	Possible with some assumptions
Water regulation (in terms of sponge)	Absorption of wet season flows and provision of dry season flows for agricultural, industrial and household use (spatially and temporally)		Unknown, possibly Medium	Assessment of change in yield due to influence on dry season flows	Not possible, requires a fine scale hydraulic model.	Value will come out in water use value estimate	n/a

Erosion control and sediment retention	Prevention of siltation of water infrastructure		Low	Change in sediment load relative to natural conditions	Not possible (very difficult to define simple functional relationship between flow and load)	Cost of engineering solution	Possible with specialist input
	Added agricultural output in floodplains		Low except possibly an input into the 'saaidam' agricultural system in the Doring catchment	Change in the frequency of floodplain flooding	Possible	Relationship between amount of flooding and agricultural output	Might be possible with specialist input, but complicated
Waste treatment	Breaking down of waste, detoxifying pollution; dilution and transport of pollutants		High	Current loads; and how loading capacity (quantity of effluent that does not impact on water quality beyond acceptable levels – see DWAF, 1996) changes under different scenarios	Possible, but current load capacity and actual loads of the system could not be estimated for this study due to the limitations of the models used	Replacement cost, i.e. treatment cost per kg pollutant	Possible
	External costs of overloading (not an ecosystem service *per se*, but will be accounted for as reduction in water use value)		High	How concentrations change under different scenarios	Possible	How changes in concentrations impact on downstream production	Possible (with some assumptions)
Amenity	Riparian trees providing shade for livestock and people		Low/Negligible	Change in tree cover	Possible (using change in riparian vegetation cover as a proxy)	Information on amenity uses	Not possible
Ecological regulation	Regulation of malaria, bilharzia, liver fluke, black fly, invasive plants, etc.	Human diseases	None	N/A	N/A	N/A	N/A
		Livestock pests and pathogens	Low	Change in abundance	Possible	Value of livestock production and how impacted by pests under different levels of abundance	Possible (rough) by using existing literature from Orange River
		Invasive aquatic/riparian plants	Low	Change in abundance	Possible	Control costs and how they relate to abundance/area	Possible

Refugia, nursery value and export of materials and nutrients	Critical habitat for migratory fish and birds, important habitats for species		Negligible/None		No information	N/A	
	Critical breeding habitat, nurseries for marine fish		High	Change in abundance of estuary dependent fishes by category	Possible	Contribution of estuary dependent fish to marine fisheries and value of those fisheries	Possible
	Export of nutrients to marine ecosystems		Negligible/None	N/A	No information	N/a	
Structure and composition of biological communities	Tourism and recreation	Dam-based fishing and other water-sports	High	Change in water area (dam level) and change in abundance of fish	No information	Property investment at Clanwilliam Dam	
		Freshwater fly fishing	Low/Medium	Proportional change in availability and abundance of key species, grouped in terms of use and response to change in flow	Possible	Some measure of fishing activity e.g. angler days per year and associated expenditure (can be obtained from literature)	Not possible at desk-top level (unless licence data could yield some estimate)
		Freshwater coarse fishing in rivers (bass, etc.)	Low		Possible	Some measure of fishing activity e.g. angler days per year and associated expenditure (can be obtained from literature)	Not possible at desk-top level (unless licence data could yield some estimate)
		Estuary angling	Low/Medium		Possible	Some measure of fishing activity e.g. angler days per year and associated expenditure (both can be obtained from literature)	Possible
		River rafting/canoeing	Medium	Change in period during which water level is above some depth threshold (could estimate this based on months that they raft)	Possible, but might be difficult at desk-top level	Some measure of total rafting activity (trips and occupancy)	Possible at rough level

		Aquatic attractions – Niewoudtville waterfall	Low/Medium	Change in period during which waterfall flowing	Possible, but might be difficult at desktop level	Value of attraction (data exist)	Possible
		Hiking, 4x4 trails, wilderness usage (rivers add value)	Unknown, possibly Medium	Data requirements unknown without having done a survey	Too complex	Value of terrestrial tourism and contribution of aquatic ecosystem attributes to that value	Not possible without major survey
	Cultural, educational, spiritual and scientific values of ecosystems	Unknown	Unknown, probably Low	Unknown		Types and frequency and importance of use	Not available
Genetic resources	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species		Unknown	Cannot value	N/A	N/A	N/A

.

Table 11-2 Summary and prioritisation of values to be considered for the Olifants/Doring catchment

EGSAs		Specific component	Probable significance	Likely degree of change in value under different catchment configuration scenarios	Level of available information or knowledge on which to base an estimate	Include (Yes or No)
Goods	**Water**	Water for BHN	Low	Low	High	No
	Food, medicines and grazing	Fish	Medium	Medium	High	Yes
		All other	Low	Low	Low	No
Services	**Raw materials**	All	Low	Low	Low	No
	Gas regulation	Carbon Sequestration	Low	Low	Low	No
	Disturbance regulation	Flood attenuation	Low	Low	Low	No
	Water regulation	Timing of flows	Medium	Low	Low	No
	Erosion control and sediment retention		Medium	Low/Medium	Low	No
	Waste treatment	Assimilation capacity	High	High	Low	No
Attributes		Externalities	Medium	Medium	Medium	Yes
	Nursery areas	Estuary-dependent marine fish	Medium	Medium	High	Yes
	Genetic resources		High	Low	Low	No
	Structure and composition of biological communities	Recreational value	High	Low/Medium	Low	Selected aspects

12 DESCRIBE THE RELATIONSHIPS THAT DETERMINE HOW ECONOMIC VALUE AND SOCIAL WELLBEING ARE INFLUENCED BY ECOSYSTEM CHARACTERISTICS AND SECTORAL USE OF WATER (STEP 2B)

The aim of this step is to describe the relationships that exist between outputs of EGSAs and sectoral productivity, water supply and sectoral productivity, outputs of EGSAs and community wellbeing, and sectoral productivity and community wellbeing. This will allow for the estimation of the impacts of changes in ecosystems and sectoral productivity at an IUA scale for different catchment configuration scenarios (see Section 14) (Figure 12.1).

The purpose of defining the relationships is to be explicit about the functions and assumptions used in predicting changes in value under the different catchment configuration scenarios. Note that some of the values are measured in terms of sectoral outputs, while others are quantified in terms of cost savings, etc. The ecological and economic changes that are likely to occur under different scenarios will also have to be evaluated in the light of concomitant changes in societal wellbeing.

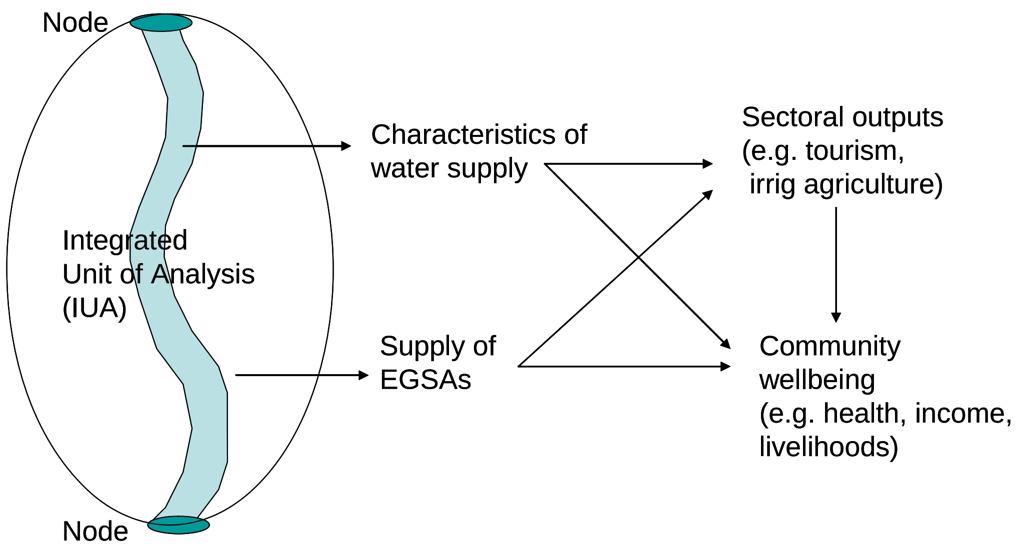

Figure 12.1 Diagram showing some of the within-IUA relationships that will be described

12.1 Guidelines for estimating change in economic value generated by aquatic ecosystems

This component of sub-step 2b involves describing predictive relationships between economic value and aquatic ecosystem characteristics that will be used to determine changes in each of the values estimated for different catchment configuration scenarios (see Brown *et al.*, 2007). The examples developed should be viewed as a starting point, as it is necessary to constantly refine these relationships as new information and understanding comes to light. Further, these relationships will need to be developed for the catchment targeted for classification.

The present-day value should be described as appropriate, and may only be partially valued (e.g. the affected portion only). For scenarios, all values will be expressed as change from present-day, and in Rands per year. A common base-year will have to be agreed upon, e.g. all in 2006 Rands. Valuation should take place at the level of the IUA. In all cases the values should be estimated based on existing information from the catchment if possible, or from a broader knowledge base, if necessary, in conjunction with reasonable and explicit assumptions. It will not be possible to generalize these relationships in detail, since the circumstances and data availability may require some modifications. The description presented below is linked to the socio-economic valuation framework described in Section 2, while the numbers (e.g. V19) refer to points on Figure 9.1.

The descriptions presented below are categorized according to EGSAs that contribute to social wellbeing and economic prosperity (see Section 12.1.1), EGSAs that result in costs/avoided/incurred and therefore contribute to economic prosperity (see Section 12.1.2), and sectoral turnover that contributes to economic prosperity and social wellbeing (see Section 12.1.3) (Figure 2.2).

12.1.1 Valuing EGSAs that contribute to social wellbeing and economic prosperity

12.1.1.1 Domestic use of instream water (V19)

Domestic use of instream water is akin to the notion of BHN. While BHN is incorporated as a constraint, the way in which BHN is calculated is controversial, and the incorporation of actual instream use is to express the way in which base flows contribute to household welfare.

From Census data, it is possible to establish the number households that depend on the resource for water supply. The use of water can be valued in terms of the market value of water (reflecting willingness to pay). However, it does not need to be valued in the classification procedure, but can be an input into the community wellbeing index. If it was valued, then the value would go down when the population was provided with tap water. If it were incorporated into the social wellbeing index, then the value would go up.

It is necessary to know the extent to which the demand for domestic use of instream water can be met under different catchment configuration scenarios. Changes in this value could be estimated based on an assessment of the change in period for which the current use can be met (Eq. 1).

Eq. 1 $$\text{Score (e.g.} 1-12) = \frac{\text{months for which flows can supply needs under scenario x}}{\text{months for present} - \text{day}}$$

12.1.1.2 Livestock production (V14)

Livestock production in an area will be a function of water supply, grazing capacity and other inputs such as labour, feed, veterinary medicines etc. (Eq. 2).

Eq. 2 $$\text{Turnover in livestock production} = f\left(\text{water supply, grazing capacity, x, y, z}\right)$$

Different inputs will be more important in different areas. For example, groundwater allocation may be an important variable in a typical commercial enterprise, whereas instream flow and riparian, floodplain or wetland grazing productivity may contribute significantly in some subsistence or commercial enterprises. While the sectoral output should be calculated in relation to water allocation in the water use valuations described in section 6, the resource or agricultural economist will need to determine the degree to which aquatic ecosystems contribute to livestock production through provision of water and grazing inputs.

In terms of water, it will need to be determined whether groundwater or instream flow is a limiting resource during the dry season, or the level of dry season base flows at which it would become limiting.

In terms of grazing, the grazing capacity differential between utilized aquatic ecosystems and upland grazing areas will have to be estimated, and the contribution of this differential to production estimated on the basis of relative use of different grazing areas. The relationship between flows and grazing differential will need to be assumed based on current understanding (e.g. see Figure 12.2).

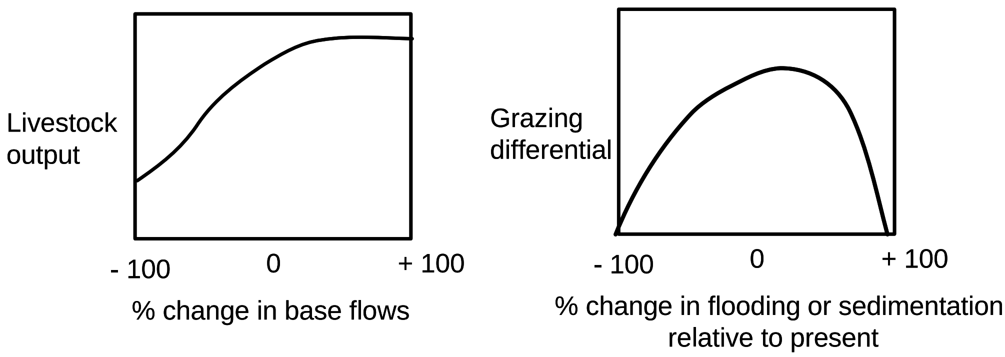

Figure 12.2 Graphs illustrating examples of the types of relationships that might have to be estimated to value changes in aquatic ecosystem inputs to livestock production

12.1.1.3 Flow contribution to floodplain agriculture (V15)

This is a measure of the contribution of aquatic ecosystems to agricultural productivity due to flooding and sediment deposition. It would be necessary to estimate the extent of floodplain agriculture (ha) and the output per ha; and to compare this with output per ha for a comparable dryland area in order to estimate the differential that is attributed to instream flow. The differential is the value of interest, and it will be necessary to estimate how this differential changes under different catchment configuration scenarios. This will have to be estimated as a function of either flood frequency or sediment deposition (Eq. 3).

Eq. 3 $$\text{Turnover in floodplain agriculture} = f\begin{pmatrix}\text{probability of flooding (P) and/or} \\ \text{sediment deposition} \\ \text{(\% change in tonnes/year), x, y, z}\end{pmatrix}$$

In some cases the difference will be that use of the floodplain saves on irrigation costs. In this case the turnover approach will not be sufficient, as it is input costs, not turnover, that varies (Eq. 4).

Eq. 4 $$\text{Surplus or value added in floodplain agriculture} = f\left(\text{cost of water supply, x, y, z}\right)$$

12.1.1.4 Tourism and recreational value (V16)

This is a measure of the value associated with recreational use of aquatic ecosystems. This value will be determined by the utility provided by the eocsystem, which will be a function of various ecosystem attributes (depending on the type of recreation). It is expressed in terms of both expenditure by users (trade sector) and turnover in the real estate sector. However, it is also noted that recreational use generates consumer surplus, and this will be recognised by a link to the index of social wellbeing (see Joubert *et al.*, 2007).

Change in tourism and recreational value is first considered in terms of changes in utility under different catchment configuration scenarios. For each type of recreational use (Eq. 5):

Eq. 5 $\text{Utility or turnover} = \text{f}\left(\text{ecosystem attributes, x, y, z}\right)$

For example, angler utility might be a function of fish abundance, while river rafting turnover might be a function of the number of months for which depth at point A is greater than X, and estuarine recreational use might be a function of angling fish, waterbird and saltmarsh abundance and state of the estuary mouth (open/closed).

Once the above relationships are determined it is possible to adjust the value of each recreational activity on the basis of changes in the input variables.

The above is best done using survey data (for example using conjoint and contingent valuation methods). There are examples of this in the context of aquatic ecosystems in South Africa (Turpie and Joubert, 2001; Turpie *et al.*, 2006). In the absence of empirical research, such relationships will need to be assumed and the assumptions outlined in detail.

Similarly, obtaining baseline recreational values can be done using thorough methods, or could be estimated roughly. The most important information required for estimating recreational value in terms of expenditure is the total amount of use (e.g. users and user days) coupled with estimates of associated expenditure. In many cases recreational value will also be reflected in the investment in property for which a premium is paid for access to (or view of) the resource. The property price premium and associated real estate turnover can be estimated using hedonic pricing methods (data-intensive) or using more short-cut methods involving key informant interviews.

In some cases other novel methods can be used, according to the circumstance or type of recreation, such as river rafting.

12.1.1.5 Refugia/nursery/other outputs (V17)

This is the turnover of user sectors (not necessary aquatic ecosystem users) that utilise organisms elsewhere that depend to some extent on the aquatic ecosystems in the target catchment.

It would be necessary to first establish which activities benefit from the aquatic ecosystems and identify the organisms or populations involved. For example elephants that depend on a wetland system in dry season being hunted in a different area in wet season, or species of fish caught in marine fisheries that depend on an estuary as a nursery area.

The next step would be to establish the proportion of current value of those activities attributable to those populations dependent on the aquatic ecosystems in the target catchment. Change in the value of those activities will be a function of the change in this input (Eq. 6).

Eq. 6 $\text{Turnover in external sector} = \text{f}\left(\text{adundance of export x, external inputs}\right)$

In the examples given earlier, this would generally be assumed to be a simple function of abundance. In other cases (e.g. output of sediments and nutrients to offshore prawn fishery value) the relationship might be more complex.

12.1.1.6 Value of harvested goods (V18)

It will be necessary to establish the degree to which aquatic resources (e.g. fish, plants, sand) are harvested for subsistence or commercial purposes, the degree to which demand is met by supply (i.e. resource scarcity) and the market value of the resources. Existing literature describing this value is scarce and key informant interviews may be a minimum information requirement. The total (commercial + subsistence) value of production should contribute to sectoral output. Any subsistence use influences the natural capital value in the social wellbeing index.

Changes in these values could be estimated on the basis of how the stocks of those resources would be affected by changes in class, in the context of resource scarcity. For example if a community harvests reeds but these are superabundant, then a change in the resource may not impact on use value (Eq. 7).

Eq. 7 $\text{Value of resource use} = \text{f}\left(\text{quantity demanded, quantity supplied}\right)$

Where the quantity supplied is expressed in terms of percentage change in abundance under the different scenarios.

12.1.2 EGSAs that result in costs/avoided/incurred and contribute to economic prosperity

There is no easy way to estimate most of the values in this section. Although it has already been acknowledged that these values could not be estimated for the Olifants/Doring catchment within the limitations of the ‘proof of concept’ exercise, a short discussion on the most likely approach to be used is included for some of the more important values. Ideally, resources should be made available to estimate these values, particularly where they are considered to be significant.

12.1.2.1 Carbon sequestration (V1)

Changes in vegetation biomass due to changes in class are converted to changes in Carbon stock (using ratios in the literature, e.g. Mills, 2003) and converted to an annual change in Carbon. A range of value estimates is available in literature (US$ per tonne), either based on impact on GDP, or based on the market value of Carbon. Although these values are often similar, the latter would only be applicable if a scenario involved the restoration of a natural forest.

12.1.2.2 Flood attenuation (V2)

This would be estimated as damage costs avoided or incurred. An improvement in an ecosystem such that a flood amelioration function is restored would result in a cost savings, and vice versa. Estimation of this value requires an estimate of the change in flood risk to a downstream area, and an estimation of the value of assets (land and capital) in that area expressed as annual ‘insurance’ cost (Eq. 8):

Eq. 8 $\text{Flood attenuation value} = \text{ change in flooding x value of assets}$

This often remains a theoretical value, since it is extremely difficult to estimate and very seldom applied in practice. Nevertheless the effect should be flagged if it is considered to be significant, even if it is not estimated.

12.1.2.3 Erosion control/Sediment trapping (V3)

This value would be estimated in terms of the costs that would be incurred or saved with a change in sediment transport. This would require specialist input from relevant experts. It would first be necessary to identify whether a change in sediment transport would lead to either (a) increased loads that might lead to downstream siltation or (b) decreased loads leading to downstream erosion. In the former case it would require obtaining a professional estimate of an engineering solution. In the latter case it would require an estimate of area of land lost and the value of that land per ha.

12.1.2.4 Waste absorption (V4)

The waste absorption value is the capacity of the system to assimilate a (waste) load with no deterioration of downstream water quality below an acceptable limit. For example, if the load capacity is 3 tonnes, and input is 4 tonnes, then the waste absorption value only pertains to the first 3 tonnes. The remainder creates an externality, which also has to be taken into account in the scenario analysis. The assimilated load is valued using costs of removal of that load in a waste treatment plant.

Current understanding means the ecological component of this project can only consider assimilation of conservative pollutants and will not be able to describe assimilation of organic pollutants. The ecological component of the classification procedure will need to describe load capacity (e.g. tonnes per year) (Eq. 9).

Eq. 9 $$\text{Value of waste absorption} = \begin{pmatrix} \text{load that is released from pollution sources x} \\ \text{treatment cost per unit} \end{pmatrix}$$

12.1.2.5 Pests and pathogens (V5)

This is the cost of prevention or treatment as a result of a change in the occurrence of human or livestock health as a result of change in the abundance undesirable organisms such as invasive plants.

It would be necessary to first identify those pests or pathogens occurring or potentially occurring in the target catchment, and then to estimate the proportional change in incidence of disease or control costs (Eq. 10).

Eq. 10 $$\text{Change in disease and control cost} = f\left(\text{change in abundance of pest or vector}\right)$$

Anticipated inputs from the ecosystem component of the classification procedure are percentage change in abundance of disease vectors, insect pests, and riparian and aquatic invasive plants.

Costs of control will be estimated as a percentage change relative to current costs as the most basic method, but more sophisticated cost measurements could be made if data are available. Cost data should be sourced from the catchment as far as possible, or further afield if necessary.

12.1.3 Intangible use and non-use values (V20 and V21)

These will not be valued in monetary terms, but will be considered in the social wellbeing index (see Joubert *et al.*, 2007). Intangible use and non-use values are expected to be positively related to ecosystem health. A relationship between ecosystem condition and intangible use and non-use values needs to be defined, along the lines of that shown in Figure 12.3.

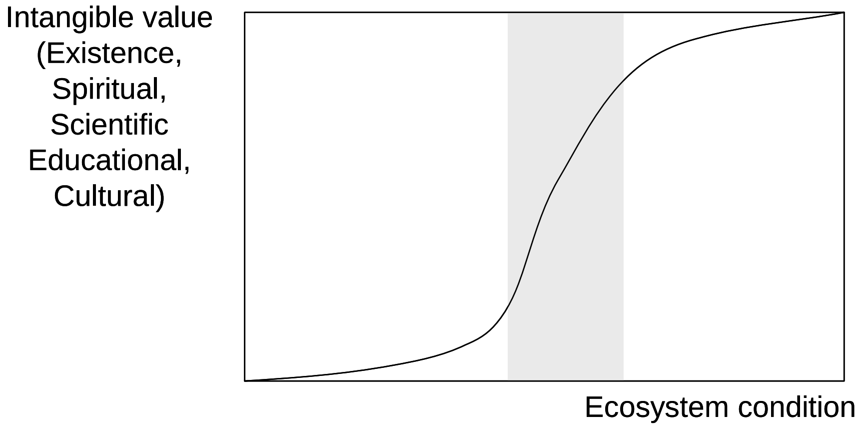

Figure 12.3 Expected shape of the relationship between intangible values and ecosystem condition, with value falling off sharply below some threshold level of ecosystem condition

12.1.3.1 Valuing sectoral turnover that contributes to economic prosperity and social wellbeing (V6 to V13)

Estimating the economic value of sectoral use of water requires (as one input) a description of the annual yield and assurance of supply requirements for each sector. This is generally supplied from a water resource yield model. The present-day output for each affected water sector can then be determined in terms of turnover and/or economic outputs (Gross Geographic Product (GGP), employment, income distribution etc.) using a macro-economic model such as a SAM. These two broad information requirements require specialist input from a yield modeler and a macro-economist. For each sector the following general relationship should be described (Eq. 11):

Eq. 11 $$\text{Turnover for sector}_{\text{i}} = f\left(change\ in\ allocated\ yield_{\text{sec}tor_i}, x, y, z\right)$$

In each case, the relationship will depend on limiting factors (e.g. water, land, other inputs) and demand, and in some cases, simple assumptions will need to be made. It is likely that streamflow reducing activities will be assumed constant and domestic needs are assumed to be met. In this case, these need not be valued or varied in the scenarios.

12.1.3.2 Relationships between water supply and output

Each water user sector has its own particular pattern of production output relative to the volume of water it uses, and the level of water provision assurance it has. For most users, a specific change in the volume of water available for productive usage or the level of water provision assurance does not have a directly proportional affect on the volume of output produced. For instance, a 5% increase in water availability may only have a 3.5% increase in the output of citrus fruit per hectare over the long-term. For this reason, two demand schedules (so-called elasticity curves) should be used for each individual water user, one that accommodates changes in the volume of water available, and another that accommodates changes in water provision assurances, i.e.

- volume of water elasticity's that reflect the productivity of water usage; and
- water provision assurance elasticity's that reflect the effective utilisation of water

In the discussion of these two curves, the emphasis will be on water used for agricultural activities since these are the activities that are most affected by changes in the volume of water available and variances in water provision assurances.

When the volume of water available to a farmer is changed, it has a definite impact on the quantity of hectares that can be maintained, i.e. once water is in short supply, the area that can be cultivated is jeopardized. However, the farmer will strive to sustain as many as possible of the existing hectares currently under production.

In order to do so, the farmer can invest in new, technologically-advanced irrigation equipment that will apply the water at his/her disposal more effectively. This implies that the number of hectares under irrigation will not be as badly affected as they may have been had technological changes not been allowed for. For this particular exercise, four alternative irrigation technologies have been identified, namely:

- flood irrigation;
- non-mechanized sprinklers (i.e. drag lines);
- mechanized sprinklers (i.e. centre pivots); and
- micro-irrigation (i.e. drip systems).

Starting with flood irrigation, each system becomes technologically more advanced. This implies that micro-irrigation distributes water more efficiently than, for instance, the flood irrigation system, making it possible to use the same amount of water for a larger number of hectares under irrigation.

In developing water provision assurance demand schedules, the following aspects of each of these irrigation systems could be included in the calculation process:

- the efficiency of each system (as a percentage);
- the average hectares per labourer;
- the life expectancy of the irrigation system; and
- the capital cost of the system.

Further, it is necessary to take into account whether the composition of irrigation systems would change in the case of volume changes.

In terms of water assurance, the assumption is made that farmers will protect their crops over the long-term. They will rather suffer losses in production per hectare (yield) than losses in terms of the number of hectares under irrigation. In the case of tree crops such as citrus, younger trees that are less sturdy than older, more rooted trees will enjoy preference when water is allocated. This will lead to a drop in the yield per hectare since younger trees are less productive than older ones. This illustrates the non-linear relationship between changes in water provision assurances and subsequent changes in the yield per hectare.

The annual yield per crop as well as the annual water usage is an important aspect when considering changes in the yield per hectare per type of crop.

12.2 Guidelines for estimating change in social wellbeing

This component of sub-step 2b involves describing predictive relationships between numbers of jobs, proportion of non-poor households, health and happiness, and social wellbeing for different catchment configuration scenarios (see Brown *et al.*, 2007). There is very little precedent for doing this in a quantitative fashion, and thus it is expected that these guidelines will improve with testing in future applications.

12.2.1 Change in number of jobs

From a local (IUA-level) perspective, change in the number of jobs could be estimated using multipliers associated with turnover or a related measure that changes under the different scenarios. The local employment multipliers need to be estimated based on available information for the relevant sectors. From a regional perspective, the output of the macro-economic analysis can be used.

12.2.2 Change in proportion of non-poor households

Changes in aggregate income to local households need to be estimated on the basis of the estimated change in turnover in the different sectors. The ratios used to do this can be based on existing information or professional opinion. The change in the proportion of non-poor households can then be predicted on the basis of the relationship between overall average income per household and this proportion.

12.2.3 Change in health

Although the health component of the social wellbeing index considers general health, only those aspects associated with aquatic ecosystems and water quality should be changed under the different catchment configuration scenarios.

Change in the prevalence of water related diseases such as malaria and bilharzia should be estimated on the basis of change in abundance of these pathogens estimated by the ecological component of the classification procedure.

Change in the occurrence of complaints that are related to water quality, such as diarrhoea and skin irritations, will be estimated on the basis of estimated changes in coliform bacteria, and professional opinion.

12.2.4 Change in utility

Since it is impossible to consider other sources of happiness in the scope of a classification procedure, it will only be considered in terms of happiness derived from aquatic ecosystems. It is assumed that this is directly proportional to the state of the ecosystems (see Volume 4 for a description of scoring methods).

12.3 Example: Olifants/Doring catchment

Based on the outcomes of Step 2a (see Table 11-2), Table 12-1 presents the EGSAs and sector to be taken forward into Steps 3, 4 and 5 for the 'proof of concept' catchment. While this is presented as an example, it demonstrates that there is often limited information available[11] to value EGSAs, and that for a more comprehensive assessment, a full field survey would be required. Similarly, to value turnover for different water user sectors, a significant investment would be required in the Classification Process.

For the purpose of this section, the examples of the values that describe the relationships that determine how economic value is influenced by ecosystem characteristics and sectoral use of water are presented for a) EGSA values (see Section 12.3.1), and b) water sector values (see Section 12.3.2). Section 12.3.3 presents an example of how this can be converted into a description of social wellbeing.

[11] In a catchment where the local communities make extensive use of aquatic EGSAs, this step would require considerable resources.

Table 12-1 EGSA and sectoral values considered for the 'proof of concept' catchment, the Olifants/Doring

Category of EGSA	EGSA/Sector	Specific component	Section
Good	Food, medicines and grazing	Small-scale commercial fishing	12.3.1.1
Service	Ecological regulation	Pests and pathogens (specifically alien invasive plants)	12.3.1.2
Attributes	Structure and composition of biological communities	Recreational fishing	12.3.1.3
		Non-consumptive recreation (specifically river-rafting)	12.3.1.4
		Non-use value (option and existence value)	12.3.1.6
	Refugia, nursery value and export of materials and nutrients	Nursery areas (involving recreational and commercial fishing)	12.3.1.5
Agriculture		Irrigation agriculture	12.3.2

12.3.1 EGSA values

12.3.1.1 Small-scale commercial fishing (good)

The value of commercial fisheries depends on stock levels in relation to carrying capacity (K) of the stock, the effort levels and their costs, and the catches generated for that particular stock size and effort level combination (Figure 12.4). The sustainable yield increases from zero at zero stock to a maximum level at around half of carrying capacity, and decreases as stock size approaches carrying capacity and growth is limited by density-dependent factors. Catch per unit effort increases with stock size. In a privately-owned fishery in which growth rates exceed interest rates in alternative investments, the owner would maintain the fishery at just above 0.5K in order to maximise its value. However slower growth rates will tend to drive the fishery to be managed at a lower stock rate. In an open access situation, more fishers will enter the fishery as long as excess profits are being made, until the open access equilibrium is reached, shown as economic extinction in Figure 12.4. The fishery will be mined to a lower stock level when costs of fishing are lower.

Lower costs per unit of effort, as might be expected in small-scale fisheries, would be expected to be associated with the fishing of stocks to lower levels, particularly where property rights are not well defined, or where there is open access. In the latter case, it might be expected that a fishery is maintained at a level that is close to economic extinction. In other words, a reduction in stock could render the fishery unviable. Thus small-scale, relatively un-monitored fisheries are likely to be fairly vulnerable to changes in stock due to environmental factors. For the purposes of this study, it is assumed that the Olifants/Doring catchment is such a fishery (Lamberth, 2005).

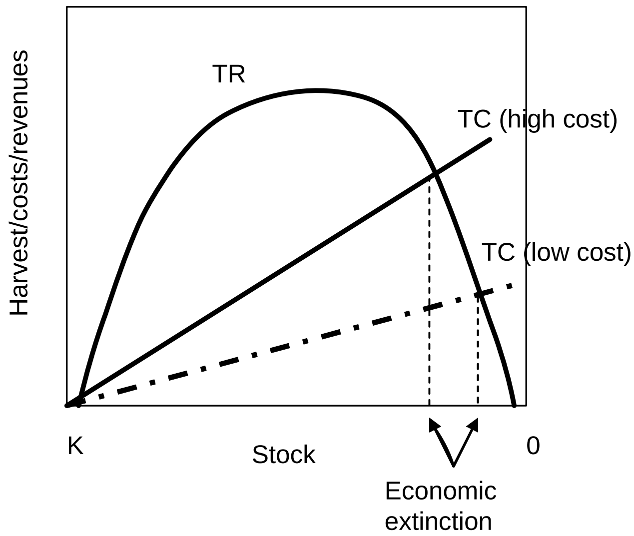

Figure 12.4 Theoretical relationship between Total Revenues (TR) and Total Costs (TC) in relation to stock size of a fishery. Effort levels increase on the x-axis from left to right. Total cost curves are shown for fisheries with high and low marginal costs (costs per unit effort).

Changes in the abundance of fish stocks might be expected to have a proportional effect on the turnover generated by the fishery as long as stocks are above the economic extinction threshold. If outputs are increased, it is assumed there would be no saturation of the market. If stocks fall below the extinction threshold, then it would be expected that the value of the fishery would drop of very steeply (Figure 12.5). However, because fishers tend to be risk takers, the value would be unlikely to fall to zero immediately. It is assumed that changes in catches will have no impact on fish prices, as these are determined on a much broader scale.

Thus it is important to have an estimate of the status of the fish stocks (current stock levels as a percentage of pristine stock levels), and to have an idea of the status of the fishery in relation to the point of economic extinction.

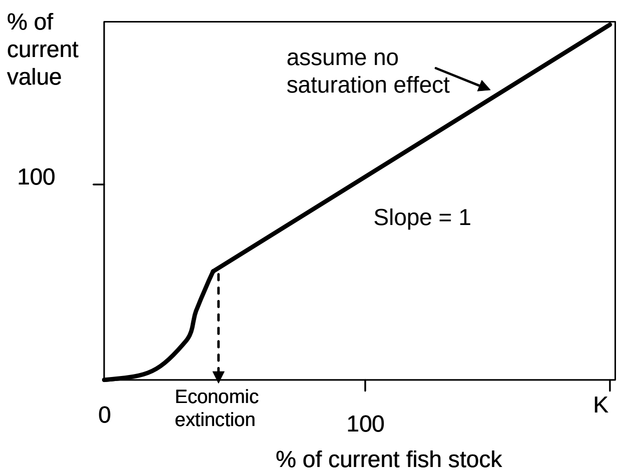

Figure 12.5 Assumed relationship between small-scale commercial fishery turnover value and status of the fish stocks relative to present-day stocks, used for estimating impacts of different catchment configuration scenarios

12.3.1.2 Pests and pathogens: alien invasive plants (service)

In the case of the Olifants/Doring catchment, one measure that is supplied by the ecological component of the classification procedure (Brown *et al.*, 2007) is the percentage change in abundance of alien trees in the riparian zone.[12] The catchment configuration scenarios could be evaluated in terms of the additional cost incurred due to a change in ecosystem condition leading to the spread of aliens, or the costs saved due to a change in ecosystem condition leading to the reduction in alien cover. Costs could be incurred or saved due to either a change in the area invaded by aliens or the change in density of aliens in an area that is already invaded. Costs are directly proportional to density (Figure 12.6).

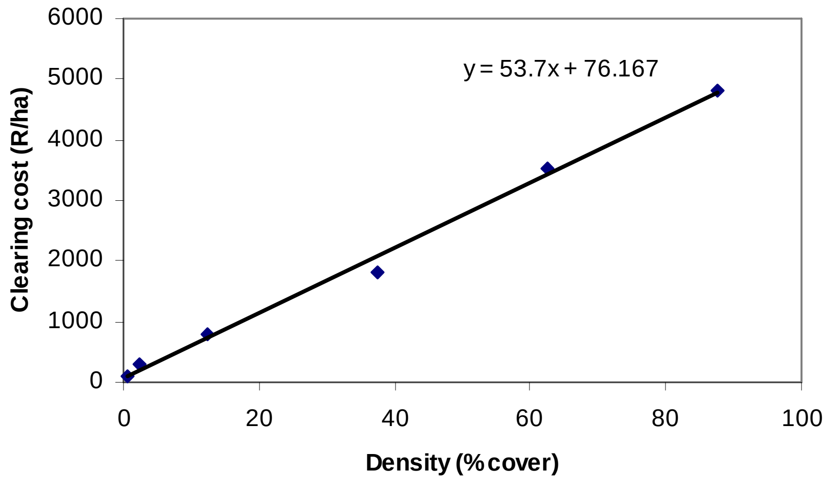

Figure 12.6 Estimated total costs of clearing riparian alien vegetation in relation to density, based on data in Marais *et al.* (2001)

The change can therefore be estimated by estimating the current cost required to clear existing aliens from the catchment, and multiplying this cost by the percentage change in abundance of aliens as supplied from the ecological component of the classification procedure (see Brown *et al.*, 2007). Estimation of current cost requirement ideally involves estimating the area of aliens under each density category (using GIS data), multiplied by the cost of clearing in this category. A simpler way to do this is to estimate the total area under aliens and multiply this by the average cost of clearing for the catchment. In the absence of average cost data, the midpoint can be used. In the case of the ‘proof of concept’ catchment the midpoint value was R2 760 per ha.

12.3.1.3 Recreational fishing (attribute)

In the case of recreational fisheries, the value is considered in terms of turnover generated by angler spending on their activities. Anglers are generally considered to be fairly unresponsive to small changes in catch (McGrath *et al.*, 1997), but would nevertheless gravitate more to areas where catches are likely to be higher than to areas where fishing is highly unproductive. Thus it is assumed that demand for fishing is relatively inelastic (small change in activities levels relative to changes in catch rates) above a threshold level which is analogous to the economic extinction point described earlier (Figure 12.7). This is a purely hypothetical relationship which needs further research.

[12] Anywhere along or in the river and its channel or floodplain.

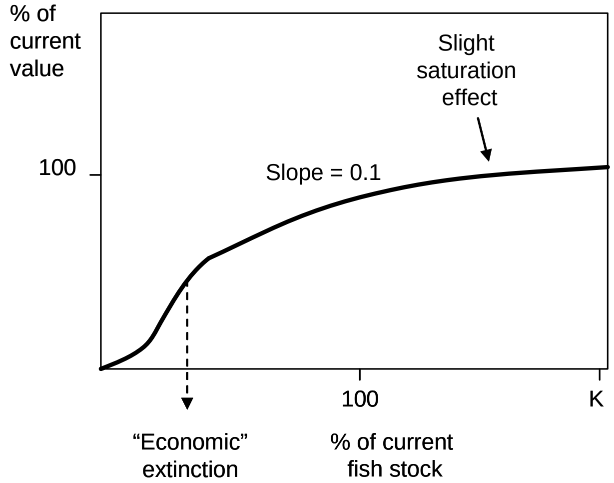

Figure 12.7 Assumed relationship between recreational fishery turnover value and status of the fish stocks relative to present-day stocks, used for estimating impacts of different catchment configuration scenarios

12.3.1.4 Non-consumptive recreation: river rafting (attribute)

The main aquatic recreational activity considered in the Olifants/Doring catchment was the river-rafting activities that take place on the Doring River. River rafting activities are determined primarily by the flow, which in turn determines whether the conditions are favourable for rafting. Since the current season length is known, it should be relatively straightforward to estimate the flow conditions at the start and end of the season, which are effectively the threshold conditions for rafting. The timing of these thresholds will change for different catchment configuration scenarios, and need to be recorded. The change in turnover of this activity can be changed proportionately, but bearing in mind that below some threshold season length, the business would not be viable. Ideally this would be determined using an enterprise model, but in the absence of collecting new data, the breakeven point can be estimated using professional opinion.

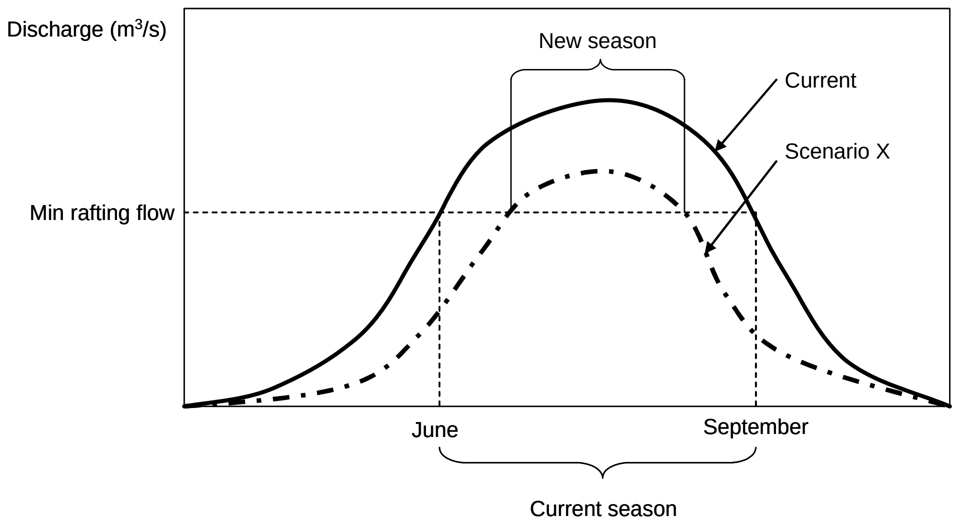

Figure 12.8 Conceptual model of the change in season length for a river-rafting enterprise due to a change in flow conditions

12.3.1.5 Nursery value: involving recreational and commercial fishing (attribute)

It is assumed that the value of West Coast fish catches attributed to the Olifants estuary changes in the same proportion to the change in the stocks of those groups of species that contribute to this value. This is a simple assumption which does not take ecosystem impacts of a change in the abundance of one or more species into account. Nevertheless it is probably a reasonable assumption where the predicted changes are relatively small or where the affected species only make up a small proportion of marine catches, as is the case here.

12.3.1.6 Non-use value (cultural, spiritual, educational, scientific, option and existence) (attribute)

Intangible values associated with aquatic ecosystems have not been quantified in the Olifants/Doring catchment. However, a score is incorporated in the measure of wellbeing (Eq. 12).

A hypothetical relationship between ecosystem health and intangible use and non-use value was derived in order to convert health scores to an intangible value score, as follows (Figure 12.9):

Eq. 12 $$IV = \frac{\mathrm{IV}_{\max} x EI^{Q}}{\left(k^{Q} + EI^{Q}\right)}$$

Where:

IV= intangible value

IV_{max} = maximum intangible value (105.033 was used in order to ensure that the resulting max was 100)

K = the value at which IV is half IV_{max}

Q = is a parameter which controls the slope near K

EI = Ecosystem Index value.

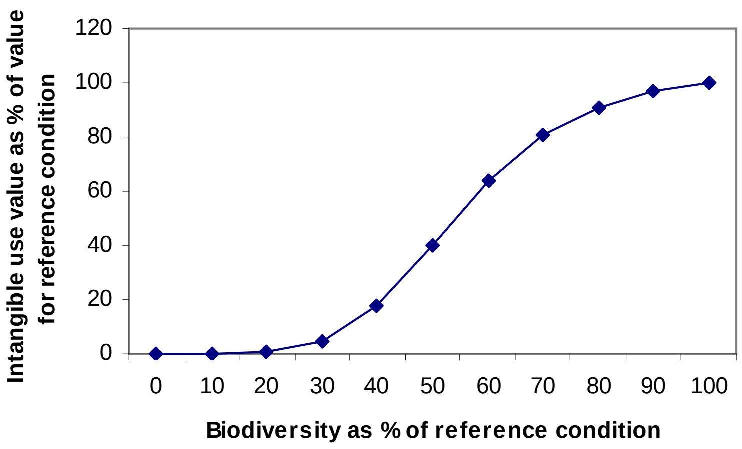

Figure 12.9 Utility as a function of ecosystem health, in terms of percentage resemblance to the pre-development condition

The shape of the relationship described above ideally needs to be tested in order to provide a better empirical basis for assumptions of this nature.

12.3.2 Sectoral values (Irrigation agriculture)

Each catchment configuration scenario has implications in terms of water quality in each IUA. For this study, water quality was measured in terms of Total Dissolved Salts (TDS). No measures of coliforms were obtained, and thus health implications could not be assessed. Nevertheless, these implications are unlikely to be significant in this catchment. Changes in TDS are likely to impact on irrigation agriculture, but are not likely to have any measurable impact on domestic users. Thus the estimated changes in TDS were evaluated in terms of their potential impacts on the irrigation sector.

Changes in TDS were valued in terms of impacts on downstream water users, by estimating the changes in the 'leaching requirement' for irrigation farmers. The leaching requirement is the additional water required over and above the amount needed by the crops to flush salts out of the soils and prevent salinisation (Lambrechts, 2006). The leaching requirement thus depends on the irrigation water quality as well as plant tolerance and the soil type. It also depends on the accepted rate of salinisation, in other words, the degree of sustainability required. If water quality deteriorates, then the leaching requirement increases. This requires either that the amount of water use per ha has to increase, or the water quantity is fixed, in which case, the area irrigated has to be reduced in order to meet the adjusted crop water requirements. The approach taken here was therefore to estimate the percentage change in area planted as a result of a change in water quality, and to adjust the irrigation area estimates made on the basis of water quantity accordingly.

The leaching requirement (LR) is expressed as a percentage of crop water requirement, and is calculated as follows (Eq. 13):

Eq. 13 $$LR = \frac{\text{EC of irrigation water}}{\text{EC of drainage water}}$$

Where:

EC = electrical conductivity.

The EC of drainage water in the Olifants/Doring catchment is taken to be 800 S m^{-1} (siemens per metre), equivalent to the upper limit of salt tolerance, but 400 S m^{-1} is a more sustainable measure to use (Lambrechts, 2006). EC can be converted to TDS as follows (Eq. 14):

Eq. 14 $$TDS = EC \times 6.5$$

Thus the leaching requirement can be related to TDS as in Figure 12.10.

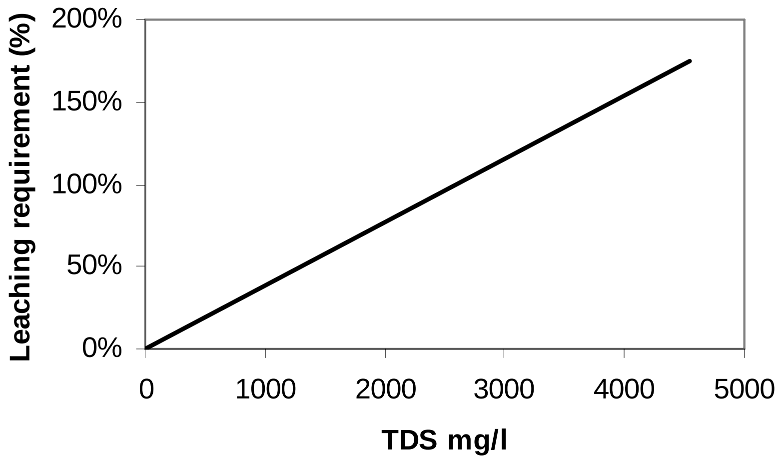

Figure 12.10 Relationship between the quality of irrigation water and the additional leaching requirement as a percentage of crop water requirement

The equivalent reduction in area for a given water volume is calculated as (Eq. 15):

Eq. 15 $$\%\ \text{area} = \frac{\text{Initial requirement} + \text{LR}}{\text{Initial requirement}}$$

The relationship between LR and percentage area is shown in **Figure 12.11**. The water quality in the Olifants/Doring catchment is generally high and the current leaching requirement is less than 3% (Lambrechts, 2006).

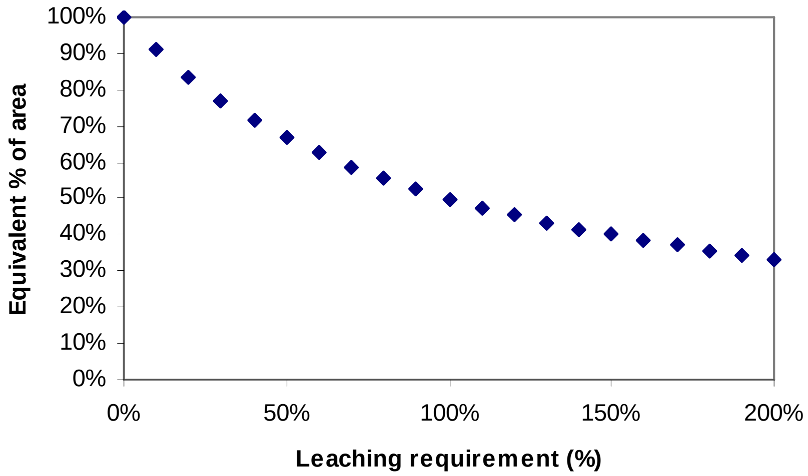

Figure 12.11 Relationship between leaching requirement (LR) and equivalent reduction in area (percentage of original area) for a given water volume

12.3.3 Changes in social wellbeing

12.3.3.1 Change in number of jobs

The following ratios were derived from existing information and used to estimate changes in numbers of jobs generated locally (Table 12-2).

Table 12-2 Local employment multipliers used for estimating changes in wellbeing

Sector	Low income jobs	High income jobs	Source
Small-scale fisheries	1 per R5 065 turnover	None	Good estimate of number of jobs at present
Recreational activities	0.2 per R55 000 turnover	0.8 per R55 000 turnover	Based on 10% of total average cost of job creation in tourism sector (Naude and Harmse, 2001) and estimated ratio of low to high income jobs
Irrigation agriculture	0.045 per ha	0.319 per ha	Based on farm enterprise data Prof. A. Laubsher, Stellenbosch University, *in litt*.

12.3.3.2 Change in proportion of non-poor households

The relationship between average income and the percentage of households falling into the non-poor category in the IUAs of the Olifants/Doring (Figure 12.12) was used to estimate changes in percentage of households in this category under different catchment configuration scenarios.

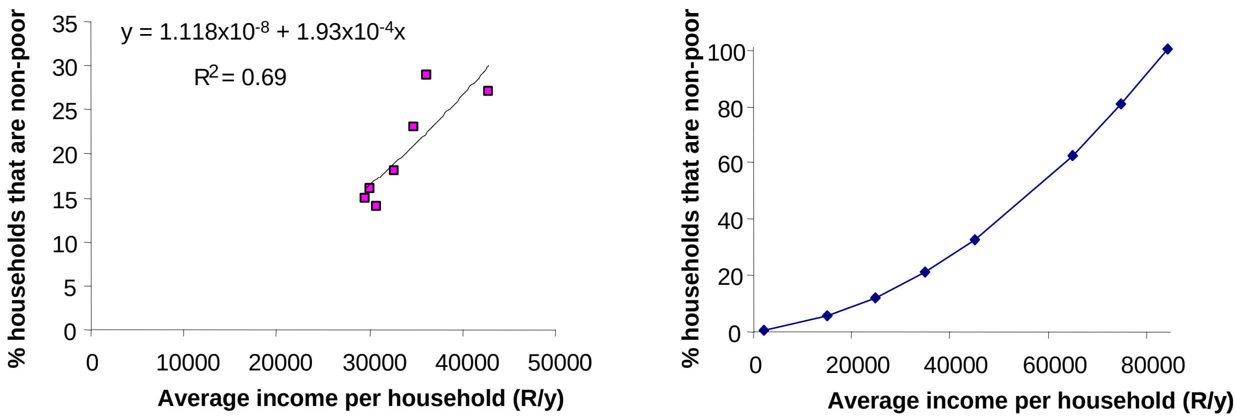

Figure 12.12 Relationship between average income and percentage of households falling into the non-poor category for the different IUAs in the Olifants/Doring catchment, and the extrapolated relationship used to predict impacts of catchment configuration scenarios

12.3.3.3 Change in health

Water related diseases such as malaria and bilharzia do not occur in the Olifants/Doring catchment. Lack of data or predictions of coliform bacteria meant that these potential health impacts could not be assessed. Nevertheless, it is considered unlikely that their impact would be significant.

12.3.3.4 Change in utility

Change in happiness or utility derived from aquatic ecosystems was quantified using the intangible value score (Section 12.3.1).

13 VALUE THE CHANGES IN AQUATIC ECOSYSTEMS AND YIELD (STEP 5D)

13.1 Introduction

The objective of this sub-step is to value the changes in aquatic ecosystems and water yield for each of the catchment configuration scenarios that have been refined and adjusted through use of a water resources yield model (Step 5a – see Volume 2, Brown *et al.*, 2007) and the water quality model (Step 5b – see Volume 2, Brown *et al.*, 2007). This requires applying the relationships that link value and condition defined in Step 2b (see Section 12) to the socio-economic framework refined in Step 1i (see Section 9) to value the changes in aquatic ecosystems and yield. The socio-economic framework (see Figure 9.1 for the example set up for the Olifants/Doring catchment) should be set up either in the form of a spreadsheet model (as was done for the 'proof of concept' catchment) or utilising a programme such as Delphi. The spreadsheet or model should be set up to receive relevant ecological and hydrological data for the different catchment configuration scenarios.

The valuation process should provide the changes in value for each of the scenarios emerging from Steps 5a and 5b for each IUA in terms of:

1. Values of EGSAs that contribute to social wellbeing and economic prosperity that may include:

    - flow contribution to floodplain agriculture;
    - livestock production;
    - tourism and recreation;
    - refugia, nursery areas and export of sediment and nutrients;
    - value of harvested goods; and
    - domestic use of instream water.

2. Values of EGSAs that result in costs avoided/incurred and contribute to social wellbeing and economic prosperity that may include:

    - carbon sequestration;
    - flood attenuation;
    - erosion control and sediment trapping;
    - waste absorption;
    - pests and pathogens; and
    - domestic use of instream water.

3. Values of intangible use and non-use values that contribute to social wellbeing that may include:

- cultural and spiritual value;
- educational and scientific value; and
- option and existence value.

4. Values of sectoral use of water that contribute to social wellbeing and economic prosperity that may include:

- coal power;
- urban industry;
- non-urban industry;
- domestic use;
- mining;
- streamflow reducing activities;
- hydroelectric power; and
- irrigated agriculture.

13.2 Curtailment and assurance rules for assessing changes in sectoral output

In order to assess the implications of the potential changes in output for different sectoral uses of water for different catchment configuration scenarios, it will be necessary to apply assurance and curtailment rules in a water resource yield model. While this process will be performed as part of the classification procedure, and will be applied on a case by case basis, for the 'proof of concept' catchment, 'dummy' curtailment and assurance rules needed to be applied to assess the turnover implications for the sector under consideration, the irrigation agriculture sector. These 'dummy rules' are presented in Table 13-1.

Table 13-1 'Dummy' target assurance of supplies

User sub-sector	Sectoral rule	
	Assurance level	Maximum curtailment level
High value irrigation	95%	30%
Medium value irrigation	90%	50%
Low value irrigation	80%	70%
Urban	95%	30%
Rural	100%	0%
Mining	98%	20%

13.3 Estimating changes in irrigation area

In assessing the changes in value of the sectoral use of water for different catchment configuration scenarios, it is necessary to derive a procedure for estimating the change in irrigation area. For the Classification Process, this will need to be developed on a case by case basis. However, for the 'proof of concept' catchment, a procedure was developed using the Lower Olifants Irrigation IUA as an example. This is presented below.

In the Lower Olifants Irrigation IUA, irrigators are supplied from the Clanwilliam Dam via the Bulshoek Barrage. The crops irrigated are table and wine grapes and irrigators required a high level of assurance. The Ecologically Sustainable Base Configuration (ESBC) scenario (see Brown *et al.*, 2007) indicates that the level of assurance for high value crops is met at the required high level of assurance.

In the first scenario, Reserves for the Present Ecological State (PES) are included in the model and supplied by means of releases from Clanwilliam Dam as a priority over the irrigation supply. The red line in Figure 13.1 represents the supply duration curve to irrigators, while the blue line is the target rule curve. In the case of the blue line, the water requirement is met for 95% of the time. In the case of the red line, water requirements are fully met only about 60% of the time, and for most of the remaining time, the farmer only gets about 70% of his water requirement.

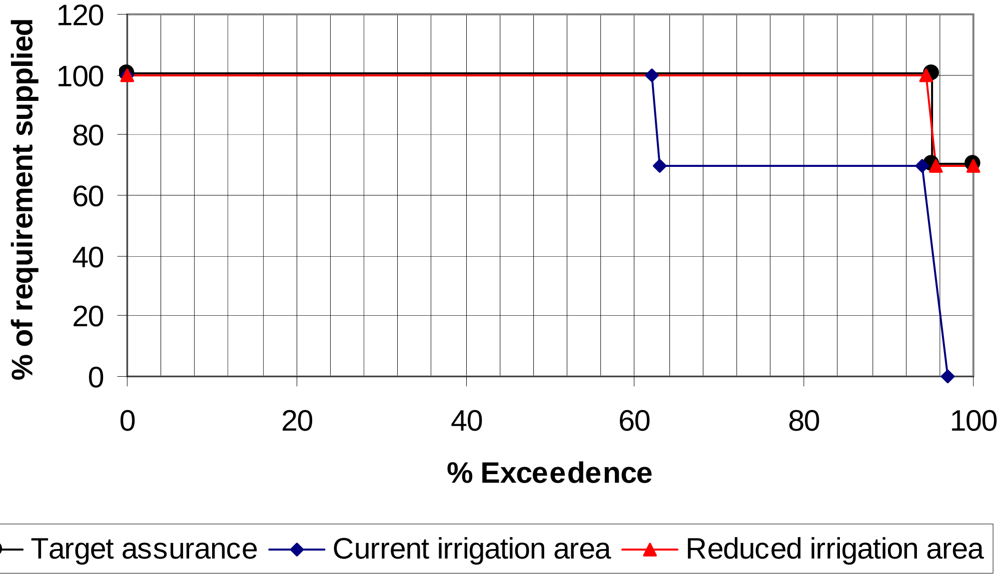

Figure 13.1 Duration curve of target supply assurance and curtailment levels and actual supply from the Clanwilliam Dam (via the Bulshoek Barrage) to the Lower Olifants Irrigation IUA under the PES scenario. Blue line: full demand of 130 million m^3/a; red line: demand reduced to 65 million m^3/a to meet the required level of assurance

Clearly the irrigation water cannot be supplied at the current required level of assurance. The irrigated area is then reduced until the required level of assurance is met, as indicated by the blue line.

Figure 13.2 shows the same process applied to a second scenario (Recommended Ecological Category plus Freshwater Conservation targets (REC + Cons.))

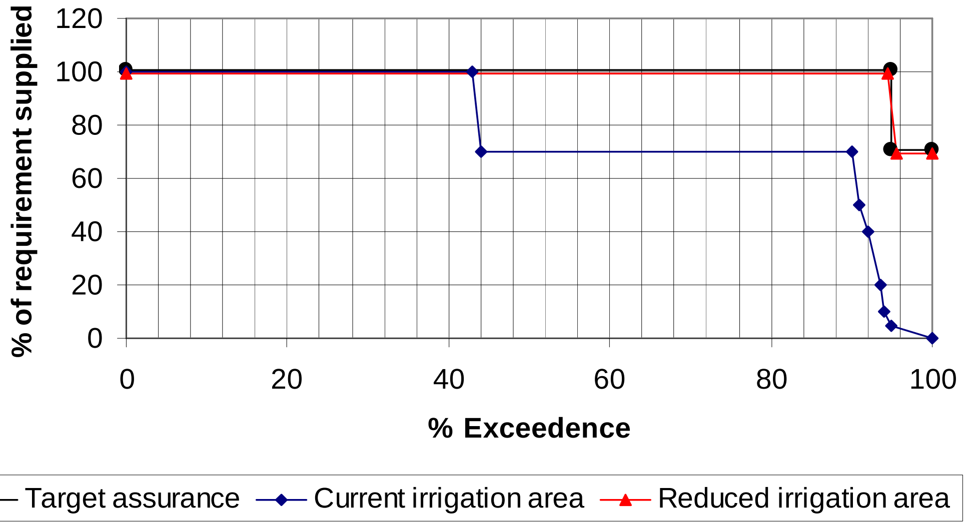

Figure 13.2 Duration curve of target supply assurance and curtailment levels and actual supply from the Clanwilliam Dam (via the Bulshoek Barrage) to the Lower Olifants Irrigation IUA under the REC+CONS. scenario. Blue line: Full demand of 130 million m^3/a; Red line: Demand reduced to 5 million m^3/a to meet the required level of assurance

The curtailment of the demand (or crop area) required in the above two scenarios is shown in Table 13-2. This suggests that scenario 2 cannot be achieved without an almost total loss of irrigation farming in the Lower Olifants Irrigation area.

Table 13-2 Reduction in crop area required for different catchment configuration scenarios

Scenario	**Curtailment of crop area**
PES	50%
REC + Cons.	100%

To go through the above curtailment procedure for all users and for all possible catchment configuration scenarios would be very time consuming but will be required to finalise the class determination. For the pre-screening exercise in the Olifants/Doring catchment (i.e. Step 4 – Brown *et al.*, 2007), a simplified procedure was followed in which rules were put in place to ensure that water gets supplied to the ecological Reserve without necessarily meeting the assurance of supply requirement of irrigators. The supply mechanisms applied were as follows:

- where irrigators are supplied from farm dams, releases were made from these dams to meet the ecological Reserve of the quaternary catchment downstream of the dam. This often resulted in very low levels of assurance of supply to existing irrigators sourcing water from farm dams; and
- where irrigators are supplied from run-of-river, the crop area was scaled down until the ecological Reserve could be met.

13.4 Procedure for determining the impact of catchment configuration scenarios on yield

Ideally, given sufficient time and budget, the method to be applied to determine the impact of various ecological scenarios on the availability of water is as follows:

1. Carry out a base scenario analysis to ascertain the assurance of supply to all users. This would typically be without any provision of the ecological Reserve.
2. Assign target assurance of supplies to all users.
3. Run the model with the ecological Reserve in place, and curtail users as follows in order to meet the Reserve:
   - Establish a curtailment rule based on the natural flow in the case of run-of-river users or the water level in the dam in the case of users supplied from dams. Typically these rules can be established by analysing the duration curves of Reserve requirements and actual river flow in order to establish in which months curtailments are required and at which points on the duration users should be curtailed.
   - Having established these curtailments rules for all users, if the assurance of supply/curtailment rule cannot be met, then the total requirements will have to be reduced. This essentially entails cutting back on the total area irrigated or implementing water conservation and demand measures. In many cases compulsory licensing will be required to implement this step.

13.5 Example: Olifants/Doring catchment

For the ‘proof of concept’ catchment, the results of the valuation process are presented with reference to the values considered in Step 2b (see Section 7). The examples presented below represent the valuation of three ‘dummy’ scenarios generated in Step 4 which included:

1. Scenario 1: Present Ecological Status (PES).
2. Scenario 2: Recommended Ecological Category (REC) plus Freshwater Conservation Targets (Cons.)
3. Scenario 3: Ecologically Sustainable Base Configuration (ESBC) scenario.

For a further description the scenario generation process, see Brown *et al.* (2007).

13.5.1 EGSA values

13.5.1.1 Small-scale fishery

The only significant small-scale fishery was in the Estuary IUA, associated with the Ebenhaesar community. Changes in value were estimated on the basis of percentage changes in fish stocks provided by the ecological component (see Brown *et al.*, 2007), and the relationship described in Step 2b (see Section 12). The results are summarised in Figure 13.3.

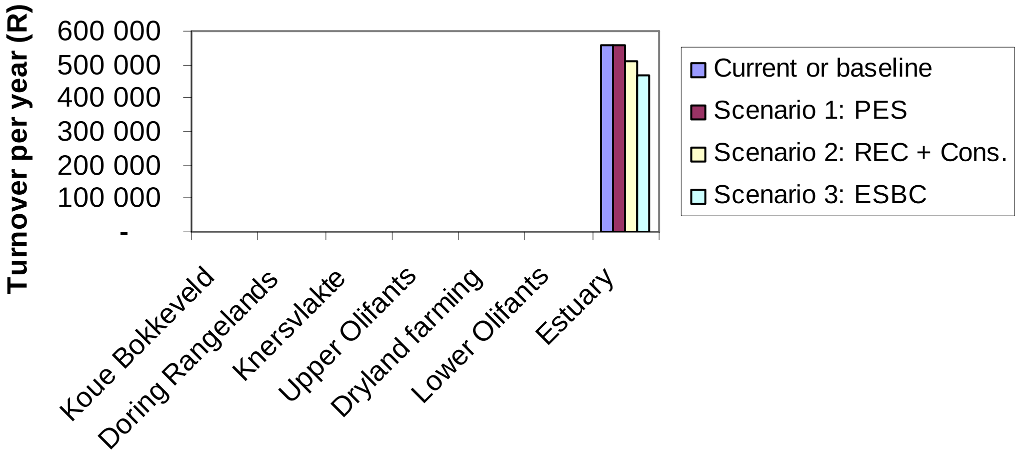

Figure 13.3 Estimated impact of different catchment configuration scenarios on the value of the small-scale fisheries

13.5.1.2 Pests and pathogens: alien invasive plants

An example of the results obtained in scenario analysis for pests and pathogens: alien invasive plants are provided in Table 13-3.

Table 13-3 Estimation of the change in costs associated with change in abundance of alien invasive plants

	Koue Bokke-veld	**Doring Range-lands**	**Kners-vlakte**	**Upper Olifants**	**Dryland farming**	**Lower Olifants**	**Estuary**
Baseline							
Current level of infestation (ha)*	150	200	80	150	100	100	20
Current cost implication (R/year)	41 400	55 200	22 080	41 400	27 600	27 600	5 520
% change in alien abundance under different scenarios							
PES	0	0		0	0	0	0
REC+Cons.	0	0		-24	-33		0
ESBC	102	396		78	58		0
Estimated costs incurred (+) or saved (-)							
PES	-	-	-	-	-	-	-
REC+Cons.	-	-	-	- 9 936	- 9 108	-	-
ESBC	42 228	218 592	-	32 292	16 008	-	-

*Note that the area is unknown, areas are thus dummy numbers for the sake of the method testing.

13.5.1.3 Recreational fishing

Recreational fishing includes angling for indigenous fishes in the rivers and estuary. Angling for exotic species, which takes place mostly in dams and is unlikely to be affected, was not included. Changes in value were estimated on the basis of percentage changes in freshwater and estuary fish stocks provided by the ecological component (Brown *et al.*, 2007), and the relationship described in Step 2b (see Section 12). The results are summarised in Figure 13.4.

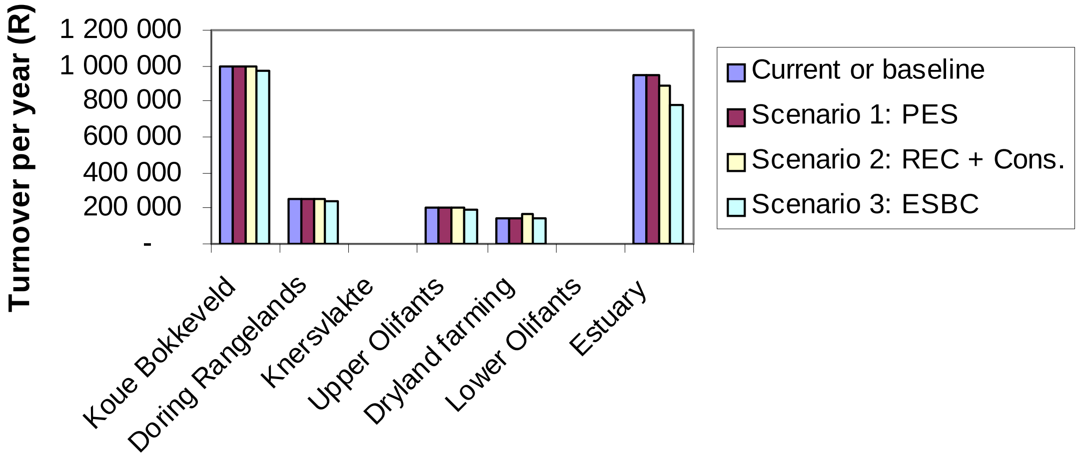

Figure 13.4 Estimated impact of different catchment configuration scenarios on the value of the recreational fishing

13.5.1.4 Non-consumptive recreation (river rafting)

River rafting only takes place in one of the IUAs, the Olifants/Doring Dryland Farming IUA. Changes in season length could not computed by the ecological component as anticipated in the development of the predictive relationships in Step 2b, and thus change in % MAR was used as a surrogate for the proportional change in season length. The results are summarised in Figure 13.5.

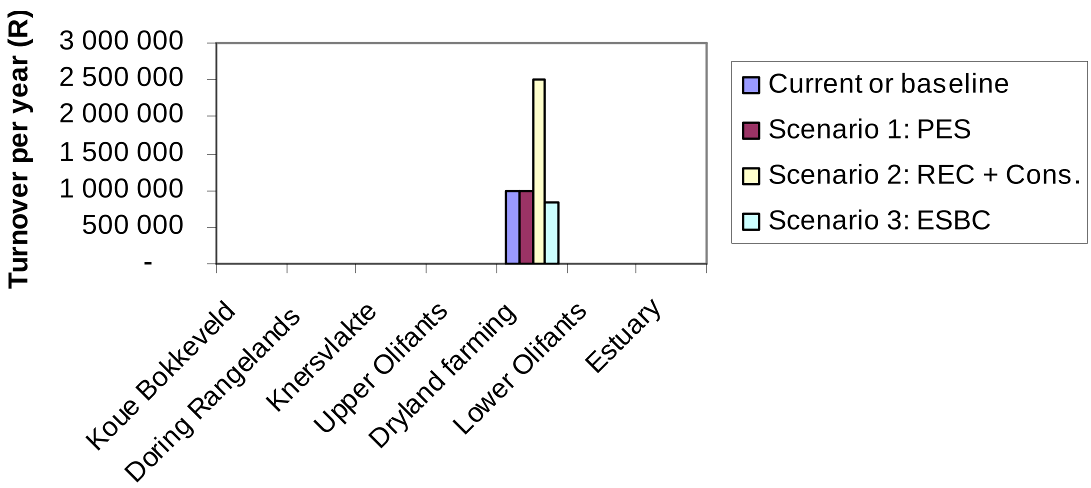

Figure 13.5 Estimated impact of different catchment configuration scenarios on the value of the river rafting

13.5.1.5 Nursery value (involving recreational and commercial fishing)

Change in the nursery value of the estuary was estimated on the basis of predicted percentage change in estuary fish stocks provided by the ecological component (Brown *et al.*, 2007). The results are summarised in Figure 13.6.

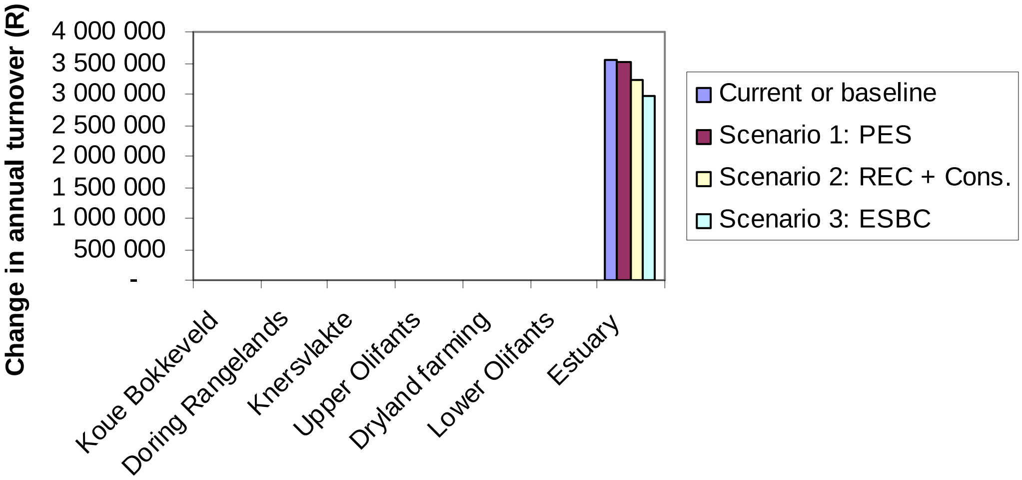

Figure 13.6 Estimated impact of different catchment configuration scenarios on the nursery value of the estuary

13.5.2 Sectoral values

13.5.2.1 Impacts of changes in water quality

As discussed in Section 12, in order to determine the impacts of different catchment configuration scenarios on turnover in the irrigation sector, it is first necessary to determine the Leaching Requirements (LR) under the different scenarios. These are summarised in Table 13-4.

The LR for the water quality at the 95th percentile was taken as the LR for that IUA. Where there was a range of estimates for a single IUA, the midpoint of the range was used. The percentage increase allowed or percentage decrease required due to changes in water requirements per ha are summarised in Table 13-5.

Table 13-4 Estimated percentage Leaching Requirement (LR) for each IUA based on changes in TDS under different scenarios. TDS values in mS/m based on water quality estimates at the outflow point of each IUA.

	Current		PES		REC+Cons.		ESBC	
	Median	95%tile	Median	95%tile	Median	95%tile	Median	95%tile
Doring Rangeland (1)[1]	5.6	10.2	5.6	10.2	5.6	10.2	5.6	10.2
Doring Rangeland (2) [21]	5.6	10.2	5.6	10.2	5.6	10.2	5.6	10.2
Knersvlakte[3]	21.7	28.4	21.7	28.4	21.7	28.4	21.7	28.4
Koue Bokkeveld[4]	1.9	3.5	1.9	2.6	1.9	2.5	1.9	2.6
Lower Olifants[5]	87.5	134.7	87.5	134.7	87.5	134.7	87.5	134.7
Olifants/Doring dryland farming (1) [6]	5.0	23.5	6.5	24.2	6.5	18.5	6.6	24.2
Olifants/Doring dryland farming (2) [7]	1.9	3.5	1.9	2.6	1.9	2.5	1.9	2.6
Upper Olifants[8]	1.9	2.7	1.8	1.9	1.8	2.0	1.8	1.9

[1] Only one sampling point, E4R001 in this IUA. Fair observed data record but no flow data to develop concentration/flow relationship.
[2] No monitoring points, assumed to be same as E4R001, low confidence assessment.
[3] There is only one monitoring pointy in the Knersvlakte with 7 observations. Low confidence assessment.
[4] Good data point, sufficient data to develop concentration/flow relationship.
[5] Only one monitoring point E2H016 at Lutzville. May be marine influence.
[6] Good data record at E2H003 and flow data to develop concentration/flow relationship.
[7] Water quality in the TraTra River was assumed to be the same as those observed at E2H002 close by.
[8] Assumed same as outflow from Clanwilliam Dam. No flow data at Bulshoek Barrage to develop a concentration/flow relationship, used total outflow from Clanwilliam Dam.

Table 13-5 The percentage adjustment required to cropping area under different scenarios (100% means no change).

	Kouebokke-veld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants
Current	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PES	100.9%	100.0%	100.0%	100.8%	100.0%	100.0%
REC+Cons.	100.9%	100.0%	100.0%	100.7%	102.7%	100.0%
ESBC	100.9%	100.0%	100.0%	100.8%	100.0%	100.0%

13.5.2.2 Irrigation sector outputs

The 'dummy' yield modelling utilising the assurance and curtailment rules presented in Table 13-1 yielded a combination of reduced demands (Table 13-6) and reduced assurances (Table 13-7).

Table 13-6 Crop area as a percentage of present due to curtailment necessary under different catchment configuration scenarios

	Koue Bokke-veld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants
Present	100%	100%	100%	100%	100%	100%
Scenario 1: PES	87%	81%	39%	73%	96%	60%
Scenario 2: REC + Cons.	87%	81%	39%	73%	96%	0%
Scenario 3: ESBC	87%	81%	39%	73%	96%	60%

Table 13-7 Change in assurance of supply to the changed crop areas under the different catchment configuration scenarios

	Koue Bokke-veld	Doring Range-lands	Knersvlakte	Upper Olifants	Dryland farming	Lower Olifants
Present	69.3%	67.1%	94.8%	69.2%	63.4%	100.0%
Scenario 1: PES	73.8%	58.6%	48.5%	93.6%	87.6%	95.0%
Scenario 2: REC + Cons.	79.0%	53.1%	55.1%	83.2%	96.7%	N/A
Scenario 3: ESBC	76.0%	62.8%	32.4%	73.1%	64.3%	95.0%

The change in irrigation output value (in terms of sectoral turnover) was adjusted by the change in area, change in assurance of supply and change in water quality, as follows (Eq. 16):

Eq. 16 $$\text{Scenario value} = \begin{pmatrix} \text{present value} \times \text{original field area} \times \%\ \text{assurance of supply} \\ \times\,\%\ \text{additional change in field area due to change in LR} \end{pmatrix}$$

The results are shown in Table 13-8 .

Table 13-8 Change in irrigation sector turnover (R millions) under different catchment configuration scenarios

	Koue Bokke-veld	Doring Range-lands	Knersvlakte	Upper Olifants	Dryland farming	Lower Olifants
Present	423	73	22	478	73	635
Scenario 1: PES	396	52	4	475	97	362
Scenario 2: REC + Cons.	424	47	5	422	110	-
Scenario 3: ESBC	408	55	3	371	71	362

14 DESCRIBE THE MACRO-ECONOMIC AND SOCIAL IMPLICATIONS OF DIFFERENT CATCHMENT CONFIGURATION SCENARIOS (STEP 5E)

14.1 Introduction and rationale

Different catchment configuration scenarios need to be evaluated in terms of their implications on the broader economy, typically evaluated at a regional scale. This sub-step describes how the measures used to assess the macro-economic and social implications of different catchment configuration scenarios are derived using a Social Accounting Matrix (SAM).[13] In the assessment of macro-economic and social implications of different catchment configuration scenarios, it is proposed that any activities, whether water user activities or aquatic ecosystem user activities, that have impacts on any sectors in the economy, be included in a macro-economic analysis of impacts. There are other values that impact on the economy, such as those incurring health costs and infrastructural costs (which are not considered here). It is thus proposed that these are dealt with separately, so as not to include them as value added to national income, as this would be potentially misleading. For example the increase in infrastructural damage due to floods actually leads to an increase in economic output. However, money spent on repairs could have been directed to other important social causes. Thus damage costs are calculated separately, and the

[13] The development of up-to-date regional SAMs has been commissioned by the Development Bank of South Africa (DBSA) for all the provinces, which will also eventually be used to update the existing national SAM.

macro-economic analysis consider only those changes in sectoral outputs as a result of changes in water supply and ecosystem quality.

The values to be considered in the macro-economic analysis are summarised in Sections 13.5.1 and 13.5.2.

14.2 Procedure for estimation of macro-economic implications

Changes in turnover (Step 5d – see Section 13) generated in the different sectors under different catchment configuration scenarios can be used to estimate macro-economic impacts using an array of multipliers. These multipliers can be derived from input-output models which are developed by professional econometricians. The type of input-output model required in the classification procedure is a Social Accounting Matrix (SAM). The reasons for the requirement of a SAM, a description of the economic multipliers, and a discussing on the calculation of sectoral multiplier are presented in Sections 14.2.2, 14.2.1, and 14.2.3 respectively.

14.2.1 Economic multipliers

All economic models incorporate a number of "multipliers" that form the nucleus of the modelling system. The nature and extent of the impact of a change in a specific economic quantity (e.g. exports) on another economic quantity or quantities (e.g. production output or employment), is determined by a "multiplier". For example, a R5 billion change in investment spending may give rise to a R15 billion change in the output-income level of a country (Samuelson, 1955). This is typically called the "multiplier effect" or, more simply, the multiplier. Although this multiplier effect is usually associated with investment spending for the simple reason that investment is the most volatile component of the macro-economic aggregates. However, it must be emphasised that changes in other aggregates are also subject to a multiplier effect.

On account of their global nature, the economic application of the above-mentioned multipliers is somewhat restricted, both for policy and analysis purposes. However, input-output analysis provides a method by which global multipliers can be broken down to a more detailed level, and, therefore, causal factors can be better identified. The most important causal factors that determine multipliers are, firstly, the industry structures (technical coefficients) and, secondly, the final demand structure.

14.2.2 The Social Accounting Matrix

A SAM is a matrix that depicts the linkages that exist between all of the different role players in the economy i.e. business sectors, households and government. A SAM is very similar to the traditional input-output table in the sense that it reflects all of the inter-sectoral linkages that are present in an economy. However, in addition to these inter-sectoral linkages, a SAM also reflects the activities of households, which are the basic unit where significant decisions regarding important economic variables such as expenditure and saving are taken (Lange *et al.*, 2004). By combining households into meaningful groups, the SAM makes it possible to clearly distinguish between these household groups, and to study the economic welfare of each household group separately.

The SAM serves a dual purpose in the national accounts of a country. Firstly, it is a reflection of the magnitude and linkages that exist between the various stakeholders in the economy. Secondly, once a SAM has been developed, it becomes a powerful tool that can be used to conduct various macro-economic analyses such as calculating sectoral multipliers.

In undertaking this study, permission was obtained to use the Western Cape regional SAM. The Western Cape SAM is based on input from the official 2000 SAM for South Africa, which is based on the official 2000 Population Census published by Stats SA.

The direct, indirect and induced multipliers for each economic sector have been calculated. The so-called “direct multiplier” measures the effect occurring in a specific sector, whilst the “indirect multiplier” measures those effects occurring in the different economic sectors that link backwards to this sector due to the supply of intermediate inputs. The “induced effect” on the other hand, refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumer spending.

An example of the agriculture sector multipliers that could be used is as follows:

- direct effect: refers to effects occurring directly in the agriculture sector;
- indirect effects: refers to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertilisers, seeds, etc.; and
- induced effects: refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.

14.2.3 Calculation of sectoral multipliers

Sectoral multipliers are calculated using information contained in the Sectoral SAMs and data obtained from the Reserve Bank of South Africa and Stats SA. These inverse matrices capture all of the direct and indirect relationships among the inputs and outputs of the various entities included in the Sectoral SAM.

The following multipliers could be calculated from the appropriate regional SAM (the Western Cape SAM in the case of the Olifants/Doring catchment):

- economic growth (i.e. the impact on GDP);
- job creation (i.e. the impact on labour requirements);
- impact on capital formation; and
- income distribution (i.e. the impact on low-income, poor households and the total income households).

Direct GGP, labour and capital multipliers for each sector are calculated using the following formulae (Eq. 17, Eq. 18 and Eq. 19):

Eq. 17 $$\text{GGP multiplier} = \frac{\text{Value added}}{\text{Production}}$$

Eq. 18 $$\text{Labour multiplier} = \frac{\text{Employment}}{\text{Production}}$$

Eq. 19 $$\text{Capital multiplier} = \frac{\text{Capital stock}}{\text{Production}}$$

14.3 Example: Olifants/Doring catchment

14.3.1 Implications for irrigation agriculture

The macro-economic implications of the three catchment configuration scenarios (PES, REC+Cons. and ESBC) for the irrigation agriculture sector are described below as an example of the sort of outcome that could be expected as part of Step 5e. Two of the scenarios (PES and ESBC) improve the profitability of irrigation agriculture, mainly because of the improved assurance of supply. For the other parameters (i.e. GDP, Capital, Low income households, Total households, Total employment, Direct employment) all three scenarios will have a drastic negative impact on the irrigation sector (Table 14-1).

Table 14-1 Macro-economic impacts of irrigation agriculture under different catchment configuration scenarios (2005 prices, Rand million)

	Current Situation	Incremental impact changes		
		Scenario 1: PES	Scenario 2: REC+Cons.	Scenario 3: ESBC
Surplus value	R472.89	R152.38	R-152.07	R45.06
GDP	R4 729.92	R-790.48	R-1 947.66	R-935.36
Capital	R13 085.10	R-2 683.18	R-5 452.91	R-2 984.45
Low income households	R859.61	R-168.55	R-356.62	R-184.64
Total households	R2 195.48	R-462.23	R-891.67	R-487.98
Total employment	54 557	-12 659	-17 342	-12 817
Direct employment	47 160	-9 480	-14 793	-9 480

Scenario 1 (PES) reduces the direct employment by 9 480 or 23.9% with a very negative influence on the low income households in the catchment. Scenario 2 (REC+Cons.) has an even more drastic impact on employment in the catchment and reduces the employment by 14 793 or 37.2% with the induced result that 41% of the income aimed at the low-income households being effected. Scenario 3 (ESBC) has a similar impact to Scenario 1.

14.3.2 Implications for ecosystem-dependent sectors

The data provided above were fed in to the model to generate a number of macro-economic parameters. The capital formation parameter was in this instance not calculated because of a lack of data.

Table 14-2 Macro-economic impacts of ecosystem-user sectors under different catchment configuration scenarios (2005 prices, Rand million)

	Current Situation	Incremental impact changes		
		Scenario 1: PES	Scenario 2: REC+Cons.	Scenario 3: ESBC
Surplus value	R6.65	R0.99	R2.09	R3.42
GDP	R8.89	R1.34	R2.82	R4.61
Capital	R1.00	R0.15	R0.31	R0.51
Low income households	R1.60	R0.24	R0.50	R0.82
Employment	266	27	38	30

From the table it is deducted that all three scenarios improve the economic parameters, with Scenario 3 (ESBC) being the most beneficial.

14.3.3 Procedure for estimating the social implications

The outputs of Step 5d (see Section 13) as well as the results from the SAM (see Section 14.2) can be used to assess the local economic effects for each IUA in terms of changes in the percentage in the non-poor category (see Section 5) and the percentage employed (see Section 5) for each of the catchment configuration scenarios. Disaggregation of the economic impacts to the IUA level is done on the basis of the proportional contribution to direct sectoral outputs from each IUA. This information can be used to assess, in part, the implications of the scenarios on social wellbeing, and can ultimately contribute to an overall assessment of the scenarios (see Joubert *et al.*, 2007). The socio-economic framework set up in Step 1h (see Section 8) can be used to calculate these data.

14.4 Example: Olifants/Doring catchment

14.4.1 Change in number of jobs

The estimated total number of jobs lost or gained under the different catchment scenarios is presented in Table 14-3. This is based on the local employment rates per unit of output described in Section 12.3.3.

Table 14-3 Total number of local jobs lost or gained under the different catchment configuration scenarios

Scenario	Koue Bokke-veld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary	Total
Scenario 1: PES	- 679	- 222	- 166	- 1 262	- 62	- 1 541	- 0	- 3 930
Scenario 2: REC+Cons.	- 675	- 222	- 166	- 1 265	5	- 3 852	- 10	- 6 184
Scenario 3: ESBC	- 0	- 0	- 0	- 0	- 3	- 0	- 19	- 22

14.4.2 Change in proportion of non-poor households

The estimated changes in the percentage of non-poor households under the different catchment configuration scenarios are given in Table 14-4. This is based on the regression described in section 12.3.3. There is an overall drop in the number of households that are non-poor, or in other words, an increase in poverty, under all three scenarios. Only one area, the dryland farming IUA appears to benefit under two of the scenarios.

Table 14-4 Percentage of households falling into the non-poor category under different catchment configuration scenarios

Scenario	Koue Bokke-veld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary
Baseline	17	19	16	21	17	30	23
Scenario 1: PES	10	14	8	21	24	6	23
Scenario 2: REC+Cons.	17	13	8	13	28	1	22
Scenario 3: ESBC	13	15	8	8	16	6	22.4

14.4.3 Change in health

Changes in health were not estimated and are assumed to be negligible.

14.4.4 Change in utility

The utility scores under the different scenarios are summarised in Table 14-5. These are calculated from the ecosystem health score, using the relationship described in Section 12.3.3. Whereas scenario 1 maintains current ecosystem health, and hence utility, Scenario 3 results in a significant loss of utility and scenario 2 results in a very significant increase in utility. Note however, that these results are only indicative, and a proper survey-based study would be required to verify these results.

Table 14-5 Scores of utility derived from aquatic ecosystems under different catchment configuration scenarios

Scenario	Koue Bokke-veld	Doring Range-lands	Kners-vlakte	Upper Olifants	Dryland farming	Lower Olifants	Estuary
Baseline	21.7	74.9	63.8	30.5	78.0	21.7	63.8
Scenario 1: PES	21.7	74.9	63.8	30.5	78.0	21.7	63.8
Scenario 2: REC+Cons.	98.3	87.6	63.8	87.6	97.6	100.0	91.0
Scenario 3: ESBC	17.8	17.8	17.8	17.8	17.8	17.8	17.8

The way in which the above measures and scores are combined in an overall index of wellbeing is described in Volume 4 (Joubert *et al.*, 2007).

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16 APPENDIX A REVIEW OF AVAILABLE DATASETS

Prior to 1994, there was a paucity of national coverage data of all ethnic groups and a lack of transparency and availability of data in the public domain. Since 1994 more robust quantitative socio-economic research has been possible because of the availability of data and a focus by government on the collection and dissemination of regular national datasets. The section below gives a brief overview of National and Regional Surveys that have filled a gap in data availability. Nevertheless, it is clear that there is a gap between an ideal set of socio-economic descriptors for describing communities and the actual set that could be used in the Classification Process.

Brief overview of national and Western Cape surveys

The first post-1994 countrywide household income and expenditure survey was the **Project for Statistics on Living Standards and Development** (PSLSD) conducted by the Southern Africa Labour Development Research Unit (SALDRU). It covered details of living conditions amongst 8 500 households in 360 clusters in the country. This was part of the Living Standards Measurement Study that was established by the World Bank in 1980. This was followed in 1993 by the survey undertaken by StatsSA (then the Central Statistical Service) who completed an annual **October Household Survey** (OHS) that has been repeated annually in October. The October period was chosen for this national survey because the population tends to be more stable in terms of mobility in October. The OHS is the official survey undertaken by StatsSA as one of the so-called presidential projects. The sample size was 16 000 in 1996 and 30 000 in 1997 and 1998.[14]

The **South African Labour Force Survey** is conducted by StatsSA twice a year to measure dynamics of employment and unemployment in South Africa, to identify issues related to the labour market and to estimate unemployment rates. The data from both waves of the Labour Force Survey for 2000 and 2001 are available and the first data from 2002 are available. Detailed Incomes and Expenditure Surveys (IES) were conducted in 1995 and 2000. The IES is a five-yearly household survey based on a sample drawn for the Labour Force Survey. The 2000 IES questionnaire contains questions about all sources of household income and is a national survey. The sample was based on 3 000 Prime Sampling Units (PSUs) drawn from urban and rural areas. Ten dwelling units were sampled in each of the 3 000 PSUs.

The **Afrobarometer** is an independent non-partisan research project that measures the social, political and economic atmosphere in Africa. The first round of the Afrobarometer took place from June 1999 to June 2001 and the second round from May 2002 to October 2003. The South African sample was a nationally representative sample of 1 200 respondents.

It is important to note, however, that data at the household level do not take into account intra-household inequalities or dynamics of distribution of income/goods and services amongst household members. An exception is the **Langeberg Survey** that was conducted in 1999 by SALDRU. The Langeberg Survey was unique because it drew its sample at the individual and not the household level; administering a comprehensive and complex questionnaire to every household member 15 years and older. It also provided data on health and wellbeing through the anthropometric module that was able, for example, to relate height and weight of children to education levels of mothers. The **Mitchells Plain/Khayelitsha Survey** was conducted in 2000 and collected data from all adult household members on labour market issues. In 2002, the **Cape Area Panel Study** (CAPS) collected data on a panel of young people over several years.

[14] http://www.nrf/ac.za/sada/ahdetails.asp

The 1998 **South Africa Demographic and Health Survey** (SADHS) was a national survey that collected information on the demographic and social characteristics of household members. The sample was drawn for 12 247 households and 17 500 people. The SADHS was funded by the Department of Health (DoH) and co-ordinated through the Medical Research Council (MRC). The first antenatal survey was conducted in 1990 in South Africa and provided a baseline from which HIV trends have been assessed annually.[15] A further Health Survey, the National HIV and Syphilis sero-Prevalence Survey conducted on women attending public antenatal clinics in South Africa in 2000 was run across nine provinces in October 2000. A total of 16 607 women were tested (blood specimens) at 400 sites. Further health data, for instance, on cases of malaria and HIV prevalence have been made available through the Health Systems Trust. This includes data on population density.

The only national data mentioned here that can be used for any particular catchment is provincial-level or regional-level data from the PSLSD and OHS. These data sets cannot, however, be used to provide reliable, valid data at the community-level on demographic and social characteristics. The only data that makes a descriptive assessment at the community-level possible are census data.

Census: StatsSA[16]

Census 1996 was the first national population census conducted after 1994. **Census 2001** was conducted over 5 years later. The data from these large-scale national-level censuses are now available through StatsSA.[17] A comprehensive set of descriptors are provided to the public at the provincial, district and municipal level. The typologies and descriptions of communities in catchments will have to rely largely or solely on data available from the Community Profiles of StatsSA and possibly from the StatsSA Small Area Survey (SAL).

StatsSA has made a community profile database accessible through its programme, SuperCROSS. It is difficult to make comparisons between the two censuses and to draw any conclusions on the dynamic nature of socio-economic development since 1994 - firstly because the Demarcation Board adjusted municipal boundaries in 2000 and the municipal boundaries do not correspond across censuses, and secondly, because Census 1996 and Census 2001 do not distribute data to the public at the same spatial unit. Although sampling for both Census 1996 and Census 2001 were at the Enumerator Area (EA)[18], data are only available at this level for Census 1996. Further, the geographical hierarchies for the two censuses differ. The 1996 Census refers to 12 852 place names while there are only 3 109 main-places (towns and tribal authorities) and 21 234 sub places (suburbs and villages) available for the 2001 Census.

Census 2001 presents a hierarchical structure that is used for geographical areas on seven levels:

1. National.
2. Provincial.
3. District Council (Category C) or Metropolitan Area (Category A).
4. Local Municipality (Category B) or District Management Area (DMA).
5. Main Place.
6. Sub-place.

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[15] http://www.doh.gov.za/docs/reports/2000/hivreport.html.
[16] Information in this section sourced from StatsSA.
[17] The Olifants/Doring Water Resource Situation Assessment (WRSA) report of March 2002 draws on labour force data from 1991 census updated by theDevelopment Bank of Southern Africa utilizing the 1995 October Household Survey.
[18] An Enumerator Area is the smallest spatial unit at which the census sample was drawn.

7. Small Area Layer (SAL).
8. Enumerator Area (EA).

As indicated earlier there are approximately 21 000 sub-place units across the country. Many of these sub-places cover large areas and populations. As characteristics of these areas, in particular access to services, are not even throughout the areas, planners at provincial- and local-levels find that information at this level is insufficient to enable specific planning and intervention, or to effectively monitor service delivery targets. The SAL has been developed as a response to this gap in availability of data. In order to respond to continued user requests for Census 2001 information at a higher spatial level of resolution than the community profiles, this 'off-the-shelf' information product has been designed to provide small area statistics based on Census 2001.

According to StatsSA, this national product is the *only* product to be provided to users who request data at a level-lower than sub-place name. The product is based on a SAL that was created by combining all EAs with a population of less than 500 with adjacent EAs within the same sub-place. The final SAL consists of 56 255 polygons. Apart from the SAL the product also contains all the higher levels of geography.

Variances between Census 1996 and Census 2001

An index to describe the wellbeing of communities may be dependant on a set of indicators that aggregate data from descriptors such as income, health, age and education. However, as Cronje and Budlender (2004) note 'income data in the census is far from ideal' and although an income-based approach presents only one of the many dimensions of socio-economic wellbeing in South Africa, it has been widely used by economists in measuring changes in inequality over time, and in guiding and informing national policy. A specific problem flagged by Leibbrandt *et al.* (2005) is that personal incomes were aggregated into household incomes in 1996 and 2001, and as these authors note 'a sizeable number of household are captured as having zero incomes or missing incomes' with the result that households that are at the bottom of the distribution are removed from the analysis.

Other indicators that could be incorporated into the description of communities are, for instance, access to water and 'main activity'. Here it should be noted that there are slight differences in the way the data were collected in the past two censuses. In the 1996 Census respondents were asked the question: 'What is your main water supply' but in the 2001 the respondent was first asked 'In which way does this household obtain piped water for domestic use?' with alternatives ranging from 'no access to piped water' through to the response category 'piped water inside dwelling'. The question asked in Census 1996 was different in 2001 where a follow up question was phrased as follows: 'What is this household's main source of water for domestic use?' In this case, the response category was different and referred now to 'Regional/local water scheme' and not 'piped water' as an option. Comparisons over time that rely on 'water' data are therefore unreliable because there are units of analysis that have access to piped water, but the responses relate to water that is extracted from a borehole and not from a shared water scheme.