Wetland Health and Importance Research Programme

11

Wetland Valuation Volume IV

A Protocol for the Quantification and Valuation of Wetland Ecosystem Services

Authors: J Turpie & M Kleynhans

Series Editor: H Malan

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11

WETLAND VALUATION. VOL IV

A PROTOCOL FOR THE QUANTIFICATION AND VALUATION OF WETLAND ECOSYSTEM SERVICES

Report to the
Water Research Commission

by

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Front Cover: Small seepage wetland in the Western Cape, South Africa
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PREFACE

This report is one of the outputs of the Wetland Health and Importance (WHI) research programme which was funded by the Water Research Commission. The WHI represents Phase II of the National Wetlands Research Programme and was formerly known as "Wetland Health and *Integrity*". Phase I, under the leadership of Professor Ellery, resulted in the "WET-Management" series of publications. Phase II, the WHI programme, was broadly aimed at assessing wetland environmental condition and socio-economic importance.

The full list of reports from this research programme is given below. All the reports, except one, are published as WRC reports with H. Malan as series editor. The findings of the study on the effect of wetland environmental condition, rehabilitation and creation on disease vectors were published as a review article in the journal Water SA (see under "miscellaneous").

An Excel database was created to house the biological sampling data from the Western Cape and is recorded on a CD provided at the back of Day and Malan (2010). The data were collected from mainly pans and seep wetlands over the period of 2007 to the end of 2008. Descriptions of each of the wetland sites are provided, as well as water quality data, plant and invertebrate species lists where collected.

An overview of the series

Tools and metrics for assessment of wetland environmental condition and socio-economic importance: handbook to the WHI research programme by E. Day and H. Malan. 2010. (This includes "*A critique of currently-available SA wetland assessment tools and recommendations for their future development*" by H. Malan as an appendix to the document).

Assessing wetland environmental condition using biota

Aquatic invertebrates as indicators of human impacts in South African wetlands by M. Bird. 2010.

The assessment of temporary wetlands during dry conditions by J. Day, E. Day, V. Ross-Gillespie and A. Ketley. 2010.

Development of a tool for assessment of the environmental condition of wetlands using macrophytes by F. Corry. 2010.

Broad-scale assessment of impacts and ecosystem services

A method for assessing cumulative impacts on wetland functions at the catchment or landscape scale by W. Ellery, S. Grenfell, M. Grenfell, C. Jaganath, H. Malan and D. Kotze. 2010.

Socio-economic and sustainability studies

Wetland valuation. Vol I: Wetland ecosystem services and their valuation: a review of current understanding and practice by Turpie, K. Lannas, N. Scovronick and A. Louw. 2010.

Wetland valuation. Vol II: Wetland valuation case studies by J. Turpie (Editor). 2010.

Wetland valuation. Vol III: A tool for the assessment of the livelihood value of wetlands by J. Turpie. 2010.

Wetland valuation. Vol IV: A protocol for the quantification and valuation of wetland ecosystem services by J. Turpie and M. Kleynhans. 2010.

WET-SustainableUse: A system for assessing the sustainability of wetland use by D. Kotze. 2010.

Assessment of the environmental condition, ecosystem service provision and sustainability of use of two wetlands in the Kamiesberg uplands by D. Kotze, H. Malan, W. Ellery, I. Samuels and L. Saul. 2010.

Miscellaneous

Wetlands and invertebrate disease hosts: are we asking for trouble? By H. Malan, C. Appleton, J. Day and J. Dini (Published in Water SA 35: (5) 2009 pp 753-768).

EXECUTIVE SUMMARY

Introduction

This study builds on three earlier volumes which include a review of current understanding of wetland ecosystem services, their quantification and valuation, a set of valuation case studies, and an index for the assessment of the livelihood value of wetlands. This volume provides a protocol for the quantification and valuation of wetland ecosystem services.

This report is written for the use of planners and decision-makers wishing to understand the purpose and potential for use of wetland valuation in a variety of decision-making contexts, and to guide them in the setting of terms of reference for specialist studies. In addition, the report aims to guide student and professional resource economists in their understanding of the purpose of and trade-offs in valuation studies, the choice of their detailed methodological approach, and the role of biophysical specialists in wetland valuation. Although the report provides advice on how to achieve relatively rapid estimates of wetland values, it does not offer a shortcut tool for rapid valuation by non-professionals.

Wetland services and values

Wetlands provide provisioning, regulating and cultural services that contribute to the economy and societal wellbeing. Provisioning services include the provision of goods such as water, food, grazing and raw materials. Regulating services are processes that contribute to economic production or save costs, such as flow regulation (including flood attenuation and maintenance of base flows), sediment retention, water purification and carbon sequestration. Cultural services relate to ecosystem attributes such as beauty and rarity, and include the spiritual, educational, cultural, recreational, existence and bequest value that is derived from the use or appreciation of biodiversity. These services generate direct use, indirect use and non-use value.

Processes requiring wetland valuation

Wetland valuation studies may be carried out for a number of purposes, including: lobbying for conservation, conservation and development planning, designing financing and incentive mechanisms, allocation of water, management plans, appraisal of development applications, strategic environmental assessment, monitoring and natural resource accounting. The way in which valuation informs these processes is briefly described here.

Determining the level of comprehensiveness required for a valuation study

While methods for the comprehensive and rigorous valuation of ecosystem services have become increasingly refined, there is also pressure to carry out rapid evaluations, due to budgetary or time constraints. It is therefore important to determine the level of confidence or certainty required for the decision-making process for which the valuation study has been commissioned, as well as to ascertain the potential impact of the more rapid methods on the reliability of those results. The comprehensiveness of a study can be described in terms of its scope (coverage of different values), the extent of valuation (how beneficiaries are defined and value expressed) and accuracy (or methodological rigour). Methodological rigour is the primary determinant of the level certainty or confidence associated with the results. The scope and extent of the valuation affect confidence in as much as there is a danger of omitting important values or beneficiaries, or an important way of expressing value. Such omissions can lead to distorted decision-making. Since resources for valuation studies are generally limited, increasing the scope of the study to include all types of value may come at the cost of the methodological rigour or extent of the valuation for one or more types of value. It may be necessary to put more effort into values that are considered to be the most important, or in other cases it might be better to spread the research effort among all values. The choice involved in these types of trade-offs will be dictated by the needs of the study. The geographical scale of the study also limits the approach that can be taken, with larger scale studies having to adopt a more extrapolative or rapid approach.

At the outset of any valuation study it is necessary to align the methodology with the objectives of the study, and to define the scale and comprehensiveness of the study accordingly. All of these aspects are primarily determined by the purpose of the study, subject to budgetary constraints. Rough guidelines are provided in this regard.

Selection of valuation methods

This section concentrates on the methods required to quantify and value key wetland services at different levels of comprehensiveness and different spatial scales. Thus, once the scope and extent have been decided (i.e. which services and beneficiaries are to be considered and how values are to be expressed), this section provides a guide to design the methodological approach for each. Standard valuation methods such as the Travel Cost Method and the Contingent Valuation Method are reviewed in Volume I. Guidelines are provided for the valuation of the following services:

- provision of natural resources (comprehensive valuation – local and catchment scale; rapid valuation – local, catchment and national scale);
- flow regulation (comprehensive valuation – local scale, with and without observed flow data; intermediate valuation – local scale; rapid valuation – local and catchment scale);
- water quality amelioration (comprehensive valuation – regional scale; intermediate valuation – regional scale; rapid valuation – regional scale);
- recreation and tourism (comprehensive valuation – local scale; rapid valuation – local to regional scale);
- scientific and educational value; and
- cultural, spiritual and existence value.

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ABBREVIATIONS

ACRU – Agricultural Catchments Research Unit (hydrological model)

CBA – Cost-Benefit Analysis

CV – coefficient of variation

CVM – Contingent Valuation Method

DEAT – Department of Environmental Affairs and Tourism

DWAF – Department of Water Affairs and Forestry

EIA – Environmental Impact Assessment

GDP – Gross Domestic Product

GIS – Geographical Information System

MAP – Mean Annual Precipitation

MAR – mean annual runoff

NEMA – National Environmental Management Act

NFEPA – National Freshwater Ecosystems Priority Areas (project)

NWRCS – National Water Resource Classification System

PPF – production possibilities frontier

RDM – Resource Directed Measures

RQO – Resource Quality Objectives

SAM – Social Accounting Matrix

SEA – strategic environmental assessment

TCM – Travel Cost Method

USACE – United States Army Corps of Engineers

WHI – Wetland Health and Importance (Research Programme)

WMA – Water Management Area

WRC – Water Research Commission

WTA – Willingness to Accept compensation

WTP – Willingness to Pay

1. INTRODUCTION

1.1 Background

This study forms part of the resource economics component of the Wetland Health and Importance (WHI) research programme. Understanding socio-economic values of wetlands is important for management, conservation and development planning, and helps to justify investment in conservation or rehabilitation of wetlands. It will be an essential element of the determination of freshwater allocation to wetlands as water resources become increasingly limited in the future.

Valuation of wetlands entails identifying the types of services and values they provide, quantifying their supply in biophysical terms, evaluating the demand for the services and estimating their value. There is no standardized methodology for valuation of wetlands (Turpie *et al., 2*010a), and there are no guidelines for use in South Africa, although very general guidelines for valuation are currently being developed under the Department of Water Affairs and Forestry (DWAF's[1]) Classification Project (which is not considering wetlands *per se*).

Current valuation methods are designed for comprehensive application, which means they are expensive. There is a need for more rapid methods to be investigated in terms of their feasibility for use, by assessing their relative accuracy and sufficiency for decision-making. However, in order to test the efficiency of a rapid method, it has to be compared with the results of a comprehensive assessment.

The overall objectives of the resource economics component of the WHI were as follows (volume numbers refer to the supporting reports listed below):

a) Conduct a **scoping study** of methods to value wetland "goods and services" (Volume I);
b) **Evaluate WET-EcoServices** (an approach developed by Kotze *et al., 2*008) as a basis for determining the economic value of wetlands (Volume I);
c) Develop a metric to assess **socio-economic dependency** on a given wetland (Volume III); and

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[1] Note that the Forestry division of DWAF has since been incorporated into the Department of Agriculture, Fisheries and Forests, and Water and Environmental Affairs have been linked into a single Department of Water and Environmental Affairs (DWEA).

d) Develop a wetland **valuation protocol** which takes into consideration the different types and geographical location of wetlands (Volume IV, which builds on the above and on Volume II which documents valuation case studies for South African wetlands).

This report proposes a protocol for the valuation of wetlands, based on the purpose or type of decision being made, the scale of the problem, and the time and financial resources available.

1.2 Supporting reports

This study builds on the reports produced as outputs of the preceding tasks described above, and listed below.

Turpie J, Lannas K, Scovronick N and Louw, A. 2010a. *Wetland valuation* Vol. I. Wetland ecosystem services and their valuation: a review of current understanding and practice. .

Turpie, J (Ed.). 2010a. *Wetland valuation* Vol. II. The valuation of provisioning, regulating and cultural services provided by wetlands: case studies from South Africa and Lesotho.

Turpie J. 2010b. *Wetland valuation*, Vol III. The Wetland Livelihood Value Index: A tool for the assessment of the livelihood value of wetlands.

1.3 Target audience

This report is written for the use of planners and decision-makers wishing to understand the purpose and potential for use of wetland valuation in a variety of decision-making contexts, and to guide them in the setting of terms of reference for specialist studies. In addition, the report aims to guide student and professional resource economists in their understanding of the purpose of and trade-offs in valuation studies, the choice of their detailed methodological approach, and the role of biophysical specialists in wetland valuation. Although the report provides advice on how to achieve relatively rapid estimates of wetland values, it does not offer a shortcut tool for rapid valuation by non-professionals.

1.4 Structure of this report

The report provides a rationale and overview of the approaches to be taken to value wetlands under different circumstances.

- **Chapter 2** provides a brief reminder of the types of services that wetlands provide and the types of value generated by these.
- **Chapter 3** describes the types of applications that might require or benefit from wetland valuation.
- **Chapter 4** considers how the different purposes of valuation and the scale of the exercise required influence the scope and level of the valuation approach.
- **Chapter 5** provides a set of guidelines for the valuation of each ecosystem service at three levels.

There is a glossary at the end of the report.

2. WETLAND SERVICES AND VALUES

Wetlands provide a range of ecosystem goods, services and attributes that contribute to the economy and societal wellbeing (Table 2.1). These can be classified into provisioning, regulating and cultural services (Millennium Ecosystem Assessment, 2003; Table 2.2).

Provisioning services include the provision of goods such as water, food, grazing and raw materials. Regulating services are processes that either contribute to economic production or save costs, such as flow regulation, sediment retention, water purification and carbon sequestration. Cultural services relate to ecosystem attributes such as beauty and rarity and include the spiritual, educational, cultural, recreational, existence and bequest value that is derived from use of or appreciation of biodiversity. There may also be disservices associated with wetlands, such as the provision of breeding grounds for pests and pathogens. The ecosystem services generated by wetlands are described in detail in Volume I (Turpie *et al., 2*010a).

Although flow regulation has been referred to in other texts (e.g. Kotze *et al., 2*008) as specifically about maintenance of base flows, the term in fact includes flood attenuation as well, as it is the high flows, including floods, that provide the water for later release as increased base flows. The usage of the term flow regulation in this report is consistent with the terminology used by Smakhtin and Batchelor (2005) and includes both the flood attenuation and base flow maintenance functions.

Economic value can be defined in terms of people's willingness to pay for a commodity or “state of the world”. Net economic value can be expressed as the sum of **consumer surplus** and **producer surplus**. Under the Total Economic Valuation framework, value generated by ecosystems can be disaggregated into consumptive or non-consumptive direct use value, indirect use value, option value and non-use value (Table 2.2). Different methods are appropriate for the estimation of each of these types of value, and are described in detail in Turpie *et al.* (2010a). In addition to these positive values generated by wetlands, there are opportunity costs, which are the benefits forgone by not converting the wetland area to alternative uses, such as agriculture or housing.

Table 2.1: Types of services provided by inland wetlands, and their potential significance at any given scale (based on Turpie *et al., 2*010a). H = high, M = medium, L = Low

Types of Services		Description	Significance
Provisioning services	Water	Provision of water for livestock or domestic use	H
	Food, medicines	Production of wild foods and medicines	M
	Grazing	Production of grazing for livestock	H
	Raw materials	Production of fuel, craftwork materials, construction materials	H
	Genetic resources	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species	L
Regulating services	Climate regulation	Carbon sequestration – Wetlands are believed by some to be carbon sinks that contribute towards reducing carbon emissions, but the opposite may in fact be true.	L
	Flow regulation	Flood attenuation – Reduction of the peak flow, water level and velocity of flood waters at downstream locations by wetlands, reducing downstream damage	L-H
		Base flow maintenance – Increase in base flows due to storage of floods and high flows in the wetland for later and more gradual release	L-M
		Groundwater recharge – Wetlands are commonly thought to provide differential recharge to groundwater, relative to surrounding vegetation types, and to contribute to dry season base flows.	L
	Sediment retention	Retention of soil and fertility within an ecosystem	H
	Water quality amelioration	Breaking down of waste, detoxifying pollution; dilution and transport of pollutants	H
	Regulation of pests and pathogens	Change in ecosystem health affects the abundance or prevalence of malaria, bilharzia, liver fluke, black fly, invasive plants, etc.	?
	Refugia	Critical breeding, feeding or watering habitat for faunal or floral populations that are utilized elsewhere	M
Cultural services	Abundance, rarity and beauty of species, habitats and landscapes	Providing opportunities for : • cultural activities and heritage • spiritual and religious activities and wellbeing • social interaction • recreational use and enjoyment • research and education	H

Table 2.2: The way in which the original (Barbier, 1994) and the Millennium Ecosystem Assessment (2003) concepts of ecosystem services relate to one another and to the components of Total Economic Value (Turpie *et al., 2*010a)

<table>
<tr><th>Goods and Services</th><th>Millennium assessment</th><th>Total Economic Value</th></tr>
<tr><td>Goods</td><td>Provisioning services</td><td>Consumptive use value</td></tr>
<tr><td>Services</td><td>Regulating services</td><td>Indirect use value</td></tr>
<tr><td rowspan="3">Attributes</td><td rowspan="3">Cultural services</td><td>Non-consumptive use value</td></tr>
<tr><td>Option value</td></tr>
<tr><td>Existence value</td></tr>
<tr><td>n/a</td><td>Supporting services</td><td>n/a</td></tr>
</table>

3. PROCESSES REQUIRING WETLAND VALUATION

3.1 Introduction

Wetland valuation may be carried out for a number of reasons. The primary reason for such studies in the past was to build local and political support for their conservation and sustainable use. Valuation studies are now increasingly being used to allow more balanced planning and decision-making with regard to land and resource use, to help diagnose the causes of environmental degradation and biodiversity loss, and to develop incentive and financing mechanisms for achieving conservation and sustainability goals. Situations in which wetland valuation may be useful are discussed below.

3.2 Lobbying for conservation

In South Africa, where biodiversity issues are a low priority in many government sectors, there is still a significant demand among the conservation lobby to demonstrate that biodiversity provides social and economic benefits. For example, a rough estimation of the economic value of Durban's Metropolitan Open Space System (Roberts *et al., 1*999) led to key changes in the management priorities of eThekweni municipality. Estimation and communication of the value of biodiversity in South Africa is one of the key requirements of the National Biodiversity Strategy and Action Plan (DEAT, 2005).

3.3 Conservation and development planning

Conservation and development planning may be focussed on one aspect (conservation or development) or may explicitly be integrated. **Conservation planning** tends to be focussed at the regional or national level. **Development planning** now takes the form of **Integrated Development Plans** at the municipal, district and provincial level. There has been relatively little interaction between conservation and development planning in South Africa. However, valuation is now being applied in conservation planning studies to add a social dimension to what was previously a purely biodiversity issue, and this will make conservation plans easier to integrate into development plans.

As a signatory of the UN Convention on Biodiversity (Rio, 1992), Agenda 21 (1992), the Ramsar Convention (1971), the Nairobi Convention (1985), the Abidjan Convention (1985), the World Heritage Convention (1972), the World Conservation Union Policy framework (1988) and the UN Framework Convention on Climate Change (1992), and through its National Water Act (1998), South Africa is obliged to provide a certain level of protection to its wetland ecosystems. Roux *et al.* (2006) have defined a national goal for freshwater conservation policy in South Africa, which includes comprehensive conservation planning. This is being addressed under the **National Freshwater Ecosystems Priority Areas** (NFEPA) project.

Conservation planning is a rapidly evolving area of research. Systematic conservation planning replaces the relatively *ad hoc* way of selecting conservation areas in the past, and is becoming increasingly holistic in terms of ecological goals and in terms of integrating conservation and development needs in a region. It involves several principles, and has numerous distinctive characteristics (Margules and Pressey, 2000). Having first concentrated on the representation of species, conservation planning has generally evolved to incorporate ecosystem processes and now gives greater emphasis to biodiversity persistence (e.g. Cabeza and Moilanen, 2001). More recently, it has been recognized that conservation planning cannot take place in the absence of an understanding of socio-economic pressures and values. While there has been some consideration of the direct costs involved (e.g. Balmford *et al., 2*003; Frazee *et al., 2*003; Moore *et al., 2*004), there has been little integration of ecological and economic considerations in regional level planning initiatives (see Faith and Walker, 2002).

Conservation planning needs to take into account the **opportunity costs** involved in conserving natural habitats. These are the benefits forgone by not converting a natural area to alternative uses, such as agriculture or housing. This would include any use that is restricted in the present in order to secure a flow of value in the future, i.e. a cost that is borne mainly in the present. The opportunity cost of ecosystem conservation depends on the level of protection applied. In some cases, complete protection may be required, in which case the opportunity costs would extend to any type of use. In other cases, conservation goals may be achievable with certain types of development that are deemed compatible.

Ideally, conservation planning should also include estimates of the effect of conservation or non-conservation on the supply and value of ecosystem services. The inclusion of economic costs and benefits into conservation planning has a significant effect on the results (Turpie and Clark, 2007).

3.4 Designing financing and incentive mechanisms

Wetland conservation, and the groups who bear its costs, require funds. Valuation ascertains the magnitude and distribution of costs and benefits associated with conservation efforts, and also highlights conservation financing needs. It identifies the stakeholders who benefit freely or at low cost from wetlands, or who carry out activities which degrade wetlands without being penalized. These all present opportunities for capturing additional revenue which can be redistributed to those who bear the costs associated with wetland conservation.

Valuation studies elicit the public's willingness to pay for environmental goods and services, specifically to prevent or effect a change in their delivery. Much of this willingness to pay may be in the form of 'untapped' consumers' surplus. The understanding of demand for wetland goods and services provided by valuation studies can guide the design of revenue raising tools such as user fees and payments for ecosystem services.

Valuation also helps to predict and understand why people engage in activities which are damaging to ecosystems, and hence to develop measures that encourage people to engage in more sustainable activities. Valuation studies identify the stakeholders who benefit from ecosystems, and those who bear the costs of their conservation. This helps to identify measures that need to be implemented to achieve the optimal and sustainable use of ecosystems.

It is increasingly being realised that wherever the optimal situation for society as a whole is dissimilar to the preferred behaviour of individuals, incentives are more effective in achieving the desired goals than regulatory measures alone. It is thus necessary to create incentives to promote conservation and/or reduce damaging behaviour. This entails making damaging behaviour less profitable or beneficial than sustainable practices, which in turn, requires a good understanding of the private costs and benefits of alternatives, as well as the property rights context.

3.5 Water resource allocation and determination of the ecological 'Reserve'

The trade-offs involved in the allocation of water between users and the environment can be represented by a simplified two-dimensional production possibilities frontier curve (Figure 3.1). There is limited economic value that can be obtained from resources, and the type of value generated depends on allocation decisions. The maximum value that can be obtained from different allocative combinations is illustrated by the production possibilities frontier (PPF) curve. Current allocations would probably fall well within this curve, since use of aquatic resources is far from 100% efficient. The PPF curve illustrates the opportunity costs of licensing activities that consume or impact on water supplies to aquatic ecosystems in terms of the loss in values generated by those systems, and conversely, the opportunity costs of conserving the environment by limiting the use of water. The curve is convex because of the law of diminishing returns. As more water is allocated to agricultural and other uses, so the opportunity costs due to losses of ecosystem goods and services are likely to increase, and vice versa.

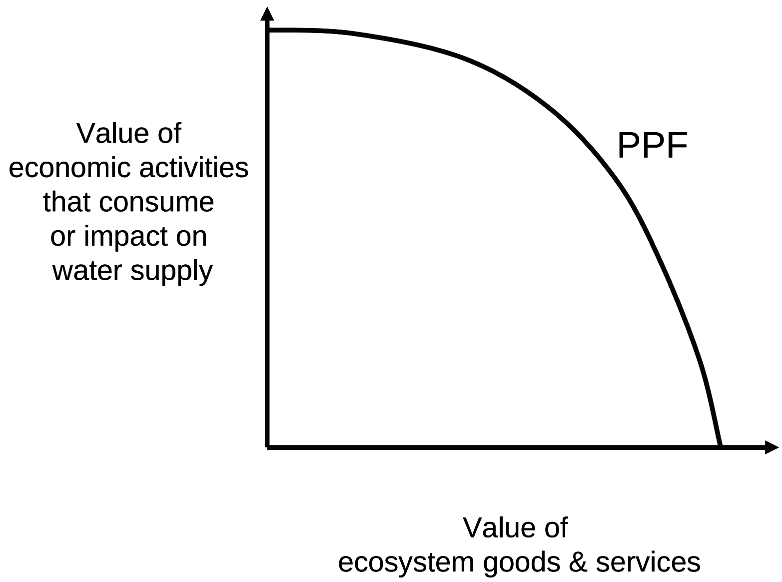

Figure 3.1: Hypothetical production possibilities frontier (PPF) curve showing the economic trade-offs between allocating water to impacting activities versus aquatic ecosystems. This assumes a non-linear relationship between ecosystem health and the value of ecosystem goods and services delivered.

In South Africa, the Water Policy of 1997 determined that water should be allocated on the basis of “some, for all, forever”, following an environmentally sound and socially just approach. This has led to the need for consideration of the value of the services provided by aquatic ecosystems and the impacts of changes in flow on this value.

Among other strategies such as ‘Source Directed Controls’, the National Water Act (No. 36) of 1998 requires **‘Resource Directed Measures’** (RDM), including the setting of an “ecological reserve” to protect aquatic ecosystems. This requires the classification of all significant water resources (river reaches, wetlands, estuaries and groundwater resources) in terms of their desired future management state. This state, or class, will simultaneously determine the health of the ecosystem and the amount of pressure that can be brought to bear on the quantity and quality of river flow through the use of water. The class will guide the setting of the Ecological Reserve, which is the quality, quantity and timing of flows allocated to ecosystems. The Reserve will assure a basic level of ecosystem health, and can also result in stronger levels of protection where this is desirable. Once resources are classified, monitoring programmes will be put in place to evaluate whether the reserve and associated resource quality objectives are being met. Resource economics studies are expected to inform both the classification and monitoring processes.

Since 1998, the Reserve determination methods have provided protocols for determining the present condition, importance and, based on these, the desired (or recommended) future condition of significant water resources from an ecological point of view. Through a process of scenario analysis using modelled flows, the flow requirements for meeting this recommended future condition are described. In comprehensive assessments, a valuation study is also required, which describes the current economic value of ecosystem services and potential changes under different scenarios. Unlike the ecological methods, there has been no standard protocol available for the resource economics component of comprehensive RDM studies, but one is now under development. The ecological and socio-economic information has then been evaluated, along with other socio-economic considerations relating to water demand, in order to finalize the class of the system, and hence its level of protection and use. Nevertheless, these studies only yield a 'preliminary reserve' until such time as water resources are classified under the more holistic **National Water Resource Classification System** described below.

The **National Water Resource Classification System** (NWRCS; Dollar *et al., 2*006) was recently developed to provide a more holistic framework and methodology for determining the class of each resource, taking ecological, social and economic criteria into consideration, at a broad (catchment rather than reach or individual wetland) scale, and was gazetted in 2008. Not to be confused with classification of wetlands by type, the NWRCS Classification Process is to determine environmental flows (water allocations) by deciding on a management class for water resources (including wetlands). The NWRCS Classification Process provides a 7-step procedure to be followed to recommend a class (Figure 3.2). The economic, social and ecological implications of choosing a class are established and communicated to all Interested and Affected Parties.

The NWRCS Classification Process involves establishing a quantitative framework for determining how economic value and social wellbeing are affected by changes in aquatic ecosystem condition and by different water use scenarios (Dollar *et al., 2*006, Figure 3.2). Ecological characteristics and processes that have an important bearing on economic value or social wellbeing are identified. Quantitative relationships have to be established in order to estimate the broad scale economic and social implications of given levels of ecosystem condition and associated ecosystem services. These then feed into three overall index scores which are compared for different scenarios – an ecosystem score, a regional economic prosperity score and a social wellbeing score (Dollar *et al., 2*006).

The Classification Process thus requires not only information on the value of ecosystem services, but also on how they change in relation to changes in ecosystem condition.

Some of the most important early work on wetland valuation has been in the context of environmental water allocations (EWAs)[2]. This included a major study on the Hadejia-Jama'are floodplain in Nigeria, which investigated the impact of dam construction on the value of the downstream wetlands for cropping, grazing, fishing and firewood provision (Barbier *et al., 1*991), and a similar study on the impacts of hydropower development on the value of Kenya's Tana River floodplains (Emerton, 1994). While these were groundbreaking studies, such assessments have generally remained rare in the determination of environmental flows. Nevertheless, such studies are increasing in both the developed and developing world.

[2]Previously referred to as 'environmental flows'

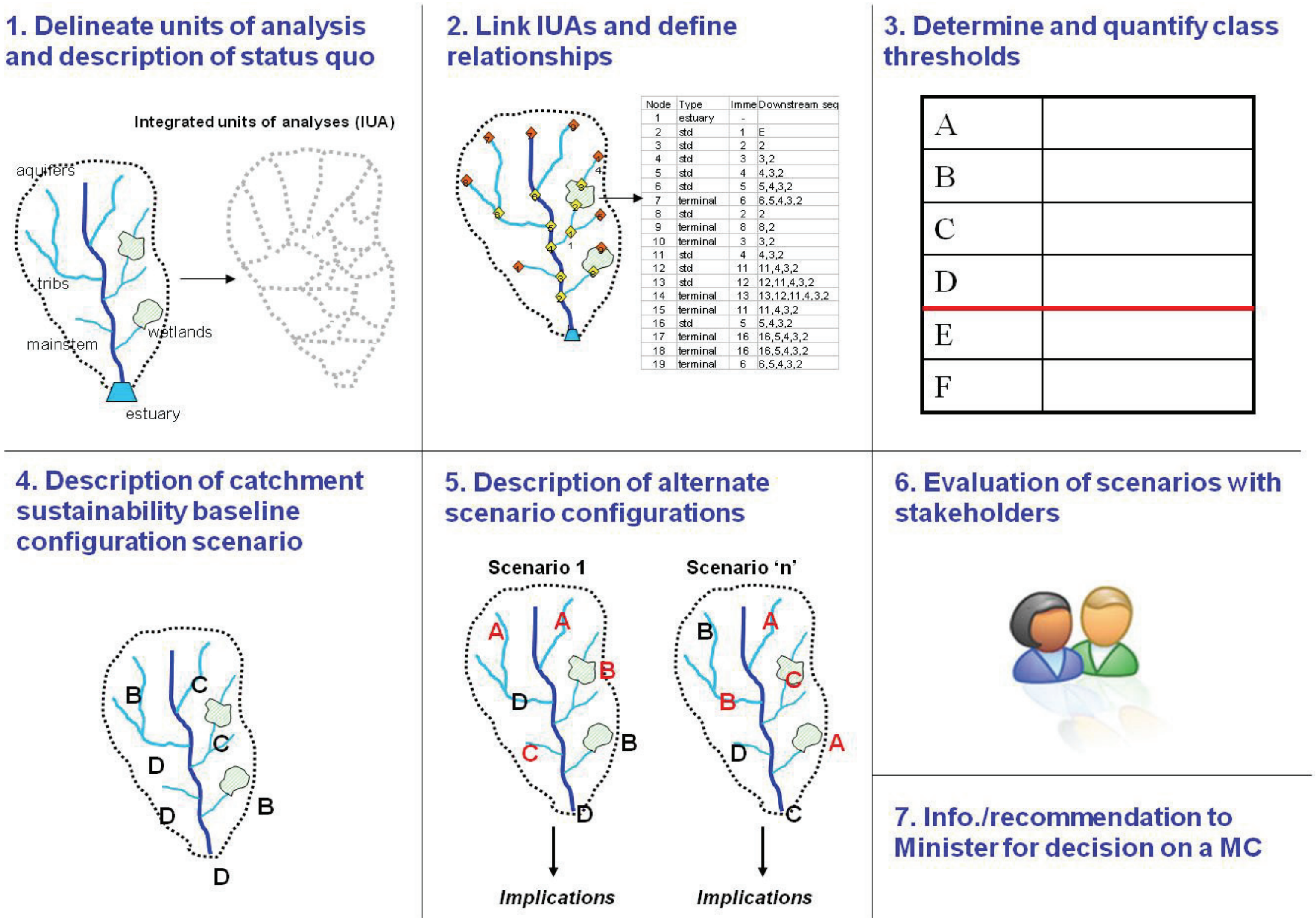

Figure 3.2: Diagram of the NWRCS Process. IUA = Integrated units of analysis, which may contain several river reaches or aquatic ecosystems; MC = management class.

3.6 Management plans

Management decisions require an understanding not only of the current value of wetlands, but also the trade-offs that would occur between wetland values under different management scenarios. These trade-offs are generally between direct use values and other types of value (Figure 3.3), even where direct use is managed to be sustainable (Turpie *et al., 2*006a). Ecosystem values are derived from the **direct use** of their habitats and products (e.g. harvesting of fish, ecotourism), from the services that yield value elsewhere (**indirect values**; e.g. amelioration of water quality for downstream users) and from the **non-use values** derived from the existence of certain features of biodiversity (expressed as people's willingness to pay just to know that these are conserved). All of these values are dependent on the functional health of the ecosystem. Nevertheless, ecosystems that are exploited (generating direct use value) will have altered ecosystem functioning, which affects their indirect and non-use values, even in cases where exploitation is sustainable (can be maintained into perpetuity).

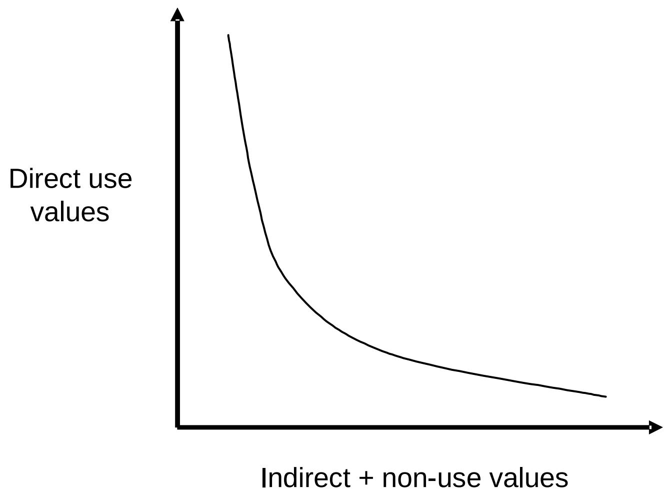

Figure 3.3: Hypothetical trade-off relationship between direct use values and other types of value generated by ecosystems (based on Turpie *et al., 2*006a).

Valuation of natural resource use, in conjunction with ecological understanding, can be used to construct ecological-economic models with which to analyze management alternatives. Ecological-economic modelling highlights the ecological linkages and is potentially a very powerful tool for informing stakeholders of the economic consequences of over-exploitation, or of the benefits of preserving part of a wetland (for example, as a source area for a fishery; Turpie *et al., 1*999).

3.7 Appraisal of development applications

Property development is simultaneously of significant economic value and also one of the biggest threats to wetland fauna and flora in terms of habitat loss, exploitation, disturbance and pollution. Properties adjacent to any type of wetland tend to be more expensive (Boyer and Polasky, 2004), which means that the opportunity costs of protecting wetlands in urban areas are likely to be high.

The degree to which wetlands are developed affects the type of value they generate (e.g. direct versus indirect and non-use values), as well as their overall value (measured in terms of utility or economic contribution). As hypothesized for estuaries by Turpie *et al.* (2006a), with no development, a wetland would be expected to have little or no direct use value (e.g. perhaps a little derived by passing hikers), but high indirect and non-use value, owing to its high level of biodiversity and healthy functioning. Sensitive development around the wetland might add significant value in terms of direct uses such as ecotourism, while having negligible impact on biodiversity and ecosystem functioning. Thus overall utility or economic value would be raised. As development around a wetland progresses, direct use value increases, but its attributes and delivery of ecosystem services are likely to become somewhat impacted. Thus the total value of ecosystem goods and services may initially be enhanced by low levels of increased use, but would decrease again beyond a particular level. The point at which value is maximized would depend on the nature and relative magnitude of the two curves described in Figure 3.4.

In general, the values associated with conservation management would be the indirect and non-use values, plus the additional direct use value that would be secured by ensuring that use levels are sustainable. The latter would accrue mainly in the future.

Unlike planning, which is proactive and takes place at a regional or national scale, project appraisal is a reactive approach, which is used to evaluate the potential worth and impacts of proposed developments and identify ways in which potential environmental impacts can be reduced. Project appraisal usually involves some form of **Cost-Benefit Analysis** (CBA) and **Environmental Impact Assessment** (EIA). The findings of the environmental impact assessment may or may not be quantitatively integrated into the Cost-Benefit Analysis of alternative options.

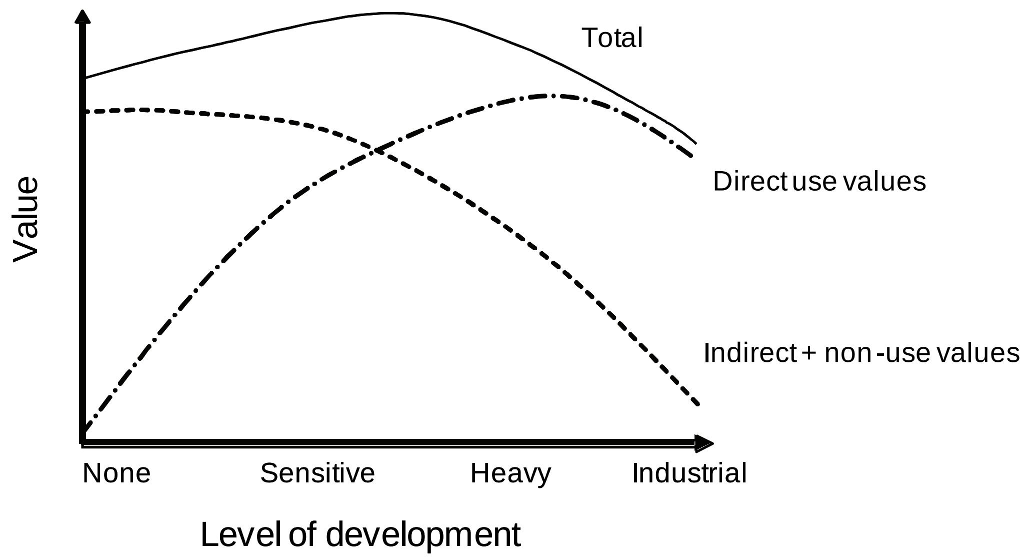

Figure 3.4: Hypothetical relationship between the level of development and the magnitude of direct versus indirect and non-use values provided by the ecosystem. Note that the shape of the total value curve is dependent on the relative scales of the other two curves, but is likely to be roughly hyperbolic and that the development scale could be logarithmic. (Source: Turpie *et al., 2*006a).

South Africa formally commenced EIAs in 1997, when regulations under the Environment Conservation Act, No. 73 of 1989, were promulgated. These regulations were replaced in 2006 by new EIA regulations set out under the National Environmental Management Act (NEMA).

The regulations contain procedures to be followed in the EIA process, including public participation, and they also specify “listed” activities that require either a basic or full assessment. The competent authorities mandated to consider and decide on applications under the regulations are the Department of Environment Affairs and Tourism DEAT[3], at a national level, and the nine provincial environmental departments. In considering an application, the competent authority is required to take into account several relevant factors, including the impact on the environment and measures to protect the environment or to prevent, control, abate or mitigate environmental impacts or degradation. There is much scepticism regarding the EIA process (Mosakong Management 2008). De Villiers (2007) and De Villiers and Hill (2008) assert that the EIA

[3] Note that the Forestry division of DWAF has since been incorporated into the Department of Agriculture, Fisheries and Forests, and Water and Environmental Affairs (DEAT) have been linked into a single Department of Water and Environmental Affairs (DWEA).

has been inadequate in stemming habitat transformation arising as a consequence of cultivation in areas of biodiversity importance.

While socio-economic impact studies have become commonplace in EIAs, the valuation of environmental impacts in EIA and CBA is still a voluntary process which is seldom applied (Leiman and Van Zyl, 2004), although guidelines for it are in place. It is argued that the inclusion of such studies in project appraisal would increase the efficacy of the process. Nevertheless, recognizing some of the shortcomings inherent in valuation, there is a strong move away from the CBA towards **multi-criteria decision analysis**, which allows some of the more intangible costs and benefits of alternative options to be assessed in non-monetary terms.

3.8 Strategic environmental assessment (SEA)

Strategic environmental assessment is a proactive means of evaluating options at a larger scale than project appraisal, but often using the tools of project appraisal (e.g. CBA). For example, SEA might be used to evaluate the potential economic costs of legislating for a 100m buffer zone around all rivers, or the impacts of development in one area versus another.

3.9 Monitoring and Natural Resource Accounting

The monitoring of ecosystem values is confounded by changes in context, such as changes in population, people's preferences, income levels, and the value of the Rand. Thus monitoring of the value of ecosystem services should ideally concentrate on monitoring the underlying biophysical characteristics that have been found to be key to the service provision, as well as the factors that contribute to the demand for the services provided by wetlands. The interpretation of the importance of these values will also be more important than the absolute values themselves. For example, it would be pertinent to monitor whether ecosystems are able to continue providing an important role in people's livelihoods, or whether this is being undermined due to a loss of ecosystem health.

Monitoring may be carried out at a number of scales. At the local scale, monitoring will be a necessary follow-up to water resource classification for determining whether Resource Quality Objectives (RQOs) are being met for all significant water resources for which the Reserve has been determined, or to observe the impacts of management plans or measures put in place for specific wetlands.

At a broader scale, the value of ecosystems is increasingly being monitored through some form of **Natural Resource Accounting**, which is affiliated with National Accounting systems.

The way in which ecosystem services should be monitored has yet to be worked out in detail. In South Africa, the development of Natural Resource Accounting is in its infancy. The first water accounts are available, which describe the supply, use and value of water resources, but there are no wetland accounts at this stage.

4. DETERMINING THE LEVEL OF DETAIL REQUIRED FOR A VALUATION STUDY

4.1 Introduction

Methods for the comprehensive and rigorous valuation of ecosystem services have become increasingly refined over the past decade. However, there is also growing pressure for the rapid estimation of these values, especially when large scale assessments are required or resources (money and skills) are limited. Rapid methods are increasingly being tested and applied, both for assessments in non-monetary terms (scoring approaches, e.g. Kotze *et al., 2*008) and for those in monetary terms (e.g. Van Zyl and Leiman, 2002), although usually at the expense of the confidence of the study results (Woodward and Wui, 2001). Because of the correlation between the quality of data and statistical analysis and accuracy of the output, there is an inevitable trade-off between minimising resources allocated to the problem and confidence in the results. It is therefore important to determine the level of confidence or certainty required for the decision-making process that the valuation study informs, as well as to ascertain the potential impact of the more rapid methods on the reliability of those results.

For the purposes of this protocol, the **comprehensiveness** of a study can be described in terms of its **scope** (coverage of different values i.e. how many ecosystem services and/or types of value it includes), the **extent of valuation** (how beneficiaries are defined and value expressed) and **accuracy** (or methodological rigour; Figure 4.1). These concepts are explained in more detail below, including their relationship to the geographic scale of the area to be valued. Thereafter, the typical expectations for different types (in terms of purpose) of valuation study are laid out.

4.2 Scope (coverage of values)

The scope of a valuation study is defined here as its completeness in terms of the extent of its coverage (how many ecosystem services and/or types of value it includes), and may range from a partial to a comprehensive valuation. A comprehensive valuation study will consider all provisioning, regulating and cultural ecosystem services, and all the components of Total Economic Value yielded by those services (see Table 2.2), and will also consider the opportunity costs involved in maintaining those outputs. At the other end of the scale, a partial valuation study may only concentrate on a single type of value of a single ecosystem service. It is generally accepted that some types of value are easier to estimate than others, with the level of difficulty generally increasing from the direct use values (such as grazing, fishing, tourism) to indirect use values (such as water purification) and non-use values (such as existence value). Studies that have partial coverage tend to concentrate on the direct use values, although this is not always the case.

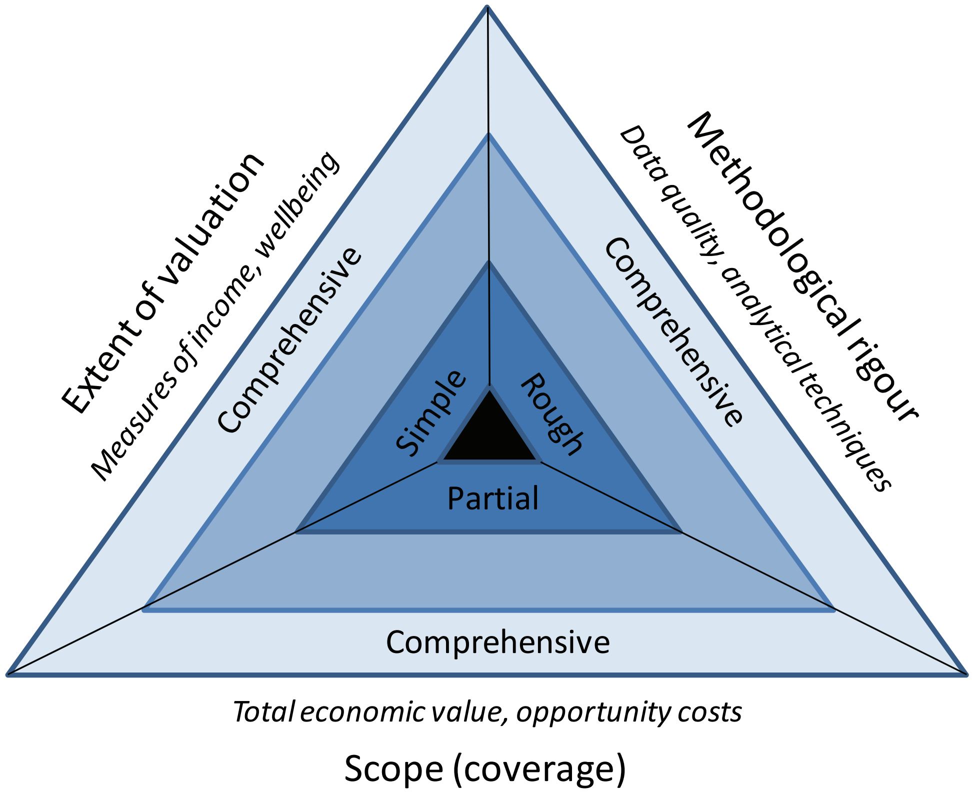

Figure 4.1: Three dimensions that define the comprehensiveness of a valuation study: scope (coverage of values), extent of valuation (measures of income, wellbeing) and methodological rigour (data and analytical techniques).

4.3 Extent of valuation (the way in which values are expressed, and to whom)

For market values derived from ecosystems, a comprehensive study might estimate the extent to which an ecosystem service contributes to Gross Domestic Product (GDP) or Gross Geographic Product (GGP), through estimation of direct and indirect contributions to national or regional income using macro-economic models (Table 4.1).

It might also investigate how much of that national or regional income accrues to lower income sectors of the population, using tools such as a Social Accounting Matrix (SAM)[4], and how the wetland(s) contribute(s) to people's livelihoods (e.g. using the Wetland Livelihood Value Index, Turpie 2010b). At their simplest, partial valuation studies might only estimate the direct gross income generated, such as the total revenue generated from fish sales. The difference between gross private value and net private value is the cost of offering the services involved; it will also exclude depreciation, interest, and taxes. This can be important if looking at a resource which is being harvested at an unsustainable rate, in which case the unsustainable part of the harvest should be treated as depreciation in some sense. Private value, like personal income, excludes taxes. Gross Domestic Product, on the other hand, includes them, while national income (which is disposable income) subtracts them.

Non-consumptive uses are challenging, because one has to estimate how much value should be attributed to the resource.

In the case of non-market values of intangible benefits (such as the feeling of wellbeing gained from knowing that a wetland is in good condition), all studies are bound to estimates of Willingness to Pay (Table 4.1) derived from stated preference methods (discussed in more detail in the final section).

It is important to distinguish between the geographic extent of the study area and the extent to which beneficiaries beyond the study area are considered (Figure 4.2). Beneficiaries can be considered up to a global level, even if the study is considering a single wetland. Nevertheless, there tends to be a positive relationship between the geographic scale of the study area and the scale at which beneficiaries need to be considered. It may be overkill to estimate the impact of a small wetland on GDP and employment, but this becomes increasing relevant as the size of the study area increases.

For any particular wetland, direct use values (such as resource use and property values) are normally considered at the local level, indirect use values (such as flood attenuation) at a broader scale, and non-use values (e.g. society's willingness to pay to conserve the wetland) at the broadest scale. The Okavango Delta is a good example of a single

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[4] **Social Accounting Matrix (SAM)** – an economic input-output model of the national economy, used as a tool for impact analysis. SAM expands the national accounts to show the linkages between production and generation and distribution of income.

wetland that yields resource use benefits at a local scale, flow regulation services at a regional scale, tourism value at a national scale and existence value at a global scale (Turpie *et al., 2*006b).

It is also important to consider that local scale benefits may incur regional scale costs, and vice versa. Thus the extent to which opportunity costs are investigated also has to be carefully considered.

Table 4.1: Different ways in which monetary values can be expressed

	Simple, local	**>>**	**>>**	**Comprehensive, national, global**
Direct consumptive use (e.g. harvesting of resources)	Gross private value (income from sales + value of subsistence use)	Net private value (total income less input costs, i.e. producer surplus, + buyers' consumer surplus)	Direct value added to GDP/GGP (total revenue less intermediate expenditure)	Gross (direct + indirect) value added to GDP/GGP (Previous + modelled estimate of multiplier effects)
Direct non-consumptive use (e.g. tourism)	Gross private value (tourist expenditure / gross income generated by tourism businesses)	Net private value (turnover less input costs, i.e. producer surplus, plus tourists' consumers' surplus)		
Indirect use (e.g. refuge service)	Gross turnover generated in surrounding area	Net income generated in surrounding area	Direct value added at regional / national scale	Gross value added at regional / national scale
Indirect use (e.g. water purification service)	Cost savings in terms of damage or replacement costs avoided			
Non-use (existence value of biodiversity)	Willingness to Pay (local)	Willingness to Pay (regional)		Willingness to Pay (national)

4.4 Methodological rigour

Data quality and depth of analysis are the most important determinants of the level of comprehensiveness of a study, in that they affect the level of certainty or confidence in the results.

The most comprehensive study will be based on statistically robust data which can cope with spatial and temporal variability in ecosystem and socio-economic parameters that influence value. At the other end of the scale, estimates may be used that have been derived from expert knowledge based on findings from other systems. The data quality aspect is the main determinant of the confidence level of the study.

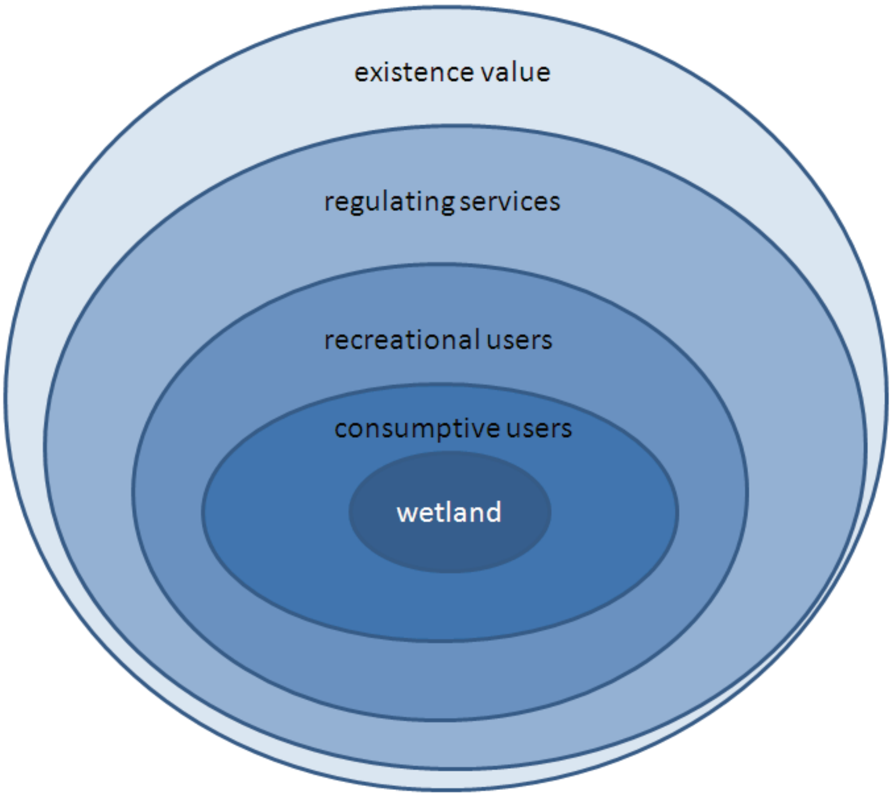

Figure 4.2: An example of how beneficiaries of different types of value might differ in their spatial distribution.

The depth of analysis determines the predictive ability of the outputs. The outputs of the most comprehensive study will be in the form of a robust dynamic model which allows the computation of marginal values[5] and is able to predict the consequences of changes in ecosystem condition or socio-economic circumstances. At the other end of the scale, a valuation study may only provide an estimate of the current average value. The latter has less reliability for extrapolation in time or place. As shown in Figure 4.1, methods may range from rapid (rough) to comprehensive estimates.

[5] **Marginal value** – change in economic value associated with a unit change in output, consumption or some other economic choice variable.

4.5 Effects of scope, extent and rigour on confidence

Methodological rigour is the primary determinant of the level of certainty or confidence associated with the results. Nevertheless, it is important to note that the level of confidence of rough or intermediate studies which involve some element of extrapolation or expert opinion is strongly related to the extent to which assessments have been carried out on similar systems elsewhere. Where few or no comparable data are available, rough assessments can have unacceptably low levels of confidence.

The scope and extent of the valuation affect confidence in as much as there is a danger of omitting important values or beneficiaries, or an important way of expressing value. For example, a study might produce a very accurate estimate of income derived from a wetland (which could be small), but fail to express how important that income is in the livelihoods of the surrounding community. Such omissions can lead to distorted decision-making.

4.6 Trade-offs between scope, extent and methodological rigour

Since resources for valuation studies are generally limited, increasing the scope of the study to include all types of value may come at the cost of the methodological rigour or extent of the valuation for one or more types of value. It may be necessary to put more effort into values that are considered more important, or in other cases it might be better to spread the research effort amongst all values.

There may also be a trade-off between data quality and depth of analysis. In other words, it is possible to develop simple predictive models with relatively few data and low confidence, but with the ability to produce rough predictions of the consequences of change.

The choice involved in these types of trade-offs will be dictated by the needs of the study. The level of confidence and the scope of the analysis limit the way in which the valuation results can be applied.

4.7 Effect of geographic scale of study area on comprehensiveness of the study

Valuation might be required for an individual wetland, wetlands within a small area, or at a catchment scale, regional scale or even national scale. The scale of the study limits the approach that can be taken, with larger scale studies having to adopt a more extrapolative or rapid approach (Figure 4.3).

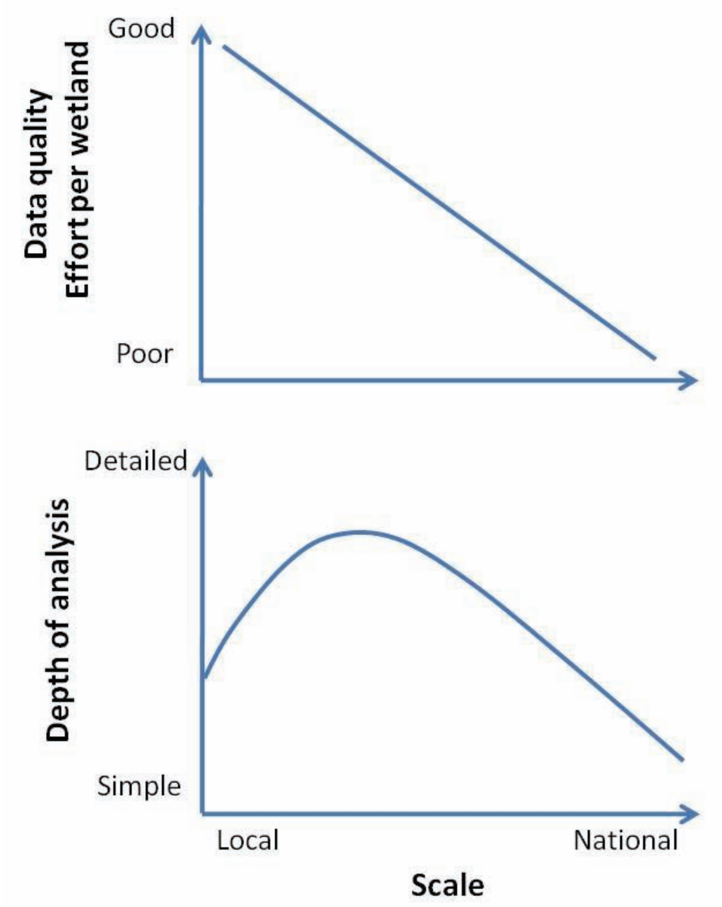

Figure 4.3: The relationship between geographic scale and data quality (effort possible per wetland) and depth of analysis.

At a local level, all available resources can be concentrated on the focal wetland, whereas at a broad scale, resources are stretched more thinly, data have to be collected at a broad scale (i.e. simple data) and the analysis will rely more heavily on assumptions and extrapolation. Nevertheless, analysis at a single wetland level is potentially limiting in terms of the depth of analysis possible (Figure 4.3). For example, if a good understanding of the relationship between resource use and community characteristics is required, then this will be better achieved by studying many wetlands at a catchment or regional scale. Again, there will be a trade-off when the number of wetlands increases to a point where it is no longer possible to sample comprehensively.

To achieve the same level of confidence, level of effort has to increase with scale of study.

4.8 Deciding on the scope, extent and rigour of the valuation study

At the outset of any valuation study it is necessary to align the methodology with the objectives of the study, and to define the scale and comprehensiveness of the study accordingly. All of these aspects are primarily determined by the purpose of the study, subject to budgetary constraints. Typical information requirements and likely scale of valuation studies carried out for different purposes, and the recommended scope, extent and rigour of the study are summarized in Table 4.2 and discussed in more detail below.

These should be seen as rough guidelines only. At this early stage of the development and application of wetland valuation studies in South Africa, it is not possible to advocate that a study for a certain purpose has to meet certain criteria in order for the decision to be valid, because limited information is often better than no information. As more valuation studies are undertaken, our understanding should deepen, and it may then be possible to be more prescriptive.

4.8.1 Geographic scale of study area

The scale of the study (in terms of size of primary study area) goes hand in hand with the purpose. For example, a conservation planning study will usually take place at a regional scale.

There are relatively few occasions where valuation is required at a national scale. This is mainly for lobbying purposes, e.g. for mainstreaming biodiversity issues into general policy, or for monitoring purposes such as natural resource accounting (Table 4.2). Conservation and resource allocation decisions occur at a regional or catchment scale, and assessments related to project appraisal, management and monitoring occur at a local scale, sometimes encompassing only part of a wetland.

Table 4.2: Typical information requirements and likely scale of valuation studies carried out for different purposes, and the recommended scope, extent and rigour of the study

Purpose of valuation	**Main information requirements**	**Likely scale**	**Scope (Coverage of ecosystem services and their values)**	**Extent (how values are expressed and the scale of beneficiaries)**	**Method-ological rigour**
Conser-vation lobby	Current value and opportunity costs, effects of degradation	Local to national	Complete	Economic net values (GDP / cost savings), societal willingness to pay, livelihoods	Rough or intermediate
Conser-vation planning	Current value and opportunity costs plus prediction of effects with or without conservation action	Regional	Complete	Economic net values, societal willingness to pay, livelihoods	Rough
Designing economic incentives	Analysis of demand for natural resources / features	Regional	Partial	Financial (private) and economic (social) net values	Rough or intermediate
Reserve deter-mination	Current value plus prediction under different flow scenarios	Catch-ment	Complete	Economic net values and social wellbeing	Compre-hensive
Strategic environ-mental assess-ment	Current value plus prediction under different policy scenarios	Regional, National	Complete	Economic net values and social wellbeing	Rough
Project appraisal	Current value plus prediction under different development scenarios	Local	Partial or Complete depending on criteria	Financial and economic net values	Intermediate or compre-hensive
Manage-ment plans	Current value plus prediction under different management scenarios	Local	Partial	Financial and economic net values	Intermediate to compre-hensive
Project level monitoring	Physical / social indicators and current value	Local	Partial	Local wellbeing (income etc)	Intermediate
National accounting	Physical / social indicators and current value	National	Tangible values only	Economic net values	Rough or intermediate

4.8.2 Scope or coverage

In most applications, it is desirable to value all ecosystem services as far as possible. A notable exception might be where there is a focus on a particular service that might be marketable, such as in the case of developing markets for ecosystem services. In reality, in local scale assessments, coverage is often partial due to the main political or investor interest in tangible aspects of value (e.g. profits, jobs generated). At a national scale, such as in the case of National Accounting, this is due to the sheer scale of the analysis being too large to be sufficiently resourced, leading to a trade-off between coverage and reliability. Where full coverage is desirable, Barbier (1994) suggests determining the major characteristics and values in terms of relevance to the study or contribution to overall value and ranking them, tackling most important values first and least important only if necessary. The recently developed tool "WET-EcoServices" (Kotze *et al., 2*008) can be used to assess the importance of ecosystem services provided by wetlands. It scores various ecosystem services according to the extent to which they are likely to be supplied by a given wetland and thus can be used as a useful scoping tool prior to a valuation exercise.

4.8.3 Extent of valuation

The way in which values need to be expressed is guided by the requirements of the decision-makers and also affects the amount of work involved in the valuation study. This factor is often linked to the level of the study, since values expressed in different ways are usually of the same order of magnitude. In other words, rough estimates can be expressed in simple ways, such as gross income generated, but more accurate estimates need to be expressed in the right 'currency', depending on the application. For National Accounting, the way in which values are calculated is particularly standardized. In other applications there is still considerable flexibility. If the results of different studies are to be comparable, then the values need to be calculated in the same way.

4.8.4 Methodological rigour

The information requirements of different types of decision processes dictate the level of comprehensiveness required, and hence the analytical methodology used, but only to a degree, because of increasing pressure to adopt relatively rapid methods. This is where the greatest guidance is required in the protocol for valuation methods, as provided in the following chapter.

The conservation lobby, where valuation studies began, usually has the simplest requirement, which is the provision of an estimate of current value provided by ecosystems (Table 4.2). The most well known example of this is Costanza *et al.*'s (1997) estimate of the value of the world's ecosystems. These assessments, like that of Costanza *et al.'s* (1997) estimate, do not have to be comprehensive in order to have the desired impact; they only need to be accurate to within an order of magnitude.

Similarly, regional scale conservation planning assessments can be guided by relatively rough estimates of value (e.g. Turpie and Clark, 2007). This is appropriate to the relatively coarse nature of the biodiversity data used, as well as the assumptions made about dealing with ecosystem functions and processes.

Reserve determination studies, on the other hand, result in the allocation of scarce water resources down to a fine scale. Because of the high levels of competition for these resources, the need for certainty is high, and there is pressure to undertake relatively comprehensive assessments of current value, and provide reliable estimates of how values change as a result of ecosystem changes under different flow scenarios. This can be fairly labour intensive at the scale required for these studies (catchments or Water Management Areas), however, and a relatively rapid method for this work is unavoidable. On the trade-off between coverage and comprehensiveness, it is likely that greater coverage will be desirable (spatial as well as types of value) at the expense of data quality, because of the upstream-downstream trade-offs that would become difficult to assess with patchy data.

Valuation studies that inform the design of incentive measures need not be overly data rich, but should cover all the potential factors that may affect demand. Ultimately, the system will have to be closely observed and managed adaptively.

Local scale studies for project appraisal, management or monitoring usually require intermediate to comprehensive levels of information if they are to be effective. In some cases, it is possible to eliminate options on the basis of broad-brush estimates, but where options compete more closely, it is desirable to have a high degree of certainty.

5. SELECTION OF VALUATION METHODS

5.1 Introduction

This section concentrates on the methods required to quantify and value key wetland services at different levels of comprehensiveness and at different spatial scales. Thus, once the scope and extent have been decided (i.e. which services and beneficiaries are to be considered and how values are to be expressed), the following can be used as a guide to design the methodological approach for each. Methods required for different expressions of monetary value are readily available in the literature and are not described here. Volume III (Turpie 2010b) deals with the assessment of value in livelihood terms, which places value in the context of household income and includes consideration of non-monetary benefits.

Guidelines are provided for the valuation of the following services:

- **provision of natural resources** (comprehensive valuation – local and catchment scale; rapid valuation – local, catchment and national scale);
- **flow regulation** (comprehensive valuation – local scale, with and without observed flow data; intermediate valuation – local scale; rapid valuation – local and catchment scale);
- **water treatment** (comprehensive valuation – regional scale; intermediate valuation – regional scale; rapid valuation – regional scale);
- **recreation and tourism** (comprehensive valuation – local scale; rapid valuation – local to regional scale);
- **scientific and educational value**, and
- **cultural, spiritual and existence value.**

The comprehensive methods suggested below are based on an in-depth review of existing methods and experience (Volume I; Turpie *et al., 2*010a) as well as experience gained in the case studies conducted for this project (Volume II; Turpie 2010a). Intermediate and rough assessments involve taking shortcuts for certain or all aspects of the comprehensive methodology. The reliability of extrapolation and expert opinion is highly dependent on the extent to which comprehensive assessments have already been carried out on similar services elsewhere.

5.2 Provision of natural resources

This section refers to the estimation of direct use values arising from the provision of water (for *in situ* use), wild foods and medicines, raw materials and grazing. The approaches used at different levels at a local scale are summarized in Table 5.1. The way in which methods can be simplified for broader scales and/or rougher assessments is discussed below.

The study should involve an ecologist as well as a resource economist, or resource economist with an ecological background. Experience in survey design and social survey methods is very important.

5.2.1 Comprehensive estimation – local scale

Comprehensive estimation of the value of provision of natural resources at a local scale (single wetland) entails the steps outlined below.

Step 1: Gathering of general information (existing sources, key informant interviews and focus group discussions)

General information is required on the wetlands and other variables pertaining to the socio-economic context and resource use. Of particular importance is the property rights setting, as value will be influenced by the amount and type of access allowed. Information gathered includes inputs, prices, trends, rules, players etc.

Step 2: Define the user community(ies)

Local communities have to be defined on the basis of estimated patterns and extent of use. Numbers of users can be expected to decrease with distance from a wetland, although some users (e.g. pastoralists) may travel considerable distances to a wetland. Thus information from the community is usually helpful in defining the community for sampling purposes. The heterogeneity of communities surrounding wetlands also has an important influence on how valuation studies are tackled, with greater heterogeneity requiring more sub-sampling. Census data (obtained from Statistics SA) can also be used.

Step 3: Description of the resource (field surveys and/or GIS)

The assessment should describe the nature of the wetland and its supply of utilized resources, including grazing capacity. The setting of the wetlands in question and availability of substitute resources should also be described.

Table 5.1: Methods required for valuation of the provision of natural resources at different levels of rigour

	Step	Comprehensive	Intermediate	Rapid
1	Obtain general information on socio-economic context and resource use, including prices etc.	Use existing data, key informant / focus group discussions	Use existing data, key informant / focus group discussions	Use existing data, key informant interviews
2	Define user community	Use map and census info, key informants	Use map and census info	Use map and census info
3	Describe wetland and supply of resources	Ecological assessment, key informants / focus group discussions	Key informants / focus group discussions	Infer from other studies / expert opinion
4	Quantify resource use	Survey of statistically representative sample of households	Key informants / focus group discussions	Literature / expert opinion
5	Estimate current net value	Household production models or enterprise models, macro-economic models or Social Accounting Matrices	Informed calculation, e.g. “bean methods”	“Back-of-envelope” calculation
6	Estimate change in value under alternative scenarios	Modelled response curves	Estimated response curves	“Back-of-envelope” estimation

Step 4: Gathering of quantitative data (household surveys)

Quantitative data on resource use and other variables affecting use and value (in a survey of a statistically representative sample of households) are gathered. The household survey includes questions on demographic data, agricultural activities and income, natural resource use and income, income from other activities, household assets and any other pertinent information.

Step 5: Estimation of the current net value of resource use

This involves statistical analysis of the data and estimation of values using simple spreadsheets, household enterprise models and/or appropriate macro-economic tools such as Social Accounting Matrices.

Step 6: Construction of predictive models

Resource use needs to be modelled as a function of socio-economic variables, access to and supply of resources, so that changes in value can be predicted as a result of changes in these drivers. This involves estimation of a demand function, and setting up an ecological-economic model to estimate overall use and value under scenarios of changing variables that affect either demand or supply. For example, one can consider the responses to changing resource abundance as a result of changes in environmental flows. If the user community is very small, it will not lend itself to statistical analysis, and users will have to be asked directly about scenarios.

5.2.2 Comprehensive estimation – catchment / regional scale

Application at a broader spatial scale involving multiple wetlands will entail a similar methodology to the above, except that it would require far more emphasis on the estimation of supply and demand, since these relationships will be used to estimate current values as well as values under alternative scenarios. Resources and resource use will have to be assessed over a greater area, requiring greater overall effort. Sampling strategies for wetlands and the user population could be entirely random, or could be stratified, depending on the level of heterogeneity involved.

5.2.3 Rapid estimation – local scale

A rough estimate at a local scale differs from a comprehensive estimate in that there is no household survey. However, it is assumed at this scale that a site visit is possible, allowing the opportunity for key informant interviews. Estimates may rely primarily on existing information from similar areas (benefits transfer), based on available data concerning the resource and its socio-economic context.

5.2.4 Rapid estimation – catchment or national scale

At a catchment or national scale, rough estimation will be purely a desktop exercise.

5.3 Flow regulation

Flood attenuation is probably the main flow regulation service provided by wetlands. Flood attenuation refers to the ability of a wetland to reduce the flood peak discharge in a river reach downstream of a wetland. The flood attenuation functions can be analyzed in terms of the inundated area, or water levels downstream of the wetland, during a flood event of defined return period(s). This requires determination of design flood discharges for the with-wetland and no-wetland scenarios in the downstream reach. This also requires conversion of these flood flow discharges to water levels, which requires some degree of hydraulic river modelling.

The other potential flow regulation service provided by wetlands is the maintenance of dry season flows through a combination of (a) temporary storage of water and (b) groundwater recharge.

Temporary storage is dependent on the permeability and porosity of the wetland soils, wetland vegetation (which provides resistance to flows and hence relates to above ground storage), wetland bathymetry and the relative size and location of the wetland within the catchment. Smakhtin and Batchelor (2005) in an analysis of observed flows at Rustenburg Wetland using regionalized flow duration curves to generate a reference "no-wetland" condition, estimated that the wetland may contribute to an approximate 13% increase in base flows over the reference "no-wetland" condition. However evidence at Nylsvlei indicates that the wetland generally consumes inflows, with outflows occurring far less frequently than inflows (Tarboton, 1989; Morgan, 1996; Higgins *et al., 1*996).

Although it has been widely asserted that wetlands provide a groundwater recharge service that ultimately helps to maintain dry season base flows in downstream areas, it is unproven and unlikely to be significant, if not to the contrary (R. Parsons, Parsons & Associates, pers. comm., 2008). Groundwater recharge is difficult to quantify without good data on inflows and outflows to the wetland, including all other losses to floodwaters, such as evapotranspiration, and additions, such as rainfall (i.e. a mass balance approach), or with monitoring boreholes in the region which can monitor changes in groundwater levels. Groundwater recharge can be estimated using less expensive methods relying on equipment such as the double ring infiltrometer or the Guelph Permeameter, but at a lower level of confidence, due to influences which may be beyond the reach of these methods, such as the positions of deeply located impermeable clay layers in the wetland sediments. Groundwater recharge and later supply to base flows may be the most difficult and expensive to estimate of the wetland services. Hence this aspect is not discussed in great detail in this report.

In the case of indirect use values arising from the flow regulation function of wetland ecosystems, values take the form of cost savings (in terms of engineering costs that would have to be incurred to replace the service, e.g. constructing levees to avoid flood damage, and constructing dams to provide water during the dry season) or damage costs avoided (if the wetland were lost and the service not replaced by an engineering solution, i.e. estimating the flood damage that would occur). The valuation approaches are accordingly termed either “replacement cost” or “damage cost” estimates. The latter provide the more realistic value estimate, but are more difficult to estimate. Replacement cost estimates are less reliable because they do not necessarily take into account the degree to which the service is actually demanded (or needed). For example, the ability of a wetland to attenuate floods will not have any value if there is nothing of value downstream.

The quantification of the function described in this section should only be carried out by an experienced engineer and/or hydrologist, due to the high levels of complexity and required knowledge of this type of modelling. A resource economist is required for the valuation component.

5.3.1 Study of a single wetland with observed flow data

If gauging data in close proximity to the upstream and downstream limits of the wetland, of sufficient length (preferably at least 20 years to include dry and wet periods but as long as possible to allow probabilistic analysis of floods) and of sufficient quality (preferably continuous flow data) are available, then these can be used to compare the wetland and no-wetland scenarios using hydrographs, flow duration curves and inundated areas (see Smakhtin and Batchelor, 2005). This is the preferred method as it relies largely on observed flow data with a minimum of simulation. Unfortunately only limited use of this method will be possible due to the general lack of gauging stations close to wetland inflow and outflow points.

The level of study using observed data depends on the length and quality of the observed flow data sets and the desired output of the downstream impacts data. For example if the observed data set is short (of the order of 20 years), then a reasonable estimate of the return period floods using probabilistic analysis of the annual flood peaks is limited to the

1:20 year flood and lower return periods. Higher return period floods can be estimated using a short data set but at decreasing levels of confidence as the return period increases.

Alternatively, an approach such as that adopted by Smakhtin and Batchelor (2005) can be used *in lieu* of design floods, where instantaneous maximum daily flows were analyzed in a separate data set using flow duration curves. In this instance the percentage exceedence by various flows will be indicated.

The level of confidence also depends on the amount of patching that may be required to fill in the gaps in the data. If any major tributaries contribute water to the river downstream of the wetland which should be accounted for, then this may require modelling of the flows or estimation of the flow regulation functions for a shortened reach, only as far as the tributary inflow point. A comprehensive study could include this aspect through modelling, while a rapid study might only determine the impact of the wetland as far as this tributary inflow.

The desired output of the downstream impacts data for valuation also has an influence on the level of comprehensiveness. For example for a rapid study, flood water levels might be estimated at a few sites only, using hydrological routing methods (such as the Muckingum method) and application of the Manning equation at a single cross-section at each site. An intermediate or comprehensive study might include a longer observed flow data set of say 50 years or more, as well as the application of hydraulic modelling throughout the river reach to map inundation areas for the entire reach for the wetland and no-wetland scenarios.

All three levels of study would use flow duration curves to describe the impact of the wetland on base flow maintenance. In a rapid study the flow duration curves could be estimated at sites downstream of the wetland outflow point, using hydrological routing methods, while in more comprehensive studies these may be routed using the hydraulic model set up for the estimation of the flood attenuation function.

The methods are summarised in Table 5.2 and described in more detail below.

A: Setup

Step 1: Define the study area, including wetland and downstream extent of influence

This entails identifying the potential extent of influence on base flows and flood risk downstream, which will be confirmed by the study. If base flows are likely to be influenced by groundwater recharge in the wetland, this requires careful consideration of whether and where base flows might be augmented (or diminished) downstream.

Table 5.2: Estimation of the flow regulation value of a single wetland with observed flow data available

	Step	**Comprehensive, intermediate or rapid study**
A	Setup	
1	Define study area, including wetland and downstream extent of influence	Identify/estimate potential extent of influence on base flows and flood risk downstream, to be confirmed by study
2	Describe present day wetland flows	Present day wetland flows are described through analysis of observed flows at wetland outflow point
3	Estimate flows under no-wetland scenario	Use (a) rainfall-runoff model, (b) flood routing methods, or (c) regionalized flow duration curves (see Smakhtin and Batchelor, 2005)
B	Estimate capacity of the system for maintaining base flows	
4	Estimate change in base flows relative to the "wetland" scenario	Analyze the flows through inspection of the long term time series, determination of statistical descriptors and flow duration curves for the with- and without-wetland scenarios
C	Estimate flood attenuation capacity	
5	Analyze flows of with-wetland and no-wetland scenarios	Analyze the flows in the two scenarios at the wetland outflow point probabilistically, to determine design flood discharges, or alternatively use flow duration curves of daily instantaneous peak flows
6	Convert design flood discharges to water levels and extent of inundated areas	Comprehensive / intermediate: Use a suitable hydraulic river model such as HEC-RAS to map inundated areas Rapid: Use hydrological routing methods and application of Manning equation at a few single cross-sections to determine water levels
7	Estimate change in risk of downstream flooding	Compare flood peaks and inundation areas for wetland and no-wetland scenarios
D	Valuation	
8	Estimate the value of any additional base flow due to wetland	Estimate willingness to pay for water in the region or calculate net value based on use and productivity data
9	Estimate the cost savings associated with reduced flood risk	Costs avoided; use an insurance valuation approach based on land-use and infrastructure

Step 2: Describe present day wetland flows

The current flows are described through analysis of the observed flows at the wetland outflow point. If significant tributary inflows occur between the wetland and the downstream study area then observed data or hydrological modelling of these inflows will also be required.

Step 3: Estimate the flows under a no-wetland scenario

The following methods are then used to simulate the downstream flows after the wetland is removed from the model (Smakhtin and Batchelor, 2005).

a) Using hydrological rainfall-runoff modelling calibrated using the observed flows, and a wetland or reservoir module within the rainfall-runoff model, to model the wetland portion (requires good rainfall data, observed flow data for calibration, catchment development data, data on wetland volume and surface area and delineation of the catchment), remove the wetland from the rainfall-runoff model and re-run to obtain the no-wetland flow regime.

b) Flood routing (requires observed flow data at a detailed temporal resolution). Remove the wetland from the flood routing model by adjusting the parameters of the model.

c) Produce flow duration curves (Smakhtin and Batchelor, 2005). Remove the wetland through hydrological regionalization, combined with spatial interpolation of stream flow records, using regionalized flow duration curves, consisting of three steps:

- estimation of a regional non-dimensional flow duration curve;
- calculation of the actual flow duration curve at the required site by multiplying the non-dimensional curve by the long term mean discharge at the site, and
- conversion of an actual flow duration curve at a site into a continuous stream flow hydrograph using a spatial interpolation technique.

B: Estimate capacity for maintenance of base flows

Step 4: Route wetland and no-wetland long term time series to points of interest downstream

Using hydrological routing methods or the hydraulic river model set up for the flood attenuation function, route the long term flow time series downstream to the points of interest. Analyze the flows at the points of interest through inspection of the long term time series, determination of statistical descriptors and flow duration curves.

C: Estimate flood attenuation capacity

Step 5: Analyze the flows of the wetland and no-wetland scenarios to determine design flood discharges

Analyze the flows in the two scenarios at the wetland outflow point probabilistically to determine design flood discharges. The accuracy of these will depend on the length of the flow record used and the temporal resolution of the flow data, and it may only be possible to estimate design floods for fairly short return periods.

Step 6: Convert design flood discharges to water levels and/or extent of inundated areas

Using hydrological routing and the Manning equation for a rapid study, or hydraulic river modelling for an intermediate or comprehensive study, produce projected water levels and/or maps of inundated areas. Compare the extent of inundated areas under the wetland and no-wetland scenarios.

D: Valuation

Step 7: Once the changes in base flow patterns and flood risk have been ascertained, these are valued as follows

Estimate the value of any additional base flow due to the presence of the wetland. Change in base flow due to the wetland should be valued in terms of society's willingness to pay for that water. This can be derived by estimating the replacement costs of water lost or the opportunity cost of the water in terms of the net value of outputs that are forgone (Box 3).

Step 8: Estimate cost savings of reduced flood risk

The value of the flood attenuation function depends on land-use and infrastructure in the area at risk downstream. At the local scale, these can be assessed using detailed maps or on-the-ground assessment. The capital value of infrastructure and the productive value of agricultural lands need to be estimated. The value estimate should approximate the change in insurance premium that would be paid under the flood risk in the wetland and no-wetland scenarios.

5.3.2 Study of a single wetland without observed flow data at wetland limits

If suitable gauging data are not available (as is usually the case), then modelling will be required to determine the flow regulation services delivered by a wetland to downstream areas. The confidence level associated with the estimates produced, decreases somewhat, due to the lack of observed data for calibration. The methods are summarized in Tables 5.3, 5.4 and 5.5 and described in more detail below for each level of study: comprehensive, intermediate and rapid, for either local (i.e. reach scale) or regional scale, such as catchments or national scale.

Table 5.3: Methods required for estimation of the flow regulation value of a single wetland at different levels of study detail, in the absence of upstream and downstream gauging data

	Step	Comprehensive	Intermediate	Rapid
A	Setup			
1	Define study area, including downstream extent of influence and scale of modelling	Sub-quaternary catchment scale (tributary scale)	Quaternary catchment scale	Quaternary catchment scale
2	Obtain hydrological information	Set up hydrological model of catchment and study area. Use standard design flood methods for design flood determination.	Use simplified methods using quaternary runoff flows scaled from observed flows. Use standard design flood methods for design flood determination.	Use simplified methods using quaternary runoff flows scaled from observed flows. Use standard design flood methods for design flood determination.
3	Set up a model of the wetland and downstream reach	See details in Table 5.4: 1-D or 2-D hydraulic model	See details in Table 5.4: 1-D hydraulic model	See details in Table 5.4: flow routing model
4	Construct a no-wetland version	Remove wetland from hydraulic model	Remove wetland from hydraulic model	Remove wetland from flow routing model
B	Estimate the capacity of the system for maintaining base flows			
5	Produce an inflow time series (continuous)	Use at least 20 years of sub-daily or daily data	Use at least 20 years of daily data	Use at least 20 years of daily data
6	Estimate evaporative and infiltration losses and rainfall inputs	See text	See text	See text
7	Estimate change in base flows relative to the "wetland" scenario	Produce time series, statistical descriptors and flow duration curve(s) for wetland and no-wetland scenarios	Produce time series, statistical descriptors and flow duration curve(s) for wetland and no-wetland scenarios	Produce time series, statistical descriptors and flow duration curve(s) for wetland and no-wetland scenarios

C	Estimate flood attenuation capacity			
8	Calculate design flood hydrographs for each quaternary catchment	Use 3 or more return periods, e.g. 1:20, 1:50 and 1:100	Use 2 return periods, e.g. 1:50 and 1:100	Use 1 return period, e.g. 1:50
9	Route design flood(s) through the system, for wetland and no-wetland scenarios	Unsteady hydrodynamic modelling (1-D or 2-D)	Unsteady hydrodynamic modelling (1-D)	Flow routing modelling
10	Estimate change in risk of downstream flooding	Compare flood peaks, plot inundation areas for wetland and no-wetland scenarios	Compare flood peaks, plot inundation areas for wetland and no-wetland scenarios	Compare flood peaks and levels at defined sites
D	Valuation			
11	Estimate the value of any additional base flow due to wetland	Estimate willingness to pay for water in the region or calculate net value based on use and productivity data		Impute a value using average productivity of water
12	Estimate the cost savings associated with reduced flood risk	Costs avoided; use an insurance valuation approach based on land-use and infrastructure		Damage costs avoided; obtain expert opinion on values

Each level of study can be done at different scales. All three can be used at a local scale (i.e. at a reach scale). For a catchment or national scale less comprehensive methods would generally be required, due to the presence of multiple wetlands and the cost implications associated with conducting a study on so many wetlands.

Comprehensive study at a local scale

A: Setup

Step 1: Define study area and downstream extent of influence

The flood attenuation functions can be analyzed in terms of the inundated area downstream of the wetland during a flood event of defined return period(s). This requires determination of design flood discharges for the wetland and no-wetland scenarios in the downstream reach. This also requires conversion of these flood flow discharges to water levels, which requires some degree of hydraulic river modelling.

Table 5.4: Inputs used in setting up the river and wetland model (Step 3 in Table 5.3), according to the level of assessment

Input	Comprehensive	Intermediate	Rapid
a. Choice of hydraulic or flow routing modelling software package	Two-dimensional hydraulic such as Mike 21 or one-dimensional hydraulic such as HEC-RAS (dependent on wetland characteristics)	One-dimensional hydraulic such as HEC-RAS	Flow routing (such as HEC-HMS) in conjunction with determination of water levels at selected points
b. Source of terrain data	Surveyed or LiDAR data	Digital contour data from Chief Directorate: Surveys and Mapping	Cross-sections from digital contour data or paper maps at points of interest
c. Inclusion of in-stream structures such as dams and bridges	Include all	Include major in-stream structures and dams	Include major dams or storages
d. Resolution of hydraulic resistance values or flood routing parameters	Estimate hydraulic resistance values on the basis of an in-depth study of the floodplain	Use different hydraulic resistance values for floodplain and channel (preferably) or single value for both based on field study	Estimate routing parameters using expert judgement
e. Observed flow or stage data at points in wetland or river for calibration	Used for calibration if present	Used for calibration if present	Used for calibration if present

Table 5.5: Data required on, and methods involved in estimating, inflows and losses of water for different levels of assessment (Step 4 in Table 5.3)

Input	Comprehensive	Intermediate	Rapid
Resolution of inflow time series	Daily or sub-daily	Daily	Daily
Derivation of daily inflow time series	Use daily inflows derived from a daily hydrological model such as ACRU	Use scaled observed flows using ratios of Mean Annual Runoff (MAR) or use daily inflows derived from a daily hydrological model such as ACRU	Use scaled observed flows using ratios of MARs
Inclusion of evapotranspiration and rainfall in the hydraulic model	Estimate using pumps or other available method, depending on software	Estimate using pumps or other available method, depending on software	Include by subtracting and adding to inflow time series, or ignore
Inclusion of infiltration and ponding losses	Determine these and include in a uniform fashion using pumps or other available method, depending on software	Determine these and include in a uniform fashion using pumps or other available method, depending on software	Ignore

Step 2: Set up a one-dimensional or two-dimensional hydraulic model of the wetland, depending on the complexity of the wetland topography (Table 5.4)

Two-dimensional hydraulic modelling can be done using a hydraulic modelling package such as DHI Water and Environment's Mike 21 or the University of Alberta's River2D, and requires considerable computing power. If flow through the wetland is not complex, a one-dimensional model such as HEC-RAS may be acceptable. In this case a one-dimensional hydraulic model would be preferable due to the savings in the work required for setup and running of the model. The hydraulic model setup requires information on bathymetric data, structures located in the wetland and river reach, hydraulic resistance values (see Box 1) and boundary conditions describing the wetland.

- A detailed **bathymetric study** of the wetland is required to estimate the shape and volume of the wetland. If a comprehensive assessment is being undertaken, then it is recommended that a spot shot survey by a surveyor (only feasible for small wetlands) or an airborne survey using light detection and ranging (LiDAR) is conducted, to generate a high resolution contour map.
- Any **structures** in the study area such as dams and bridges that have a significant effect on flows or water levels need to be incorporated.
- Estimation of hydraulic resistance **values** by an experienced engineer or hydraulician (see Box 1).

Step 3: Setup a hydraulic model of the downstream river reach.

Step 4: Construct a no-wetland version (Table 5.5)

Remove the wetland from the hydraulic model by changing the wetland section to a canal or other engineered conduit, or by changing hydraulic resistance values, depending on what kind of scenario is most appropriate to the threats facing the wetland. The canal option effectively 'removes' the wetland most completely, while the change in resistance value might simulate a change in land-use, such as conversion of the wetland to agricultural land or a golf course, with a reduced resistance to flow.

B: Estimate capacity for maintenance of base flows

Step 5: Produce an inflow time series

Use daily hydrological modelling to determine daily inflow time series for all tributaries that feed into the wetland / river system / study area represented in the hydraulic models.

Box 1: Hydraulic resistance values

The selection of appropriate hydraulic resistance values for a river or wetland reach is crucial to obtaining reasonable results from a model. The selection of hydraulic values should only be done by an experienced engineer or hydraulician. Unfortunately, not much information is available in the literature on appropriate hydraulic resistance values for wetlands.

Open channels
References such as Chow (1959), Hicks and Mason (1991) and Arcement and Schneider (undated) have been traditionally used to aid in the Manning's resistance determination for open channels. Hirschowitz *et al*. (2007) include in their report a pictorial guide to resistances determined at various river sites in South Africa, published in a Microsoft Access database that includes photographs and various other relevant information. This is the recommended reference to use for river reaches in South Africa.

Wetlands and floodplains
Wetland resistances depend to a large degree on site specific factors, and resistances for open channels cannot be extrapolated to wetland environments. Kadlec and Knight (1996) provide an example of where the traditional open channel method (French 1985) to calculate the Manning's resistance value for a channel, using the maximum values for all components, will result in a value of 0.29, which is approximately an order of magnitude less than measured values for constructed wetlands.

Manning's *n* values are strongly depth dependent due to the complexity added by emergent vegetation. Kadlec and Knight (1996) include a summary of Manning's resistance values from various studies for constructed wetlands. The Manning's resistance values from the studies vary from 0.1 to greater than 50. They present two general curves for dense and sparse emergent vegetation in constructed wetlands for North America, based on various experimental data.

Jordanova and James (2007) present an alternative resistance equation for emergent vegetation. For reed beds, it is recommended that in the absence of better resistance information in a wetland, the reed diameter and spacing is estimated, and the resistance is calculated using the equation of Jordanova and James (2007), and then that resistance is converted to the equivalent hydraulic resistance, using the conversion functions published in a Microsoft Excel add-in by Hirschowitz *et al*. (2007).

Step 6: Estimate losses and rainfall inputs

Evaporation, infiltration and ponding 'losses' can be significant in wetland and floodplain environments (Birkhead *et al., 2*007). Estimation of these losses involves the following steps (summarised in Table 5.5).

- Determination of the daily inundated area will be required to estimate losses. In 1-D models, an inundated volume – inundated area relationship can be derived, which can be used to predict inundated areas for long time series, based on inundated volume, which is a possible output from 1-D models.

- Evaporation losses can be estimated using daily inundated area and evapotranspiration rates for wetlands in the area. Evapotranspiration rates for wetlands are generally not available and hence observed evaporation data from a nearby weather station (Symons or A pan) or published data for the relevant quaternary catchment from WR90 (Midgley *et al., 1*994) or WR2005 (Middleton and Bailey, in press) can be used instead. Pan evaporation data will need to be adjusted to account for the difference between evaporation from a pan and from a wetland – the pan measures open water evaporation (Midgley *et al., 1*994; Middleton and Bailey, *in press*) and can be used as a first approximation, although it should be borne in mind that significantly lower pan factors were determined for Nylsvlei (Birkhead *et al., 2*004).
- Infiltration losses, if known, should be included as a function of inundated area.
- Ponding losses will automatically be accounted for in a 2-D model. In a 1-D model they will need to be estimated.

Rainfall can be taken into account using daily observed data from a nearby rain gauge and the daily inundated area. The addition and losses of water should then be distributed through the model according to inundated area.

Step 7: Produce flow duration curve(s) and determine statistical properties of flow time series, such as mean annual runoff (MAR), coefficient of variation (CV) and minimum base flows for the wetland and no-wetland scenarios.

C: Estimate flood attenuation capacity

Using the hydraulic model setup in the Setup phase (Phase A, Table 5.2), the following steps are used to estimate the flood attenuation capacity of a wetland.

Step 8: Calculation of design flood hydrographs

Calculate design flood hydrographs for each tributary that enters the study area. The recommended method for the determination of the design flood hydrographs is the Unitgraph method (Midgley, 1972; HRU, 1973; see Box 2). This has a relatively low data input requirement and is widely used in South Africa for design flood determination. It is a method that is familiar to hydrologists and engineers, and because it is widely used for other studies such as those done for dams, the outputs from these wetland services studies can be used in comparisons with other competing projects that would perhaps transform or affect the wetland. A recent review of the Unitgraph method can be found in Cullis *et al.* (2007).

Step 9: Route design flood(s) through the system, under both the wetland and no-wetland scenarios

Route the design flood hydrographs through the hydraulic model under a "wetland" and then "no-wetland" scenario, and through a hydraulic model of the river reach downstream using unsteady hydrodynamic modelling.

Box 2: Summary of the Unitgraph procedure for calculating design flood hydrographs

Rainfall arising from a storm event uniformly covering the entire catchment, including areas upstream and downstream of the wetland, is used for the calculation of the design rainfall, to ensure that the correct return period for floods in the entire catchment is used. In other words, the rainfall event is chosen to correspond with a certain flood return period, e.g. 1:50 years.

1. Calculate the design rainfall for each tributary catchment. Choose several relevant rainfall gauges in or close to the study area which are listed in "Long duration rainfall estimates for South Africa" (Smithers and Schulze 2000).
2. Calculate or select the relevant catchment characteristics required for the method, including the length of the longest water course, slopes, veld zone type and lag coefficient. Calculate the basin lag and distance to catchment centroid from the outflow point. This can be done using 1:50 000 topographical maps or in a GIS package.
3. Decide on a range of critical storm durations, taking into account the basin lag.
4. Apply the factor of 1.11 recommended by Adamson (1981) to convert design rainfalls based on daily observed rainfall data (starting and ending at 08:00) to any 24 hour period. For sub-daily durations, apply the factors recommended by Adamson (1981) to the 24 hour design rainfalls calculated previously.
5. Apply the "Thiessen polygon method" (Thiessen 1911) to obtain design rainfalls for the entire catchment for each return period and storm duration.
6. Apply an area reduction factor to account for aerial variations in rainfall between single rain gauges and a catchment. Area reduction factors are given by Alexander (1990).
7. Include storm losses using veld zone and duration.
8. Multiply the design rainfalls for the entire catchment by the ratio of the mean annual precipitation (MAP) of each quaternary into which the tributary falls to the area-weighted MAP of the entire catchment, to ensure that high rainfall areas receive more storm rainfall than dry areas, as would be expected in reality. Quaternary catchment MAPs are available in WR2005 (Middleton and Bailey, *in press*) and WR90 (Midgley *et al., 1*994), and the entire catchment's MAP can be calculated using an area-weighted approach.
9. Use the programme HDYPO1 or a spreadsheet employing the same methodology (HRU 1973) to calculate the hydrographs for each catchment at a range of storm durations.
10. Route the hydrographs through the study area, using a flow routing method or a programme such as HEC-HMS, to estimate which duration gives the worst case storm.
11. Select the worst case storm hydrographs for input to the hydraulic model.

Step 10: Estimate change in risk of downstream flooding

This involves plotting maps of inundated areas in the river reach downstream of the wetland for both scenarios, for each design flood return period. This is followed by comparison of inundated areas and flow hydrographs, for each return period design flood in the river reach downstream of the wetland. Finally, it is necessary to determine changes in return period of design floods, at points on the downstream river reach, due to the presence of the wetland, in order to determine the change in risk caused by the presence or absence of the wetland.

Box 3: Estimating the value of water

There is no standard way of valuing water runoff or changes in water runoff. Several approaches have been used in South Africa, which can be broadly categorized into two groups: replacement cost approaches and opportunity cost approaches. Replacement cost approaches entail the valuation of water or water losses in terms of the costs of buying water from state water supply schemes (average bulk water costs; Hosking and Du Preez 1999), or in terms of the higher costs of supplying that water from planned future supply schemes in the area (van Wilgen *et al*.1997, Marais 1998, Higgins *et al., 1*997, Turpie and Heydenrych 2002).

Opportunity cost approaches entail valuing water or water losses in terms of the opportunity cost of water forgone to downstream uses, or the value that use of this water could have added to national income. This could be in terms of direct use, such as in agriculture, or indirect use, through provision of goods and services by downstream aquatic systems. Hassan (2000) used the value forgone in irrigated agriculture as a proxy for the full social cost of water losses due to plantation forestry.

In a similar approach, water has also been valued using the average value added to the economy per unit of water used, multiplied by the proportion of total available water used (CSIR 2001, King and Crafford 2001, de Wit *et al., 2*003, DWAF 2004). This approach has emerged due to the valuation of water for the purpose of Natural Resource Accounting (NRA; CSIR 2001, King and Crafford 2001). NRA is increasingly recognized as a standardized and defensible technique for water valuation, both in South Africa and globally (CSIR 2001, King and Crafford 2001, DWAF 2004), and the valuation of water losses due to changes in catchment vegetation (van Wilgen *et al., 2*004, de Wit *et al., 2*003). This method links water use and supply data to established National Accounting methods, by estimating the value added (VAD) per m^3 of water to recognized economic sectors (King and Crafford 2001, van Wilgen *et al., 2*004).

Hassan and Farolfi (2005) estimated the economic cost of the Ecological Reserve, in terms of the value of the forgone water resources, for part of the Olifants River catchment, where use was primarily for agriculture (70%). As is generally the case, consumers paid rates that were less than the market price of water. The current water allocation not only deviated from economic efficiency principles in this way, but also had another social cost, in that the total water requirements exceed the water supply (yield), with the deficit supplied at the expense of the Ecological Reserve. This loss could be valued in terms of the value of ecosystem services lost. Ideally, the benefit of meeting the Reserve (in terms of ecosystem service value) should at least equal the net social loss, or the opportunity cost of the water allocated to meet the Reserve. Hassan and Farolfi (2005) provided a framework for estimating this opportunity cost, by estimating the marginal opportunity cost of a unit of water. They estimated an opportunity cost of R1.71 for every m^3 of water withdrawn from economic activity for environmental protection.

D: Valuation

Once the changes in base flow patterns and flood risk have been ascertained, these are valued as follows.

Step 11: Estimate the value of any additional base flow due to the presence of the wetland

Change in base flow due to the wetland should be valued in terms of society's willingness to pay for that water. This can be derived by estimating the replacement costs of water lost, or the opportunity cost of the water in terms of the net value of outputs that are forgone (Box 3).

Step 12: Estimate cost savings of reduced flood risk

The value of the flood attenuation function depends on land-use and infrastructure in the area at risk downstream. At the local scale, this can be assessed using detailed maps or on-the-ground assessment. The capital value of infrastructure and the productive value of agricultural lands need to be estimated. The value estimate should approximate the change in insurance premium that would be paid under the flood risk in both the wetland and no-wetland scenarios.

Intermediate study at a local scale

The same approach is used as described above for the comprehensive level of study, but a number of shortcuts may be employed, as described below and in Table 5.3.

At the intermediate level, a **one-dimensional hydraulic model** can be used throughout the study area in order to reduce the input data requirements and run times. It is recommended that the hydraulic model is set up using HEC-RAS and HEC-GeoRAS (Box 4), interfacing with a GIS package such as ArcMap. These programmes, developed and maintained by the United States Army Corps of Engineers, Hydrologic Engineering Centre, are widely used and free to download from the internet[6]. HEC-RAS and HEC-GeoRAS were used to model the Nylsvlei floodplain and Mogalakwena River in this project (Kleynhans *et al., 2*010).

Alternatively, other one-dimensional hydraulic modelling programmes such as the Danish Hydraulic Institute's (DHI) Mike 11 or Wallingford Software's Infoworks can also be used, as long as the relevant software is available for the mapping of inundated areas. Various other pre- and post-processing software exists for use with HEC-RAS which can be used in place of HEC-GeoRAS and ArcMap. An example of an alternative programme is Boss International's RiverCAD, which interfaces with HEC-RAS and can also perform floodplain mapping.

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[6] http://www.hec.usace.army.mil/

Box 4: HEC-RAC and HEC-GeoRas in a nutshell

HEC-RAS is a water surface profiling computer programme capable of simulating both steady and unsteady one-dimensional flow (USACE 2002). The programme can be used to perform hydraulic analysis of channel networks, dentritic systems, or a single river reach. In order to perform the hydraulic calculations, the HEC-RAS programme requires the definition of the flow data for the hydrological events, the land surface, major obstructions (such as bridges, culverts, and weirs) along with boundary conditions, friction coefficients and other parameters. The land surface data include the geometric data representing river networks, channel and floodplain cross-section data.

The preparation of the land surface data can be completed with the aid of HEC-GeoRAS (USACE 2000). HEC-GeoRAS is a pre- and post-processing GIS software package that runs in conjunction with ArcView or ArcInfo GIS software. Pre-processing involves preparing GIS data for import into HEC-RAS from a triangulated irregular network (TIN) topographic model. Post-processing involves the generation of GIS data from HEC-RAS programme output.

HEC-RAS and HEC-GeoRAS include excellent user manuals and documentation.

5.3.2.1 Bathymetry data

Instead of obtaining detailed **bathymetry** data, coarse terrain data with a vertical resolution of 5m or 20m can be used for rapid and cost effective setup of the hydraulic model. Data are available for parts of the country at 5m contour intervals, and for the rest at 20m contour intervals. These can be obtained from the Chief Directorate: Surveys and Mapping. It is also recommended that structures in the study area such as dams and bridges be ignored, unless it is likely that they would have a significant effect on storage upstream (thereby attenuating flows) or on water levels. However, if the budget is available, then these structures should be included.

5.3.2.2 Inflow time series

Time series data for each quaternary catchment outflow point can be determined without detailed daily hydrological modelling, by using observed data available from a gauging station(s) located within or near the study area. The time series may need to be patched, and scaled to each quaternary catchment. Scaling was done in Kleynhans *et al.* (2010) using ratios of MAR figures, which are available in WR90 for quaternary catchments.

The use of quaternary catchments simplifies the process by obviating the need to delineate catchment areas and making use of readily available data, such as MAR figures used for scaling flows.

5.3.2.3 Valuation approach

Contribution to base flows can be estimated using imputed values. For valuation of the flood attenuation function, the same approach would be followed as for the comprehensive methodology.

5.3.3 Rapid estimation at a local scale

The same approach is used as described above for the comprehensive and intermediate methods, but some extra shortcuts may be employed, as described below and in Table 5.3.

At the rapid level, the use of hydrological routing methods (such as the well known Muskingum method) employed in programmes such as HEC-HMS can be used. The parameters required for the routing equations for the wetland and no-wetland scenarios would need to be estimated using expert judgement and analysis of observed flows in nearby rivers, if the data and budget are available. In order to translate flows into estimates of flood levels, which are required for the determination of the flood attenuation services a wetland performs, certain key points could be chosen along the river reach where cross-sections of the river valley would be determined. The cross-sections would be determined from available mapping data, and with the use of Manning's equation a water level could be estimated. This could then be extrapolated to give a ballpark idea of inundation areas in that vicinity.

Valuation of base flows can be estimated using available data on the value of water in different uses, or even the average price of water. As long as the flood risk is represented spatially, the flood attenuation value can be estimated using the costs avoided approach. However, a rapid methodology might rely on expert opinion of the value of land and infrastructure.

5.3.4 Rapid estimation at a catchment or regional scale

It may not be possible to produce a satisfactory estimate of the contribution of wetlands to base flows using rapid methods at a broad scale, and a rapid study is unlikely to require estimation of a function that is unlikely to be significant.

The flood attenuation capacity of wetlands can be estimated at a catchment scale by estimating their effect on a flood hydrograph and scoring the potential for damage downstream, rather than attempting to plot flood lines. This involves estimating the volume or water holding capacity of wetlands in each catchment. Estimates can be made on the basis of data or assumptions on wetland types and depths, and these estimates may be refined using GIS data on soil quality. The effectiveness of the wetlands in regulating flows will be assessed by routing design flood hydrographs (probably 1:20 years) through the "lumped" wetland storages for each catchment to estimate attenuation (expressed as a percentage of flood peak).

The most practical way to produce a rough valuation of the flow regulation function is using the Replacement Cost method. In this case the engineering solution to replace the service would be the construction of dams of equivalent capacity. Demand for the service can be assessed based on GIS data on downstream land use, showing infrastructure and population density. Rather than using an area of constant width around downstream rivers, the potentially affected area can be modelled in a GIS package, by calculating the area less than a given height above the river channel for a reasonable distance downstream. In this way, the value of the service can be estimated by modifying the replacement cost for the service by a score indicating the downstream demand for flood control.

5.4 Water quality amelioration

Removal of **sediments, nutrients, pathogens and other pollutants** is considered together as water treatment because these substances are interrelated, require a similar approach and can be quantified together[7]. All of these issues are addressed in the treatment of water for domestic use. As is the case for flow regulation, the indirect use values arising from the sediment retention and water treatment functions of wetland ecosystems are valued in terms of cost savings (engineering costs that would have to be incurred to replace the service), or damage costs avoided (if the wetland were lost and the service not replaced by an engineering solution), with the latter providing a more realistic value estimate. Replacement cost estimates are easier but less reliable because they do not necessarily take into account the degree to which the service is actually demanded (or needed).

For these functions, the most comprehensive estimates will be derived from broader scale studies of the biophysical processes, rather than local scale studies of single

[7] Erosion control (sediment removal) is sometimes treated separately in the literature.

wetlands. Single wetland studies are likely to be hampered by the difficulty of measuring both surface and subsurface water flows through wetlands. Thus it is better to take a landscape level approach. Ideally, such studies need to be carried out at a regional (e.g. biome) level. Once biophysical data are available from such studies, it will make the estimation of value relatively easy for any wetland within those regions.

The approaches used at different levels at a regional scale are based on Turpie and Day (2010) and are summarized in Table 5.6. The study should be carried out by a water quality specialist and resource economist working together as a team.

5.4.1 Comprehensive valuation at a regional scale

Step 1: Define the study area

The study area should be defined as an area of relatively homogeneous natural vegetation and geology (e.g. a biome), and should incorporate a range of land-uses. Land-use and habitat data need to be accurately mapped.

Step 2: Divide the study area and identify sampling points

The study area should be divided into its catchment and sub-catchment areas. Sampling points need to be identified at the outflow points of a representative sample of catchments. The sample size should be sufficiently large (e.g. 100 catchments). Catchment areas of sampling points should not overlap unless specifically designed to be analyzed as a series of inflows and outflows.

Step 3: Collect and analyze water samples

Multiple field trips are undertaken during periods of varying flow, to incorporate seasonal variability. During each trip, water quality samples are collected at each sampling point. If flow data are not available (from a gauging weir), cross-sections and flow rates must be measured at the sampling site in order to estimate flows. Water quality samples are analyzed by a reputable lab for suspended solids, total phosphorous, ammonia, nitrates, nitrites, *Escherichia coli* and any other constituents that are likely to be of concern in the area.

Table 5.6: Methods required for estimation of the sediment retention and water treatment functions at a regional scale, at different levels (rapid to comprehensive)

	Step	Comprehensive	Intermediate	Rapid
1	Define boundaries of study area	Use GIS data	Use GIS data	Use GIS data
2	Divide study area and identify sampling points	Use GIS data	Use GIS data	Use GIS data
3	Collect and analyze water samples	The study area is sampled several times; physical data collected; suspended solids, nutrients, *E. coli* and heavy metals analyzed	The study area is sampled once; physical data collected; suspended solids and nutrients analyzed.	N/A
4	Prepare data	Quantify land-use and habitats (GIS); estimate flow and loads	Quantify land-use and habitats (GIS); estimate flow and loads	N/A
5	Estimate removal rates by wetlands	Undertake multivariate statistical analyses, model removal rates of study area wetlands	Undertake multivariate statistical analyses, apply average	Obtain estimates from the literature (see Vols. I and II), modify using appropriate assumptions
6	Estimate value of services	Use damage costs avoided approach	Use replacement cost and demand	Use replacement cost and demand

Step 4: Prepare data

This step involves quantifying the area of major land-uses and habitats in the catchment area for each sampling point. Flow rates are calculated from the flow velocity and cross-sectional data collected at the sampling points, and loads of sediments, nutrients, *E. coli* and heavy metals (mass per unit time) are calculated based on measured concentrations and flow rate data for each sampling point.

Step 5: Estimate removal rates by wetlands

Data are analyzed using multivariate statistical analyses in order to express sediment and pollution loads as a function of variables such as the proportional area of the catchment under wetlands and other land cover types, etc. See Turpie and Day (2010) for an example.

Step 6: Estimate value of water treatment service

For a comprehensive study, the valuation of water treatment functions should be undertaken using a **Damage Costs Avoided** approach.

The off-site or downstream costs incurred as a result of soil erosion include sedimentation behind dams, reduced water storage capacity, reduced electricity production, siltation of roadways and sewers, and drainage disruption, among others (Pimentel *et al., 1*995). The ability of wetlands to trap sediments can alleviate these costs to an extent. Valuation of this service requires an estimate of the damage costs that are incurred per unit of eroded sediment that is otherwise transported downstream. Generally, most of the sediment would otherwise end up in the first major impoundment downstream. The cost of this can be estimated in terms of loss of production or the engineering costs, such as dredging, that are incurred in order to deal with it (see Pimentel *et al., 1*995). They can also be assessed in terms of the costs of reducing the lifespan of the impoundment.

Downstream ecosystems such as rivers and estuaries may be impacted by the combination of elevated sediments, nutrients and other pollutants generated in their catchments, affecting the ecosystem services delivered by the downstream systems. These, together with pathogens such as *E. coli*, affect the wellbeing of downstream communities.

The proper application of this valuation method requires intensive study of the ecosystem services of downstream environments, and quantifying the change in value generated by provisioning, regulating and cultural services in relation to the change in sediments, nutrients and other pollutants entering the systems, as well as changes in human health and the costs associated with these changes. Alternatively, information on the costs incurred in dealing with the problems (such as dredging or human health interventions) may be available. The best way to tackle this kind of valuation study is through a combination of ecological modelling and the collection of economic and human health data. There are many examples of attempts to estimate exposure-response functions and the cost of human health impacts (e.g. see Künzli *et al., 2*000, Gaioli *et al., 2*002).

5.4.2 Intermediate estimation at a regional scale

An intermediate valuation study could consider fewer pollutants, for example it could concentrate on nutrient aspects, and use these to make estimations of the value of the service in general, since the wetland's ability to remove different types of pollutants is likely to be correlated with the nutrient removing capacity already estimated.

Valuation of water treatment functions can be considered together using the **Replacement Cost method**. For sediment trapping in particular, this can be considered in terms of the costs of creating artificial storage with the equivalent capacity for capturing sediments. In general, the Replacement Cost approach would consider the costs saved in terms of treatment costs of water and/or implementation of human health services. The actual use of the service will have to be estimated, taking into consideration factors such as land-use, population and natural erodibility in the catchment. Since water quality is of paramount importance in South Africa because of the scarcity of water in general, and the high level of direct reliance on rivers (*in situ* use and run-of-river abstraction), it is reasonable to assume that good water quality is demanded in all systems.

5.4.3 Rapid estimation at regional scale

A rapid estimation of the value of water treatment services, performed by wetlands at a regional or catchment scale, can be carried out by taking shortcuts in the estimation of the capacity of a wetland to remove sediments, nutrients and other contaminants. In this case estimates of this capacity will have to be based on the literature or on expert opinion. Valuation will require use of the Replacement Cost method, plus consideration of the need for the service as described above.

5.5 Recreation and tourism

This section refers to the estimation of direct use values arising from the appreciation of wetland ecosystem attributes. Usually the use of these ecosystems for recreational or tourism experiences is intricately linked to other landscape features, and the influence of the wetland needs to be isolated in order to estimate its contribution to the value. This essentially means estimating how the value would differ without the wetland(s). For example, how would the value of avitourism in Wakkerstroom be affected by the loss of the wetlands in the area?

5.5.1 Comprehensive estimation at the local scale

The comprehensive assessment of recreational and tourism value involves examining the amount that people are willing to pay to visit and use these amenities, and the premium people are willing to pay to live close to them. The steps involved in estimating tourism and property values generated as a result of the amenity related attributes of wetlands are summarized in Table 5.7. Comprehensive methods are described below, followed by a brief description of the ways in which they can be simplified for broader scales and/or rougher assessments. The case study by Scovronick and Turpie (2010) in Volume II provides an example of an intermediate level valuation study at a local level.

A: The comprehensive estimation of tourism value at a local or catchment/regional scale

Step 1: Define study area

This should be based on the typical 'package of attractions' of the area that is associated with the wetland, e.g. the whole protected area if the wetland is within a protected area. South Africa's provincial tourism regions (available on provincial tourism websites) can be used as a guide when working at larger scales.

Step 2: Estimate overall tourism activity and expenditure

Tourism statistics, e.g. on numbers of visitors, total expenditure, etc., are available for most protected areas, some towns and regions, most provinces and for South Africa as a whole, all from the relevant government agencies. The data should be obtained at the scale appropriate to the study area. If, for example, data are only available at a provincial or national level, then substantial data need to be collected (e.g. on number of beds, occupancy rates, etc.) at the scale of the study area in order to estimate the value of the study area on a proportional basis.

Step 3: Estimate overall tourism value

Estimate producer surplus and value added using enterprise models constructed on the basis of interviews with key types of tourism businesses; estimate indirect value added using a regional social accounting matrix.

Estimate consumer surplus using the Travel Cost Method (TCM), which involves surveys of visitors. Details on this method are readily available in the literature. An outline of the method is provided in Volume I (Turpie *et al., 2*010a). Adaptations for developing country contexts (e.g. estimating the recreational use value of a wetland by a local rural community) are uncommon and will require considerable adaptation.

Step 4: Describe the contribution of wetland(s) to tourism value

As part of a visitor survey, establish the contribution made by the wetland(s) by direct questioning in different ways, relating to influence on decisions, time spent, and utility gained from recreational activities (e.g. see Turpie and Joubert, 2001). This proportion is then applied to the values obtained above, in order to estimate how much of the overall tourism value estimated above is attributable to the wetland.

Table 5.7: Methods required for estimation of the recreation / tourism and property / aesthetic value at the local or regional scale, at different levels. For empty cells, comprehensive methods should be adopted as far as possible, depending on data availability and time / budgetary constraints

	Step	Comprehensive	Intermediate	Rapid
1	Define study area using tourism regions as guide	GIS data	GIS data	GIS data
A	Tourism value			
2	Estimate overall tourism activity and expenditure	Visitor statistics, adjusted to study area, for example use data on bed-nights		Visitor statistics, adjusted to study area, based on expert opinion
3	Estimate tourism value	Tourism business interviews; Enterprise models; Social accounting matrix; Travel Cost Method		Step omitted or inferred using findings / multipliers from other studies / expert opinion
4	Describe contribution of wetland(s)	Visitor surveys, using triangulation		Infer from other studies / expert opinion
5	Estimated value change under alternative scenarios	Modelled using Conjoint Valuation methods from survey data	Estimate based on interviews with industry stakeholders	Simple estimate using expert opinion
B	Property value			
6	Define study area around wetland(s)	GIS, Google Earth, municipal plans		GIS, Google Earth, municipal plans
7	Gather property data	Household survey or detailed sales data		Google Earth, municipal plans, estate agent websites
8	Estimate wetland related premium (extra paid for property in proximity)	Hedonic pricing method		Estate agent expert opinion
9	Estimate aggregate value	Extrapolate from base data		Extrapolate from base data
10	Estimated value change under alternative scenarios	Household survey data OR expert opinion (agents)		Simple estimate using expert opinion (agents)

Step 5: Estimate the value change under alternative scenarios

As part of the visitor survey, Conjoint Valuation methods are used to model the change in visitors' utility as a result of changes in a suite of wetland characteristics, such as vegetation diversity, bird numbers or species richness. Contingent valuation questions need to be used to anchor utility to value. For example, Turpie and Joubert (2001) ascertained the expected change in the amount of time spent in the Kruger National Park under the best and worst case scenarios, and used this to link utility scores to time spent in the park.

B: The comprehensive estimation of property value at a local or catchment / regional scale

Step 1: Define study area

This should go slightly beyond the area of expected influence of the wetland(s) on property value, so that properties that are not influenced by the wetland are included in the statistical analysis.

Step 2: Gather property data

Data on the properties such as size, number of bedrooms and number of bathrooms, as well as on relevant environmental variables, such as distance to the wetland and the quality of views, are collected. Data on property values also need to be collated. This can be a desktop exercise if it is possible to assess the environmental variables from maps or the database obtained. Data can be obtained from the Deeds Office (at a price) or from estate agents. Alternatively, data can be collected in a household survey, but would rely on the property owners' assessment of value. The latter approach has the advantage of generating better quality data on environmental variables such as proximity to, or views of, a wetland.

Step 3: Estimate wetland related premiums

Undertake statistical analysis (such as generalized linear modelling) in order to model the influence of the wetland(s) on property value as per the Hedonic Pricing Method (see Volume I; Turpie *et al., 2*010a).

Step 4: Estimate aggregate value

Use the model in conjunction with information on the total numbers of properties in the area pertaining to different variables (e.g. distance from wetland), to estimate the total contribution of the wetland to property value. From this, estimate the total annual contribution to turnover in the property sector that is attributable to the wetland, based on estimated income to estate agents and rates of turnover in the area.

Step 5: Estimate value change under alternative scenarios

If required to estimate the change in this value that might occur as a result of a change in wetland condition or size, it will be necessary to undertake a stated preference study in which property owners are asked to describe how they would respond to alternative scenarios in a way that can be quantified in a model. See the discussion on these methods in the next section.

5.5.2 Rapid estimation – local to regional scale

5.5.2.1 Tourism value

Various shortcuts can be taken in estimating tourism value. The first is to use expert opinion to estimate the proportion of a region's tourism value that is attributable to the study area in general, such as how much of Western Cape tourism is in the Cape Peninsula. Simple estimates of overall value can be generated from the above, and might be refined or modified using findings from other studies. The contribution of wetlands might be inferred from the results of other similar studies elsewhere, but since this kind of transfer of values carries a high risk, it is recommended that expert opinion, such as that of tourism operators, is used here. The latter can also be used to estimate change in value under different wetland management scenarios.

5.5.2.2 Property value

Rough estimates of the property value associated with wetlands can be generated fairly easily. The expert opinion of estate agents can replace models generated by comprehensive data, since experienced estate agents tend to have a reliable feel for the premiums paid for different features. They are also likely to have a good feeling for the way in which the market will be affected by changes in wetland condition or management.

5.6 Scientific and educational value

This section refers to the estimation of the scientific and educational value of wetlands. It is impossible to quantify how science and education impact on the economy or people's wellbeing. However, the amount that is spent on their pursuit provides evidence of society's belief in their value, and can be considered as society's minimum willingness to pay for the service.

The steps involved in estimating scientific and educational value are described below. Given the inherent limitations, only a rapid approach is described.

Step 1: Define the study area and its main feature

The features, such as place names, biomes or habitat types will help to narrow down the search for information and literature.

Step 2: Obtain data on educational use and expenditure

These can include records from visitor centres or schools and tertiary institutions. If visitors use a broader area, then the proportional contribution of the wetland(s) will have to be estimated on the basis of key informant interviews.

Step 3: Obtain data on research expenditure

This is obtained from government and scientific institutions that carry out research in the study area.

Step 4: Estimate value of scientific outputs

Quantify the average annual output of scientific publications that emanate from the wetlands in the study area. The value can be estimated by multiplying this output by the subsidies paid by government to tertiary institutions for publications.

Step 5: Overall value

The overall value is the sum of the above.

5.7 Intangible value – cultural, spiritual, existence

Intangible values can only be assessed using stated preference methods such as Contingent Valuation and Conjoint Valuation (or Choice Modelling) which involve questionnaire surveys. The Contingent Valuation Method (CVM) elicits respondents' Willingness to Pay (WTP) or Willingness to Accept compensation (WTA) in response to an environmental change such as loss of biodiversity. For example, the aggregate WTP to prevent a loss of a wetland would represent the value of that wetland. Conjoint Valuation goes one step further, in that it can identify how different attributes of the wetland contribute to its value, such as its beauty versus the presence of a rare species.

These methods are well covered in the literature and are summarized in Volume I of this series (Turpie *et al., 2*010a).

Stated preference methods require considerable expertise in order to achieve unbiased and accurate results, and require large samples of respondents in order to be statistically robust. Thus the methodology used in carrying out a study on intangible value is usually comprehensive. The scale of the study can vary, and has a strong bearing on the interpretation of the results. Smaller scale studies (in terms of the area being valued) may yield an overestimate of value due to embedding bias in which respondents are forced to focus more on the wetland in question than they might have done on their own. Larger scale studies probably give a better idea of average value, since respondents are not very good at adjusting their responses to area, and tend to state their maximum willingness to pay for wetlands, whether being asked about all wetlands or just one. For a regional or larger scale study, various techniques can be used to spread the overall value among different wetlands (see Turpie and Clark, 2007).

The use of stated preference methods in estimating the intangible value of ecosystems in rural, developing country contexts is particularly challenging and requires very careful design (Turpie *et al., 2*006c).

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7. GLOSSARY

Base flows: The portion of stream flow that comes from groundwater and not from surface runoff.

Bathymetric study: Mapping of water depth in a large body of water such as the ocean, a lake or a wetland.

Conjoint Valuation Methods: A statistical technique that requires participants to make a choice from a series of alternatives. An analysis of these choices reveals the relative importance of the attributes or alternatives under consideration.

Consumer surplus: A net benefit realized by consumers when they buy a good at the prevailing market price. It is the difference between the maximum price consumers would be willing to pay and that which they actually pay for the units of the good purchased.

Consumptive use value: Part of the direct use value, associated with the harvesting or consumption of the resources provided by an ecosystem, such as harvesting these resources for subsistence or commercial purposes.

Continuous stream flow hydrograph: A hydrograph of stream flow over a relatively long period, which includes a series of flood and low flow events (as opposed to only one flood event) and has no gaps.

Cost Benefit Analysis (CBA): A method of evaluation that seeks to reach the optimal decision that will yield the greatest advantage, by analyzing the cost effectiveness of various alternatives, in which all the relevant costs and benefits of the alternatives are considered, including the non-market costs and benefits derived from the environment.

Cultural services: The intangible services provided by ecosystems, such as recreation, aesthetic enjoyment and spiritual fulfilment.

Daily hydrological model: A hydrological model that produces stream flow at desired locations on a daily time step.

Damage costs avoided approach: A method to value a service provided by an ecosystem by estimating the damage costs avoided by the provision of the service, i.e.

the cost of the damage that would be incurred in the absence of the ecosystem service or an engineered alternative.

Direct use value: Within the total economic value framework, the benefits derived from the direct utilization of goods and services provided by an ecosystem. These include consumptive uses (e.g. harvesting goods) and non-consumptive uses (e.g. enjoyment of scenic beauty).

Ecosystem health: A measure of the condition of an ecosystem, its individual parts, their interactions, and their ability to perform their natural functions.

Environmental water allocations: The allocation of water flows to ensure the protection and functioning of aquatic ecosystems.

Existence value: The value that individuals may attach to the wellbeing that comes from the knowledge that an environmental resource exists, without the intention, necessarily, of using it.

Flood attenuation: Reduction in the amplitude of the flood wave (peak flow), and hence peak water levels and flow velocities at downstream locations, through temporary storage of flood waters by wetlands, thereby reducing downstream damage.

Flood routing: The process of progressively determining the timing, shape, and amplitude of a flood wave as it moves downstream along a waterway.

Flow duration curve: A graphical representation of the percentage of time in a flow record for which a flow of any given magnitude has been equalled or exceeded.

Gross Domestic Product (GDP): The measure of total value added (total value of all the goods and services produced in an economy, less raw materials, and other goods and services used in the production process) in all resident producing units, during a defined accounting period – usually a year.

Gross Geographic Product (GGP): A regional subset of the GDP.

Groundwater recharge: Wetlands are often thought to provide differential recharge to groundwater relative to surrounding vegetation types, and to contribute to dry season base flows.

Hedonic Pricing Method: A method that seeks to isolate the contribution that environmental quality makes to the total market value of an asset. It is commonly applied in property prices, where environmental factors such as aesthetics can increase the value of real estate.

Hydraulic model: In this publication, a “hydraulic model” refers to numerical computer models that model the free surface flow of water along a channel, taking into account its bathymetry through solution of various equations of flow. A hydraulic model can produce flow rates, and can include in its output various hydraulic variables (such as velocity, water depth, Froude number, and many others) at various predetermined sites where bathymetric information is provided.

Hydrodynamic modelling: Hydrodynamic modelling is another term for unsteady hydraulic modelling (i.e. modelling of flows along a river reach that vary both spatially – along the river reach – and temporally). Hydrodynamic or unsteady flow modelling is distinct from steady flow modelling, where the flow is constant at each point temporally, although it may vary spatially along the river reach. Hydrodynamic modelling is necessary to model flood waves along a river reach, for example.

Indirect use value: The benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. For example, an agent at some distance from an ecosystem may derive benefits from drinking water that has been purified as it passed through the ecosystem.

Marginal value: The change in economic value associated with a unit change in output, consumption or some other economic choice variable.

Multi-criteria decision analysis: An analysis tool that assists decision-makers to choose the best alternative from a range of alternatives with conflicting and competing criteria, where such multiple criteria, including intangible costs and benefits that are expressed in monetary terms, are used in evaluating the alternatives.

Natural Resource Accounting: The compilation of asset and flow accounts for natural assets, to complement the national accounts. Asset accounts are valued in terms of 'natural asset value'; flow accounts are valued in terms of 'national income'.

Non-consumptive use value: Part of the direct use value, being the resources that are used directly but are not consumed by the user, for example, appreciation of the landscape.

Non-use value: The non-use values of ecosystems, being the existence, option and bequest values.

Opportunity cost: The value of the next best alternative use forgone. For example, the opportunity cost of a protected area might be the income that would be derived from livestock grazing.

Option value: The value of preserving the option to use services in the future.

Producer surplus: A net benefit realized by firms. It is the amount that producers benefit by, by selling at a market price that is higher than they would be prepared to sell for.

Provisioning services: The provision of natural resources by ecosystems such as food, water, timber and fibre.

Rainfall-runoff model: A model that takes rainfall, evaporation, soil data and various land-use and development data and produces flow rates at various desired locations. A rainfall-runoff model is generally used to produce a time series of flows, at a desired time step and at various points from a time series of rainfalls, evaporations and other relevant data, such as abstractions and transfers of water from/to rivers, using observed flow data for calibration.

Regulating services: The services provided by ecosystems which regulate the environment, such as the regulation of climate, floods, disease, waste and water quality.

Replacement Cost Method: The costs (infrastructure, engineering etc) that would have to be incurred to replace the natural service provided by an ecosystem.

Resource economics: A field of economics dealing with the supply, demand and allocation of natural resources. It is a multi-disciplinary field that considers the connection and interdependence between human economies and ecosystems.

Social accounting matrix (SAM): An economic input-output model of the national economy, used as a tool for impact analysis. Expands the national accounts to show the linkages between production and generation of income, and distribution of income.

Strategic environmental assessment: A proactive means of evaluating options at a larger scale than project appraisal, often using the tools of project appraisal, such as CBA.

Supporting services: The services provided by ecosystems which maintain the conditions for life on earth, such as nutrient cycling, soil formation and primary production.

Travel Cost Method: A valuation method to estimate the recreational use value of a site, involving analyzing the travel expenditure incurred by visitors to the site and measuring their willingness to pay to visit it.

Water Management Area (WMA): An area established under the National Water Act as a management unit in the national water resource strategy, within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources. South Africa has been divided into 19 WMAs.

Willingness to Pay: The amount that a person is willing to pay for a good or service.