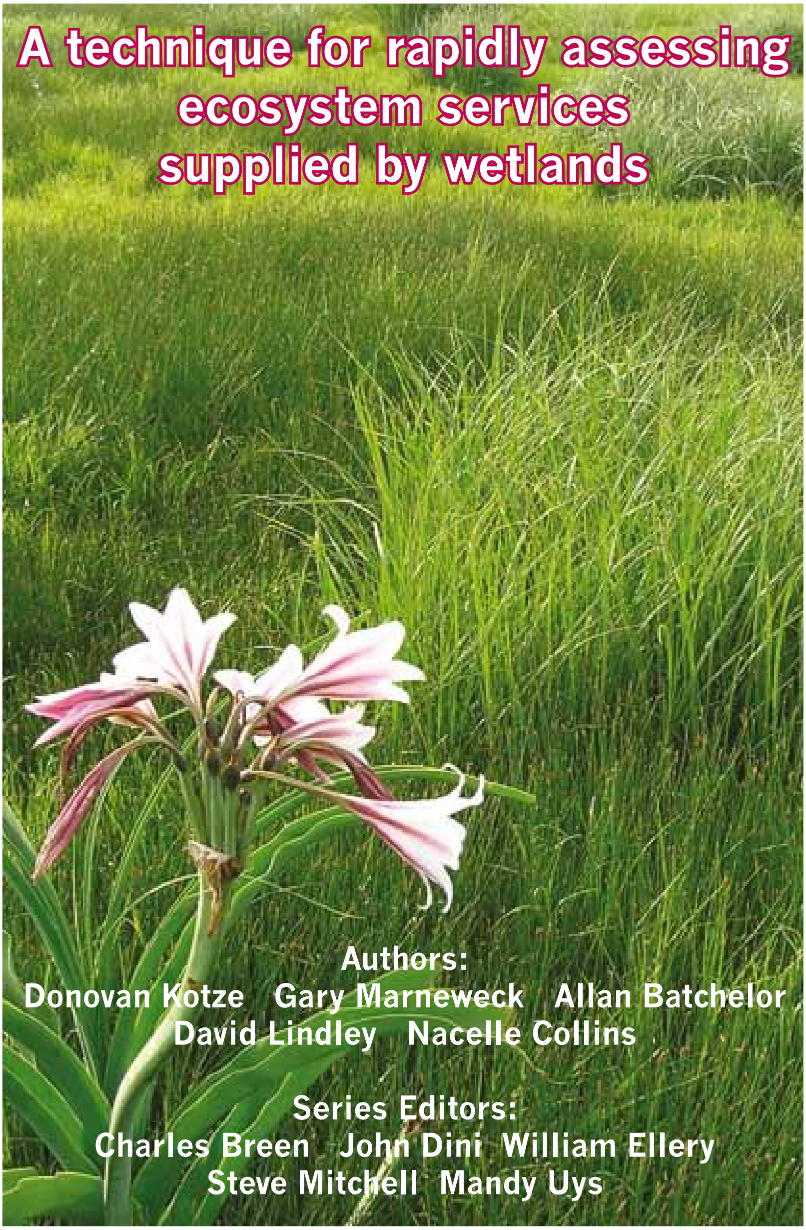
Wetland Management Series

WET-EcoServices



A technique for rapidly assessing ecosystem services supplied by wetlands

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Environmental Affairs and Tourism
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Working for Wetlands

UNIVERSITY OF KWAZULU-NATAL

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Water Research Commission

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Front cover: The beautiful vlei lily (*Crinum macowanii*) growing within a sedge marsh in the Midlands of KwaZulu-Natal.
Photograph: Donovan Kotze

Inside front cover: Boneberg's frog (*Natalobatrachus bonebergi*), commonly known as Ngoye frog, is a threatened endemic species along the coastal region of KZN.
Photograph: Errol Douwes

Preface: Background to the *WET-Management* Series

The need for wetland rehabilitation in South Africa is compelling: loss and degradation of wetlands have been great and national policy and legislation provides clear direction and support for rehabilitation. However, rehabilitating wetlands is often complex because wetlands and their links with people are complex (e.g. through the ways that people use wetlands and the different benefits that people receive from the ecosystem services that wetlands supply). Thus, a series of tools has been developed to assist those wishing to undertake wetland rehabilitation in a well-informed and effective way (Box 1P).

These tools were developed as part of a comprehensive nine-year research programme on wetland management which was initiated in 2003 by the Water Research Commission (WRC) and a range of partners that examines wetland rehabilitation, wetland health and integrity and the sustainable use of wetlands. The rehabilitation component, which was co-funded by the WRC and the Department of Environmental Affairs and Tourism, through the Working for Wetlands (WfWetlands) programme, was prioritised to take place first because of the need to provide a firm scientific and technical foundation for the extensive rehabilitation work already underway.

The Working for Wetlands Programme is a national initiative that seeks to promote the protection, rehabilitation and wise use of wetlands in South Africa. As part of this initiative, WfWetlands has a national programme for the rehabilitation of wetlands, including a structured process of prioritising rehabilitation sites and supporting their rehabilitation. At the same time, however, it is acknowledged that sustainable use of wetlands in the long term can be achieved only through the dedicated participation of civil society, whose wetland interests may have a strong local focus. Thus, the tools have been developed in such a way that they can be applied outside of the Working for Wetlands Programme, and without having to engage the process of national or provincial prioritisation should the user not desire to do so. Even so, the tools encourage local wetland rehabilitation efforts to strengthen links with the national initiative and the opportunity this provides for fruitful partnerships.

The series consists of a roadmap, two background documents, eight tools and an evaluation of the success of six individual projects (Box 1P). From Table 1P it can be seen that some of the tools (e.g. *WET-RehabMethods*) are designed to be used by those dealing specifically with wetland rehabilitation and its technical requirements. Other tools (e.g. *WET-Health*) have much wider application such as assessing impacts associated with current and future human activities in Environmental Impact Assessments or assessing the Present Ecological State of a wetland in an Ecological Reserve Determination.

One can locate the tools in terms of some basic 'who', 'what', 'where' and 'how' questions that any team undertaking wetland rehabilitation should be asking (Table 2P). Furthermore, each of the tools can be used individually, but there are close links between them (Figure 1P).

Box 1P: Overview of the *WET-Management* Series

The series includes documents that provide background information about wetlands and natural resource management, tools that can be used to guide decisions around wetland management, and an evaluation of rehabilitation outcomes in a number of case studies.

WET-Roadmap

WET-Roadmap provides an introduction to the *WET-Management* tools and includes:

- A brief outline of the documents and tools in the *WET-Management* series and how they inter-relate
- An index of wetland rehabilitation related terms
- Reference to specific sections in the relevant tools.

WET-Origins

WET-Origins describes the remarkable geological and geomorphological processes that give rise to wetlands in South Africa, and provides a background description of:

- The geology, geomorphology, climate and drainage of southern Africa
- An introduction to wetland hydrology and hydraulics
- Geomorphic controls on different wetland types
- Wetland dynamics due to sedimentation and erosion.

It incorporates this understanding into a methodology that can be used to help develop insight into the hydrological and geomorphological factors that govern why a wetland occurs where it does, which is useful when planning rehabilitation.

WET-ManagementReview

WET-ManagementReview has four parts:

1. An assessment of effectiveness at programme level, including:
   - a national overview of land-uses affecting the status of wetlands and the institutional environment that affects wetlands.
   - an overview of 5 natural resource management programmes affecting wetlands and their impact in different land-use sectors; Working for Wetlands, Working for Water, LandCare, the Crane Conservation Programme of the Endangered Wildlife Trust, and the Mondi Wetlands Programme.
2. An assessment, using the *WET-EffectiveManage* tool, of the management effectiveness of 21 wetland sites in a variety of different land-use and land-tenure contexts.
3. An assessment of stakeholder participation in wetland rehabilitation at six wetland sites.
4. A framework for assessing the effectiveness of collaboration between partners, described and applied to a site where a rehabilitation project has been underway for several years.

WET-OutcomeEvaluate

WET-OutcomeEvaluate is an evaluation of the rehabilitation outcomes at six wetland sites in South Africa, including an evaluation of the economic value of rehabilitation. The six sites are:

1. Killarney Wetland
2. Manalana Wetland
3. Kromme River Wetland
4. Dartmoor Vlei
5. Kruisfontein Wetland
6. Wakkerstroom Vlei.

WET-RehabPlan

WET-RehabPlan offers a process that can be followed to develop comprehensive wetland rehabilitation plans. It has three main elements:

- Introduction to rehabilitation, planning and stakeholder involvement.
- General principles to follow in planning wetland rehabilitation.
- Step-by-step guidelines for undertaking the planning and implementation of wetland rehabilitation at a range of scales from national/provincial to catchment to local. It directs the user to the right tools and sections at appropriate points in the rehabilitation process.

Good planning ensures a rational and structured approach towards rehabilitation as well as a clear understanding of the reasons for rehabilitation, the actions and interventions required, and the benefits and beneficiaries.

WET-Prioritise

WET-Prioritise helps to identify where rehabilitation should take place once the objectives of rehabilitation are identified. It works at three spatial levels. At national and provincial level, an interactive GIS modelling tool assists in identifying priority catchments by evaluating a range of scenarios, based on different combinations of 13 socio-economic and bio-physical criteria (e.g. Biodiversity Priority Areas, High Poverty Areas). Once a catchment is selected, the tool helps to identify areas for rehabilitation within that catchment. Finally, individual wetlands are selected based on the predicted cost-effectiveness and sustainability of rehabilitation.

WET-Prioritise provides step-by-step guidelines applicable at all three spatial scales, including:

- Identifying objectives and an appropriate scale.
- Developing prioritisation criteria.
- Applying the criteria, usually in a two step process of rapidly screening all candidate sites to arrive at a preliminary set of sites, from which individual priority sites are selected.

Three case examples of prioritisation are described.

WET-Legal

WET-Legal presents South African legislation that is relevant to wetland rehabilitation, including the Conservation of Agricultural Resources Act (CARA), National Environmental Management Act (NEMA), and National Water Act (NWA), as well as relevant international agreements such as the Ramsar Convention on Wetlands. *WET-Legal* lists the environmental impacts potentially associated with typical wetland interventions and the legislative provisions that apply to each of these impacts. It also covers laws compelling rehabilitation and the legal responsibilities of different parties involved in rehabilitation.

TOOLS

WET-EcoServices

WET-EcoServices is used to assess the goods and services that individual wetlands provide, thereby aiding informed planning and decision-making. It is designed for a class of wetlands known as palustrine wetlands (i.e. marshes, floodplains, vleis or seeps). The tool provides guidelines for scoring the importance of a wetland in delivering each of 15 different ecosystem services (including flood attenuation, sediment trapping and provision of livestock grazing). The first step is to characterise wetlands according to their hydro-geomorphic setting (e.g. floodplain). Ecosystem service delivery is then assessed either at Level 1, based on existing knowledge or at Level 2, based on a field assessment of key descriptors (e.g. flow pattern through the wetland).

WET-Health

WET-Health assists in assessing the health of wetlands using indicators based on geomorphology, hydrology and vegetation. For the purposes of rehabilitation planning and assessment, *WET-Health* helps users understand the condition of the wetland in order to determine whether it is beyond repair, whether it requires rehabilitation intervention, or whether, despite damage, it is perhaps healthy enough not to require intervention. It also helps diagnose the cause of wetland degradation so that rehabilitation workers can design appropriate interventions that treat both the symptoms and causes of degradation. *WET-Health* is tailored specifically for South African conditions and has wide application, including assessing the Present Ecological State of a wetland for purposes of Ecological Reserve determination in terms of the National Water Act, and for environmental impact assessments. There are two levels of complexity: Level 1 is used for assessment at a broad catchment level and Level 2 provides detail and confidence for individual wetlands based on field assessment of indicators of degradation (e.g. presence of alien plants). A basic tertiary education in agriculture and/or environmental sciences is required to use it effectively.

WET-EffectiveManage

WET-EffectiveManage provides a framework that can be used to assess management effectiveness at individual wetlands based on 15 key criteria (e.g. the extent to which a regularly reviewed management plan is in place for the wetland). A scoring system is provided for rapidly assessing the criteria. This tool is Chapter 2 in the *WET-ManagementReview* manual.

WET-RehabMethods

WET-RehabMethods is used to guide the selection and implementation of rehabilitation methods that are appropriate for the particular problem being addressed and for the wetland and its catchment context. It provides detailed practical rehabilitation guidelines for inland palustrine wetlands and their catchments, and focuses particularly on wetlands associated with natural drainage networks. It can be adapted to meet specific needs. Some aspects of the tool require high levels of civil engineering expertise, but it is designed primarily for rehabilitation workers who have completed training in soil conservation, life sciences or engineering at a diploma level or higher, and who have practical field experience.

WET-RehabMethods includes the following:

- Key concepts relating to wetland degradation, particularly those resulting from erosion.

- Guidelines for the selection of an appropriate type of rehabilitation intervention (including both 'soft' and 'hard' engineering options).
- Detailed guidance, provided for designing a wide variety of intervention types (e.g. determining an adequate spillway to account for runoff intensity).
- Detailed guidance provided for the implementation of the different intervention types.

WET-RehabEvaluate

WET-RehabEvaluate is used to evaluate the success of rehabilitation projects, and is designed with the understanding that monitoring and evaluation are closely tied to planning, which, in turn, should accommodate monitoring and evaluation elements. *WET-RehabEvaluate* provides the following :

- Background to the importance of evaluation of wetland rehabilitation projects.
- Step-by-step guidelines for monitoring and evaluation of rehabilitation projects, both in terms of project outputs and outcomes. The outcomes are based on system integrity and the delivery of ecosystem services, and results from *WET-Health* and *WET-EcoServices* are therefore included. The guidelines include: review project objectives, identify performance indicators and standards, develop and implement a monitoring and evaluation plan, evaluate and report on performance.

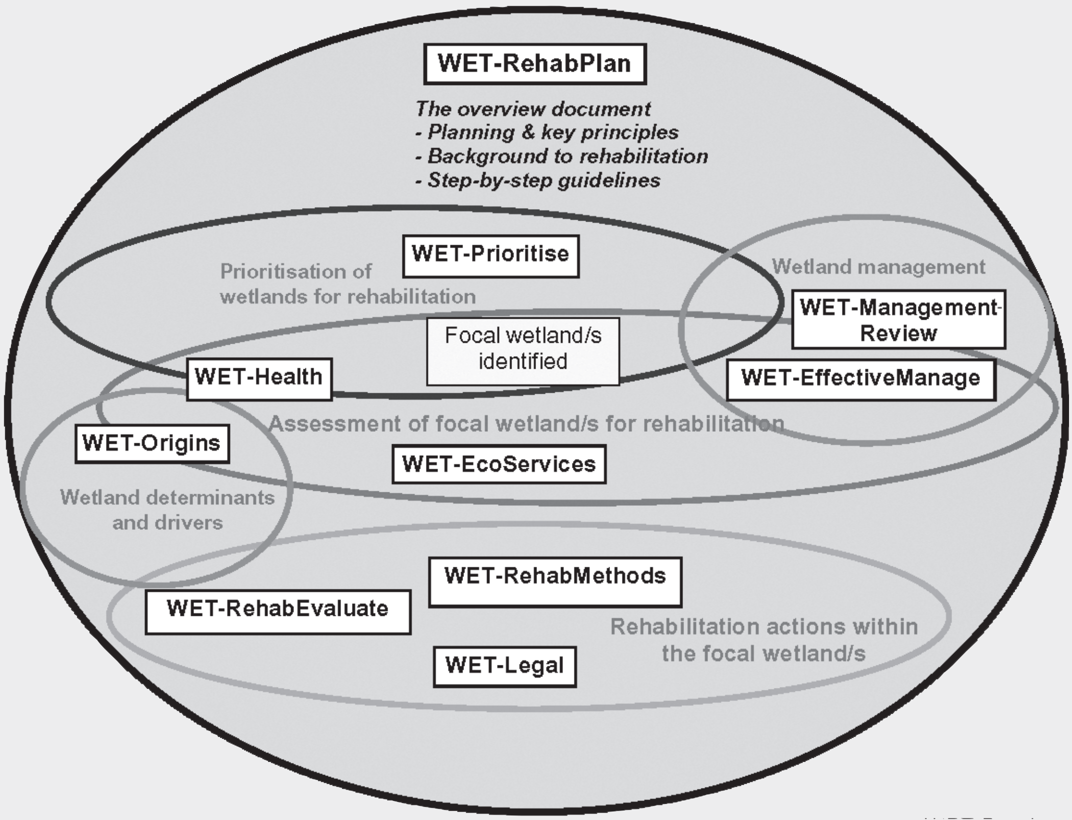

Figure 1P: How do the *WET-Management* tools relate to each other in a rehabilitation context?

Table 1P: Likely relevance of the background reading and tools in the *WET-Management* series to a variety of different potential uses

Potential users	*WET-Origins*	*WET-Management - Review*	*WET-RehabPlan*	*WET-Prioritise*	*WET-Effective-Manage*	*WET-Legal*	*WET-Rehab-Methods*	*WET-Eco-Services*[1]	*WET-Health*[2]	*WET-Rehab-Evaluate*
Rehabilitation planning - wetland specialist	[very high relevance]	[some relevance]	[some relevance]	[some relevance]	[some relevance]	[some relevance]	[some relevance]	[very high relevance]	[very high relevance]	[very high relevance]
Rehabilitation planning - engineer	[some relevance]	Part 1 [some relevance]	Step 5 [some relevance]			[some relevance]	[very high relevance]			
Rehabilitation programme coordination - *national*	[some relevance]	[very high relevance]	[very high relevance]	[very high relevance]	[some relevance]	[very high relevance]	[some relevance]	[some relevance]	[some relevance]	[some relevance]
Rehabilitation programme coordination - *provincial*	[some relevance]	[very high relevance]	[very high relevance]	[some relevance]	[very high relevance]	[very high relevance]	[some relevance]	[some relevance]	[some relevance]	[some relevance]
Rehabilitation implementation			Step 5 [some relevance]		[some relevance]	[some relevance]	[very high relevance]			[very high relevance]
Impact assessment	[some relevance]	Part 1 [some relevance]				[some relevance]		Level 1 [very high relevance]	Level 2 [very high relevance]	
Wetland management	[some relevance]	[some relevance]	[some relevance]		[very high relevance]	[some relevance]				
Ecological Reserve Determination - DWAF officials & consultants	[very high relevance]	Part 1 [some relevance]		[some relevance]		[some relevance]		Level 1 [very high relevance]	Level 2 [very high relevance]	
Catchment planners - CMAs and others	[some relevance]	Part 1 [some relevance]		[very high relevance]		[some relevance]		[some relevance]	[some relevance]	
Broad-scale biodiversity conservation planning	[some relevance]	Part 1 [some relevance]		[very high relevance]		[some relevance]		[some relevance]	[some relevance]	

The tool is likely to have some relevance (light grey) — The tool is likely to have a very high level of relevance (dark grey)

[1] *WET-EcoServices* is of particular relevance in determining the Ecological Importance and Sensitivity (EIS) of a wetland.
[2] *WET-Health* is of particular relevance ino determining the Present Ecological State (PES) of a wetland.

CMA = Catchment Management Agency
DWAF= Department of Water Affairs and Forestry

Table 2P: Rehabilitation-related questions typically posed at different spatial levels, and the tools most relevant to assisting the user in answering each question

Common questions	Tool/s likely to be relevant in addressing the question
Questions that might typically be asked at the national or regional level	
What is causing the degradation of wetlands?	*WET-Health* (Level 1) & *WET-ManagementReview*
Which are the most important wetlands?	*WET-Prioritise* & *WET-EcoServices* (Level 1)
Which wetlands should we rehabilitate?	*WET-Prioritise*
How should wetland rehabilitation be integrated within broad-scale catchment management?	*WET-Prioritise* & Dickens *et al*. (2003)
Questions that might typically be asked at the local level	
How effectively is the wetland being managed?	*WET-EffectiveManage*
What is causing the degradation of the wetland?	*WET-Health* (Level 2)
Is the wetland in need of rehabilitation?	*WET-Health* (Level 2) & *WET-Origins*
How do I decide what rehabilitation interventions will be appropriate for meeting my rehabilitation objectives?	*WET-RehabPlan* (Step 5F) & *WET-RehabMethods*
What are specific technical considerations I must make when designing a rehabilitation intervention?	*WET-RehabMethods*
Will the planned project be legally compliant?	*WET-Legal*
How do I evaluate my rehabilitation project?	*WET-RehabEvaluate*
Who should be involved in the rehabilitation project?	*WET-RehabPlan*
How do I align my rehabilitation project with catchment-, regional- or national-level programme/s?	*WET-RehabPlan* & WfWetlands Strategy (Working for Wetlands, 2005)

The National Water Act defines wetlands as:

'....land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which in normal circumstances supports or would support vegetation typically adapted to life in saturated soils.'

This is the definition used by the *WET-Management* Series.

Summary of ***WET-EcoServices***

WET-EcoServices is designed for inland palustrine wetlands, i.e. marshes, floodplains, vleis and seeps. It has been developed to help assess the goods and services that individual wetlands provide in order to allow for more informed planning and decision-making.

The process of applying *WET-EcoServices* begins with the characterisation of hydro-geomorphic wetland types (e.g. floodplain, hillslope seep etc.) based primarily on interpretation of aerial photographs. Individual wetlands are then assessed either at a desktop assessment level (Level 1) or at a rapid field assessment level (Level 2) where 15 benefits are assessed. Regulatory and supporting benefits (e.g. toxicant removal, sediment trapping, erosion control and flood attenuation) and cultural and provisioning benefits (e.g. tourism and recreation, provision of water and natural resources such as reeds for human use) are included.

In a Level 1 assessment, ecosystem services are assigned to a particular wetland based on existing knowledge of the features associated with different hydro-geomorphic (HGM) types since different HGM types offer different ecosystem services. For example, floodplains characteristically contribute effectively to the attenuation of floods while unchannelled valley bottom wetlands effectively trap sediments.

A Level 2 assessment is undertaken based on a desktop synthesis of available data followed by a rapid field assessment (2-5 hours per hydro-geomorphic unit depending on the size and complexity of the unit). Each of 15 benefits may be assessed based on a list of characteristics (e.g. slope of the wetland, pattern of flow through the wetland, toxicant sources in the wetland's catchment etc.) that are relevant to the particular benefit. Each characteristic used in the system has an information box which provides the rationale for the choice of characteristics and has directions on how to assign scores. Therefore the logic behind the system is open to scrutiny. Finally, the system prompts the user to identify any threats to the benefits currently being supplied or any opportunities for enhancing these benefits.

Acknowledgements

The Water Research Commission (WRC), South African National Biodiversity Instutute (SANBI) and Working for Wetlands (WfWetlands) are gratefully acknowledged for funding the development of this tool. The entire WfWetlands team has taken an active interest and participated in the development of this tool. The WRC has been very supportive in offering strategic and administrative assistance. The research programme was managed by Fred Ellery of the University of KwaZulu-Natal (UKZN), who was ably assisted by Kerry Philp.

Recognising the need for a wetland assessment system for South Africa, the Mondi Wetlands Project commissioned the development of a prototype of *WET-EcoServices* (initially referred to as WETLAND-ASSESS). A collaborative approach was used, involving the following organizations in the core team: the University of KwaZulu-Natal, Mondi Wetlands Project, Wetland Consulting Services and Free State Nature Conservation. Thanks are extended to John Dini, Piet-Louis Grundling, Michael Braack and Japie Buckle of WfWetlands, Vhangani Silima, Vaughan Koopman and Damian Walters of Mondi Wetlands Project, Morné Lizamore and Barbara Weston of the Department of Water Affairs and Forestry, David Kleyn of the Department of Agriculture, Anton Linström of the Mpumalanga Parks Board, Carol Goge of Ezemvelo KZN Wildlife, and Fred Ellery of UKZN, who all applied the prototype system in the field, and provided very valuable comments on earlier drafts. Further useful comment was also received from Heather Malan of the University of Cape Town, who commented extensively on two successive versions of *WET-EcoServices*, Adrian Wood of the University of Huddersfield, and Craig Cowden of Land Resources Institute (LRI), who extensively applied *WET-EcoServices* and discovered several 'gremlins' for us. Sue Davies provided very useful editorial assistance and Mandy Uys of Laughing Waters conducted a valuable review of the penultimate version of *WET-EcoServices*. Karen Ellery provided substantial editorial input during the production of this document.

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Feedback

In South Africa the rehabilitation of wetland ecosystems is still in its infancy. In order to promote the growth of this activity, this manual needs to be revised by including the experiences of those individuals involved in wetland rehabilitation within South Africa. Any comments or advice can be sent to:

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TABLE OF CONTENTS

1 AN OVERVIEW OF *WET-ECOSERVICES* AND ITS DEVELOPMENT

1.1 Background

While a host of different wetland functional assessment techniques have been developed, none of these is directly transferable to the South African situation. Many of the systems are geared primarily to the developed world and mainly to wetlands in the northern temperate regions, rather than to wetlands in the developing world, where livelihoods tend to be more directly dependent on wetlands. This tool is an outcome of the need for locally relevant tools of this kind.

1.2 Purposes and scope of *WET-EcoServices*

In today's modern world of high technology and global transport of food and other commodities, our attention has been diverted from the ecosystems on which our long-term economic prosperity and wellbeing depend. Wetlands are among the most globally threatened and important ecosystems, providing a host of services to society (Millennium Ecosystem Assessment, 2005). Thus every individual wetland is important. However, individual wetlands differ according to their characteristics and the particular ecosystem services that they supply to society. In this context, society may deem some wetlands to be more important than others.

The overall goal of *WET-EcoServices* is to assist decision makers, government officials, planners, consultants and educators in undertaking quick assessments of wetlands, specifically in order to reveal the ecosystem services that they supply. This allows for more informed planning and decision making. *WET-EcoServices* includes the assessment of several ecosystem services (listed in Table 1.1) – that is, the benefits provided to people by the ecosystem. '*These benefits may derive from outputs that can be consumed directly, indirect uses which arise from the functions or attributes occurring within the ecosystem, or possible future direct outputs or indirect uses*' (Howe *et al*., 1991). Ecosystem services of wetlands include regulating services such as flood control, supporting services such as nutrient cycling, provisioning services such as food and water, and cultural services such as education and recreation (Millennium Ecosystem Assessment, 2005). For a more detailed description of the above benefits see Howe *et al*. (1991); Kotze and Breen (1994), Kotze (1996a) and Millennium Ecosystem Assessment (2005).

Due to differences in the pattern of water flow through different hydro-geomorphic (HGM) type, the tool requires that the wetland is divided into discrete HGM units at the outset. Ecosystem services for each HGM unit are assessed separately.

The specific purposes for which the results of the assessments are intended include the following:

- Prioritise for the allocation of management and rehabilitation resources across a set of wetlands (especially for large landholders such as forestry companies).
- Assess potential and actual ecosystem service outcomes of wetland rehabilitation projects by applying the assessment to '*with rehabilitation*' and '*without rehabilitation*' situations and comparing the difference between the two situations.
- Plan catchment management to determine the relative importance of individual wetlands in a catchment context.
- Flag important ecosystem services in a basic assessment or in the scoping stage of a full Environmental Impact Assessment (EIA) that would need to be considered when assessing and planning

Table 1.1: Ecosystem services included in, and assessed by, WET-EcoServices[1]

Ecosystem services supplied by wetlands	**Indirect benefits**	**Regulating and supporting benefits**	Flood attenuation		The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream
			Streamflow regulation		Sustaining streamflow during low flow periods
			Water quality enhancement benefits	Sediment trapping	The trapping and retention in the wetland of sediment carried by runoff waters
				Phosphate assimilation	Removal by the wetland of phosphates carried by runoff waters
				Nitrate assimilation	Removal by the wetland of nitrates carried by runoff waters
				Toxicant assimilation	Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff waters
				Erosion control	Controlling of erosion at the wetland site, principally through the protection provided by vegetation.
			Carbon storage		The trapping of carbon by the wetland, principally as soil organic matter
	Direct benefits	Biodiversity maintenance[2]			Through the provision of habitat and maintenance of natural process by the wetland, a contribution is made to maintaining biodiversity
		Provisioning **benefits**	Provision of water for human use		The provision of water extracted directly from the wetland for domestic, agriculture or other purposes
			Provision of harvestable resources		The provision of natural resources from the wetland, including livestock grazing, craft plants, fish etc.
			Provision of cultivated foods		The provision of areas in the wetland favourable for the cultivation of foods
		Cultural benefits	Cultural heritage		Places of special cultural significance in the wetland, e.g. for baptisms or gathering of culturally significant plants
			Tourism and recreation		Sites of value for tourism and recreation in the wetland, often associated with scenic beauty and abundant birdlife
			Education and research		Sites of value in the wetland for education or research

[1] The wetland benefits included in *WET-EcoServices* are those considered most important for South African wetlands, and which can be readily and rapidly described. This is by no means exhaustive. Other benefits include groundwater recharge and discharge and biomass export, which may all be important but are difficult to characterize at a rapid assessment level.

[2] Biodiversity maintenance is not an ecosystem service as such, but encompasses attributes widely acknowledged as having potentially high value to society.

A rapid assessment is not a substitute for a more detailed multi-disciplinary assessment

different development options.

- Educate and raise awareness (influence perceptions about the values of wetlands and to substantiate why wetlands are important)
- Flag important ecosystem services that need to be considered when managing an individual wetland.

It is perhaps just as important to emphasize what *WET-EcoServices* is *not designed to do*, because users of the system must be fully aware of the limitations of the system.

- Although the system assists in identifying key issues to be considered in a scoping report, it is not designed to quantify in detail the specific level of impact of a current or proposed development. This requires specialist input and a much more detailed investigation than that undertaken at the rapid assessment level of this procedure.
- The system is not designed to provide a single overall measure of value or importance of a wetland, nor is it designed to quantify (in monetary or other terms) the benefits supplied by a wetland. *WET-EcoServices* only goes as far as to assist in assigning indices to these benefits for comparative purposes.
- The system is not designed to assess the integrity (health) of a wetland. Although *WET-EcoServices* includes a few descriptors relating to integrity in the assessment of the biodiversity value of a wetland, integrity is dealt with very uperficially and *WET-EcoServices* does not yield a health score. If the purpose is to assess wetland health, readers are referred to *WET-Health* (Macfarlane *et al*. 2007)[1] which provides a general assessment procedure at two levels of detail. Both levels generate a score for the present ecological state of the wetland according to the DWAF categories.
- Although the system can assist in identifying suitable candidate wetlands for rehabilitation, the system cannot be used as a guide for designing management and rehabilitation systems. For this, users are directed to other tools in this series as described in *WET-RehabPlan*.
- The system does not give a detailed description of a wetland site, including the direct description of hydro-geomorphic processes.
- The system assists in assessing individual wetlands for comparative purposes and does not account for the cumulative value of a group of wetlands.

There is no such thing as an ideal wetland assessment technique. The suitability of any technique depends on the particular wetland and the purpose of the assessment. The subject of assessing wetlands is a controversial one and there are many issues to be taken into account when developing a wetland assessment technique (Bartoldus, 1999).

WET-EcoServices is designed for inland palustrine wetlands. The term palustrine refers to non-tidal wetlands dominated by emergent plants (e.g. reeds), shrubs or trees and includes a variety of systems commonly described as marsh, floodplain, vlei or seep.

1.3 Who are the anticipated users of *WET-EcoServices*?

- Environmental consultants, particularly those undertaking a basic assessment or the scoping component of a full EIA
- Government
  - National and provincial Department of Environmental Affairs (DEAT), particularly those officials reviewing development applications
  - Department of Water Affairs & Forestry (DWAF), particularly in determining the ecological importance and sensitivity of wetlands as part of the Reserve Determination process

1 *WET-Health* and *WET-EcoServices* assess complementary aspects, but in order to make their joint application as integrated as possible, both use a similar scoring approach and logic, and the same descriptors for describing a wetland's hydrogeomorphic setting, hydrological zonation and geologic and climatic settings.

- Catchment Management Agencies
  - Provincial Nature Conservation Bodies
  - Department of Agriculture (national and provincial)
  - Municipalities, particularly those officials dealing with integration of the environment into the Integrated Development Plan (IDP) process
- Parastatals:
  - Working for Wetlands
  - Parks Boards
- The forestry and agriculture sectors
- NGOs dealing with environmental issues
- Educationists dealing with environmental issues

Users of *WET-EcoServices* should have good general experience and training, with a minimum of a diploma or degree in the biophysical sciences, hydrology or agriculture. Further, they should have attended at least a basic introductory course on wetland functioning and values and should have had at least eight weeks experience in field assessment of wetlands. In addition, input is required of someone (e.g. a local extension worker or farmer) with specific local knowledge of the geographical area to which *WET-EcoServices* is to be applied.

2 OVERALL STRUCTURE OF THE WETLAND SYSTEM

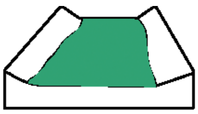
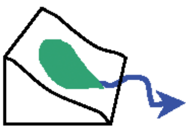
Central to *WET-EcoServices* is the characterisation of hydrogeomorphic (HGM) types, which have been defined based on the geomorphic setting of the wetland in the landscape (e.g. hillslope or valley bottom, whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated), how water flows through the wetland (diffusely or channelled) and how water exits the wetland (Table 2.1). The rationale behind characterizing the hydro-geomorphic types of a wetland is that areas belonging to the same HGM type and falling within a similar geological and climatic setting are likely to have a similar structure and exhibit similar processes. Thus HGM types provide a useful way of delimiting broad units of assessment, and currently the HGM approach (Brinson, 1993; Brinson and Rheinhardt, 1996) is the most widely used in the US for wetland functional assessment.

The HGM types should be identified based primarily on interpretation of aerial photographs of a 1:30 000 scale or finer, viewed through a stereoscope, together with ground verification for a Level 2 assessment. Individual HGM units are distinguished based on HGM type (Section 3.3), and are then assessed, with two levels of assessment being available.

Level 1 is undertaken as a desktop assessment. The ecosystem services assigned to the HGM unit are those that, based on previous studies and experience, have been shown to be generally associated with the particular HGM type/s identified (see Section 3.5). For example, floodplains are characteristically associated with the attenuation of floods and the trapping of sediment. There will inevitably be some wetlands which are incorrectly assessed, for reasons that would only become apparent at a more detailed level. Nevertheless, the desktop level assessment provides a useful overview at a catchment level.

Level 2 is undertaken based on a desktop synthesis of available data followed by a rapid field assessment (2-5 hours per HGM unit depending on the size and complexity of the HGM unit). Each of 15 benefits may be assessed based on a list of characteristics (e.g. slope of the wetland) that are relevant to the particular benefit. Each characteristic used in the system has an information box which provides the rationale for the choice of characteristics and has directions on how to assign scores. Therefore the logic behind the system is open to scrutiny.

Table 2.1: Wetland hydrogeomorphic (HGM) types typically supporting inland wetlands in South Africa (modified from Brinson, 1993; Kotze, 1999; and Marneweck and Batchelor, 2002)

Hydrogeomorphic types		Description	Source of water maintaining the wetland[1]	
			Surface	Sub-surface
Floodplain		Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*
Valley bottom with a channel		Valley bottom areas with a well defined stream channel but lacking characteristic floodplain features. May be gently sloped and characterized by the net accumulation of alluvial deposits or may have steeper slopes and be characterized by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*/ ***
Valley bottom without a channel		Valley bottom areas with no clearly defined stream channel, usually gently sloped and characterized by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.	***	*/ ***
Hillslope seepage linked to a stream channel		Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from sub-surface flow and outflow is usually via a well defined stream channel connecting the area directly to a stream channel.	*	***
Isolated Hillslope seepage		Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs mainly from sub-surface flow and outflow either very limited or through diffuse sub-surface and/or surface flow but with no direct surface water connection to a stream channel.	*	***
Depression (includes Pans)		A basin shaped area with a closed elevation contour that allows for the accumulation of surface water (i.e. it is inward draining). It may also receive sub-surface water. An outlet is usually absent, and therefore this type is usually isolated from the stream channel network.	*/ ***	*/ ***

[1] Precipitation is an important water source and evapotranspiration an important output in all of the above settings

Water source: * Contribution usually small

*** Contribution usually large

 Wetland

*/ *** Contribution may be small or important depending on the local circumstances

*/ *** Contribution may be small or important depending on the local circumstances.

This classification is aligned closely with the 'inland wetland' classes of the classification of Ewart-Smith et al. (2006), which was developed subsequent to *WET-EcoServices*. The main difference between the classification in this table and that of Ewart-Smith *et al*. (2006) is that Ewart-Smith *et al*. (2006) include 'depressions linked to streams', which is a rarely occurring wetland type, and 'channels' (i.e. streams and rivers), which are beyond the scope of *WET-Health* since they would for part of an assessment of River Health.

The characteristic hydrological conditions associated with the different HGM types is complicated particularly in the case of coastal plain wetlands, such as those occurring on the Cape Flats and the Maputoland coastal plain, which are in direct contact with the regional water table. Thus, they are fed by both their local topographically-defined catchment as well as by a much larger catchment feeding the regional water table, and the relative contribution of these two sources is likely to vary from wetland to wetland. This is probably of greatest significance for depressions, which, outside of the coastal plain, are characteristically inward draining. However, on the coastal plain, although a depression may be inward draining in terms of surface drainage, in terms of subsurface drainage it is simply an expression of the regional water table, and therefore clearly has an open drainage system.

Wetland hydrogeomorphic (HGM) types used in the *WET-Management* Series

Floodplain

Channelled valley bottom

Unchannelled valley bottom

Unchannelled valley bottom

Hillslope seepage linked to a stream channel

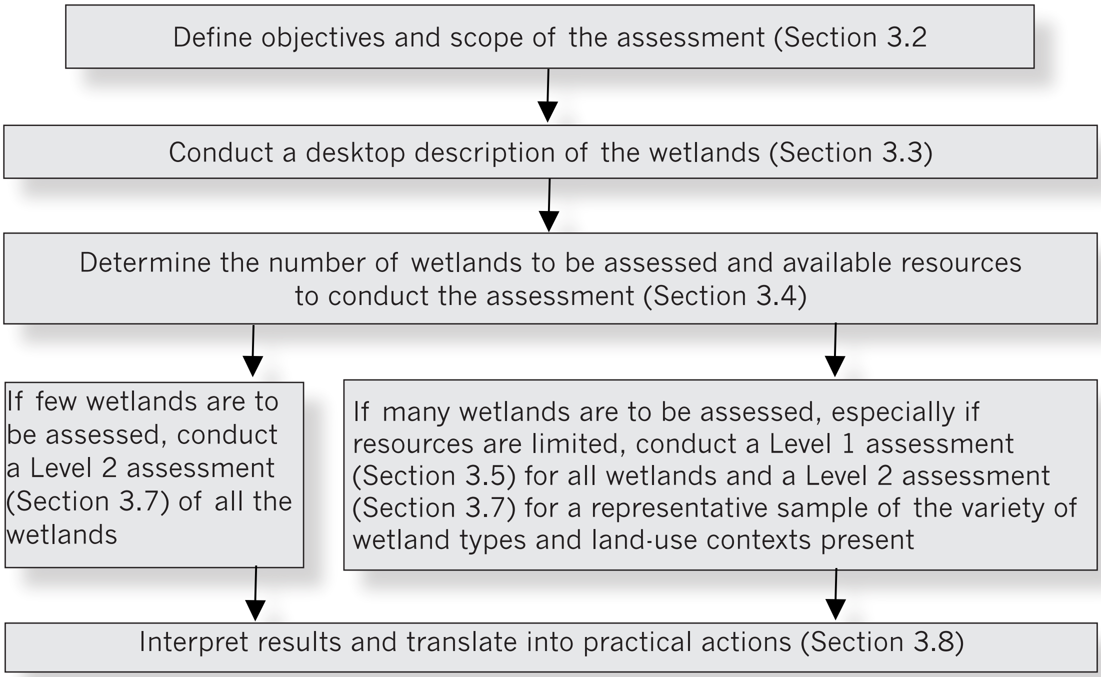
Isolated hillslope seepage

Depression

3 THE ASSESSMENT PROCEDURE

3.1 Steps to follow in applying the procedure

The steps involved in applying *WET-EcoServices* can be summarised as follows.



3.2 Define your objectives and the scope of your assessment

Define clearly the objectives of your intended wetland assessment. For example, you may wish to assess the importance of 20 different wetlands for their contribution to the enhancement of water quality in a sub-catchment, which has a water pollution problem. State also how you intend to use the results of the assessment (e.g. to prioritise the allocation of limited resources for protecting the wetlands in a particular catchment for the purposes of enhancing water quality in that catchment). To do this you need to think carefully about how the information you collect will be used for supporting decisions. See Dickens *et al*. (2003), which provides guidelines for integrating wetlands into planning and decision making for catchments.

Read through *WET-EcoServices*, making sure that you understand the capabilities and the scope of the system. Is *WET-EcoServices* appropriate for your assessment objectives? If so, continue with the assessment.

Based on your defined objectives, decide which of the ecosystem services listed in Table 1.1 you need to assess. For example, your objective may be to describe the wetlands for catchment planning purposes and you therefore need to assess the hydrological benefits (including flood attenuation, phosphate assimilation etc.). You may have an even more specific objective, e.g. phosphates have been identified as a problem in a catchment and the wetlands need to be assessed for their phosphate assimilation capacity.

Alternatively, you may be undertaking a basic assessment of the wetlands in an area to be affected by a proposed development and you need to assess all of the benefits included by *WET-EcoServices* so as to assist in highlighting any potential impacts (i.e. a broad assessment is required). Once you have decided which ecosystem services you need to assess, refer to Section 4 to see which characteristics of the wetland you will need to describe. This ensures that you do not waste time collecting information that is not required.

3.3 The desktop description

Begin by obtaining wetland data from the National Wetland Inventory, undertaken as part of the National Land Cover (NLC) 2000 initiative to provide a broad overview of the wetlands in the catchment. Contact SANBI: Working for Wetlands at 012 8435000 for further information. It is important to emphasize, however, that this inventory is at a very low resolution and provides no attribute details on the individual wetlands.

Next, obtain aerial photographs covering the assessment area, preferably the most recently available. Contact the Surveyor General at 021 6584300, and remember to allow for time to order the photographs. The photographs should be at a minimum scale of 1: 30 000. Satellite imagery is not suitable for mapping of this detail (Thompson *et al.*, 2002) but may provide useful supplementary information. Based on interpretation of the aerial photographs with the aid of a stereoscope, delineate the boundary of the different wetlands and identify to which of the seven HGM types represented in Table 2.1 the wetland belongs. Some wetlands, particularly smaller wetlands, consist of a single HGM unit. Other wetlands, particularly large wetlands extending across a heterogeneous landscape, consist of several different HGM types. An example has been given in Figure 3.1. If this is the case, the wetland should be divided into individual units based on these types and each unit should be assessed individually. The boundary between one unit and another may be unclear and you will need to read carefully the descriptions of the types in Table 2.1. Remember that the transition is often, but not always, associated with a change in slope. For example, a transition from floodplain to hillslope, as in Figure 3.1, is associated with an increase in slope.

The interpretation of aerial photographs requires experience, some degree of familiarity with the area being covered, and preferably a certain amount of field verification of the interpretations made. Field verification would generally be most efficiently carried out during the field-based Level 2 assessment (see Section 3.7) and should involve observation in the field of at least one representative example of all of the different HGM types identified in the aerial photograph interpretation. Refer to the delineation guidelines provided by DWAF (2006), and for information on delineating the wetland's catchment view: *http://www.nh.nrcs.usda.gov/technical/WS_delineation.html*. It is important to note that errors in delineation may profoundly influence the outcome of the assessment, where, for example, a wetland boundary is delineated at the edge of the valley bottom when in fact it extends some distance up the hillslope.

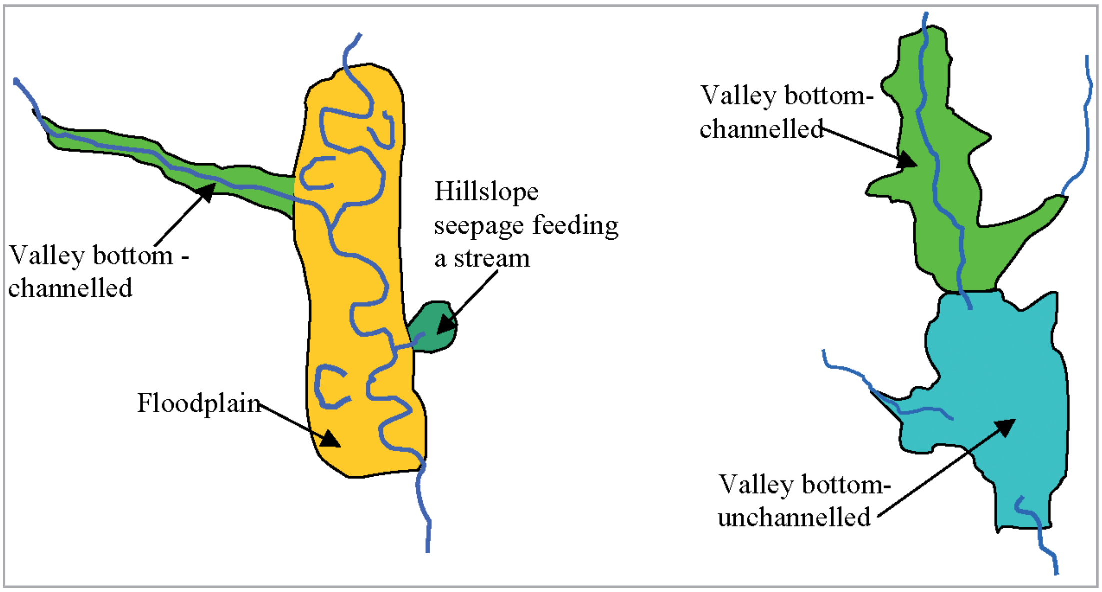


Figure 3.1: Two wetlands, the first comprising three different HGM units and the second comprising two units (see Table 2.1 for definitions of the types)

3.4 Determining the number of wetlands to assess and the level of assessment

If only a few wetlands (i.e. fewer than about 10) are to be assessed on a localised scale, then a Level 1 assessment is generally required for all of the wetlands. For broad-scale catchment-wide assessments, a Level 1 desktop assessment is generally required for all wetlands in the area of interest (using Table 3.1) and a Level 2 assessment of a sample of the wetlands. Make sure that for each bioclimatic/ecoregion (e.g. defined by DWAF) represented in the sample, a reasonable number (about 3-10 wetlands) of each of the different HGM types represented is assessed at Level 2. This is necessary because the composition, structure and functioning of wetlands are strongly influenced by both climate and hydro-geomorphology (Kotze and O'Connor, 2000; Brinson, 1993). It is important to also include in the sample the variety of land-use contexts represented (e.g. large-scale commercial agriculture, urban etc.) because the impacts on wetland functioning are likely to vary according to the particular context.

Compare the Level 1 scores with those obtained from the Level 2 assessment. This provides some measure of cross-checking of the assessments. If there is a noticeable difference, then an adjustment of the scores may be made, provided that the justification for the adjustment is clearly explained. Particular local circumstances may, for example, poorly fit some of the broad assumptions made in the Level 1 assessment as contained in Table 3.1. For example, some floodplains may be relict, with stream channels much more deeply incised than historically so, with bank overspill and spreading of the floodwaters no longer taking place, which would be revealed by a Level 2 assessment. Prescriptions for making the adjustments (e.g. through specified weightings) are not provided. However, with field-testing of *WET-EcoServices*, it is anticipated that the relationship between the two levels will become better understood and that the guidelines will then be improved for linking these two levels of assessment.

3.5 Level 1 assessment

At Level 1, wetlands are screened using a desktop assessment to establish whether they are likely to be providing any of the listed hydrological benefits. For the HGM type/s which are identified, refer to Table 3.1 to see which hydrological benefits are likely to be provided by the wetland given its particular HGM type/s.

Table 3.1: Preliminary rating of the hydrological benefits likely to be provided by a wetland based on its particular hydro-geomorphic type[1]

WETLAND HYDRO-GEO-MORPHIC TYPE	REGULATORY BENEFITS POTENTIALLY PROVIDED BY WETLAND							
	Flood attenuation		Stream flow regulation	Enhancement of water quality				
	Early wet season	Late wet season		Erosion control	Sediment trapping	Phos-phates	Nitrates	Toxicants[2]
1. Floodplain	++	+	0	++	++	++	+	+
2. Valley-bottom - channelled	+	0	0	++	+	+	+	+
3. Valley-bottom - unchannelled	+	+	+?	++	++	+	+	++
4. Hillslope seepage connected to a stream channel	+	0	+	++	0	0	++	++
5. Isolated hillslope seepage	+	0	0	++	0	0	++	+
6. Pan/ Depression	+	+	0	0	0	0	+	+

Notes: [1] The rationale for the rating of benefits is given in Section 3.6
[2] Toxicants are taken to include heavy metals and biocides.

Rating: 0 Benefit unlikely to be provided to any significant extent
+ Benefit likely to be present at least to some degree
++ Benefit very likely to be present (and often supplied to a high level)

Carbon trapping is not included above because it is difficult to relate carbon trapping and the occurrence of peat to particular HGM types. However, the occurrence of peat has been related to factors such as climate and geology, and users are referred to the peat eco-regions described and mapped by Marneweck *et al.* (2001).

From a biodiversity point of view, no one particular HGM type is considered to be more valuable than another type. Biodiversity conservation is about ensuring representation of a diversity of different types. To establish whether the wetland is known to be important from a biodiversity conservation point of view, contact the provincial Nature Conservation body to see if there are any records of the wetland supporting a threatened species or being of a rare or threatened wetland type or possessing other notable natural features. Also check whether the wetland falls within a vegetation type that has been subject to a high cumulative loss/ transformation. Remember, however, that in South Africa the majority of wetlands have not yet been examined in any detail for the species that they support, except for conspicuous species such as cranes.

Unless existing surveys exist, it is generally not possible to undertake a desktop assessment of the direct benefits of wetlands (e.g. water supply, harvestable resources etc.) unless obvious features such as cultivated lands in wetlands are visible on the aerial photographs. Therefore a Level 2 assessment will be required to reveal these benefits.

3.6 Rationale for assigning of hydrological benefits to HGM types

1. Floodplains

Floodplains generally receive most of their water during high flow events when waters overtop the streambanks. Floodplains are considered to be important for flood attenuation because of the nature of the vegetation and the topographic setting that they occupy. Flood attenuation is likely to be high early in the season until the floodplain soils are saturated (see McCartney, 2000 and McCartney *et al.*, 1998) and the oxbows and other depressions are filled. In the late season, the flood attenuation capacity is usually reduced. Nevertheless, even in the late season flood attenuation is still likely to be carried out to some extent, particularly in drier years.

Floodplains are generally unlikely to contribute significantly to stream flow regulation. The generally clayey floodplain soils retain water, which is then likely to be lost through evapotranspiration. This, in turn, limits their contribution to streamflow and groundwater recharge. Nevertheless, floodplains with coarse sediments could contribute significantly to streamflow and groundwater recharge.

Floodplains often contribute significantly in trapping phosphorus. In general, once the flood overtops the river banks, the velocity of flow decreases laterally, permitting the deposition of sediment particles within the floodplain landscape. Thus phosphorous, which tends to be bound strongly to mineral sediments, is likely to be effectively retained on the floodplains (Boto and Patrick, 1979; Hemond and Benoit, 1988); see Box 4.4a.

Nitrogen removal via nitrification/denitrification is likely to occur but be limited due to short residence times during flood events (which limits contact between the bulk of the water and the sediments) and due to the generally limited sub-surface water movement within the wetland. Furthermore, the concentration of nutrients in flood waters entering the floodplain is often low due to dilution effects. However, the behaviour of nitrogen in oxbows and depressions is likely to be similar to that in pans, with cycling between dissolved and organic forms and with some removal from the water through denitrification.

Seekoeivlei in the Free State and the lower portions of Blood River Vlei, in KwaZulu-Natal, are examples of floodplain wetlands.

2. Channelled valley-bottom wetlands

Channelled valley bottom wetlands resemble floodplains. However, they are characterized by less active deposition of sediment and an absence of oxbows and other floodplain features such as natural levees and meander scrolls. They tend to be narrower and have somewhat steeper gradients and the contribution from lateral groundwater input relative to the main stream channel is generally greater.

From a functional point of view, they tend to contribute less towards flood attenuation and sediment trapping, but would supply these benefits to a certain extent. Some nitrate and toxicant removal potential would be expected, particularly from the water being delivered from the adjacent hillslopes (The Federal Interagency Stream Restoration Working Group, 1998).

3. Non- channelled valley-bottom wetlands

This type resembles a floodplain in its location and gentle gradient, with potentially high levels of sediment deposition. In contrast, however, stream channel input is spread diffusely across the wetland even at low flows, resulting in extensive areas of the wetland remaining permanently saturated and tending to have high levels of soil organic matter. Nitrate and toxicant removal is consequently expected to be higher than in floodplains owing to the greater contact of the wetland with **runoff** waters, particularly if there is a significant groundwater contribution to the wetland. The shallow waters promote sunlight penetration, contributing to the photo-degradation of certain toxicants. However, phosphate retention levels tend to be lower than in floodplains because a certain amount of phosphate may be re-mobilized under prolonged **anaerobic** conditions (Cronk and Siobhan Fennessy, 2001; Keddy, 2002). In addition, the nitrate removal potential would generally not be as high as in seepage slopes because sub-surface water movement through the wetland (where the greatest levels of nitrate removal generally take place associated with high organic matter levels and low dissolved oxygen levels) occurs to a lesser degree owing to the generally finer, less permeable soils and lower gradients. However, where sub-surface water inputs are high, nitrate removal levels in unchannelled valley bottoms may be similar to hillslope seepage wetlands.

Streamflow regulation may take place to some extent, but this is likely to depend strongly on factors such as transpirative loss from the vegetation, and the nature of the soil, which would require field description to characterize.

Typical examples of this type include Wakkerstroom vlei in Mpumalanga, Mgeni vlei in KwaZulu-Natal, and Bedford/ Chatsworth wetland in the eastern Free State.

4. Hillslope seepage wetlands connected to a stream channel

These systems are normally associated with groundwater discharges, although flows through them may be supplemented by surface water contributions. These wetlands are expected to contribute to some surface flow attenuation early in the season until the soils are saturated, after which their contribution to flood attenuation is likely to be limited (WRP, 1993; McCartney, 2000; McCartney *et al*., 1998).

It is recognized that evapotranspiration in the wetland may result in a considerable reduction in the total volume of water which would otherwise potentially reach the stream system (this would also apply to other wetland types). Nonetheless, the accumulation of organic matter and fine sediments in the wetland soils results in the wetland slowing down the sub-surface movement of water down the slope. This ‘plugging’ effect increases the storage capacity of the slope above the wetland, and prolongs the contribution of water to the stream system during low flow periods. For some hillslope seepage wetlands this contribution may continue into the dry season, but for many others it is confined mainly to the wet season.

Seepage wetlands are commonly considered to supply a number of water quality enhancement benefits, for example, removing excess nutrients and inorganic pollutants produced by agriculture, industry and domestic waste (Rogers *et al.*, 1985; Gren 1995; Ewel, 1997; Postel and Carpenter, 1997). Hillslope seepages generally would be expected to have a relatively high removal potential for nitrogen in particular. Nitrogen and specifically nitrate removal could be expected as the groundwater emerges through low redox potential zones within the wetland soils, with the wetland plants contributing to the supply of organic carbon necessary to 'feed' the denitrification process. Particularly effective removal of nitrates has been recorded from diffuse sub-surface flow, as characterizes hillslope seepages (Muscutt *et al.*, 1993).

Owing to their generally steep slope, which increases the risk of erosion, hillslope seepages tends not to be very important from an erosion control point of view, provided that the vegetation remains intact.

5. Isolated hillslope seepage wetlands

This wetland type closely resembles the previous type in terms of sources of water and functioning. The key difference, however, is that these systems tend to have a lower degree of wetness and make little direct contribution to streamflow regulation as they are not directly connected to a stream channel. Some of these settings do, however, contribute via sub-surface water flow, e.g. on slopes with very sandy soils.

6. Depressions (pans)

Depressions can receive both surface and groundwater flows, which accumulate in the depression owing to a generally impervious underlying layer which prevents the water draining away (Goudie and Thomas, 1985; Marshal and Harmse, 1992). The relative contributions of these different water sources may vary considerably amongst different depressions. The opportunity for attenuating floods is limited by the position of pans in the landscape, which are generally isolated from stream channels. However, they do capture runoff because of their inward draining nature, and thus they reduce the volume of surface water that would otherwise reach the stream system during stormflow conditions. This inward draining nature, together with their generally impermeable underlying layer, however, also means that pans are unlikely to play a significant role in streamflow regulation, although in the Highveld there appear to be some exceptions to this (see Section 4.2, Box 4.2a). In addition, pans are also not considered important locations for sediment trapping, with many pans, in fact, originating from the removal of sediment by wind, thus creating what are referred to as deflation basins (Goudie and Thomas, 1985; Marshal and Harmse, 1992).

Temporary pans allow for the precipitation of minerals, including phosphate minerals due to the concentrating effects of evaporation. Nitrogen cycling is likely to be important with some losses due to denitrification, and volatilization in the case of high pHs. Water quality in pans is influenced by the pedology, geology, and local climate (Allan *et al.*, 1995). These factors, in turn, also influence the response of these systems to nutrient inputs. In pans that dry out completely at some stage or another (non-perennial pans), some of the accumulated salts and nutrients (such as organic nitrogen, and various phosphate and sulphate salts) can be transported out of the system by wind and be deposited on the surrounding slopes. Those remaining may dissolve again when waters enter the system again as the pan fills after rainfall events.

3.7 Level 2 assessment

3.7.1 The procedure used for scoring wetland characteristics

Begin by reviewing the results of the desktop description of the wetland, taking particular note of the HGM type/s making up the wetlands. A separate assessment will be required for each of the types represented, given their distinct functional features highlighted in Section 3.3. When conducting a Level 2 assessment, it is important to bear in mind that the delivery of ecosystem services is linked to climate through the wetland's hydrology (Box 3.1).

For a level 2 assessment, the site should ideally be visited in both the dry and wet seasons. However, it is recognized that often this is not possible. If this is the case, then the wet season is preferable, but it is still feasible to carry out an assessment in the dry season.

Before undertaking the field visit, refer to Appendix 1, Sheet 1 in the form of a CD appended to back cover, which lists all of the wetland characteristics that need to be described, and highlights those that can be described in the office before the field visit. Appendix 1, Sheet 1 also lists the ecosystem services for which each characteristic is relevant. If you intend assessing all the ecosystem services, which is generally the case, then all characteristics should preferably be described. However, if you intend assessing only some of the ecosystem services, Sheet 1 highlights those characteristics which you can omit. You will notice that some characteristics are used for assessing several ecosystem services (e.g. hydrological zonation is used to assess streamflow regulation, nitrogen assimilation, toxicant assimilation and carbon storage etc.) while other characteristics are relevant to only one ecosystem service.

The full checksheets for all 15 ecosystem services included in *WET-EcoServices* are given in Section 4, Tables 4.1 to 4.15, and the blank datasheet is given in Appendix 1, Sheet 2. The checksheet for one of the ecosystem services, nitrate removal, has been copied in Table 3.2 with two hypothetical wetlands represented to indicate how the scoring system operates. Each characteristic for a given wetland service must be scored from 0 to 4, and for each information is supplied in a box on the rationale for the score classes and guidance on how to collect the necessary data.

Box 3.1: The importance of considering climatic fluctuations when assessing ecosystem services

South Africa is well known for its fluctuating climate, particularly in the drier portions of the country. Wetlands are generally hydrologically very dynamic, responding to these climatic fluctuations. This, in turn, often leads to fluctuations in the delivery of ecosystem services (e.g. the provision of reeds used for craft production may decrease in dry years and increase in wetter years). Climatic fluctuations may also profoundly influence the demand for these resources (e.g. the demand for livestock grazing in a wetland may increase during dry years as a result of greatly diminished grazing outside of the wetland. Although the total biomass production in a wetland may be less during drier years than wetter years, the availability of grazing may, in fact, increase during drier years owing to the drier wetland being more accessible to livestock). Thus the ecosystem services supplied by a wetland should be assessing based on consideration of a time period including both wetter and drier years rather than the assessment reflecting the situation in only a single year.

For several of the ecosystem services assessed, including that given in Table 3.2, characteristics are grouped according to:

- The effectiveness of the wetland for supplying a particular benefit (e.g. for flood attenuation, the more gentle the slope then the more effective the wetland is likely to be. Similarly, for nitrate assimilation, the more diffuse the pattern of low flows the more effective the wetland is likely to be); and
- The opportunity afforded the wetland supplying the ecosystem service (e.g. the greater the extent of nitrate point sources in the wetland's catchment, the greater will be the likely inputs of nitrates to the wetland and therefore the greater will be the opportunity afforded the wetland for assimilating nitrates). It should be added that some 'opportunities' (e.g. nitrate point sources) would diminish wetland integrity.

To obtain an overall rating for the particular wetland benefit, *WET-EcoServices* purposefully avoids complicated weighting systems, and is based on an average. Where there are characteristics relating to effectiveness and opportunity, as in Table 3.2, an average is calculated for each of these two groups. For example, for nitrate removal, an average for effectiveness is calculated based on the average for Characteristics 1 to 5, and the average for opportunity is based on the average for Characteristics 6 and 7. Calculate the overall score as the average for these two scores (Table 3.2) and then refer to the rating classes in Table 3.3. For HGM Unit A in Table 3.2 this would be a moderately high class, and for Wetland B it would be a high class.

Table 3.2: Checksheet for two hypothetical HGM units (A and B) for the ecosystem service 'nitrate removal'

Characteristics Score:	0	1	2	3	4
Effectiveness					
1. Representation of different hydrological zones (temporary/ seasonal and permanent (Box 4.5a)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60%
2. Pattern of low flows within the HGM unit(Box 4.4b)	Strongly channeled	Moderately channeled	Intermediate	Moderately diffuse	Very diffuse
3. Extent of vegetation cover (Box 4.5b)	Low	Moderately low	Intermediate	Moderately high	High
4. Contribution of sub-surface water inputs relative to surface water inputs (Box 4.5c)	Low (<10%)	Moderately low (10-20%)	Intermediate (20-35%)	Moderately high (36-50%)	High (>50%)
5. Extent to which fertilizers/biocides are added directly to the HGM unit (Box 4.4d)	High	Moderately high	Intermediate	Moderately low	Low

Opportunity:					
6. Extent of nitrate sources in the HGM unit's catchment (Box 4.5d)	Low	Mod low	Intermediate	Mod high	High
7. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance

Effectiveness score: Average of characteristics 1 to 5. HGM A = 2.2; HGM B = 3.8

Opportunity score: Average of characteristics 6 to 7. HGM A = 2.5; HGM B = 2.0

Overall score: Average of the effectiveness score and the opportunity score. HGM A = 2.4; HGM B = 2.9

Note: for some characteristics (e.g. important wetland or aquatic system downstream) some classes are blanked out because the resolution is not adequate to distinguish 5 classes.

The boxes referred to in the table appear in Section 4 and provide the rationale for the score classes and guidance in how to collect the necessary data.

Table 3.3: Classes for determining the likely extent to which a benefit is being supplied based on the overall score for that benefit

Score:	<0.5	0.5-1.2	1.3-2.0	2.1-2.8	>2.8
Rating of the likely extent to which a benefit is being supplied	Low	Moderately low	Intermediate	Moderately high	High

Scoring can be undertaken directly in the checksheets given in Section 4 and calculated manually. In addition, Appendix 1 provides a spreadsheet on Sheet 2 for entering the data that you gather. The spreadsheet then automatically copies those values to where they are required in Sheet 3, where the overall scores for each of the ecosystem services are automatically calculated. You will notice in Sheet 3 that the scores for some ecosystem services are used as characteristics for other ecosystem services (e.g. the score for flood attenuation is used to assess sediment trapping, given that the more effective the wetland is in slowing down floodflows and attenuating floodpeaks the greater will be the level of deposition of sediment).

For each characteristic to which a score is allocated, the datasheet allows for the assessor to rate the confidence that they place in their score, based on the reliability of the source of information and the level of accuracy. The following scale should be used:

- Very high confidence = 4
- High confidence = 3
- Moderate confidence = 2
- Marginal/low confidence = 1

If, for example, an accurate delineation of the wetland and its catchment had been undertaken, then the confidence placed in the score for the size of the wetland relative to its catchment would be very high (i.e. a score of 4). Similarly, *if* the flow pattern of stormflows in a wetland is assessed based on existing hydraulic data for the wetland and on good local knowledge from people who have been living nearby the wetland for many decades, *then* the confidence would be high. In contrast, *if* the flow pattern was inferred from landform based on a once-off visit with no hydraulic data or local knowledge, *then* the confidence would be low (i.e. a score of 1).

The fact that *WET-EcoServices* determines the score for the benefit based on an average of the scores for the relevant characteristics makes it possible to calculate a score even if not all of the characteristics are known (i.e. the overall score is not penalised by any missing characteristics). However, the more of the relevant characteristics that are known, particularly those for which one has a high confidence, the greater will be the confidence in the overall score for the benefit. Conversely, the greater the number of characteristics which are missing or for which one has a low confidence, the lower will be one's confidence in the overall score. Based on this reasoning, an overall confidence score is calculated for each benefit assessed, with missing characteristics scoring zero for their confidence value.

Finally, Appendix 1, Sheet 2, allows for entering additional notes for each of the characteristics, where valuable information concerning the justification for scoring can be provided.

As highlighted earlier, *WET-EcoServices* is not a quantitative method. In the case of the provisioning (i.e. relating to products such as food) and cultural services (Section 4.10 to 4.15), the method is sensitive to even a small amount of recorded use of the wetland, and does not make much of a distinction between wetlands used at moderate levels and those used at high levels. If quantitative data are available on the these services (e.g. quantity of food produced from the wetland and the number of poor people dependent on this food), the user may choose to use this for determining the provisioning value of the wetland instead of using the scoring system prescribed in *WET-EcoServices*. This can be done manually, provided that written justification is given and the adjusted class limits for scoring are provided.

3.7.2 Presenting and interpreting the scores

A word of warning: Scoring systems are open to misuse. Please be very careful not to misuse the ratings obtained through the application of *WET-EcoServices*! The ratings are derived to a large extent from qualitative data and provide only a preliminary indication of the likely provision of ecosystem services. Studies such as Environmental Impact Assessments (EIAs) and other such assessments may require more detailed quantitative data.

Comparing the scores of different wetlands is likely to be most reliable when confined to the same HGM type (e.g. a comparison of different individual floodplains) and HGM units of similar size. Nevertheless, the scores of wetlands from different HGM types can still be compared as a means of enhancing one's ability to make a value judgment amongst different wetlands. It is important when interpreting the scores that due attention is given to the following:

- Current vs potential future benefit
- Accounting for the size of the HGM units assessed
- Interpreting the results for wetlands consisting of a composite of several different HGM settings

Current vs potential future benefit

WET-EcoServices determines the level of service delivered based on both the current and future potential benefits. These benefits are inferred from the effectiveness and opportunity scores, as shown in Table 3.3. Some wetlands may be potentially very effective in delivering a particular benefit (and will therefore have a high sub-score for effectiveness) but currently are afforded very little opportunity for providing the benefit (i.e. a low sub-score for opportunity). Such wetlands would score at intermediate level overall, even though the benefit that they are currently delivering (what could be described as the 'actual' benefit) is low. The justification for this evaluation is that with future developments (e.g. agricultural intensification of the wetland's catchment), the high potential benefit may quickly be realized to become a current benefit. From Table 3.4, it can also be seen that if the effectiveness of a wetland is low, then the overall benefit delivered remains intermediate even if the opportunity is high.

Where it is important to make a distinction between current and potential future benefit then the sub-scores should be reported. Otherwise a reporting of the overall benefit may be adequate.

Accounting for the size of the HGM unit

It is important to remember that in *WET-EcoServices*, the ecosystem services are scored without reference to the absolute size of the wetland. A very general assumption could be made that the larger the wetland, the greater will be the provision of benefits. However, the importance that size has in the provision of benefit varies considerably depending on the particular benefit and the local circumstances at the wetland (Box 3.2). Table 3.5 provides

Table 3.4: Inferred benefit based on the joint consideration of effectiveness and opportunity, which are defined in Section 3.7.1

		Opportunity	
		Low	High
Effectiveness	Low	Low benefit	Intermediate benefit
	High	High potential future benefit	High current benefit

an indication of the general importance that wetland size has for the provision of each benefit, and should be used as a tool when interpreting the summary table. *WET-EcoServices* accounts for size of HGM unit at the stage of interpreting the Summary Table (Table 3.6). In a South African context, any wetland less than 1 ha would be considered small and that over 100ha, large.

Comparing assessment results across different HGM units

It is not possible to specify exactly how the results from different HGM units should be compared, because this will in part be determined by the particular objectives of the assessment. Nevertheless, some general recommendations should be considered.

- Agglomerating all of the individual scores for each of the different ecosystem services into a single score for the HGM unit assessed is not recommended.

Table 3.5 Importance of wetland size in contributing to the provision of particular benefits

Ecosystem service	Importance of size
Flood attenuation	****
Streamflow regulation	**
Sediment trapping	****
Phosphate assimilation	****
Nitrate assimilation	***
Toxicant assimilation	***
Erosion control	***

Ecosystem service	Importance of size
Carbon storage	***
Biodiversity maintenance	**
Water supply	**
Harvestable resources	**
Cultural significance	*
Cultivated foods	***
Tourism and recreation	**
Education and research	*

Size is seldom important	*
Size is usually moderately important	**
Size is usually very important	***
Size is always very important	****

Box 3.2: The importance of wetland size in contributing to supplying ecosystem services: some examples

Some ecosystem services may be little affected by the size of the wetland. Take, for example, a wetland considered to have a high cultural value because it contains a sacred spring. Whether the wetland containing the spring is 1 ha or 500 ha it is unlikely to have any bearing on this cultural value. In contrast, other ecosystem services may be considerably affected by wetland size. Take, for example, a one hectare wetland which scores high for flood attenuation (because it occupies a high proportion of its catchment, has a high surface roughness and a gentle slope etc.). Now compare this with another wetland having exactly the same features (e.g. high surface roughness) except that the wetland is 500 ha. Although both wetlands are being effective in attenuating floods issuing from their catchments, the larger wetland is 'servicing' a much larger catchment, and it could therefore be argued that it in order of magnitude more important than the smaller wetland for attenuating floods.

This is not to say, however, that collectively several smaller wetlands could not have an effect equivalent to or greater than a larger wetland.

- Tabular comparisons are recommended, where the size of each unit assessed is also shown, together with the scores for each of the ecosystem services assessed (see an example in Table 3.6).
- As indicated in Section 3.3, where a wetland comprises a composite of several different HGM settings, each of the different hydro-geomorphic units making up the wetland must be assessed separately. Rather than combining the results into a single score for the overall wetland, it is preferable that the results are presented in tabular form as separate assessments in a summary table using a numbering convention that allows one to see at a glance which HGM units fall within the same wetland (see an example in Table 3.6).
- It is recommended further that the data be spatially represented on a map showing the distribution and extent of each of the units represented. If only a single ecosystem service has been assessed then this may be represented in a spatial coverage, with the level of delivery of the service represented by a particular colour (e.g. from blue representing low to red representing high). However, if several ecosystem services are to be represented, then use should be made of icons, 'radar' or 'spider' diagrams such as that illustrated in Figure 3.2. Appendix 1, Sheet 5, has been set up to represent the ecosystem services in a 'radar' diagram.

3.8 Assessing threats and future opportunities, and translating the results into practical actions

'Threat' refers to potential or impending pressures likely to impact detrimentally on the ecosystem services supplied by the HGM unit (e.g. active gully erosion, a proposed transformation of the surrounding landscape etc.). 'Future opportunities' refers to the prospects of enhancing the supply of benefits by the HGM unit. This includes opportunities for enhancing effectiveness of the HGM

Table 3.6: **Summary table for two hypothetical wetlands, the first comprising three adjacent hydrogeomorphic units and the second comprising two adjacent hydro-geomorphic units (as represented in Figure 3.1)**

HGM unit code	Hydro-geomorphic type	Size (ha)	Ecosystem services				
			Flood atten-uation ****	Streamflow regulation **	Sediment trapping ****	Biodiversity maintenance **	Provision of harvestable resources**
1a	Floodplain	155	3	1	3	1	1
1b	Valley bottom - channelled	64	2	2	2	4	2
1c	Hillslope seepage connected to a stream channel	8	2	3	1	1	0
2a	Valley bottom - channelled	80	2.5	2	2	2	1
2b	Valley bottom - unchannelled	90	2.5	2.5	2	4	4

Those HGM units occurring within the same wetland share the same number in their HGM unit code but are distinguished by letters of the alphabet.

Size is seldom important * Size is usually moderately important **
Size is usually very important *** Size is always very important ****
See section 3.7.2 for details regarding the importance of size in the provision of ecological services

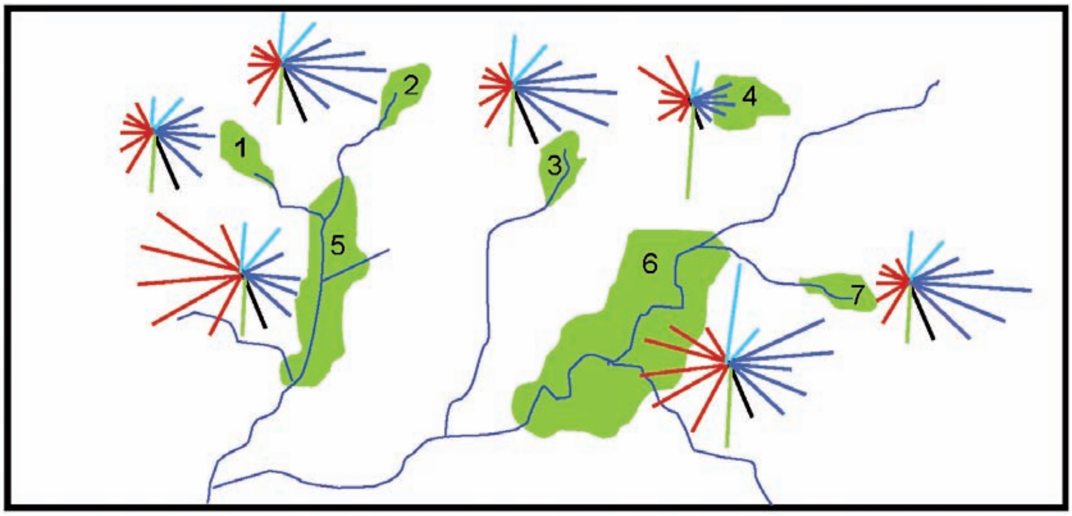
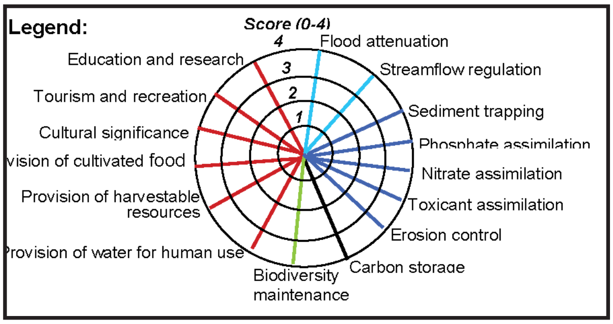


Figure 3.2: A spider diagram representation of seven hypothetical wetlands assessed in terms of their delivery of the 15 different ecosystem services shown in the legend.

A spider diagram representation of seven hypothetical wetlands assessed in terms of their delivery of the 15 different ecosystem services shown in the legend. Wetlands 2, 3 and 7 are particularly important for water quality-related services, 4 is especially important for biodiversity alone, 5 is particularly important in terms of direct benefits and wetland 6 has the widest importance across the 15 ecosystem services.



unit (e.g. by plugging artificial drains to reinstate a more naturally diffuse flow pattern) and opportunities for increasing the current level of direct use of a wetland (e.g. sustainable harvesting of unutilised Phragmites australis reeds).

Once you have completed the assessment, interpreted your results and identified threats and future opportunities then return to your objectives and statement of the intended use of the results. Now examine what needs to be done to put the results to good use. Ensure that the results of the assessment are turned into actions, as otherwise your efforts will have been wasted. The identification of threats and future opportunities will be of particular value in highlighting required actions. Generally speaking, the greater the threats and future opportunities, the greater will be the need for management interventions. For assistance in integrating your results into catchment management, consult the guidelines of Dickens *et al.* (2003). Also be sure to lodge your assessment results where they will be as readily accessible as possible to a variety of different potential users.

4 CHECKSHEETS FOR A LEVEL 2 ASSESSMENT

4.1 Flood attenuation

Flood attenuation refers to the spreading out and slowing down of flood waters, thereby reducing the severity of floods downstream and the potential damage that the floods may cause (Table 4.1).

Table 4.1: Characteristics contributing to attenuation of floods by an HGM unit

Characteristics Score:	0	1	2	3	4
Effectiveness of the HGM unit					
1. Size of HGM unit relative to the HGM unit's catchment (Box 4.1a)	<1%	1-2%	3-5%	6-10%	>10%
2. Slope of HGM unit (Box 4.1b). If the HGM unit is a depression, omit this characteristic	>5%	2-5%	1-1.9%	0.5-0.9%	<0.5%
3. Surface roughness of HGM unit (Box 4.1c). If the HGM unit is a depression, omit this characteristic	Low	Moderately low		Moderately high	High
4. Presence of depressions (e.g. oxbow lakes) (Box 4.1d)	None	Present but few or remain permanently filled close to capacity	Intermediate	Moderately abundant	Abundant, or entire HGM is a depression
5. Frequency with which stormflows are spread across the HGM unit (Box 4.1e)	Never	Occasionally but less frequently than every 5 years		1 to 5 year frequency	More than once a year
6.Sinuosity of the stream channel (Box 4.1f)	Low	Moderately low	Intermediate	Moderately high	High
7. Representation of different hydrological zones i.e. temporary/ seasonal and permanent (Box 4.1g)	Seasonal & permanent zone both present & collectively >60% of total HGM unit area	Seasonal & permanent zone both present & collectively 30-60%	Permanent & seasonal zones both present but collectively <30%	Seasonal zone present but permanent zone absent	Permanent & seasonal zones lacking (i.e. only the temporary zone present)
Opportunity for attenuating floods and reducing flood damage					
8. Average slope of the HGM unit's catchment (Box 4.1h)	<3%	3-5%	6-8%	9-11%	>11%
9. Inherent run-off potential of soils in the HGM unit's catchment (Box 4.1i)	Low	Moderately low		Moderately high	High
10. Contribution of catchment land-uses to changing runoff intensity from the natural condition (Box 4.1j)	Decrease	Negligible effect	Slight increase	Moderate increase	Marked increase
11. Rainfall intensity (Box 4.1k)	Low (Zone I)	Moderately low (Zone II)		Moderately high (Zone III)	High(Zone IV)
12. Extent of floodable infrastructure/property downstream (Box 4.1l)	Low/ negligible	Moderately low		Moderately high	High

Box 4.1a: Size of the HGM unit relative to the HGM unit's catchment

Rationale: The larger the wetland relative to its catchment, the greater will be its potential influence on floodflows (Adamus *et al.*, 1987; Ammann and Lindley-Stone, 1991).

Method: The HGM unit's catchment refers to the entire catchment upstream of the outlet of the HGM unit (i.e. it includes the HGM unit itself). The size of the HGM unit is determined once it has been delineated based on aerial photograph interpretation and field verification (see Section 3.3). To determine size of the catchment, use a topographical map. See the guidelines provided by DWAF (2006), and for further information view http://www.nh.nrcs.usda.gov/technical/WS_delineation.html for instructions on delineation of the HGM's catchment.

The percentage area of the HGM unit's catchment occupied by the HGM unit = HGM unit area ¸ HGM unit's catchment area x 100. For example, if the HGM unit is 14 ha and its catchment area is 200 ha then the % area occupied = 14/200x100% = 7%.

Box 4.1b: Slope of the HGM unit

Rationale: Given that the speed of water flow is directly influenced by slope, the more gentle the slope the greater will be the attenuating ability of the HGM unit.

Method: This characteristic should be omitted from the assessment if the HGM unit is a depression because a depression's capacity to attenuate floods is not influenced by slope (i.e. it operates by capturing flows rather than slowing them down). For other HGM units, slope should preferably be determined at least from a 1:10000 ortho-photograph or by field survey. Slope should be expressed as a percentage (e.g. in a 1% slope for every 100m traveled horizontally, there is a vertical drop of 1m). Where slope varies across the HGM unit, take the average slope.

Box 4.1c: Surface roughness

Rationale: This characteristic should be omitted from the assessment if the HGM unit is a depression because a depression's capacity to attenuate floods is not influenced by surface roughness owing to its inward draining nature (i.e. it operates by capturing flows rather than slowing them down). All of the other hydro-geomorphic types act to potentially slow down water flows. The greater the surface roughness of a wetland, the greater is the frictional resistance offered to the flow of water and the more effective the wetland will be in attenuating the floods (Reppert *et al*., 1979; Adamus *et al.*, 1987). The surface roughness of a wetland is usually determined primarily by vegetation, but hummocks may also contribute significantly. Hummocks refer to small earth mounds covered in vegetation about 20-50cm in diameter and 50cm high, commonly found in wetlands at high altitudes (>1500m).

Method: Thinking particularly in terms of the resistance offered to water flow by the vegetation, assign the HGM unit to one of the following classes:

- *Low:* smooth surface with little or no vegetation to offer resistance to water flow
- *Moderately low:* vegetation offering slight resistance to water flow, generally consisting of short plants (i.e. < 1m tall)
- *Moderately high:* robust vegetation (e.g. dense stand of reeds) or hummocks offering high resistance to water flow
- *High:* vegetation very robust (e.g. dense swamp forest) and offering high resistance to water flow

Note: where roughness varies across the HGM unit, take the average condition.

Box 4.1d: Presence of depressions rationale

Depressions (e.g. oxbow lakes) may greatly increase the detention storage capacity of the wetland, depending on the extent and depth of the depressions. However, those depressions that remain filled to near maximum capacity throughout the year are unlikely to retain floodwaters, even if deep.

Method: Determine the extent, depth and flooding history based on interpretation of maps and photographs, a rapid visual appraisal and on local knowledge.

Box 4.1e: Frequency with which stormflows are spread across the HGM unit rationale

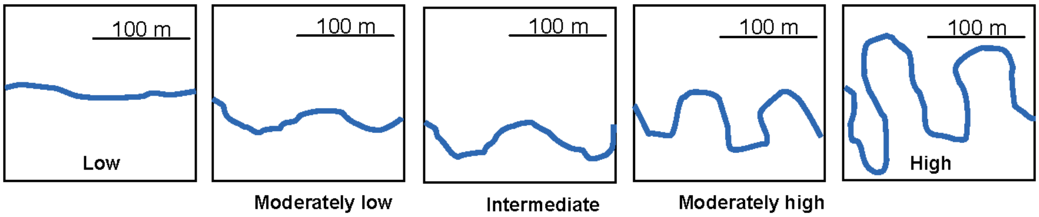
Rationale: The greater the frequency with which stormflows exceed the capacity of any channel/s passing through the HGM unit and are spread across the HGM unit, the greater will be the effectiveness of the HGM unit in attenuating floods. Conversely, the greater the extent to which stormflows are contained within a channel passing through the HGM unit, the lower will be the effectiveness of the HGM unit in attenuating floods.

Method: Use a rapid visual appraisal (look out for debris deposited by stormwater) and local knowledge. Check first if the wetland is connected to the drainage network. If not (i.e. the wetland is isolated from the drainage network, as is the case for many pans), then the wetland should not be considered to receive stormflows and should therefore score '0'. (Such isolated wetlands may nevertheless contribute indirectly to flood). If the HGM unit is connected, then consider the following features. Pay particular attention to human modifications such as straightening, widening and deepening of the channel, and artificial levees, which serve to reduce the frequency with which flooding out of the channel takes place. Note also that incision of the natural stream channel may result in a floodplain/valley bottom no longer being actively flooded, even though the system developed under regular flooding in the past, in which case the HGM unit would have lost much of its ability to attenuate floods. In hillslope seepages and unchannelled valley bottoms, stormflows are generally spread across the unit, unless they have been cut off by human modifications.

Box 4.1f: Sinuosity of the stream channel

Rationale: For a given longitudinal slope of the HGM unit, the greater the sinuosity of the stream channel the more gentle the slope within the channel and therefore the slower will be the flow of water.

Method: Identify based on interpretation of aerial photographs which of the five sinuosity classes given below best describes the situation in the HGM unit.



Note: if no clearly defined channel is present (e.g. in depressions), then omit this characteristic from the assessment.

Box 4.1g: Hydrological zonation

Rationale: If a wetland is already flooded immediately before the arrival of a flood event, its capacity to detain these flows and thereby reduce the floodpeak would be lower than if the wetland were in a dry state (McCartney, 2000; McCartney *et al*., 1998). Thus a HGM unit that is dominated by areas that remain wet for most of the rainy season (i.e. the permanent and seasonal zones) is more likely to be wet on the arrival of a flood event than a HGM unit which is dominated by the temporary zone.

Method: Use effective indicators of long-term hydrology, namely soil and vegetation, because long-term data will generally be lacking (Consult Kotze *et al.*, 1996; Kotze, 1996b ['How wet is a wetland?']; DWAF, 2006 [the DWAF guideline for delineating wetlands]). A soil auger and a Munsell colour chart will be required in order to examine colour patterns of the soil (e.g. purity of the colour and the presence of mottles) in the field as an indicator of long-term water regime. Caution must, however, be exercised in wetlands that have been desiccated (e.g. as a result of artificial drains) because the soils will often tend to reflect the hydrological conditions under which they were historically formed rather than the current hydrological conditions.

Box 4.1h: Slope of the catchment

Rationale: Given other factors being equal, the steeper the slope, the faster will be the runoff and the greater will be the runoff intensity, and therefore the greater will be the potential for floods.

Method: Use a 1: 50 00 topographic map of the catchment to measure at least five to ten representative slopes in the catchment (depending on how heterogeneous the catchment) and calculate their average. Measure the horizontal distance between the lowest and highest contour on each slope and the vertical distance based on the number of contour lines in the slope and the contour interval, which in a 1: 50 000 scale map is 20m. Remember that slope must be expressed as a percentage. For example, if the horizontal distance is 2000m and the vertical distance is 60m then the slope = 60 ÷ 2000 x 100% = 3%.

Box 4.1i: Determining the inherent runoff potential of soils

Rationale: The higher the runoff potential of the soil, the slower will be the infiltration and the greater will be the runoff intensity (Schulze *et al.*, 1989).

Method: Use the following categories and consult the local Department of Agriculture office if you are unsure. Check also the Land Type Survey report for the area (e.g. Land Type Survey Staff, 1986) which includes data on soil texture.

Low runoff potential	Moderately low runoff potential	Moderately high runoff potential	High runoff potential
Infiltration and permeability rates are high. Deep, well drained to excessively drained sands and gravels	Moderate infiltration rates, effective depth and drainage. Moderately fine to moderately coarse textures. Permeability slightly restricted	Infiltration rate low. Permeability restricted by layers that impede downward movement of water. Moderately fine to fine texture.	Very slow infiltration and permeability rates. Clay soils with high shrink/swell potential. Soils with permanent high water table or with clay pan or clay layer at or near surface or shallow soils over fairly impervious material.

Box 4.1j: The contribution of catchment land-uses to changing runoff intensity from the natural condition

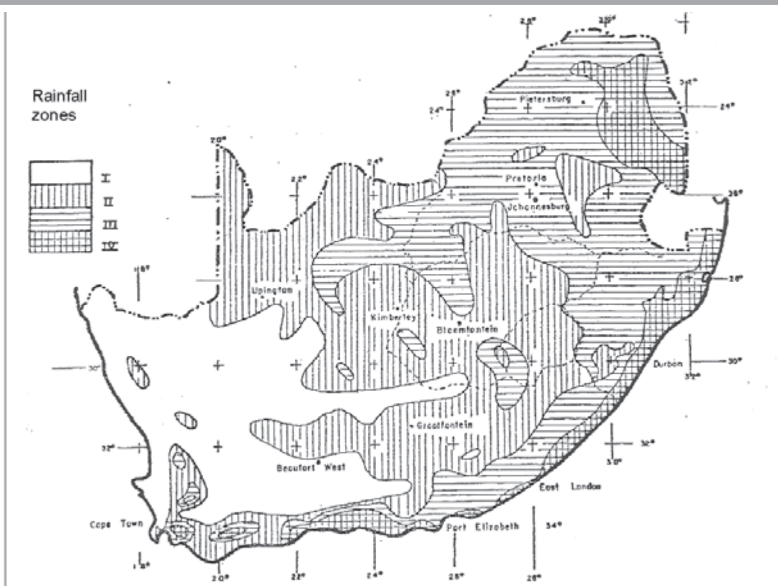
Rationale: Land-use factors may have a very important influence on runoff intensity (Schulze, *et al.*, 1989). Several land-use factors may increase runoff intensity:

- *Poor conservation practices in cultivated lands* (e.g. lack of contour tillage and contour banks, soil compaction etc.) decrease infiltration and increase surface runoff, thereby increasing runoff intensity, while good conservation practices tend to prevent this (Schulze *et al.*, 1989).
- *Poor veld condition* diminishes infiltration and increases runoff intensity compared with natural good condition veld (Schulze *et al.*, 1989).
- *Hardened surfaces in the catchment resulting from buildings, roads, footpaths, parking lots and other such developments*. The greater the extent of hardened surfaces, the smaller the area available for infiltration to take place and the greater the runoff intensity will be. If hardened surfaces are extensive, the effect will be considerable (Neal, 1998). Most industrial and commercial areas have a high extent of hardened surfaces due to the large buildings and their roofs and extensive roads and parking lots. Factors which may reduce runoff intensity include dams, particularly if they remain at relatively low levels for much of the time, and flood retention basins.

Method:

- *For factors increasing runoff intensity:* examine the National Landcover data for the catchment (particularly in the case of large catchments not readily visible from the HGM unit during the field assessment) or undertake a reconnaissance in the field to identify land-uses such as those described above which decrease infiltration.
- *For factors decreasing runoff intensity:* look out for dams, particularly those which remain at a relatively low level for most of the time, and flood retention structures.

Box 4.1k: Rainfall intensity zones of South Africa



Rationale: Stormflows result from rainfall, with the rate or intensity of rainfall usually being more important than the total amount of rain. Rates are usually expressed in mm/hour(hr) or mm / 24hr. From the map it can be seen that the level of intensity of storms varies widely across South Africa, from Rainfall Zone I which has the lowest intensities to Rainfall Zone IV with the highest.

Method: Determine the rainfall intensity zone based on the location of the wetland with reference to the adjacent map.

Box 4.1l: Extent of floodable infrastructure/property downstream of the HGM unit.

Rationale: The greater the extent of floodable infrastructure/property (e.g. bridges) downstream of the HGM unit, the greater will be the benefits potentially being derived from flood attenuation by the HGM unit.

*Method:*Speak to someone with good local knowledge of the area and examine the 1 in 50 year flood area downstream of the HGM unit for infrastructure/property which would potentially be flooded. If the HGM unit's catchment is less than 5000 ha then the 1 in 50 year flood area should be examined for 8 km downstream of the HGM unit and if greater than 5000 ha then examine this area for 16 km downstream of the HGM unit (as adapted from Adamus, 1987).

4.2 Streamflow regulation

Streamflow regulation refers to the sustaining effect of a wetland area on downstream flow during low-flow periods (Table 4.2). It is recognized, however, that wetlands clearly do not generate water. All wetlands are users of water through evaporation and transpiration, and in some wetlands this may be considerable. This clearly limits the potential of wetlands to contribute to streamflow in low-flow periods. Nevertheless, it is recognized that wetlands are an expression of broad-scale catchment processes and may be strategically located to regulate the movement of water through the catchment, particularly when they occur where sub-surface water is discharging to the surface.

Table 4.2: Characteristics contributing to regulation of streamflow

Characteristics Score:	0	1	2	3	4
1. Link to the stream network (i.e. not endorheic/inward draining) (Box 4.2a)	No link (i.e. hydrologically isolated)				Linked to the stream system
Note: If the HGM unit is hydrologically isolated (i.e. it scores 0 for the above characteristic) then STOP HERE and the score for streamflow regulation would be 0 (i.e. the HGM unit would not be in a position to augment streamflow) irrespective of the values of the other characteristics.					
2. Hydrological zonation (Box 4.2b)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zones both present & collectively 30-60%	Seasonal & permanent zones both present & collectively >60%
3. Presence of fibrous peat or unconsolidated sediments below floating marsh (Box 4.2c)	Absent	Very limited in extent/ depth	Somewhat limited in extent/ depth	Moderately abundant (0.5-1.0m)	Extensive and relatively deep (>1.0 m)
4. Reduction in evapotranspiration through frosting back of the wetland vegetation (Box 4.2d)	Low	Moderately low	Intermediate	Moderately high	High
5. HGM unit's catchment occurs on underlying geology characterized by ground-surface water linkages (Box 4.2e)	Other geological types		Underlying geology quartzite	Underlying geology sandstone	Underlying geology dolomite

Box 4.2a: Link to the stream network

Rationale: Quite simply, if a wetland is isolated from the stream system, as is the case for many pans and some seepage slopes, then the wetland would not contribute any water to the stream system. While pans are generally isolated, there is some evidence to suggest that some pans on the Highveld are 'leaky', meaning that some of the water that collects in the pans leaks through the pan floor into the underlying substrata (Marneweck and Batchelor 2002; Marneweck, 2003). Pans that lie on drainage divides, particularly where the soils are sandy and streams are abundant, may suggest a possible link to flow regulation. Whether or not this actually is the case will still need to be determined.

Method: Determine the connection with the stream system by examining aerial photographs and inspecting on the ground to see if a stream is passing through, running adjacent to or leading from the HGM unit. It is important to note, however, that HGM units lacking such an obvious feature may nevertheless, contribute to some degree through sub-surface water movement, but expert or local knowledge will be required to verify this.

Box 4.2b: Hydrological zonation of the HGM uni

Rationale: The hydrological character of a wetland provides a useful indication of the extent to which a wetland is able to release water to the stream system. A HGM unit which remains permanently saturated would generally have greater potential than an area which is seasonally saturated and this, moreover, for longer than a temporarily saturated HGM unit.The extent to which the water detained in the HGM unit contributes to sustaining streamflow would, however, depend on whether or not the HGM unit is linked with the stream system in the catchment (see Box 4.2a).

Method: Use effective indicators of long-term hydrology, namely soil and vegetation (consult Kotze, 1996b; DWAF, 2006) because long-term data will generally be lacking. A soil auger will be required in order to examine colour patterns of the soil (e.g. purity of the colour and the presence of mottles) in the field as an indicator of long-term water regime.

Box 4.2c: Extent of fibrous peat or unconsolidated mineral soils of 'floating marshes'

Rationale: Fibrous peat increases the water storage capacity of the soil in a wetland and fibrous peat's moderate hydraulic conductivity allows for the movement of water through the peat. The unconsolidated material beneath 'floating marshes' may also contribute to this storage capacity. Amorphous peat, which consists of much finer particles than fibrous peat, is also able to store water. However, this material has a very low hydraulic conductivity, as is the case for dense clay soils, thereby limiting the movement of water through the peat and its release (Joosten and Clarke, 2002).

Method: Determine the occurrence of peat in the field through sampling of soil (consult Grundling and Dada, 1999). Also consult the national office of the International Mire Conservation Group (IMCG) (www.imcg.net). Floating marshes can be detected when walked upon as their surface quakes underfoot.

Box 4.2d: Reduction in evapotranspiration through frosting back of the wetland vegetation

Rationale: A key factor limiting the extent to which wetlands contribute to sustaining streamflow is that water is lost from the wetland through evapotranspiration. However, where natural winter dieback of the leaves takes place, as characteristically occurs in areas experiencing frequent winter frosts, then this loss is greatly reduced. Following winter dieback, the amount of live transpiring plant material is very limited and the standing dead material greatly reduces evaporation from the wetland. This is particularly significant where the winter season coincides with the dry season, which pertains to the summer rainfall areas of South Africa. In the Free State, the Highveld, the Drakensberg foothills and Midlands of KwaZulu-Natal, for example, dry season dieback in wetlands is widespread owing to the high incidence of frosts. The higher the level of frosting back, the greater the reduction in potential loss of water through transpiration.

Method: Establish the occurrence of frosts and seek local knowledge. Note should also be taken here of the burning regime, as burning removes standing dead material thereby diminishing its protective effect. This is likely to be much more significant if burning takes place near the beginning of the dry season rather than at the end, as the wetland would be left exposed for much longer. If complete early winter burning occurs annually then the protection offered is likely to be low to moderately low as the protective vegetation is removed very soon after it is frosted back.

Box 4.2e: Geology underlying the wetland's catchment

Rationale: The occurrence of groundwater discharge areas (which would contribute to the regulation of streamflow) is likely to be high in geological provenances characterized by high levels of interaction between groundwater and surface waters.

Method: Check for the presence of geological provenances characterized by high levels of groundwater-surface water interactions, including dolomitic terrain, sandstones and quartzitic terrain (includes the Cape Fold Mountains). A map of the underlying geology for the HGM unit and surrounding landscape should be obtained from Geological Survey.

Box 4.2f: Presence of any important wetland or aquatic system downstream

Rationale: If a wetland were providing any ecological service related to water supply and water quality (including sediment, phosphates, nitrates and toxicants), then this service would be of added value if there were an important downstream wetland or aquatic system benefiting from the service. The downstream system (including natural systems as well as storage dams) may be considered important for several reasons, including maintenance of biodiversity and the supply of water for human use. An example is the Lake Mzingazi immediately downstream of the Mhlatuze wetland, with the lake, which provides water to Richards Bay town, benefiting from the water quality enhancement provided by the wetland.

Method: Seek any important wetland or aquatic system for 8 km downstream of the HGM unit if the HGM unit's catchment is less than 5000 ha and if greater than 5000 ha then continue for 16km downstream (as adapted from Adamus, 1987). Contact the relevant provincial nature conservation organization for information on wetlands and aquatic systems considered important for biodiversity conservation for the province or at a national level. Contact DWAF for information on aquatic systems important for human use.

4.3 Sediment trapping

Sediment trapping refers to the trapping and retention of sediment carried by runoff waters (Table 4.3). Excess sediment not only diminishes water quality by increasing turbidity but also leads to significant loss of storage capacity in dams.

Table 4.3: Characteristics contributing to sediment trapping

Characteristics Score:	0	1	2	3	4
Effectiveness					
1. Effectiveness of HGM unit in attenuating floods (Box 4.3a)	Low	Mod low	Intermediate	Mod high	High
2. Direct evidence of sediment deposition in the HGM unit (Box 4.3b)	Low	Mod low	Intermediate	Mod high	High
Opportunity					
3. Extent to which dams are reducing the input of sediment to the HGM unit (Box 4.3c)	High	Mod high	Intermediate	Mod low	Low
4. Extent of sediment sources (i.e. disturbed or unvegetated areas) delivering sediment to the HGM unit from its catchment (Box 4.3d)	Low	Mod low	Intermediate	Mod high	High
5. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance
Note: If sediment input is very high, then the effectiveness of the HGM unit in contributing to sediment trapping may be reduced where (1) vegetation is 'smothered' by recent excessive deposition or (2) the gradient and morphometry of the HGM unit is altered owing to the accumulation of sediment, resulting in flow becoming more concentrated and the HGM unit therefore being more susceptible to erosion.					

Box 4.3a: Effectiveness in attenuating floods

Rationale: The greater the extent to which sediment-laden runoff is slowed down, the greater will be the extent of deposition of the sediment carried by the runoff. Thus the greater the extent to which a wetland attenuates floods (e.g. through high surface roughness), the more effective it will be in trapping sediment (Ammann and Lindley-Stone, 1991).

Method: Calculate the average for characteristics 1 to 7 of Table 4.1 to determine effectiveness in attenuating floods.

Box4.3b: Direct evidence of sediment deposition in the HGM unit

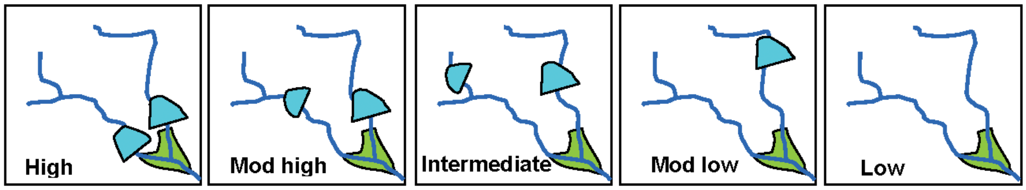
Rationale: Direct evidence of sediment deposition would indicate that the HGM unit is currently trapping sediment.

Method: Look for signs such as sediment deposited on litter or low growing plants. Look particularly in areas where there is a change from a steeper to a gentler slope and/or from channelled flow into diffuse flow. The occurrence of terrestrial and/or pioneer species may also alert you to areas where large amounts of sediment have been deposited.

Box 4.3c: Reduction in sediment inputs from the catchment

Rationale: The greater the extent of dams and other structures in the HGM unit's catchment which act to detain sediment that would otherwise reach the wetland, the more limited would be the opportunity for the wetland to receive and trap sediment.

Method: Observe on maps and aerial photographs and during the field assessment the location of dams in relation to the HGM unit. Now select that class given below which best describes the situation in the wetland's catchment in terms of the dams' effect in reducing sediment inputs.



Box 4.3d: Extent of sources of increased sediment in the catchment

Rationale: The greater the extent of sediment sources (e.g. cultivated lands and gravel roads) in the HGM unit's catchment and the closer these are located to the HGM unit, the greater will be the supply of sediment to the HGM unit. For example, where sediment sources occupy 50% of the HGM unit's catchment and some of these occur within 10 m of the HGM unit the potential supply of sediment to the HGM unit is likely to be high.

Method: Observe on maps and aerial photographs and during the rapid visual appraisal the extent and location of sediment sources. Sources of sediment to consider include: cultivated lands, particularly those poorly conserved; actively eroding gullies and bare areas of veld, forestry plantations on steep slopes or where planting and extraction practices are poor; gravel roads, particularly where they are poorly designed. It is important that due account be taken of the effect that any dams may have in trapping the increased sediment if the dams are located between the sediment source and the wetland (see Box 4.3c).

4.4 Phosphate removal

Phosphate removal refers to the removal of phosphates carried by runoff waters, thereby enhancing the quality of water in the downstream catchment (Table 4.4).

Table 4.4: Characteristics contributing to phosphate trapping

Characteristics Score:	0	1	2	3	4
Effectiveness					
1 Effectiveness in trapping sediment (Box 4.4a)	Low	Mod low	Intermediate	Mod high	High
2. Pattern of low flows within the HGM unit (Box 4.4b)	Strongly channeled	Moderately channeled	Intermediate	Moderately diffuse	Very diffuse
3. Extent of vegetation cover (Box 4.4c)	Low	Mod low	Intermediate	Mod high	High
4. Extent to which fertilizers/biocides are added directly to the HGM unit (Box 4.4d)	High	Moderately high	Intermediate	Moderately low	Low
Opportunity: i.e. level of phosphate input					
5. Level of sediment input (Box 4.4e)	Low	Mod low	Intermediate	Mod high	High
6. Extent of potential sources of phosphate in the HGM unit's catchment (Box 4.4f)	Low	Mod low	Intermediate	Mod high	High
7. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance

Box 4.4a: Effectiveness in trapping sediment

Rationale: Phosphates and many toxicants are absorbed to sediments. Thus, the greater the extent to which wetlands traps new sediment, the greater will be the extent to which the wetland removes these associated pollutants (Hemond and Benoit, 1988). Phosphates are much less mobile than nitrogen in both the aerobic and anaerobic states, and therefore much less vulnerable to leaching. Although remobilisation of phosphorus may occur following inundation, which results in the development of anaerobic conditions (Cronk and Siobhan Fennessy, 2001; Keddy, 2002), the phosphorus tends to soon become absorbed again (e.g. to iron hydroxides that form under anaerobic conditions) (Patrick and Khalid, 1974; Turner, 2006).

Method: Take the average of Characteristics 1 and 2 of Table 4.3 to determine the effectiveness of the HGM unit in trapping sediment.

Box 4.4b: Pattern of low flows within the HGM unit

Rationale: Much of assimilation by wetlands of pollutants, particularly those pollutants not carried by sediment, takes place during low flow periods. During these periods, waters are shallower and residency times in the wetland longer, which affords the wetland greater opportunity to assimilate pollutants contained in the water (Kadlec and Kadlec, 1979; Hammer ,1992). It is therefore important to determine this particular flow pattern. Some wetlands experience diffuse flow during both low flow and high flow periods, allowing for considerable contact. Conversely, other wetlands may experience diffuse flow under stormflow conditions but under low flow conditions water is contained within a small part of the wetland in the channel, allowing for little contact between wetland and water.

Method: Determine the pattern of flows based on field observation of landform, examination of aerial photographs and local knowledge.

Box 4.4c: Extent of vegetation cover

Rationale: Vegetation cover is taken as a coarse indicator of above- and below-ground living biomass. The greater the biomass, the greater will be the provision of microhabitat and organic matter critical for soil microbes involved in the assimilation of nitrates, phosphates and toxicants. In addition, the greater the vegetation biomass, the greater will be the potential of the wetland to assimilate nitrates and phosphates through direct assimilation by the plants. It is recognized, however, that at the end of the growing season significant amounts of nutrients taken up by the plants may be lost through litterfall and subsequent leaching, although this is limited by the translocation of nutrients to the below-ground storage portions of the plant (Hemond and Benoit, 1988).

Method: Cover refers to the extent of aerial cover over the entire year. Therefore it is best not to assess a wetland shortly after it has been burnt as cover would have been temporarily reduced. Assign the HGM unit to one of the following five cover classes based on a visual appraisal of the canopy cover:

- *Low cover:* Predominantly bare soil; vegetation sparse or present for only short periods (i.e. periods less than 4 months)
- *Moderately low cover:* Partially covered with vegetation on a permanent basis or predominantly well covered but with brief periods when predominantly bare soil (e.g. when preparing for planting an annual pasture)
- *Intermediate:* Reasonably well covered with permanent vegetation but with noticeable bare areas lacking vegetation
- *Moderately high cover:* Predominantly well covered with permanent vegetation but with small bare areas lacking vegetation (although aerial cover may be temporarily reduced following burning)
- *High cover:* Complete and permanent cover (although aerial cover may be temporarily reduced following burning)

Note: Even in a complete and permanent cover, there will often be a certain amount of bare ground visible, but this will be as many very small areas, generally less than $0.1m^2$

Box 4.4d: Level of direct application of fertilizers/ biocides to the wetland

Rationale: The greater the extent to which nitrates/phosphates/toxicants are applied directly to the wetland, usually occurring during commercial cultivation, the lower will be the capacity of the wetland to assimilate further nitrates/phosphates/toxicants entering the wetland in runoff water. In addition, the risk also exists of leaching from the wetland of some of that which has been applied. This is particularly relevant to nitrates owing to their much higher mobility in water than phosphates. At high application rates of fertilizer in a wetland, the system could potentially be converted from a nitrate sink to a source of nitrates. It is assumed that application of toxicants in the form of biocides are generally associated with application of artificial fertilizers, and that this application will reduce the capacity for assimilating further toxicants entering the wetland in runoff waters. However, if there is evidence that biocides are not applied, or alternatively that they will not limit the assimilation of additional toxicants (e.g. because they are of a different type), then this descriptor may be omitted from the assessment of toxicant assimilation.

Method: If possible, it is best to speak to landowners to find out what are their levels of fertilizer application. Alternatively, seek information from the local agricultural extension officer. It can generally be assumed that application rates are much higher on commercial agricultural land than on subsistence agricultural land.

Box 4.4e: Extent of sediment input

Rationale: Sediment reduces the quality of water and provides sites of attachment for other pollutants, particularly phosphate and certain toxicants. Therefore the greater the level of sediment input from the HGM unit's catchment, the greater will be the opportunity for the HGM unit to enhance water quality.

Method: See the level of sediment input described in Characteristic 4 of Table 4.3, and explained in Box 4.3d.

Box 4.4f: Level of potential phosphate sources

Rationale: The greater the extent of phosphate sources (point source and non-point source) in a wetland's catchment, the higher the likelihood that phosphate may be a problem in the river system, and the greater will be the opportunity for the wetland to trap these elements and therefore enhance water quality (Adamus *et al*., 1987).

Method: Identify non-point sources of pollution by considering areas (>0.5 ha) of fertilized crop or pasture land, areas (>0.5 ha) where the density of houses with septic tanks or pit latrines exceeds 6 houses per ha. Identify point sources by considering sewage or industrial outfalls, dairies, piggeries or feedlots. Contact your local DWAF office concerning known pollution sources.

4.5 Nitrate removal

Nitrate removal refers to the removal of nitrates carried by runoff waters, thereby enhancing the quality of water in the catchment (Table 4.5).

Table 4.5: Characteristics contributing to nitrate removal

Characteristics Score:	0	1	2	3	4
Effectiveness					
1. Representation of different hydrological zones (temporary/ seasonal and permanent (Box 4.5a)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60%
2. Pattern of low flows within the HGM unit (Box 4.4b)	Strongly channelled	Moderately channelled	Intermediate	Moderately diffuse	Very diffuse
3. Extent of vegetation cover (Box 4.5b)	Low	Moderately low	Intermediate	Moderately high	High
4. Contribution of sub-surface water inputs relative to surface water inputs (Box 4.5c)	Low (<10%)	Moderately low (10-20%)	Intermediate (20-35%)	Moderately high (36-50%)	High (>50%)
5. Extent to which fertilizers/biocides are added directly to the HGM unit (Box 4.4d)	High	Moderately high	Intermediate	Moderately low	Low
Opportunity:					
6. Extent of nitrate sources in the HGM unit's catchment (Box 4.5d)	Low	Mod low	Intermediate	Mod high	High
7. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance

Box 4.5a: Representation of different hydrological zones

Rationale: The primary process by which nitrates are removed from runoff water in wetlands is denitrification, which requires prolonged soil saturation leading to anaerobic conditions (Sather and Smith, 1984). However, this does not have to be permanent saturation (i.e. denitrification may occur extensively in seasonally wet areas, where the soils are alternately aerobic and anaerobic) (Hammer, 1992; Reddy and Patrick, 1984).

Method: Examine colour patterns of the soil (e.g. purity of the colour and the presence of mottles) in the field as an indicator of the long-term water regime (consult Kotze, 1996b; DWAF, 2006). For further details see Box 4.1g.

Box 4.5b: Extent of vegetation cover

Rationale: Vegetation makes two important contributions towards the removal of nitrates and toxicants: (1) it provides an important supply of soil organic matter required by the microbiota in order to assimilate nutrients and toxicants; and (2) it provides habitat for the microbes in the soil immediately surrounding the roots. The plants may also contribute through direct uptake of nitrates and toxicants, although these may be released following the eventual decomposition of the plant material (Hemond and Benoit, 1988). Thus, generally the more sparse the vegetation, the less will be the wetland's ability to assimilate pollutants. While the ideal would be to measure live biomass, this is generally not feasible, and cover is taken as a surrogate measure.

Method: See Box 4.4c for describing the extent of vegetation cover.

Box 4.5c: Contribution of sub-surface water inputs relative to surface water inputs

Rationale: The greater the contribution of sub-surface water relative to surface water, the greater the likely effectiveness of the wetland in assimilating nitrates in input water. This is based on the particularly efficient removal of nitrates from diffuse sub-surface flow that have been documented by authors such as Muscutt et al. (1993).

Method: Refer to the scores for the following characteristics relating to infiltration in the HGM unit's surrounding catchment given in Table 4.1:

- Slope of the HGM unit's catchment (Characteristic 8)
- Inherent runoff potential of soils in the HGM unit's catchment (Characteristic 9)
- Contribution of catchment land-uses to increasing surface runoff (Characteristic 10).

The lower these scores the greater will be the infiltration in the wetland's surrounding catchment and therefore the greater will be the potential supply of sub-surface water.

Consider the following features of the wetland:

- The extent to which the hydro-geomorphic setting is characterised by sub-surface water input (see Table 2.1)
- Size of wetland relative to its catchment, with the greater the relative size, the greater will be the likely contribution of sub-surface to surface water (Table 4.1, Characteristic 1)
- Whether the wetland is overlying geology characterized by a ground-surface water linkages (Table 4.2, Characteristic 5).

If, for example, the wetland's catchment is steep and characterized by high inherent runoff potential, it is floodplain (with floodplains being generally fed by predominantly surface water), the HGM unit has a small size relative to its catchment and it does not overlay geology characterised by ground-surface linkages then the HGM unit would score low in terms of sub-surface water inputs relative to surface water inputs.

Box 4.5d: Level of nitrate input from the HGM unit's upstream catchment

Rationale: The greater the extent of nitrate sources (point source and non-point source) in a wetland's catchment, the higher the likelihood that nitrates may be a problem in the river system, and the greater will be the opportunity for the wetland to trap nitrates and therefore enhance water quality (Adamus et al., 1987).

Method: Consider the following areas to identify non-point sources of nitrate pollution: areas (>0.5 ha) of fertilised crop or pasture land, and areas (>0.5 ha) where the density of houses with septic tanks exceeds 6 houses per ha. Point sources to consider include sewage or industrial outfalls, dairies, piggeries or feedlots. Contact the local DWAF office concerning known pollution sources, as in the case of phosphates.

4.6 Toxicant removal

Toxicant removal refers to the removal of toxicants carried by runoff waters, thereby enhancing the quality of water in the downstream catchment (Table 4.6). Toxicants are defined very broadly to include biocides, metals (e.g. mercury), salts and disease causing bacteria (e.g. E. coli). Wetlands are generally effective in contributing to the removal of toxicants. It must be emphasized, however, that certain potential toxicants (e.g. high levels of dissolved sodium and chloride) are not effectively removed by wetlands.

Table 4.6: Characteristics contributing to the trapping of toxicants

Characteristics Score:	0	1	2	3	4
Effectiveness					
1. Representation of different hydrological zones (Box 4.6a)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60%
2. Pattern of low flows within the HGM unit (Box 4.4b)	Strongly channelled	Moderately channelled	Intermediate	Moderately diffuse	Very diffuse
3. Extent of vegetation cover (Box 4.4c)	Low	Mod low	Intermediate	Mod high	High
4. Effectiveness in trapping sediment (Box 4.4a)	Low	Mod low	Intermediate	Mod high	High
5. Extent to which fertilizers/biocides are added directly to the HGM unit (Box 4.4d)	High	Moderately high	Intermediate	Moderately low	Low
Opportunity: i.e. level of toxicant input					
6. Level of sediment input (Box 4.4d)	Low	Mod low	Intermediate	Mod high	High
7. Extent of toxicant sources in the HGM unit's catchment (Box 4.6b)	Low	Mod low	Intermediate	Mod high	High
8. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance

Box 4.6a: Representation of different hydrological zones

Rationale: A variety of processes including chemical precipitation, adsorption and ion exchange contribute to the effectiveness of wetlands in assimilating different toxicants. The extent to which these processes occur depends on the physico-chemical conditions in the wetland, which are strongly affected by the hydrological regime. A variety of hydrological regimes (including permanently saturated areas) would therefore enhance the capacity of a wetland to effectively assimilate a diversity of toxicants (Zafiriou *et al.*, 1984; Wieder and Lang, 1986; Hemond and Benoit, 1988).

Method: Examine colour patterns (e.g. purity of the colour and the presence of mottles) of soil samples in the field as an indicator of long term water regime (consult Kotze, 1996b, and the DWAF guideline for delineating wetlands (DWAF, 2006)).

Box 4.6b: Level of toxicant input

Rationale: The greater the extent of toxicant sources (point source and non-point source) in a wetland's catchment, the higher the likelihood that toxicants may be a problem in the river system, and the greater will be the opportunity for the wetland to trap these elements and therefore enhance water quality (Adamus *et al*., 1987).

Method: To identify non-point sources of toxicants consider areas (>0.5 ha) of cultivated land treated with pesticides. Point sources to consider include sewage or industrial outfalls, mines and oil runoff sites. Contact local DWAF office concerning known pollution sources.

4.7 Erosion control (in the HGM unit)

This refers to the control of erosion at the site through on-site factors that prevent the loss of soil from the HGM unit (Table 4.7). It should be added that by reducing downstream flooding intensity (see Section 4.1) wetlands may also contribute to reducing the level of erosion downstream but this downstream contribution is not included in this assessment.

Table 4.7: Characteristics contributing to erosion control

Characteristics Score:	0	1	2	3	4
Effectiveness					
1. Direct evidence of active erosion in the HGM unit (Box 4.7a)	High	Mod high	Intermediate	Mod low	Low/ negligible
Note: If direct evidence of sediment loss is high then STOP HERE because this is direct evidence that the wetland is performing poorly in terms of erosion control, and the score for erosion control would be 0.					
2. Vegetation cover (Box 4.7b)	Low	Mod low	Intermediate	Mod high	High
3. Surface roughness of the HGM unit (Box 4.7c)	Low	Mod low		Mod high	High
4. Current level of physical disturbance of the soil in HGM unit (Box 4.7d)	High	Mod high	Intermediate	Mod low	Low/ negligible
Opportunity					
5. Slope of the site (Box 4.7e)	<0.2%	0.2-0.9%	1-1.9%	2-5%	>5%
6. Erodibility of the soil (Box 4.7e)	Low-very low	Mod low	Moderate	Mod high	High
7. Runoff intensity from the HGM unit's catchment (Box 4.7f)	Low	Mod low		Mod high	High
8. Presence of any important wetland or aquatic system downstream (Box 4.2f)	None		Intermediate importance		High importance
Note: If the runoff intensity is increased considerably (through poor catchment conservation practices and/or extensive hardened surfaces) this may significantly reduce the HGM unit's effectiveness in controlling erosion, ultimately leading to increased gully erosion or channel incision in the HGM unit.					

Box 4.7a: Direct evidence of active erosion in the HGM unit

Rationale: If there is currently a high level of active erosion in the HGM unit, then this is taken as direct evidence that the wetland is not effectively controlling erosion.

Method: Use aerial photograph interpretation to assist in the identification of erosion gullies and areas of bare soil. These should be checked in the field to see if there are signs of active erosion (e.g. sods of soil recently broken off the face of an erosion gully). The focus is on current erosion rather than erosion that occurred historically but which is now stable.

Box 4.7b: Vegetation cover

Rationale: The key role that vegetation plays in reducing the hazard of erosion by binding the soil with its roots and protecting the soil surface with its leaves and stems is well known.

Method: Estimate aerial cover based on a visual appraisal to determine which of the five cover classes given in Box 4.4c best describes the vegetation cover.

Box 4.7c: Surface roughness

Rationale: Surface roughness has a significant influence on the velocity of water flow across the surface of the ground. The greater the surface roughness, the greater the frictional resistance to the movement of water and the greater will be the level to which flow velocity is reduced (Reppert et al., 1979; Adamus et al., 1987). The significance of flow velocity for soil erosion is well known given that if water is flowing at a given velocity, doubling its velocity will cause a:

- 4 times increase in its power to cause erosion
- 32 times increase in the size of particle that it can carry away
- 64 times increase in the total amount of particles that can be carried away.

Method: See Box 4.1c to determine surface roughness.

Box 4.7d: Current level of disturbance of the soil

Rationale: The greater the current level of physical disturbance of the soil, the more susceptible the wetland will be to erosion. Disturbance reduces the strength and cohesion of the soil, and it also lowers vegetation cover and surface roughness, the benefits of which are described in Box 4.4c and 4.1c respectively. Tillage of the soil during cultivation accounts for much of the human disturbance of soil in wetlands. Other activities that may also contribute include sand winning, high levels of trampling by livestock, movement of vehicles, excavation for construction etc.

Method: Consider the following factors in order to describe the level of soil disturbance:

- Extent of disturbance - the greater the extent (particularly where no strips of intact vegetation are left), the higher the level
- Frequency of the disturbance - the higher the frequency, the higher the level
- Location of disturbance in areas especially susceptible to erosion
- Intensity of disturbance - the more intense (e.g. involving deep ploughing by heavy machinery) the higher the level.

For example, where the disturbance is limited in extent, frequent but not located in an area especially susceptible to erosion and carried out by hand, the level of disturbance would be considered moderately low. Remember that the focus is on the current disturbance rather than historical disturbance. In the case of peat soils also consider ground fires and drying out of the peat (e.g. because of artificial drains) as 'disturbance factors' likely to increase sediment loss.

Box 4.7e: Slope and erodibility of the soil at the site

Rationale: Two key parameters affecting the inherent erosion hazard of a site are soil erodibility and slope (Anon, 1976; Summerfield, 1991).

Method: Determine slope based on examination of an orthophotograph for the area (the contour interval of which is 5m) or a field survey, and express slope as a percentage. Erodability (i.e. the K value) of the soil is based on the soil form and family. Use Appendix 2 to determine the erodibility

Low (0.15) Mod. low (0.2) Intermediate (0.3) Mod. high (0.4) High (0.5)

Box 4.7f: Runoff intensity from the HGM unit's catchment

Rationale: Where runoff intensity increases significantly this may result in the development of gully erosion in the wetland. Because gully erosion results from several interacting factors (including runoff intensity, soil erodibility, wetland slope etc.) it is impossible to identify a threshold level of increase, above which the development of gullies is likely to take place.

Method: See Table 4.1, where the level of runoff intensity is determined based on the average score for Characteristics 8-11 (i.e. slope of catchment to rainfall intensity).

4.8 Carbon storage

Carbon storage refers to the trapping of carbon (e.g. as soil organic matter), thereby contributing positively as a carbon sink (Table 4.8). Given that organic matter decomposition is slowed down under waterlogged conditions, wetlands generally tend to have high capacities for storing organic carbon. The cumulative effect of natural carbon sinks (e.g. forests and peatlands) are of great significance for global climate change, lessening (but certainly not fully balancing) the potential catastrophic effect of carbon emissions from fossil fuel use. The contribution of wetlands to carbon sequestration is highlighted by the fact that although wetlands occupy only 4-5% of the land area of the globe, they hold approximately 20% of the carbon in the terrestrial biosphere (Roulet, 2000). Storage of carbon also has positive effects in terms of water and nutrient retention at a landscape level.

Table 4.8: Characteristics contributing to carbon storage

Characteristics Score:	0	1	2	3	4
1. Hydrological zonation (Box 4.8a)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60%
2. Abundance of peat (Box 4.8b)	Absent	Very limited in extent / depth	Somewhat limited in extent / depth	Moderately abundant (0.5-1.0m)	Extensive and relatively deep (>1.0 m)
3. On-site disturbance of the soil (Box 4.8c)	High	Mod high	Intermediate	Mod low	Low / negligible

Box 4.8a: Hydrological zonation of the HGM unit

Rationale: Waterlogging promotes the accumulation of organic matter by impeding its decomposition. Thus, for a given climate, those wetland zones subject to the most extended wet periods tend to have the highest amounts of organic matter (Tiner and Veneman, 1988).

Method: See Box 4.1g.

Box 4.8b: Abundance of peat

Rationale: Given that peat consists of soil material with a particularly high organic matter content, it stands to reason that the greater the extent of peat in a wetland, the greater would be the wetland's contribution to trapping carbon. In the long term, enormous amounts of carbon are stored as peat deposits. At present, approximately the same amount of carbon is stored in the world's peatlands as in the whole atmosphere (Joosten and Clarke, 2002). It is important to add, however, that the accumulation of peat is very slow (a few millimetres a year) and that in South Africa, where peatlands are rare, the harvesting and desiccation are placing peatlands under threat.

Method: Sample the soil in the field to establish the occurrence of peat (consult Grundling and Dada, 1999). Also consult the National office of the International Mire Conservation Group (IMCG) (www.imcg.net) for information on known peat areas in South Africa. In addition, any wetland areas with soils classified as the Champagne form according to the Soil Classification Working Group (1991) should also be included as peat areas. This is done so recognizing that although all soils in the Champagne soil form are characterized by an organic O horizon, some of these soils would have insufficient organic matter to be classed as peat.

Box 4.8c: Disturbance of the soil

Rationale: The greater the extent of disturbance of the soil, the greater will be the exposure of fresh soil surfaces to the atmosphere and therefore the greater will be the depletion of soil organic matter (Miles and Manson, 1992). Thus soil disturbance diminishes the amount of carbon being stored in a wetland.

Method: See Box 4.7d

4.9 Maintenance of biodiversity

Through the provision of habitat and maintenance of natural processes, wetlands contribute to maintaining biodiversity (Table 4.9). The capacity of a HGM unit to provide this benefit depends strongly on the integrity of the HGM unit as well as on specific attributes of the HGM unit (e.g. habitat provided for Red Data species). The assessment of biotic integrity provided below is consistent with the rapid assessment level of *WET-EcoServices*, where the number of characteristics that can be described and the amount of time and resources available to do so is very limited.

At the same time, it is recognized that biotic integrity is very complex, and that several of the descriptors used are themselves a composite of interacting factors, the complexity of which Table 4.9 does not attempt to capture. For more detail in assessing integrity, see *WET-Health* (Macfarlane *et al*., 2009).

Table 4.9: Characteristics contributing to maintaining biodiversity

Characteristics Score:	0	1	2	3	4
Noteworthiness					
1. HGM unit is of a rare type, is of a wetland type subjected to a high level of cumulative loss or falls within a veld or vegetation type or eco-region having high cumulative loss (Box 4.9a)	No				Yes
2. Level of cumulative loss of wetlands in the catchment (Box 4.9b)	Low	Mod low	Intermediate	Mod high	High
3. Red Data species or suitable habitat for Red Data species present (Box 4.9c)	No				Yes
4. Level of significance of other special natural features (Box 4.9d)	None	Mod low	Intermediate	Mod high	High
Note: if the average score for noteworthiness is high (i.e. >2.8) then this should be taken as the overall score for the contribution of the wetland to maintaining biodiversity (i.e. integrity does not need to be scored). The rationale for this is that it is recognized that even if the integrity of a wetland has been significantly reduced, it may nonetheless have a very important contribution to make to maintaining biodiversity (e.g. if it supports Red Data species or is one of only a few remaining wetlands of a particular wetland type that has been subject to high cumulative loss).					
Integrity (in relation to the wetland's natural state)					
5. Extent of buffer zone around HGM unit (Box 4.9e)	Low	Mod low	Intermediate	Mod high	High
6. Connectivity of HGM unit to other natural areas in the landscape (Box 4.9f)	Low	Mod low	Intermediate	Mod high	High
7. Alteration of natural hydrological regime (Box 4.9g)	High	Mod high	Intermediate	Mod low	Low/ negligible
8. Alteration of sediment regime (Box 4.9h)	High	Mod high	Intermediate	Mod low	Low/ negligible
9. Alteration of water quality regime (Box 4.9i)	High	Mod high	Intermediate	Mod low	Low/ negligible
10. Removal of the indigenous vegetation (Box 4.9j)	>50%	25-50%	5-25%	1-5%	<1%
11. Invasive and pioneer species encroachment (Box 4.9k)	>50%	25-50%	5-25%	1-5%	<1%
12. Presence of fences, roads, weirs, powerlines &/or other obstructive/hazardous barriers (Box 4.9l)	High	Mod high	Intermediate	Mod low	Low/ negligible

Note: Integrity is not a wetland benefit *per se*, but is important to consider when assessing the importance of the HGM unit in supporting biodiversity (see Rationale in note above). *WET-Health* (Macfarlane *et al*., 2009) provides a much more comprehensive method than that given in Table 4.9 for assessing wetland integrity, specifically focusing on hydrology, geomorphology and vegetation.

Box 4.9a: Threatened or rare wetland type

Rationale: At a national level, overall wetland loss has been high. However, certain wetland types (e.g. forested wetlands) have been much more severely affected than others. Similarly, certain vegetation types (e.g. as defined by Mucina and Rutherford, 2006) have been far more transformed than others, and the remaining natural areas of these veld types may be very important. Rare wetland types include dolomitic eye wetlands, where a dolomitic aquifer is exposed to the surface.

Method: Contact the relevant provincial nature conservation authority for information on threatened or rare wetland types, which are likely to vary from province to province.

Box 4.9b: Level of cumulative loss

Rationale: The greater the level of cumulative loss of wetlands, the more valuable will be those wetlands remaining. If, for example, the cumulative loss of wetlands in a catchment was 70%, then an existing wetland in that catchment would be considered more valuable than an otherwise similar wetland in a catchment where the cumulative loss of wetlands was 20%.

Method: Determining the level of cumulative loss is reliant on an inventory having been undertaken for the catchment, which includes an assessment of the extent of impacted wetland in relation to the historical extent of wetlands. Any loss greater than 50% would be considered high. If no such inventory exists, then this factor will need to be omitted unless someone has good local knowledge of the general status of wetlands in the catchment.

Box 4.9c: Red Data species

Rationale: Species make up an important, and readily measured, component of biodiversity, and Red Data species are those which have been identified as having particular importance from a species conservation point of view. Thus, the more important a HGM unit is for Red Data species, the greater will be the value of the HGM unit for maintaining biodiversity.

Method: Consult the relevant provincial conservation body for records on Red Data species, remembering however, that these records are incomplete.

Box 4.9d: Other noteworthy features

Rationale: The concept of biodiversity is broad, encompassing both species and genes and the ecosystems within which they are found. It therefore encompasses features such as breeding, roosting or feeding sites for large numbers of birds (migratory and non-migratory) or the unusual combination of features (e.g. a peatland adjacent to a waterfall).

Method: Consult the relevant provincial conservation body and refer to local knowledge and the rapid field assessment for information regarding particular noteworthy features in the HGM unit. See also the Ramsar Convention's website (*http://ramsar.org*) regarding particular features to look out for.

Box 4.9e: Buffer zone surrounding the HGM unit

Rationale: A buffer refers to the area surrounding a wetland comprising natural or near-natural vegetation. This applies particularly to wetlands found in generally transformed landscapes (e.g. in urban areas or in areas under very intensive agricultural use). A buffer surrounding a wetland serves several functions. Many wetland dependent species such as the giant bullfrog (*Pyxicephalus adspersus*) and wattled cranes (*Grus carunculata*) require wetland habitat as well as adjacent non-wetland habitat. Thus, if a wetland is lacking this adjacent habitat through transformation of the natural vegetation, then the value of the wetland for supporting biodiversity would be diminished even if the wetland were entirely intact in all other respects. Buffers also reduce the levels of pollutants and sediment directly entering the wetland, with some of these elements being trapped before entering the wetland.

Method: Examine a recent map or aerial photograph of the HGM unit and observe the buffer during the field visit to determine the extent of the buffer surrounding the HGM unit. Refer to Figure 4.1 and select that class which best describes the situation surrounding the HGM unit. In order to account for the quality of the buffer, if the buffer has been impaired (e.g. by heavy livestock pressure), then shift the score one class lower, and if the transformed area resembles the structure of the natural vegetation (e.g. planted pastures and natural grassland), then shift the score one class higher.

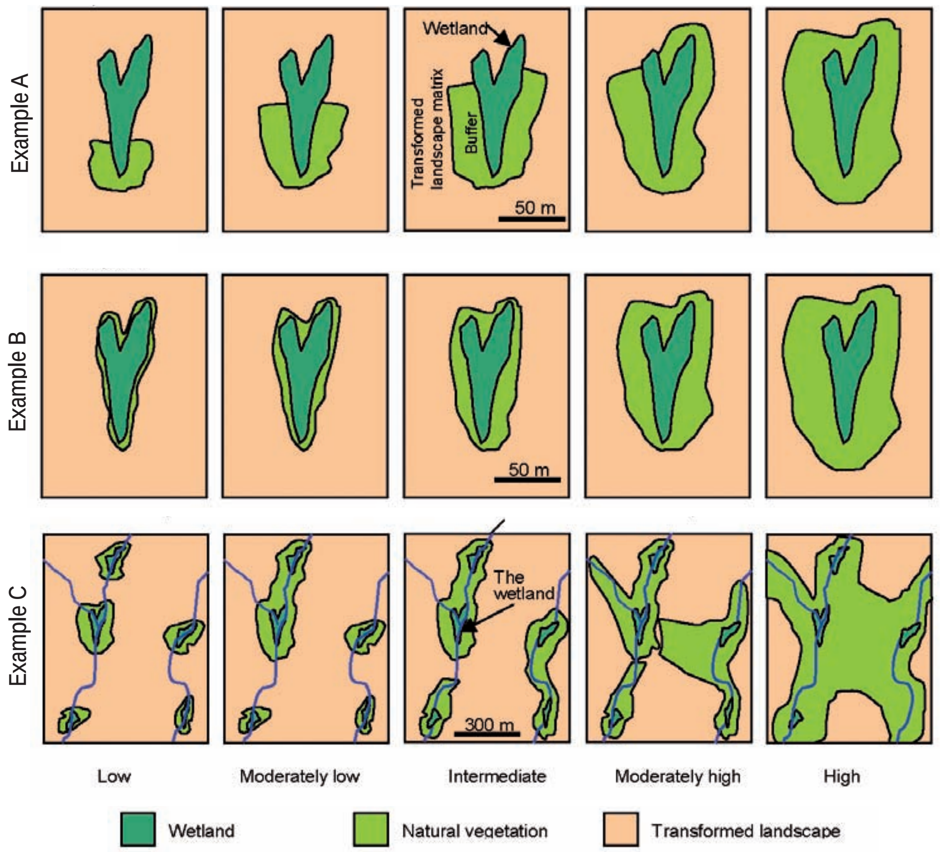


Figure 4.1: A guideline for the rapid assessment of:
(1) the level of buffering around a wetland (Examples A and B)
(2) the connectivity of the wetland with other natural areas in the landscape (Example C).
Note: For further explanation on the importance of buffers and connectivity see Box 4.9e and 4.9f respectively..

Box 4.9f: Connectivity of the HGM unit to other natural areas in the landscape

Rationale: The value of a HGM unit for supporting biodiversity derives not only from the quality of habitat contained within the HGM unit but also from the linkages it has with other natural areas (including wetland and non-wetland habitats) as many wetland-dependent species move between different wetlands and between wetland and non-wetland habitats. It is important to note that while a buffer contributes to the connectivity of a wetland, it is possible for a wetland to be well buffered (e.g. from the impacts of nutrient leaching from adjacent fields) but to be very isolated from other wetlands. Connectivity includes the concepts of interlinked 'stepping stones' and 'corridors' of natural vegetation in the landscape.

Method: Examine a map/aerial photograph of the HGM unit and its surrounding landscape to determine the level of connectivity of the HGM unit, or if time is available observe the general landscape during the field assessment. Refer to Figure 4.1 and select that class which best describes the situation in the landscape surrounding the wetland.

Box 4.9g: Alteration of the natural hydrological regime of the HGM unit

Rationale: The greater the extent to which a wetland's hydrological regime is altered, the greater will be the impact on the integrity of the wetland, given that hydrology is the dominant factor affecting the functioning of a wetland (Mitsch and Gosselink, 1986; Howe *et al*., 1991). Impacts may be on-site (including both artificial drains and deep flooding by dams) or from the wetland's catchment.

Method: Determine the extent to which the natural hydrological regime has been altered based on catchment effects (e.g. upstream water abstraction) and on-site effects such as artificial drainage channels. If, for example, the hydrology of a wetland were altered substantially by an extensive and effective network of artificial drains throughout the wetland, the impact on the integrity of the wetland would be much greater than a single drain affecting only a small portion of the wetland. Similarly, the deep flooding of the entire area of a wetland by an on-site dam would tend to impact much more severely on the integrity of a wetland than the deep flooding of only a small portion of the wetland. Extensive flow reducing activities in the wetland's catchment (e.g. abstraction and irrigation, timber plantations etc.) may significantly reduce a wetland's integrity while minor impacts from the catchment are likely to have less significant impacts. If the wetland being assessed is of a type known to be particularly sensitive to alterations to the water regime (e.g. a wetland in a very arid climate), then the user may reduce the score by a point, provided that justification is given in the *Additional notes* section.

Box 4.9h: Alteration of the natural sediment (geomorphological) regime of the HGM unit

Rationale: Each individual wetland has developed under a particular input of sediment. If this is greatly altered, either increased through disturbances in the wetland's catchment or decreased, for example through trapping of sediment by an upstream dam in the wetland's catchment, the integrity of a wetland may be negatively affected.

Excess sediment alters the substrate in which the plants grow, potentially smothering the plants as well as affecting the morphometry (i.e. the shape of the ground surface) of the wetland. Over time, this change in morphometry may contribute to increasing the erosion hazard of the wetland as the build-up of sediment increases the overall slope of the wetland or water flow is shifted and/or concentrated.

Continued on p.61.

Box 4.9h: Alteration of the natural sediment (geomorphological) regime of the HGM unit

Rationale: A significant reduction in sediment load to the wetland will alter sediment deposition in the wetland and may lead to the wetland changing from a net accumulator of sediment to a net exporter of sediment. This may, in turn, lead to the erosional degradation of the wetland as well as potentially impacting negatively on the productivity of the wetland.

The sediment regime may also be altered through on-site disturbance. All wetlands are subject to some form of natural disturbance (e.g. digging by porcupines or warthogs) which contributes to the diversity of wetlands. However, where the scale of this disturbance is increased (e.g. through cultivation or infilling) then the integrity of the overall system is likely to be compromised.

Method: Determine if the sediment input has been significantly reduced by referring to the score for Characteristic 3 of Table 4.3. A decrease in sediment inputs to the wetland will be particularly significant if bedload in the stream, which would be detained in an upstream dam is an important source of sediment to the HGM unit, as is characteristic of some floodplain systems in particular. Determine if it has been significantly increased by examining the score for Characteristic 4 of Table 4.3. Determine the level of on-site disturbance by examining the score for Characteristic 4 of Table 4.7. An increase in on-site disturbance will be particularly significant if the erosion hazard of the HGM unit is high (determined by wetland slope, erodibility of the soil, runoff intensity from the HGM unit's catchment and decreased sediment input). Score alteration of the natural sediment regime based on that factor of the three considered above, scoring the greatest change from an undisturbed situation.

Box 4.9i: Alteration of the water quality regime of the HGM unit

Rationale: The greater the change in water quality entering a wetland the greater will be the likely impacts on the integrity of the wetland. The ultimate impacts are, however, very specific to the type of change (e.g. an increase in nutrients) and the particular features of the wetland examined. For example, a significant increase in nutrient inputs is generally associated with a reduction in plant species diversity. Similarly, high inputs of heavy metals and very high solute concentrations are likely to have far reaching negative effects on a wetland. However, a significant increase in *E. coli* levels generally has much less effect on wetland vegetation and overall biotic integrity than high levels of nutrients and metals. Provided that the input levels are high, it takes only a single pollutant to substantially alter the water quality regime of a wetland. Therefore, rather than taking the average score for the different pollutant types examined in *WET-EcoServices*, the pollutant with the highest score should be taken.

Method: To determine the score for

- increased phosphate from the upstream catchment, calculate the average score for Characteristics 5 and 6 in Table 4.4
- increased nitrates from the upstream catchment, take the score for Characteristic 6 in Table 4.5
- increased toxicants from the upstream catchment, calculate the average score for Characteristics 6 and 7 in Table 4.6
- fertilizers/toxicants applied directly to the wetland, take the score for Characteristic 4 in Table 4.4.

Take the highest score for the above four assessments as the overall score for alteration of the water quality regime. For example, if a HGM unit scores 3 for increased phosphates, 1 for increased nitrates and 1 for increased toxicants, then its overall score is 3. If the wetland being assessed is of a type known to be particularly sensitive to alterations to water quality (e.g. a wetland in a catchment that is naturally nutrient poor) then the user may reduce the score by a point, provided that justification is given in the '*Additional notes*' section.

Box 4.9j: Removal of the indigenous vegetation

Rationale: This refers to the complete removal of vegetation under cultivated lands, infrastructure, deep flooding by dams and other wholesale transformations. Harvesting of reeds would not constitute vegetation removal as the indigenous vegetation continues to grow following harvesting. The greater the extent of complete removal of indigenous vegetation, the greater will be the potential effect, given that the vegetation contributes directly to the assemblage of species supported by the wetland as well as providing habitat for other species.

Method: Estimate the total extent in the wetland of land-uses resulting in the complete removal of the natural vegetation (e.g. deep flooding by dams, infilling for parking lot etc.).

Box 4.9k: Extent of invasive and pioneer species encroachment

Rationale: Invasive alien species. Alien invasive plants and animals, which out-compete the indigenous species, may greatly reduce the biotic integrity of a wetland because:

- The quality of habitat and the biodiversity maintenance benefits provided by the wetland are reduced.
- Many alien plants (e.g. wattle trees) are less effective in binding soil and controlling erosion than many of the indigenous plants in wetlands, which are specifically adapted to high energy flood events. Owing to the greater loss of soil, particularly when the plants are uprooted and washed away, alien plants are also therefore generally less effective in enhancing water quality.
- Some alien plants use more water through transpiration than the indigenous plants, which leads to a reduction in the natural flow in streams.
- The grazing value (for domestic and indigenous grazers) of most alien plants is lower than the indigenous grasses and sedges that they replace.
- Elimination or severe reduction of other species through predation by alien animals (e.g. alien trout and bass species that have been introduced into many of South Africa's rivers).

Invasive indigenous species. Some wetland plants, notably *Typ ha capensis* and *Phragmites australis*, may increase considerably in abundance so that they take over from the other species originally present in the wetland. This significantly compromises the integrity of a wetland. Several factors may be responsible for this, including: (1) increased nutrient inputs; (2) increased water input, particularly where this is sustained artificially through the dry season (e.g. from the outfall from a water treatment works); (3) reduced grazing levels which would otherwise have limited the extent of these tall dense plants; and (4) increased sediment deposition in the wetland (e.g. through increased erosion in the catchment).

Pioneer species. All wetlands are subject to some form of natural disturbance (e.g. rodents digging in the ground for tubers). This results in the destruction of the established plants, usually on a very localised scale, and later colonisation by pioneer species. In time these pioneer species are often replaced by later successional species that would have characterised the original vegetation. This disturbance and recovery, in fact, contributes to the diversity of wetlands. However, where the scale of this disturbance is increased (e.g. through cultivation) then the extent of the pioneer species may be increased dramatically relative to the other species characterising the wetland, thereby compromising the integrity of the overall system. On a large scale this also changes the structure and reduces the available cover. Generally, wetter areas tend to be colonized more readily by vegetation that is close to the original than less wet areas.

Method: Estimate the extent of alien plant infestation based on a field visit and a visual appraisal according to the five cover classes given in Box 4.4c. Several field guides exist for identifying alien plants (e.g. Bromilow, 1995). Consult your provincial nature conservation agency regarding alien animals. Determine whether a significant increase in indigenous invasive or pioneer species has occurred based primarily on historical evidence and local knowledge. One should be careful of concluding that an area where *T. capensis* or *P. australis* is abundant has always been invaded. In many cases these two species are naturally abundant. Similarly, certain wetland types may have a naturally high abundance of pioneer species.

Box 4.9l: Hazardous/obstructive barriers to fauna

Rationale: Fences, roads, weirs, dams and power lines may all have potentially significant impacts on fauna through increased mortalities (e.g. when flying into a power line) and obstruction to movement. While fences may be beneficial in terms of their control over the movement of livestock, fences may potentially interfere in the movement of wildlife, particularly where a wetland is dissected by several fences. This may be particularly significant when vulnerable wildlife such as crane chicks are being pursued by predators (McCann K, 2003. *Pers. comm*.. Southern African Crane Working Group, Mooi River). Weirs and other in-stream structures may potentially interfere significantly with the movement of fish unless they have specific design features such as fish ladders (Bruwer and Ashton, 1989). Roads, particularly those which are busy, may negatively impact upon small, slow-moving crawling animals.Power lines pose a particular threat to large wetland-dependent birds such as cranes, which may collide with the lines. The following factors should be considered when assessing the extent to which powerlines may potentially cause mortalities of wetland birds:

- Large wetland-dependent birds, particularly cranes, or habitat suitable for these birds – whether such birds or their habitat are present or not.
- Proximity of the powerline – if it is immediately adjacent to the wetland or passing through the wetland.
- Location – if it is located in the flight path of birds.
- Type of power line – if it is a transmission line with many cables it poses more of a hazard than a distribution line with a few cables.
- Marking of the power line (e.g. with bird flappers) – this reduces the hazard that the line poses.

Method: Determine the extent of fences, busy roads and instream structures based on a rapid visual appraisal of the HGM unit.

4.10 Provision of water supply for direct human use

The provision of water for direct human use includes water extracted directly from a wetland area for domestic, agricultural or other purposes (Table 4.10). Although this provisioning service is related to some extent to the regulatory service that a wetland may have in regulating streamflow, the latter is considered separately in the assessment of streamflow regulation in Table 4.2.

Table 4.10: Characteristics contributing to the supply of water for human use

Characteristics Score:	0	1	2	3	4
1. Representation of different hydrological zones (Box 4.10a)	Permanent & seasonal zones lacking (i.e. only the temporary zone present)	Seasonal zone present but permanent zone absent	Permanent & seasonal zones both present but collectively <30% of total area	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60%
2. Importance for streamflow regulation (Box 4.10b)	Low	Mod low	Intermediate	Mod high	High
3. Current level of water use for agricultural or industrial purposes (Box 4.10c).	No use	Mod low	Intermediate	Mod high	High
4. Current level of water use for domestic purposes (Box 4.10c)	No use	Mod low	Intermediate	Mod high	High
5. Number of households that depend on the resource (Box 4.10d)*	None	1-2	3-4	5-6	>6
6. Substitutability of the water source from the HGM unit (Box 4.10e)	High	Mod high	Intermediate	Mod low	Low

* If score for Characteristic 5 = 0, i.e. no dependent households, then omit scoring Characteristic 6.

Box 4.10a: Representation of hydrological zones

Rationale: The more prolonged the wetness of an area, the more reliable it will be as a source of water for human use (i.e. if a wetland is wet on a temporary basis only it is likely to be less suitable than one which is permanently wet) (Howe *et al.*, 1991).
Method: Examine colour patterns of the soil (e.g. purity of the colour and the presence of mottles) in the field as an indicator of long-term water regime (consult Kotze, 1996b). For further details see Box 4.1g.

Box 4.10b: Importance for streamflow regulation

Rationale: The greater the extent to which a HGM unit is important for streamflow regulation, the greater the likelihood that it will provide a reliable supply of drinking water. Many of the wetlands that are important for streamflow regulation would be described as springs and the importance of these areas for water supply is well known.

Method: Determine the importance of the HGM unit for streamflow regulation by examining the assessment in Table 4.2.

Box 4.10c: Current level of water use

Rationale: Current utilisation of the water resource for agricultural, industrial or domestic purposes is taken as a demonstration of the value of the area for water supply. Utilization includes that directly from the HGM unit as well as within a 5km distance downstream of the HGM unit.

Method: Visit the HGM unit and observe any activities and speak to local people, particularly older members of the community. Remember that some people may have to walk a considerable distance to collect water. When questioning people on their use, remember to ask them to think about a long period including both dry and wet years rather than thinking about only the year in which the assessment is being conducted (see Box 3.1).

Box 4.10d: Number of households depending on the water source in the HGM unit

Rationale: The greater the number of households whose livelihoods depend on the HGM unit, the greater will be the importance of the HGM unit from a livelihoods point of view.

Method: See Box 4.10c.

Box 4.10e: Substitutability of the water source in the HGM unit for its users

Rationale: The assumption is that the less easy it is to substitute the wetland water source, the greater will be the importance of the HGM unit for the direct provision of water. For example, if an alternative water source is available nearby (e.g. standpipes from a water provision scheme), then the HGM unit would be less critical from a water supply point of view than if no such alternatives existed. When assessing substitutability, particular attention should be given to the most vulnerable members of society, notably the poor, in particular women and children. A further factor contributing to the substitutability of the HGM unit as a water source is the location of the HGM unit in a water-stressed catchment.

Method: See Box 4.10c

4.11 Provision of harvestable natural resources

A wide variety of harvestable resources is potentially available in wetlands (Table 4.11), including the following, which are often important from a livelihoods perspective:

- Sedges for crafts
- Reeds for construction
- Wood for construction
- Medicinal plants
- Grazing for livestock
- Fish for food
- Game for food
- Flowers (for the floristry industry e.g. arum lilies)
- Edible plants (e.g. waterblommetjies)

Table 4.11: Characteristics contributing to the importance of a HGM unit for the provision of harvestable natural resources

Characteristics Score:	0	1	2	3	4
1. Total number of different natural resources used in the HGM unit (Box 4.11a)	None	1		2-3	>3
2. Is the HGM unit in a rural communal area? (Box 4.11b)	No				yes
3. Level of poverty in the area (Box 4.11c)	Low/ negligible	Mod low	Intermediate	Mod high	High
4. Number of households which depend on the natural resources in the HGM unit (Box 4.11d)*	None	1	2-3	4-6	>6
5. Substitutability of the wetland resources (Box 4.11e)	High	Mod high	Intermediate	Mod low	Low

1.* If score for Characteristic 4=0, i.e. no dependent households, then omit scoring Characteristic 5.

Box 4.11a: Total number of different natural resources used from the HGM unit

Rationale: It has been widely shown that wetlands are generally able to provide multiple benefits (Dugan, 1990; Roggeri, 1995), and the greater the number of resources provided by a natural area (e.g. a wetland), the more valuable it is considered to be (Shackleton *et al.*, 1999). Resources potentially supplied by the wetland include grazing for livestock, plants for crafts and construction, land for cultivation of crops, sand, clay, peat, medicines and food (notably fish).

Method: Visit the HGM unit and observe any activities and speak to local people, particularly older members of the community. Remember that some people may have to travel a considerable distance to harvest resources, particularly those which are highly sought after such as incema (*Juncus krausii*).

Box 4.11b: Location of the HGM unit in a rural communal area

Rationale: The assumption is that if a wetland is in a rural communal area, local people are more likely to be directly dependent on that wetland for resources such as water and building materials than if the wetland was situated elsewhere (e.g. in an urban area or on a commercial farm). This is given that the dependence on natural resources from systems such as wetlands is generally high amongst the rural poor (Dugan, 1990; Kotze, 2002; Kotze *et al.*, 2002; Kotze and Silima, 2003). If the wetland is in an urban area that is informally settled and lacking services, then it may also be included, given the dependency that these unserviced areas may have on wetland resources.

Method: Consult the local DWAF or Department of Agriculture office to determine if the HGM unit is located in a Rural communal area and/or Poverty Node.

Box 4.11c: Level of poverty

Rationale: It has been widely demonstrated that poor people are often particularly dependent on wetlands and their life-support functions (Dugan, 1990; Kotze et al., 2002). Thus, a general assumption can be made that the greater the level of poverty, the greater will be the potential contribution of wetlands towards livelihoods.

Method: Determine the level of poverty by consulting Statistics South Africa (www.statssa.gov.za) for information from the latest national census and/or speak to people with good local knowledge of the area.

Box 4.11d: Number of households depending on the natural resources from HGM unit

Rationale: The greater the number of households whose livelihoods depend on a wetland, the greater is the importance of the wetland from a livelihoods point of view.

Method: Visit the HGM unit and observe any activities and speak to local people, particularly older members of the community. Remember that although those households near the HGM unit are likely to make the greatest use of the HGM unit, there may be others travelling a considerable distance to harvest wetland resources (e.g. some travel over 200 km to harvest incema (*Juncus krausii*) in the wetland areas of Lake St Lucia). When questioning people on their use, remember to ask them to think about a long period including both dry and wet years rather than thinking about only the year in which the assessment is being conducted.

Box 4.11e: Substitutability of the wetland resources

Rationale: The assumption is that the less substitutable the wetland natural resources are for the user, the greater will be the importance of the wetland for the provision of those resources. For example, if a wetland is providing *Juncus krausii* (incema) to crafters for the production of specific traditional items, then the substitutability of this resource is low, given the requirement for this specific plant by crafters and the very limited occurrence of wetlands supporting harvestable stands of incema, (i.e. if the wetland were destroyed it would be difficult for the resource users to find a replacement for the resource). When assessing substitutability, particular attention should be given to the most vulnerable members of society, notably the poor, in particular women and children.

Method: See Box 4.11d

4.12 Provision of cultivated foods

In southern Africa wetlands are widely recognized for the contribution that they make towards food security of subsistence farmers, particularly in arid and semi-arid areas (Kotze, 2002). It is recognized, however, that the cultivation of a wetland requires the complete removal of the natural vegetation in the area cultivated, which often detracts considerably from the other ecological services provided by the wetland, particularly the wetland's capacity to maintain biodiversity[1] (Table 4.12).

Table 4.12 Characteristics contributing to the importance of a HGM unit for the provision of cultivated foods.

Characteristics Score:	0	1	2	3	4
1. Total number of different crops cultivated in the HGM unit (Box 4.12a)	None	1		2-3	>3
2. Location of the HGM unit in a rural communal area (Box 4.12b)	No				yes
3. Level of poverty in the area (Box 4.12c)	Low/ negligible	Mod low	Intermediate	Mod high	High
4. Number of households whose livelihoods depend on the crops grown in the HGM unit (Box 4.12d)*	None	1	2-3	4-6	>6
5. Substitutability of the wetland crops (Box 4.12e)	High	Mod high	Intermediate	Mod low	Low

* If score for Characteristic 4 = 0, i.e. no dependent households, then omit scoring Characteristic 5.

Box 4.12a: Total number of different crops cultivated in the HGM unit

Rationale: From a food security and livelihoods perspective, a cropping system with a single crop is less resilient than one with multiple crops (Altieri, 1987). Thus, if only a single crop is grown in the HGM unit, it would be considered less important as a source of cultivated foods than if several crops are grown in the unit.

Method: Visit the HGM unit and observe any activities and speak to local people, particularly older members of the community. Remember that the planting of different crops is often staggered through the year (e.g. maize in summer and cabbages in winter).

[1]The level to which wetland cultivation does, in fact, diminish other ecological services is accounted for by WET-EcoServices in as far as it includes several characteristics readily affected by wetland cultivation. These include the following characteristics:

- Extent of sources of phosphates, nitrates and toxicants (through the addition of fertilizers and biocides)
- Surface roughness
- Frequency with which stormflows are spread out across the wetland
- Hydrological zonation (e.g. desiccation through artificial drainage)
- Flow pattern of low flows in the wetland
- Extent of vegetation cover
- Level of physical disturbance of the soil
- Removal of indigenous vegetation
- Abundance of peat.

If, for example, a cultivated wetland is artificially drained to remove the seasonally and permanently wet areas, the pattern of low flows is altered from very diffuse to strongly channelled (in order to facilitate artificial drainage), the extent of vegetation cover is reduced from high (provided by permanent reed cover) to moderate (provided by the crops) then the level to which the wetland assimilates nitrates would be considerably reduced.

Box 4.12b: Location of the HGM unit in a rural communal area

Rationale: The assumption is that if a wetland is in a rural communal area, local people are more likely to be directly dependent on wetlands as areas for crop production than if the wetland were situated elsewhere (e.g. in an urban area or on a commercial farm). This is given the relatively high dependence of the rural poor on wetlands (see Dugan, 1990; Kotze, 2002; Kotze *et al*, 2002; Kotze and Silima, 2003). If the wetland is in an urban area that is informally settled and lacking services, then it may also be included, given the dependency that these un-serviced areas may have on wetlands for food production.

Method: Determine if the HGM unit is located in a rural communal area by consulting the local Department of Agriculture office or Land Affairs or speaking to local people.

Box 4.12c: Level of poverty

Rationale: It has been widely demonstrated that poor people are often particularly dependent on wetlands and their life-support functions (Dugan, 1990; Kotze *et al*., 2002). Thus, a general assumption can be made that the greater the level of poverty, the greater will be the potential contribution of wetlands towards livelihoods.

Method: Determine the level of poverty by consulting Statistics South Africa (www.statssa.gov.za) for information from the latest national census and/or speak to people with good local knowledge of the area.

Box 4.12d: Number of households whose livelihoods depend on the wetland crops

Rationale: The greater the number of households whose livelihoods depend on the crops produced in the wetland, the greater will be the importance of the wetland from a livelihoods point of view.

Method: Visit the HGM unit and observe any activities and speak to local people, particularly older members of the community.

Box 4.12e: Substitutability of the wetland crops

Rationale: The assumption is that the greater the difficulty with which crops which are cultivated in the wetlands can be substituted with crops grown elsewhere or purchased, the more important the wetland will be for the provision of food. When assessing substitutability, particular attention should be given to the most vulnerable members of society, notably the poor, in particular women and children.

Method: Visit the wetland and speak to local people who are cultivating crops in the wetland. It is useful to also remember that the lower the rainfall (particularly when the mean annual rainfall is less than 700mm) and the poorer the non-wetland soils (particularly when the soils comprise coarse sands as is characteristic of the northern KwaZulu-Natal coastal belt or the loss of topsoil in the surrounding catchment has been very high), the more difficult it will be to substitute the wetland crops with crops grown outside of the wetland. When questioning people on their use, remember to ask them to think about a long period including both dry and wet years rather than thinking about only the year in which the assessment is being conducted (see Box 3.1).

4.13 Cultural significance

Wetlands are recognized as having cultural significance for a diversity of different cultures in South Africa in terms of the culturally significant plants that they provide (for crafts, medicines and food) and in terms of being places of special cultural significance (e.g. where baptisms or cleansing ceremonies take place: Table 4.13). See the booklet produced by Working for Wetlands entitled 'Wetlands, Water, Life, Culture' which provides more information on the cultural significance of South African wetlands (WESSA, 2003a).

Table 4.13 Characteristics contributing to cultural significance

Characteristics Score:	0	1	2	3	3
1. Registered SAHRA site (Box 4.13a)	No				Yes
2.Location in a rural communal area (Box 4.13b)	No				Yes
3. Known local cultural practices in the HGM unit (Box 4.13c)	None	Historically present but no longer practised		Present but practised to a limited extent	Present & still actively & widely practised
4. Known local taboos and beliefs relating to the HGM unit (Box 4.13d)	None	Historically present but no longer so		Present but held to a limited extent	Present & still actively & widely held

Box 4.13a: Registered SAHRA (South African Heritage Resources Agency) site

Rationale: A site may have heritage value based on the presence of paleontological (i.e. fossil) sites, archeological sites, battle fields, meteorite sites, graves or burial grounds, all of which provide a basis for registration under SAHRA. If a registered site is located within or adjacent to a HGM unit, then this gives added cultural significance to the HGM unit.

Method: Contact SAHRA at 021- 4624502.

Box 4.13b: Location in a rural communal area

Rationale: In many rural communal areas wetlands still have cultural significance for a variety of reasons, as elaborated further in Box 4.13c and d.

Method: Refer to a recent cadastral map or consult local people.

Box 4.13c: Known local cultural practices in the HGM unit

Rationale: A wide variety of cultural/religious practices take place in wetlands, including traditional cleansing ceremonies, baptisms, traditional fishing practices (e.g. the fonya drives of the Pongolo Floodplain, KwaZulu-Natal), harvesting of plants for traditional crafts, and harvesting of plants for traditional medicines (WESSA, 2003a and b).

Method: Visit the HGM unit and observe any activities or evidence of recent activities (e.g. the stems of reeds that have been cut) and speak to local people, particularly older members of the community.

Box 4.13d: Known taboos and beliefs relating to the HGM unit

Rationale: Important taboos and beliefs are still associated with some wetlands and many of these taboos and beliefs help to support the sustainable utilization of the wetland (WESSA, 2003a and b).

Method: Speak to local people, particularly older members of the community, remembering that this may be a time-consuming operation, particularly if no previous contact has been made with the local people. Also refer to relevant literature (e.g. WESSA, 2003a and b).

4.14 Tourism, recreation and natural scenic value

Wetlands may have great value as sites for tourism and recreation, particularly in terms of the abundant wildlife (especially birds) that they often support, their scenic beauty and the open water that some wetlands provide for recreation Table 4.14).

Table 4.14: Characteristics contributing to the tourism and recreation value of a HGM unit

Characteristics Score:	0	1	2	3	4
1. Scenic beauty of the HGM unit (Box 4.14a)	Low/negligible	Mod low	Intermediate	Mod high	High
2. Presence of any 'charismatic' species (e.g. cranes) (Box 4.14b)	None present	Very seldom seen	Occasionally present	Generally present	Always present
3. Current use for tourism or recreation (Box 4.14c)	No use	Mod low use	Intermediate use	Mod high use	High
4. Availability of other natural areas providing similar experiences to the HGM unit (Box 4.14d)	High	Mod high	Intermediates	Mod low	Low
5. Cultural value (Box 4.14e)	Low/negligible	Mod low	Intermediate	Mod high	High
6. Location within an existing tourism route (Box 4.14f)	Low/negligible	Mod low	Intermediate	Mod high	High
7. Recreational hunting and fishing and birding opportunities (Box 4.14g)	None	Mod low	Intermediate	Mod high	High
8. Extent of open water, particularly that which is safe for swimming (Box 4.14h)	None	Present, but very limited		Extent somewhat limited	Extensive

Box 4.14a: Scenic beauty of the HGM unit

Rationale: The scenic beauty of a site is a key element of its tourism potential, and many wetlands are well recognized for their high aesthetic value (Roggeri, 1995). Wetlands may have high scenic beauty depending on features such as the diversity of colours and textures, contrast with the surrounding landscape, presence of attractive flowers or open water, and absence of litter (Ammann and Lindley-Stone, 1991).

Method: Visit the site and observe it from different vantage points, remembering that scenic beauty may change through the seasons, particularly in the case of wetlands supporting high abundances of ground orchids (e.g. Verlorenvalei wetland in Mpumlanga), kniphofias and other attractive flowering plants. Score the wetland based on consideration of the following features:

- Diversity of colours, textures, tones and vegetation structure within the wetland: for example, a wetland with uniform short, light green vegetation would be visually much less diverse than one which had a variety of different heights, including short grass and tall reed clumps, a range of colours, including several different shades of green and brown as well as both light and dark tones.
- Contrast with the surrounding landscape: a wetland with high contrast with the surrounding landscape has more visual interest than a wetland that closely resembles the surrounding landscape. Even a wetland with a low diversity may have a high contrast with the surrounding vegetation (e.g. a very dark green wetland surrounded by light green grassland or a wetland of any green surrounded by buildings).
- Bright and conspicuous flowers or leaves which turn vibrant colours (usually in the autumn): these add to the beauty of the wetland
- Litter and other unsightly human developments (electrical pylons, security fences etc.): these diminish the overall visual quality of the wetland.

Box 4.14b: Presence of "charismatic" animal species

Rationale: Nature appreciation often relates to the presence of conspicuous 'charismatic' animal species that have wide appeal such as cranes, fish eagles and hippopotami.

Method: Determine if these are present by contacting the provincial Nature Conservation Department and visit the site or ask the landholder/s.

Box 4.14c: Currently used for tourism or recreation

Rationale: Current use is taken as a demonstration of an area's value, particularly if the use has been continuing for some time. It is recognized, however, that the converse does not necessarily apply in that a site currently not used may be an 'undiscovered gem' with great potential for development in the future.

Method: Visit the HGM unit and observe any activities and speak to local people, remembering that use may be strongly seasonal, e.g. during a period when fishing is good.

Box 4.14d: Availability of other natural areas in the surrounding landscape providing similar experiences to the HGM unit

Rationale: Particularly in urban areas, or in very intensively farmed landscapes, a wetland may be one of only very few natural areas remaining in the landscape for nature-based tourism and recreation activities and for general appreciation of nature. Conversely, other natural areas providing similar experiences to the wetland may be present in great abundance. Thus, the lower the availability of these other natural areas, the more important will be the HGM unit.

Method: Consult someone with a good general knowledge of the local landscape, look out for other natural areas during a rapid reconnaissance and/or refer to an up to date map.

Box 4.14e: Cultural value

Rationale: Cultural heritage is recognized as making an important contribution to tourism potential (e.g. Lubombo SDI, undated) and wetlands may contain rich cultural heritage (Roggeri, 1995; WESSA, 2003a and b).

Method: Refer to Table 4.13

Box 4.14f: Location within an existing tourism route

Rationale: A key element potentially affecting how well any tourism destination can be marketed and accessed by the public is whether or not the destination falls within an existing tourism route.

Method: Contact your relevant provincial Tourism Authority or other regional initiatives promoting tourism. If the wetland is in an urban area, then a 'tourism route' may not be considered relevant and this descriptor may be omitted.

Box 4.14g: Recreational hunting and fishing and birding opportunities

Rationale: Wetlands may support abundant waterfowl and antelope (e.g. reedbuck) and fish that can be sustainably harvested through hunting/fishing. It is recognized, however, that many inland South African wetlands have a low potential from a hunting and fishing point of view, although there are some clear exceptions such as Barberspan in the North West Province, which has good fishing potential. Many wetlands support abundant and diverse birdlife and are often favoured locations for birding.

Method: Consult the relevant provincial nature conservation organization and speak to local people regarding the occurrence of species available for potential hunting or fishing. Contact the provincial nature conservation agency regarding relevant regulations. Contact Birdlife South Africa (www.birdlife.org, phone: 011-7891122) for information on birding and wetlands.

Box 4.14h: Extent of open water

Rationale: Open water is universally appreciated for its recreational potential, particularly if the water quality is good and there are no dangerous animals such as crocodiles.

Method: Contact your local provincial nature conservation agency and local DWAF office.

4.15 Education and research

Wetlands contain elements of both terrestrial and aquatic systems and have a strategic location in terms of catchment hydrology (Table 4.15). They may therefore be of high value for education and research, particularly when they are readily accessible.

Table 4.15: Characteristics contributing to the education and research value of a HGM unit

Characteristics Score:	0	1	2	3	4
1. Currently used for education/ research purposes (Box 4.15a)	No use	Mod low	Intermediate	Mod high	High
2. Reference site suitability (Box 4.15b)	Low	Mod low	Intermediate	Mod high	High
3. Existing data and research (Box 4.15c)	None	Mod low	Intermediate detail/ time period	Mod high	Comp-rehensive data over long period
4. Accessibility (Box 4.15d)	Very inaccessible	Moderately inaccessible	Intermediate	Moderately accessible	Very accessible

Box 4.15a: Currently used for education and/or research

Rationale: Current use is taken as a demonstration of an area's value, particularly if the use has been continuing for some time.

Method: Visit the HGM unit and enquire with local people, particularly those having authority over use of the land. Also consult the provincial conservation organisation or nearby education organisations.

Box 4.15b: Suitability as a reference wetland site

Rationale: A reference wetland site refers to a wetland that represents a good example of the type/s of wetlands common in, or unique to, a region. These systems are typically in a good or near natural state (i.e. their biotic integrity is high). Such sites serve as useful baselines for scientific understanding and research and may also provide valuable sources of information for conservation and catchment planning and management (Roggeri, 1995; Brinson and Rheinhardt, 1996).

Method: Determine the biotic integrity of the site by referring to the assessment in Table 4.9, Characteristics 5 to 12, and consult the provincial conservation agency.

Box 4.15c: Existing data and research

Rationale: Wetlands are inherently dynamic systems, changing over periods of days, seasons and years (Mitsch and Gosselink, 1986). Thus to best understand these systems requires comprehensive, long-term data and research effort. Thus the research potential of a wetland would be enhanced by the fact that it already has an existing research base and data gathered; the more comprehensive and long-term, the greater the value.

Method: Contact the nearest tertiary education institute or DWAF.

Box 4.15d: Accessibility of the site

Rationale: The more readily accessible the site, the lower will be the cost of gaining access and the greater will be the number of potential beneficiaries (Amman and Lindley-Stone, 1991).

Method: Consider the following factors when assessing accessibility:·

- Travel time to the nearest two primary/secondary education organisations and the nearest tertiary education organization
- Quality of the road to the site
- Availability of reasonable parking facilities
- Land ownership (e.g. private land with restricted access or town commonage with open access)

4.16 Identifying threats and future opportunities

'Threat' in this context refers to potential or impending pressures (forces, activities or events) in which a detrimental impact on the ecosystem services supplied by the HGM unit is likely to occur. Some threats that may be encountered include:

- Active gully erosion in the wetland which threatens to dry out an extensive portion of the wetland.
- Proposed extensive transformation of the surrounding landscape that will substantially reduce the connectivity of the wetland with other natural areas.
- Invasion by alien species.

'Future opportunities' in this context refers to the prospects of enhancing the delivery of ecosystem services by the HGM unit. Such future opportunities include:

- Opportunities for enhancing effectiveness of the HGM unit (e.g. by plugging artificial drains in a wetland and reinstating a naturally much more diffuse water flow pattern through the wetland).
- Opportunities for increasing the current level of direct use of a wetland (e.g. the HGM unit may have an extensive bed of currently unutilised Phragmites australis reeds that could be sustainably harvested.

'Future opportunities' should not be confused with the opportunity afforded a wetland for delivering a service (e.g. a high level of nitrate input provides the wetland with a high opportunity for assimilating nitrates). Such opportunities should not be to intentionally increased (e.g. by increasing pollutant input levels or runoff intensities to the wetland).

Score and describe the threats and future opportunities facing the wetland using Table 4.16.

Table 4.16: Threats and opportunities facing the HGM unit

Threats and future opportunities Score:	0	1	2	3	4
1. Level of threat to existing ecosystem services supplied by the wetland	Low	Moderately low	Intermediate	Moderately high	High
2. List (in the notes section of the datasheet) the nature of the threats (e.g. active gully erosion)					
3. Level of future opportunities for enhancing the supply of ecosystem services	Low	Moderately low	Intermediate	Moderately high	High
4. List (in the notes section of the datasheet) the nature of the future opportunities (e.g. high potential for utilization of Phragmites australis)					

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6 GLOSSARY

Aerobic	Having molecular oxygen (O_2) present.
Anaerobic	Not having molecular oxygen (O_2) present.
Aquaclude	Sediment body, rock layer, or soil horizon that is incapable of transmitting significant quantities of water under normal hydraulic gradients.
Aquatard	Sediment body, rock layer, or soil horizon that is resistant to the transmission of significant quantities of water under normal hydraulic gradients.
Biodiversity	The variety of life in an area, including the number of different species, the genetic wealth within each species, and the natural areas where they are found.
Capillary fringe	The zone just above the water table that remains almost saturated. This varies from approximately 10cm in sandy soils to about 30cm in some clay soils.
Catchment	All the land area from mountaintop to seashore which is drained by a single river and its tributaries. Each catchment in South Africa has been sub-divided into secondary catchments, which in turn have been divided into tertiary. Finally, all tertiary catchments have been divided into interconnected quaternary catchments. A total of 1946 quaternary catchments have been identified for South Africa. These sub-divided catchments provide the main basis on which catchments are sub-divided for integrated catchment planning and management (consult DWAF (1994)).
Chroma	The quantitative measure of the relative purity of the spectral colour of a soil, which decreases with increasing greyness. A Munsell colour chart is required to measure chroma.
Delineation (of a wetland)	The determination of the boundary of a wetland based on soil, vegetation and/or hydrological indicators (see definition of a wetland).
Direct (wetland) benefit	Something that has worth, quality or importance to humans and is realized by individuals actively using a wetland (e.g. for recreation, or pasture production).
Ecosystem services	The *direct and indirect benefits* that people obtain from ecosystems. These benefits may derive from outputs that can be consumed directly; indirect uses which arise from the functions or attributes occurring within the ecosystem; or possible future direct outputs or indirect uses (Howe *et al*., 1991). Synonymous with ecosystem 'goods and services'.
Floodplain	Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.
Groundwater	Sub-surface water in the zone in which permeable rocks, and often the overlying soil, are saturated under pressure equal to or greater than atmospheric (Soil Classification Working Group, 1991).
Hillslope seepage	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from sub-surface flow and outflow is via a well defined stream channel or via diffuse flow.
Hydric soil	Soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).
Hydrogeomorphic type	Classification of wetlands or portions of wetlands on the basis of their hydrologival and geomorphological characteristics: encompasses three key elements of (1) geomorphic setting (i.e. the landform, its position in the landscape and how it evolved (e.g. through the deposition of river-borne sediment); (2) water source (i.e. where does the water come from that is maintaining the wetland?) of which there are usually several sources including precipitation groundwater flow and streamflow, but their relative contributions will vary amongst wetlands; and (3) hydrodynamics, which refers to how water moves through the wetland.
Hydrology	The study of the properties, distribution, and circulation of water on the earth.

Hydrophyte	Any plant that grows in water or on a sub-stratum that is at least periodically deficient in oxygen as a result of soil saturation or flooding; plants typically found in wet habitats.
Indirect (wetland) benefit	Something that has worth, quality or importance to humans but does not require active use of wetlands by individuals in order for the benefits to be realized. Instead, the wider public benefits indirectly from the service that wetlands provide (e.g. purification of water).
Infilling	Dumping of soil or solid waste onto the wetland surface. Infilling generally has a very high and permanent impact on wetland functioning and is similar to drainage in that the upper soil layers are rendered less wet, usually so much so that the area no longer functions as a wetland.
Integrated Environmental Management (IEM)	A nationally accepted procedure for promoting better planned development by ensuring that the environmental consequences of development are understood and adequately considered in planning and implementation.
Inventory	Wetland inventory is the process of determining and recording where wetlands are, how many wetlands are in a given area, and their characteristics.
Marsh	A wetland dominated by emergent herbaceous vegetation (usually taller than 1m), such as the common reed (*Phragmites australis*). Marshes may be seasonally wet but are usually permanently or semi-permanently flooded or saturated to the soil surface.
Mitigate	To take actions to reduce the impact of a particular proposal.
Monitor	To keep a check on, and record of, something, which would allow changes to be detected.
Mottles	Soils with variegated colour patters are described as being mottled, with the 'background colour' referred to as the matrix and the spots or blotches of colour referred to as mottles.
Munsell colour chart	A standardized colour chart which can be used to describe hue (i.e. its relation to red, yellow, green, blue, and purple), value (i.e. its lightness or darkness) and chroma (i.e. its purity). Munsell colour charts show that portion commonly associated with soils, which is about one fifth of the entire range.
Open water	Permanently or seasonally flooded areas characterised by the absence (or low occurrence) of emergent plants.
Orthophotograph	A photograph derived from a conventional perspective photograph by simple or differential rectification so that image displacements caused by camera tilt and relief of terrain are removed.
Palustrine (wetland)	All non-tidal wetlands dominated by persistent emergent plants (e.g. reeds), emergent mosses or lichens, or shrubs or trees (see Cowardin *et al*., 1979).
Pan	Endorheic (i.e. inward draining; lacking an outlet) depressions typically circular, oval or kidney shaped, and usually intermittently to seasonally flooded and with a flat bottom.
Peat	Organic soil material with a particularly high organic matter content which, depending on the definition of peat, usually has at least 20% organic carbon by weight.
Perched water table	The upper limit of a zone of saturation in soil, separated from the main body of groundwater by a relatively impermeable unsaturated zone.
Ramsar Convention on Wetlands	An intergovernmental treaty which provides the framework for international cooperation for the conservation of wetland habitats.
Red Data species	All those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources.
Rehabilitation (wetland)	The process of assisting in the recovery of a wetland that has been degraded or of maintaining a wetland that is in the process of degrading so as to improve the wetland's capacity for providing services to society.

Riparian	*"The physical structure and associated vegetation of areas associated with a watercourse which are commonly characterized by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas."* (National Water Act). Riparian areas that are saturated or flooded for prolonged periods would be considered wetlands and could be described as riparian wetlands. However, some riparian areas are not wetlands (e.g. where alluvium is periodically deposited by a stream during floods but which is well drained).
Roughness coefficient	An index of the roughness of a surface; a reflection of the frictional resistance offered by the surface to water flow.
Runoff	Total water yield from a catchment including surface and sub-surface flow.
Seasonally wet soil	Soil that is flooded or waterlogged to the soil surface for extended periods (>1 month) during the wet season, but is predominantly dry during the dry season.
Sedges	Grass-like plants belonging to the family Cyperaceae, sometimes referred to as nutgrasses. Papyrus is a member of this family.
Sediment	Solid material transported by moving water, which typically comprises sand, silt and clay sized particles.
Seep	Wetland area that is created by the presence of an aquatard that forces subsurface flow to emerge on the surface of the earth and slowly flow downslope in a diffuse manner before entering a stream or re-entering the ground
Soil saturation	Soil is considered saturated if the water table or *capillary fringe* reaches the soil surface (Soil Survey Staff, 1992).
Sustainable use	Defined by the Ramsar Convention on Wetlands as "*human use of a wetland that yields the greatest continuous benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations*." Sustainable use of a specific natural resource requires that use be within the resource's capacity to renew itself, i.e. it should not be beyond the resource's biological limits.
Swamp	Wetland dominated by trees or shrubs (U.S. definition). In Europe, permanently flooded reed-dominated wetlands may also be referred to as swamps.
Temporarily wet soil	The soil close to the soil surface (i.e. within 50cm) is wet briefly but long enough for anaerobic conditions to develop, usually at least two weeks, during the wet season in most years. However, it is seldom flooded or saturated at the surface for longer than about a month.
Toxicant	An agent or material capable of producing an adverse response in a biological system, seriously injuring structure and/or function of the system and its organisms or producing death.
Transpiration	The transfer of water from plants into the atmosphere as water vapour.
Vlei	A colloquial South African term for wetland.
Water quality	The purity of the water, determined by the combined effects of its physical attributes and its chemical constituents.
Waterlogged	Soil or land saturated with water long enough for anaerobic conditions to develop.
Wetland	"Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which in normal circumstances supports or would support vegetation typically adapted to life in saturated soils." (National Water Act). Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin et al., 1979); lands that are sometimes or always covered by shallow water or have saturated soils long enough to support plants adapted for life in wet conditions.
Wetland's catchment	The area, up-slope of the wetland, from which water flows into the wetland and including the wetland itself.
Wise use	Synonymous with sustainable use

Appendix 1: *WET-EcoServices* datasheets

See the MS Excel file called '*WET-EcoServices*2007Final_Datasheets' on CD attached to back cover.

Appendix 2: Erosion hazards of soil forms common to wetlands

Erosion hazards are listed below for the primary soil forms (as described by the Soil Classification Working Group, 1991) associated with wetlands in South Africa. Soils are grouped according to soil form and listed according Code, Soil Series and Erosion Hazard Rating (K: low to v high)

Champagne Ch II Champagne: high Ch 21 Ivanhoe: high Ch 10 Mposa: high Ch 20 Stratford: high Katspruit Ka 10 Katspruit: mod Ka 20 Killarnev: high Rensburg Rg 10 Phoenix: high Rg 20 Rensburg: high Willowbrook Wo 21 Chinyike: high Wo 10 Emfuleni: high Wo 20 Sarasdale: high Wo II Willowbrook: mod	Kroonstad Kd 17 Avoca: high Kd 16 Bluebank: high Kd 22 Katarra: v .high Kd 20 Koppies: v.high Kd 13 Kroonstad: v.high Kd 14 Mkambati: v.high Kd 10 Rock1ands: v.high Kd 15 Slangkop: v.high Kd 12 Swellengift: v.high Kd 18 Uitspan: v.high Kd 21 Umtentweni: high Kd 11 Velddrif: v.high Kd 19 Volksrust: mod	Longlands Lo 22 Albany: mod Lo 32 Chitsa: mod Lo 21 Longlands: high Lo 10 Orkney: high Lo 30 Tayside: high Lo 31 Vaa1sand: high Lo 20 Vasi: high Lo 11 Waaisand: high Lo 12 Waldene: high Lo 13 Winterton: low Westleigh We 10 Chinde: high We 32 Davel: mod We 22 Devon: mod We 20 Kosi: high We 30 Langkuil: high We 31 Paddock: high We 12 Rietvlei: mod We 13 Sibasa: low We 11 Westleigh: high We 21 Witsand: high	Estcourt Es 20 Assegaai: v.high Es 11 Auck1and: v .high Es 22 Avontuur: v.high Es 35 Balfour: v.high Es 40 Beer1aagte: v.high Es 37 Buffe1sdrif: high Es 42 Darling: v.high Es 13 Dohne: v.high Es 31 Elim v: .high Es 33 Enkeldoorn: v.high Es 36 Estcourt: high Es 14 Grasslands: v.high Es 41 Heights: v.high Es 10 Houdenbeck: v.high Es 21 Langk1oof: v.high Es 30 Mozi: v.high Es 12 Potela: v.high Es 16 Rosemead: high Es 32 Soldaatskraal: v.high Es 34 Uitvlugt: v.high Es 15 Vredenhoek: v.high Es 17 Zintwala: high

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Working for Wetlands (WfWetlands) uses wetland rehabilitation as a vehicle for both poverty alleviation and the wise use of wetlands, following an approach that centres on cooperative governance and partnerships. The Programme is managed by the South African National Biodiversity Institute (SANBI) on behalf of the departments of Environmental Affairs and Tourism (DEAT), Agriculture (DoA), and Water Affairs and Forestry (DWAF). With funding provided by DEAT and DWAF, WfWetlands forms part of the Expanded Public Works Programme (EPWP), which seeks to draw unemployed people into the productive sector of South Africa's economy, gaining skills while they work and increase their capacity to earn income. Rehabilitation projects maximise employment creation, create and support small businesses, and transfer relevant and marketable skills to workers.

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The Water Research Commission (WRC) aims to develop and support a representative and sustainable water-related knowledge base in South Africa, with the necessary competencies and capacity vested in the corps of experts and practitioners within academia, science councils, other research organisations and government organisations (central, provincial and local) that serve the water sector. The WRC provides applied knowledge and water-related innovations by translating needs into research ideas and, in turn, transferring research results and disseminating knowledge and new technology-based products and processes to end-users. By supporting water-related innovation and its commercialisation where applicable, the WRC seeks to provide further benefit for the country.

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