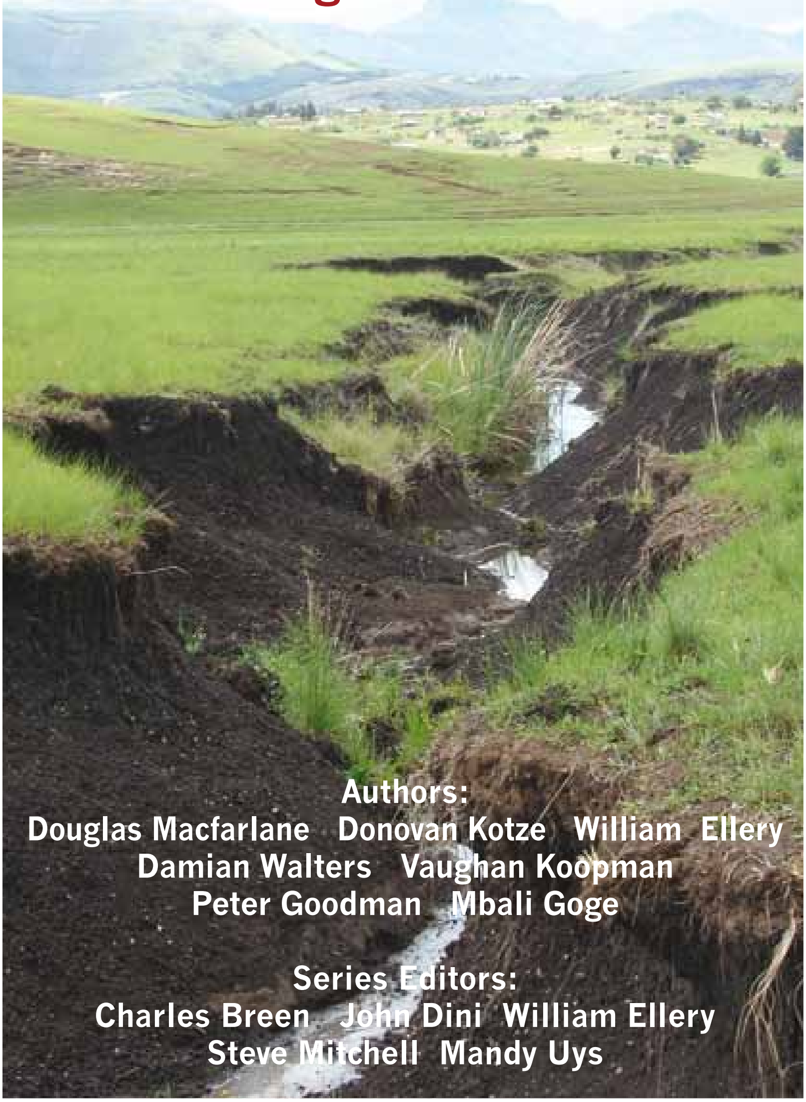
Wetland Management Series

WET-Health

A technique for rapidly assessing wetland health



Authors:
Douglas Macfarlane Donovan Kotze William Ellery
Damian Walters Vaughan Koopman
Peter Goodman Mbali Goge

Series Editors:
Charles Breen John Dini William Ellery
Steve Mitchell Mandy Uys

Environmental Affairs and Tourism
Water Affairs and Forestry
Agriculture

national biodiversity institute SANBI

Working for Wetlands

UNIVERSITY OF KWAZULU-NATAL

TT 340/09

Water Research Commission

Wetland Management Series

WET-Health

A technique for rapidly assessing wetland health

WRC Report TT 340/09
March 2009

Authors:
DM Macfarlane
DC Kotze
WN Ellery
D Walters
V Koopman
P Goodman
C Goge

Series Editors:
Charles Breen
John Dini
William Ellery
Steve Mitchell
Mandy Uys

Environmental Affairs & Tourism
Water Affairs & Forestry
Agriculture

SOUTH AFRICAN national biodiversity institute SANBI

Working for Wetlands

UNIVERSITY OF KWAZULU-NATAL

Obtainable from:

Water Research Commission
Private Bag X03
Gezina
0031

The publication of this report emanates from a project entitled: *Wetlands Research Programme: Wetland Rehabilitation* (WRC Project No. K5/1408)

DISCLAIMER:
This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

WRC Report TT 340/09

ISBN 978-1-77005-639-8

Set No 978-1-77005-631-2

Printed in the Republic of South Africa

This document includes a CD on the inside of the back cover

Authors:
DM Macfarlane
DC Kotze
WN Ellery
D Walters
V Koopman
P Goodman
C Goge

Series Editors:
Charles Breen
John Dini
William Ellery
Steve Mitchell
Mandy Uys

Front cover: An active gully in a wetland in the Upper Mzimvubu River catchment in the Eastern Cape.
Photograph: Japie Buckle

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 provide 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 under way.

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 these provide 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 (EIAs) or assessing the Present Ecological State (PES) of a wetland in an Ecological Reserve Determination (ERD).

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 five 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 under way 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

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, and evaluate and report on performance.

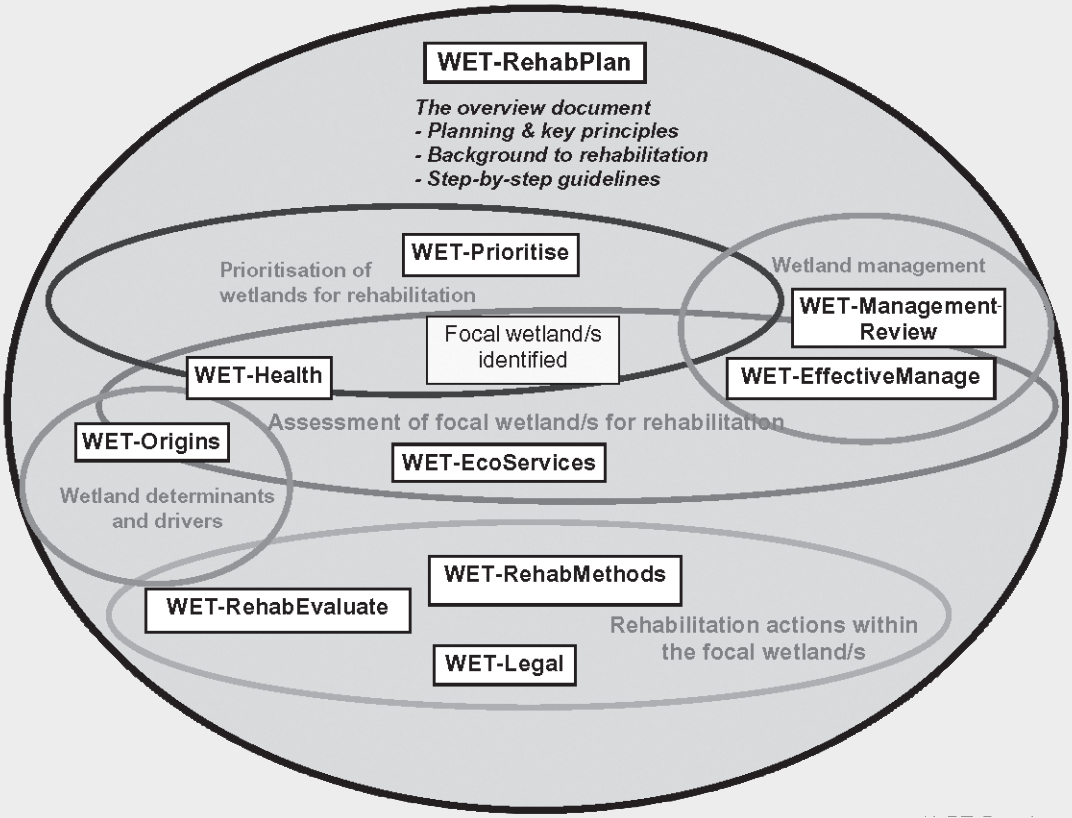


Figure 1P: How do the *WET-Management* tools relate to each other in a rehabilitation context?

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)	

(Light grey box) The tool is likely to have some relevance

(Dark grey box) The tool is likely to have a very high level of relevance

[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-Health***

WET-Health is a tool designed to assess the health or integrity of a wetland. Wetland health is defined as a measure of the deviation of wetland structure and function from the wetland's natural reference condition. This technique attempts to assess hydrological, geomorphological and vegetation health in three separate modules.

Hydrology is defined in this context as the distribution and movement of water through a wetland and its soils. This module focuses on changes in water inputs as a result of changes in catchment activities and characteristics that affect water supply and its timing, as well as on modifications within the wetland that alter the water distribution and retention patterns within the wetland.

Geomorphology is defined in this context as the distribution and retention patterns of sediment within the wetland. This module focuses on evaluating current geomorphic health through the presence of indicators of excessive sediment inputs and/or losses for clastic (minerogenic) and organic sediment (peat).

Vegetation is defined in this context as the vegetation structural and compositional state. This module evaluates changes in vegetation composition and structure as a consequence of current and historic on-site transformation and/or disturbance.

The system uses:

- An impact-based approach for those activities that do not produce clearly visible responses in wetland structure and function. The impact of irrigation or afforestation in the catchment, for example, produces invisible impacts on water inputs. This is the main approach used in the hydrological assessment.
- An indicator-based approach for activities that produce clearly visible responses in wetland structure and function such as the presence of erosion gullies or alien plant species. This approach is mainly used in the assessment of geomorphological and vegetation health.

Each of these modules follows a broadly similar approach. Prior to assessment, the wetland is divided into hydrogeomorphic (HGM) units and their associated catchments. These are analysed separately for hydrological, geomorphological and vegetation health based on extent, intensity and magnitude of impact. This is translated into a health score. The approach is as follows:

- The extent of impact is measured as the proportion of a wetland and/or its catchment that is affected by an activity. Extent is expressed as a percentage.
- The intensity of impact is estimated by evaluating the degree of alteration that results from a given activity.
- The magnitude of impact for individual activities is the product of extent and intensity.
- The magnitude of individual activities in each HGM unit are combined in a structured and transparent way to calculate the overall impact of all activities that affect hydrological, geomorphological or vegetation health. Present State health categories, on an impact score scale of 1-6 (or health category A-F), are as follows: natural, largely natural, moderately modified, largely modified, extensively modified , and critically modified.

Using a combination of threat and/or vulnerability, an assessment is also made in each module on the likely Trajectory of Change within the wetland. The five categories of likely change are: large improvement, slight improvement, remains the same, slight decline and rapid decline. Overall health of the wetland is then presented for each module by jointly representing the Present State and likely Trajectory of Change.

This approach not only provides an indication of hydrological, geomorphological and vegetation health, but also highlights the key causes of wetland degradation. This technique is therefore designed to both direct and monitor the effects of management interventions on wetland habitats.

This tool should be very useful to Working for Wetlands in planning and monitoring and evaluating the success of individual projects. In developing this methodology and attempting to make it more widely relevant, we have been mindful of DWAF's Ecostatus approach for water resources. This tool should thus be useful to institutions and parties beyond Working for Wetlands. The greatest value of the tool may lie in the structured way in which users are required to examine and therefore learn about the wetland/s they are required to manage.

Acknowledgements

The Water Research Commission (WRC), South African National Biodiversity Institute (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 Philip.

This tool has been developed by Sappi Forests, Mondi Wetlands Project, Ezemvelo KZN Wildlife, Working for Wetlands and the Institute for Natural Resources of the University of KwaZulu-Natal. The technique evolved out of a monitoring programme aimed at evaluating the state of important habitats within Sappi Forests estates. The scope of the assessment was subsequently broadened to account for different user needs and a larger suite of potential impacts to wetland habitats.

We acknowledge the invaluable inputs from Heather Malan, Kerry Philp and Olivia Bambus. Fynn Corry is thanked for his contribution to the plant lists in the vegetation module, and Karen Ellery for her substantial editorial input during the production of this document. The enclosed interactive catchment CD was compiled by Frank Sokolic of GISolutions. Much of the wisdom that is incorporated into the document stems from engagement with wetland scientists and practitioners. In particular we recognize the contribution made by Bill Russell, whose experience and wisdom have been captured and incorporated into the tool – especially in the hydrological and geomorphological modules. His contribution to wetland protection and conservation is recognized, and his legacy will live for years to come through what we have learned from him. He will be greatly missed as a friend and mentor.

Citation

The correct citation for this document is: Macfarlane DM, Kotze DC, Ellery WN, Walters D, Koopman V, Goodman P and Goge C. 2007. *WET-Health: A technique for rapidly assessing wetland health*. WRC Report No TT 340/09, Water Research Commission, Pretoria.

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:

Doug Macfarlane
Institute of Natural Resources
e-mail: macfarlaned@ukzn.ac.za
or
Donovan Kotze
University of KwaZulu-Natal
e-mail: kotzed@ukzn.ac.za

TABLE OF CONTENTS

Enclosed CD contents:
- Interactive catchment map
- Clickable catchment map
- Hydrological Health assessment data sheet
- Geomorphic Health assessment data sheet
- Vegetation Health assessment data sheet
- Level 1 assessment data sheet

SECTION 1: THE OVERALL ASSESSMENT FRAMEWORK

1.1 Introduction

Welcome to *WET-Health*! You are about to become a participant in a learning process that we have embarked upon. Hopefully you will learn along with us about how to assess the health/integrity of wetlands in South Africa. The development of this tool has evolved out of a need to monitor the state of wetland habitats nationally, and will be useful in a range of contexts such as wetland rehabilitation, wetland management, state of environment reporting and planning. We hope that users will be stimulated by the approach.

Tools of this kind involve 'engineering knowledge' about complex systems for use by relatively inexperienced and/or poorly trained and/or poorly equipped practitioners. It is not an easy task to take knowledge accumulated over many years and translate it into a simple tool, but we have done our best. An important feature is that we have tried to be transparent by including the rationale for each step in the process of assessment.

In recognition of the need for the different requirements of users, two levels of assessment have been developed – Level 1 and Level 2. The Level 1 assessment is primarily a desktop evaluation with limited field verification, while the Level 2 assessment involves structured data collection from the catchment and the wetland. The Level 1 assessment is designed for use when many wetlands need to be assessed over a broad geographical area, whereas the Level 2 assessment is for a single wetland.

This is Version 1 of the tool. The authors encourage users to provide constructive feedback about their experiences with this approach. As in other methods, it is hoped that *WET-Health* will be refined in subsequent versions to update and improve the assessment procedure.

1.1.1 Background to terms and the approach

Wetland ecosystems comprise the abiotic characteristics of an area, including its climate, geology and soil, water, nutrient supply and radiant energy, together with a biotic community suited to the prevailing environmental conditions and natural disturbance regimes. A system in which natural inputs of resources or toxins has not been modified by recent human intervention, and which experiences levels of disturbance that are regarded as natural, is considered to be in a 'natural reference condition'. Here, it is worth recognising that humans have long influenced disturbance regimes in Southern Africa through practices such as veld burning. These low-impact disturbances should be regarded as part of the natural disturbance regime. Given this context, **wetland health is defined as a measure of the similarity of a wetland to a natural or reference condition**. In thinking about wetland health, it is appropriate to consider 'deviation' from the natural or reference condition. For the purposes of this document the state of a wetland is a measure of the extent to which human impacts have caused the wetland to differ from the natural reference condition. *WET-Health* examines deviation from the natural reference condition for three components of health; hydrology, geomorphology and vegetation. These components are assessed separately in separate modules to produce three scores which indicate how much the wetland deviates largely from the natural reference condition.

Assessment of overall health in each module (hydrology, geomorphology and vegetation), is a three step process. Firstly, based on human activities and impacts in the catchment and the wetland, each module involves an assessment of Present State (Table 1.1) such that the wetland receives a score on a scale of 0 (identical to the natural reference condition) to 10 (critically altered). In order to make the assessment of health score more workable, the score on a scale of 0-10 is translated into one of six health classes (A-F, with A representing completely unmodified and F modifications having reached a critical level). Secondly, using a combination of threat and/or vulnerability, an assessment is also made in each module of the likely Trajectory of Change within the wetland. This is separated into five categories of likely change depending on the direction and/or degree of anticipated change

↑↑ = large improvement

↑ = slight improvement

→ = remain the same

↓ = slight decline

↓↓ = rapid decline.

Finally, overall Health is presented in each module by jointly representing the Present State and likely Trajectory of Change.

Table1.1: Terms used in the assessment of Present State, Likely Trajectory of Change and Health for hydrology, geomorphology and vegetation.

Assessment	Hydrology module	Geomorphology module	Vegetation module
Assessment of impacts and Present State (Categories A-F)	Present Hydrological State	Present Geomorphic State	Present Vegetation State
Assessment of Trajectory of Change (Categories ↑↑, ↑ ,→, ↓, ↓↓)	Likely Trajectory of Hydrological Change	Likely Trajectory of Geomorphic Change	Likely Trajectory of Vegetation Change
Overall health (based on Present State and Trajectory of Change)	Overall Hydrological health	Overall Geomorphic health	Overall Vegetation health

It is important to point out that the term 'health' is somewhat problematic. This is because the idea that ecosystems can be described as 'healthy' or 'unhealthy' is metaphorical. Wetlands do not get 'sick' and the notion of wetland 'health' is thus largely symbolic. Furthermore, the concept is normative and has no precise ecological meaning (Lackey, 2001; Davis and Slobotkin, 2004). Thus, a score of say 7/10 for wetland health does not provide any insight into the ecological characteristics of the system. Nevertheless, the concept of wetland health has been very widely used in formulating public policy and promoting appropriate wetland management.

If the assessment of wetland health is to be ecologically meaningful and useful, then clearly defined and quantifiable attributes of ecosystem structure, function or composition need to be specified as suitable indicators of health. Ideally, these should be compared to the natural reference condition of the wetland at some historical point in time. However, we can seldom be certain about what individual wetlands were like in an unimpacted state (the natural reference condition). An alternative might be to compare a wetland with a nearby unimpacted wetland 'of a similar type', but there are problems associated with making a choice about which wetland to use for comparative purposes, as wetlands are remarkably diverse and each and every wetland is unique. Furthermore, wetlands are naturally dynamic systems that respond to external events that happen at varying temporal and spatial scales such as daily or weekly (e.g. a major storm), seasonally (e.g. flood events), long term climate cycles (operating over time scales of decades, centuries and millennia) and the geological and geomorphological evolution of the landscapes in which they are found. These issues make an assessment of wetland health based on structural, functional or compositional characteristics difficult.

An alternative approach is to base an assessment of wetland health on quantifying impacts to those factors that underpin wetland ecosystems, such as hydrology and geomorphology. An example of an impact would be commercial forestry in the catchment that reduces water supply to the wetland. We have used this latter ‘impacts based’ approach in parts of the assessment methodology, notably the hydrology and geomorphology modules. Since water is a primary determinant of wetland structure and function, it is useful to compare the present (impacted) quantity, distribution and timing of water with the estimated quantity, distribution and timing of water in an unimpacted state.

Yet another approach is an indicator-based approach, where the effects of impacts are clearly visible within the wetland being examined. An example would be the presence of a gully that indicates erosion is taking place. The extent and magnitude of these indicators provides a useful means of examining health. The geomorphological and vegetation modules in this document use an indicator approach since erosion, deposition and vegetation transformation present features in the wetland that are visible and measurable. Interpreting these indicators and extrapolating their past development into the future can be very instructive in attempting to assess wetland health. The problem with the indicator-based approach is that it is difficult to separate natural and human-induced factors, since erosion is a natural phenomenon that can also be caused or aggravated by human activity.

The vegetation module assesses the extent to which natural vegetation in the wetland has been replaced by introduced species, invaded by alien species or been substituted by ruderal species. As such it is not a comparison of the present with a reference condition, but an assessment of the visible manifestations of transformation and/or human disturbance to vegetation within the wetland.

Overall then, we simply attempt to estimate similarity to or deviation from natural conditions, or we use clearly visible indicators to assess Present State.

Apart from the hydrology, geomorphology and vegetation modules, a water quality framework has also been compiled, which provides a simple set of guidelines for users. It is not as exhaustive as the other modules but will allow users to superficially assess wetland health with respect to water quality.

Despite its weaknesses, we have taken the metaphor of human health to heart in the assessment of wetland health. A person may for example be genetically predisposed to suffering a heart attack, but there may be no clear evidence of immediate risk (cholesterol is normal, blood pressure is normal, person is not overweight etc.). Nevertheless such a person should lead a lifestyle that maintains these conditions (exercise, diet etc.), failing which the likelihood of a heart attack increases. In the case of wetland health, we assess existing impacts and indicators to reveal ‘present state’ (hydrological, geomorphic, vegetation). Potential causes of change in wetland integrity are evaluated separately in order to identify the anticipated ‘Trajectory of Change’ in future conditions. The combination of these gives a picture of ‘health’. Thus, the term ‘State’ refers to its Present State and ‘Health’ to a combination of Present State and likely Trajectory of Change (see Table 1.1).

1.1.2 What is the purpose and scope of *WET-Health*?

Healthy wetlands are known to provide important habitats for wildlife and to deliver a range of important goods and services to society. Management of these systems is therefore essential if these attributes are to be retained within an ever changing landscape. The primary purpose of this assessment is to evaluate the ecophysical health of wetlands, and in so doing promote their conservation and wise management. An important feature of the tool is that it also allows diagnosis of the problem/s impacting on wetland health which can be used to inform management interventions.

The methodology adopted in *WET-Health* has been developed to cater for a range of requirements that are briefly described below:

- **State of Environment Assessment**
  There is an increasing move towards understanding the health of different ecosystems. This is evident through the growing number of State of Environment Reports countrywide. Such information is particularly important for decision makers such as Government, Catchment Management Agencies (CMAs), and land managers who need to make decisions that impact on the future state of wetland systems.
- **Impact Assessment**
  With a growing population and increased development, pressures on natural ecosystems are increasing at a rapid rate. An understanding of the effects of anthropogenic effects on wetlands is a key step towards identifying interventions that can safeguard the goods and services supplied by wetland systems.
- **Improved wetland rehabilitation and management**
  Many wetlands have been heavily impacted in the past. The need to improve or rehabilitate degraded areas has increased with growing awareness about the importance of these systems. Key questions are: What are the causes of wetland degradation and where should management focus resources in order to improve wetland integrity?
- **Monitoring wetland management and rehabilitation effectiveness**
  Both the State (through Working for Wetlands) and private landowners are allocating resources to rehabilitate degraded sites. Key questions, however, are whether these interventions are working, and if so, to what degree have they improved wetland health?
- **Contribution to Ecological Reserve Determination studies**
  WET-Health provides a framework for assessing the PES (Present Ecological State) of a wetland within an Ecological Reserve Determination study. *WET-Health* Level 1 is applicable to a Rapid Ecological Reserve Determination and *WET-Health* Level 2 to an Intermediate Ecological Reserve Determination. *WET-Health* does not provide for the collection of quantitative data required for a Comprehensive Ecological Reserve Determination. It is also important to emphasise that *WET-Health* is not specifically designed for calculating the ecological water requirements of a wetland, although it can be used to inform such an assessment.

1.1.3 Who are the anticipated users of the system?

Wetland Practitioners

Specialist wetland ecologists will find this framework useful for guiding their evaluation of wetland health. While designed to provide a holistic picture of wetland health, the distinction made between different components also allows specialists to select those modules pertinent to the study being undertaken.

Catchment – scale planners

When coupled with spatial information, the results of wetland health monitoring can form a valuable source for guiding catchment-scale decision making. This includes prioritising wetland rehabilitation efforts, allocation of water use licenses and evaluating development alternatives. A special effort has also been made to ensure that this technique fits in with the reporting methodology currently used by the Department of Water Affairs and Forestry (DWAF) in Reserve Determination studies and State of the Rivers reporting.

Landowners

Landowners with wetlands under their care are ultimately responsible for managing wetlands and maintaining their health. This methodology not only has elements that help landowners to identify problems and therefore guide management interventions, but also provides a tool to monitor the effects of these interventions on wetland health over time.

Rehabilitators

First-time assessments can be used to identify the causes of wetland degradation. This is key to ensuring that appropriate interventions are chosen to improve wetland health. The methodology can also be used for follow-up monitoring to evaluate rehabilitation success.

Developers

This tool can be used by Environmental Practitioners conducting EIAs for development applications that have a potential impact on wetland health. It is likely to be particularly useful for comparing the effects of development alternatives on possible future states. It can also be used to highlight potential impacts and therefore guide appropriate mitigatory requirements.

1.1.4 What are the key features of *WET-Health*?

Modular

Although it is recognised that wetlands are complex systems with many interacting components, it is easier to assess them in discrete components. The *WET-Health* approach thus assesses wetlands using three modules, hydrology, geomorphology and vegetation. Water quality has been dealt with very superficially.

Impacts- and indicators-based

Health is inferred from an analysis of catchment and/or on-site activities that have an impact on wetland hydrology, geomorphology and vegetation. Such activities may include the impacts of irrigation of crops or construction of dams in the wetland's catchment, or excavation of drains in the wetland. A second approach that is used is based on visible indicators of damage. Such indicators include gullies, plugs of sediment in the wetland, or the presence of ruderal or alien plants in the wetland. This is an 'indicator' approach that is used mainly in the geomorphological and vegetation assessments.

Quantitative scoring approach

Deviations from natural hydrological, geomorphological or vegetation conditions are assessed by identifying activities or indicators associated with a loss of wetland health. The impact of these on health is scored numerically in a coarse way in this tool. Usually, the intensity of impact and extent of impact are assessed and these are combined to determine an overall magnitude of impact score. This follows the same approach as that of Erwin (2003), except that *WET-Health* does not explicitly include duration as part of the assessment. The *magnitude* of impact scores are combined in a structured way to produce an overall wetland health score.

Prescriptive, but encourages well justified and documented adjustment by the assessor

WET-Health is a fairly prescriptive method in terms of the factors to assess, how to score these factors and how to combine the scores of the factors to produce an overall health score. This prescriptive structure is very useful from the perspective of standardization and in promoting consistency of assessments across different wetlands and by different assessors. However, its disadvantage is that it does not allow flexibility in accounting for some of the complexities of individual wetlands and their particular contexts. Wetlands are complex systems and added to this complexity are a range of potential impacts, the effects of which depend strongly on the interaction of a host of different factors. *WET-Health* has attempted to identify what are considered to be key factors and to represent how these affect health. However, this tends to be a simplification of what are very complex relationships. It is likely that with some understanding of a particular wetland and its context, the assessor will notice how the representation of the situation provided by *WET-Health* could be enhanced by addressing the following issues:

- An important factor may be missing from the assessment.
- The relative importance ascribed by *WET-Health* to the particular factors and how they relate to one another may not be well represented
- Interactions between different impacts may not be well accounted for (in some cases one impact may amplify the effect of another impact, while in other cases one impact may dampen the effect of another impact).

Thus, *WET-Health* makes provision for the assessor to adjust the assessments where, in the light of the assessor's understanding of the particular type of wetland being assessed and its particular context, inadequacies in the prescribed assessment can be seen. This would apply particularly to assessors with a lot of experience in assessment. However, for all adjustments, it is essential that the assessor provide a written justification for the adjustment, as the basis for adjustments must be clear to an outside party reviewing the assessment. Thus, *WET-Health* does not remove human judgment from the assessment.

Highlights causes of degradation

Owing to its impact-based approach, the system highlights the particular stressors and/or human activities that are contributing to the diminished health of wetlands. This information is critical for informing management plans and identifying appropriate rehabilitation efforts.

This tool has heuristic value in that it presents a set of well thought out rules of thumb that increase the likelihood of assessing wetland health in a sensible way. Its greatest value may be that it promotes learning about the wetland being assessed, which may ensure a better analysis of wetland integrity and of problems leading to loss of integrity where relevant.

Focuses on current state and assesses anticipated changes

Although *WET-Health* focuses especially on the Present State of wetlands it also includes an assessment of its Trajectory of Change (i.e. where does the state of the system appear to be heading in the future), which is very relevant to management planning.

1.1.5 What is the level of expertise required to apply *WET-Health*?

This methodology is designed for use by competent scientists with appropriate background and training in wetland evaluation, together with experience in the field. Users of Level 2 should have good general wetland 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 basic introductory courses on wetland formation, wetland functioning and wetland health, and should have undertaken evaluations of several different wetlands with a qualified and experienced practitioner before applying the tool themselves**. Users of Level 1 need at least this level of experience and training, as Level 1 requires a greater level of professional judgment than is required in the highly structured Level 2 assessment. As indicated in the previous section, the method does not remove the element of human judgment, thus highlighting again the importance of training and experience.

1.1.6 How do *WET-Health* and *WET-EcoServices* relate to each other?

With more assessment tools becoming available, wetland practitioners are faced with the challenge of choosing the right tool for the job. *WET-Health* is designed for the rapid assessment of the integrity of wetlands. It focuses on the question of how far a system has deviated from its historical, undisturbed reference condition, and does not assess ecosystem services. *WET-EcoServices* (Kotze *et al*., 2007) on the other hand, is designed for the rapid assessment of the delivery of ecosystem services by a wetland in its current state. It does not assess how far this state is from the reference condition (i.e. its integrity). There is, of course, a general relationship between the two, with healthy wetlands generally believed to provide a greater level of ecosystem services (Figure 1.1). This relationship is very poor however and will depend very strongly on the specific ecosystem service examined. This is certainly an area requiring further study and will be investigated further through the WRC funded Wetland Health and Integrity Research Programme based at the University of Cape Town.

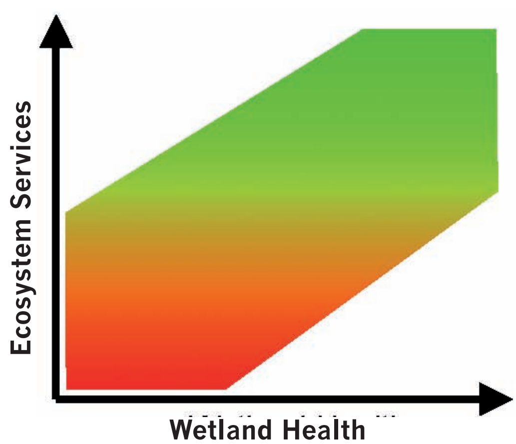


Figure 1.1: Generic relationship between wetland health and delivery of goods and services.

It should also be noted that some ecosystem services are likely to be much more severely affected by a particular impact than other ecosystem services. The progressive increase in wetland desiccation, for example, is likely to more severely affect the storage of soil organic carbon than the attenuation of floods, which may be little affected or even enhanced by a certain level of desiccation (see McCartney *et al*., 1998; McCartney, 2000).

When trying to decide which method is most appropriate for a specific study, one needs to carefully consider what information is most crucial for the study being undertaken. Some general guidelines are provided below:

- **State of the Environment Reports:** *WET-Health* is specifically designed to provide information on the state of wetland systems and would therefore generally be most appropriate. *WET-EcoServices* would be appropriate for an assessment focusing specifically on the provision of goods and services.
- **Wetland Prioritisation:** Both methods may be applied, depending on the rationale for prioritisation. *WET-EcoServices* would be more appropriate where maintenance of wetland services is the focus (e.g. nutrient retention in an urban environment) while *WET-Health* would be appropriate where the state of the wetland is an important requirement (e.g. conservation planning).
- **Impact Assessment:** Again, both methods may be useful in describing the current state (*WET-Health*) and relative importance (*WET-EcoServices*) of wetlands that could be impacted by a proposed development. These assessments form the theoretical base from which potential impacts can be objectively assessed and appropriate management and mitigation measures defined.
- **Wetland Rehabilitation:** In the planning and assessment of a wetland rehabilitation project, both methods would generally be applied together. However, their relative importance would vary depending on the particular rehabilitation objectives. If the rehabilitation objective was strongly focused on re-instating the natural (historical) conditions of a wetland then *WET-Health* would be most needed, but if the primary objective was enhancing particular ecosystem services (e.g. flood attenuation) then *WET-EcoServices* would be most needed.
- **Wetland Reserve Determination Studies:** *WET-Health* would generally be most useful in building an understanding of the wetland processes driving the system and in determining the Present Ecological State (PES) and *WET-EcoServices* would be useful in assisting in the assessment of the Ecological Importance and Sensitivity (EIS).
- **Wetland Management and monitoring:** *WET-Health* is particularly useful for diagnosing impacts and future changes to wetland health. It therefore provides a useful basis from which appropriate management interventions can be planned and the success of interventions be monitored.

In order to make the joint application of *WET-Health* and *WET-EcoServices* as integrated as possible, both use a similar scoring approach and logic, and both use the same descriptors for describing a wetland's HGM setting, hydrological zonation and geological and climatic settings.

1.2 Framework and methodology

1.2.1 Level of evaluation

It is recognized that different users will have different requirements and constraints when applying *WET-Health*. These may include available expertise, time constraints, project size/scope etc. Thus, two levels of assessment are provided by *WET-Health*.

- **Level 1:** Desktop evaluation, with limited field verification. This is generally applicable to situations where a large number of wetlands need to be assessed at a very low resolution (e.g. in order to obtain an overview of the state of health of the wetlands in a particular catchment). It is important to emphasize here that a certain level of field verification is required in order to meaningfully assess wetland health.
- **Level 2:** On-site evaluation. This involves structured sampling and data collection in a single wetland and its surrounding catchment. The time required to undertake a Level 2 assessment would be from 2 to 20 hours depending on the size and complexity of the wetland and its catchment and on the number and level of complexity of the impacts to which the wetland has been subjected. Most assessments would, however, be completed in less than 8 hours. Thus, although a Level 2 assessment is more detailed than a Level 1 assessment, it is nonetheless considered to be a fairly rapid assessment.

Both the Level 1 and Level 2 assessments require the identification of hydrogeomorphic (HGM) units making up each wetland for examination of the three main components of wetland health: hydrology, geomorphology and vegetation. However, in a Level 1 assessment, less time would be spent on gathering the information relevant to these components, and therefore the assessment would be undertaken at a lower resolution than for a Level 2 assessment. Thus, the confidence placed in the results would be lower than for a Level 2 assessment. In addition, a much less detailed account would be given of the factors contributing to any diminished integrity, making a Level 1 assessment much less valuable for the management planning of individual wetlands than a Level 2 assessment.

A Level 1 assessment requires completion of Section 5 of this document, and a Level 2 assessment requires completion of some or all of Sections 2-4 of this document.

1.2.2 Framework for assessment

A set of three modules has been synthesized from the set of processes, interactions and interventions that take place in wetland systems and their catchments: hydrology (water inputs, distribution and retention, and outputs), geomorphology (sediment inputs, retention and outputs) and vegetation (transformation and presence of introduced alien and/or ruderal species; Figure 1.2). These represent three very important factors that underpin wetland health.

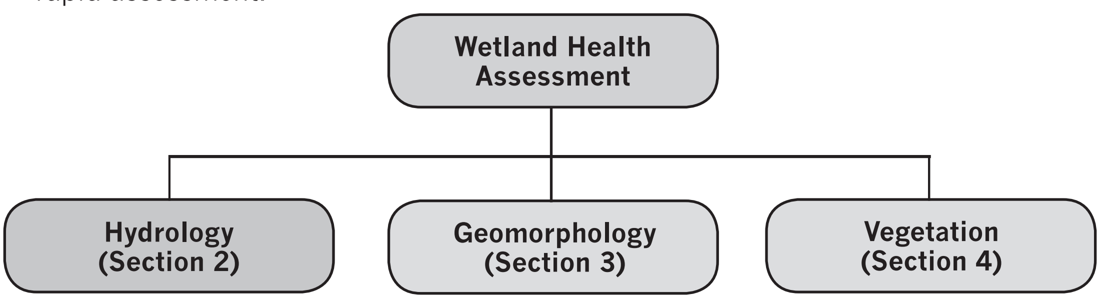


Figure 1.2: Chart showing the components evaluated as part of the current technique.

A key component that is missing is a module that deals with the impact of altered water quality on wetland health. At this stage we offer a simple framework for considering the effects of altered water quality on wetland health, which is presented as Section 7.

1.2.3 Units of assessment

Central to *WET-Health* is the characterisation of **hydrogeomorphic (HGM) units**, which have been defined based on geomorphic setting (e.g. hillslope or valley-bottom; whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated) and pattern of water flow through the wetland unit (diffusely or channelled) as described and illustrated in Table 1.2. Each HGM unit is assessed individually.

Floodplains are systems in which water and sediment inputs are mainly from a stream. Flooding takes place primarily by the stream overtopping its banks during flood events, and deposition of clastic (minerogenic) sediment is an important feature of floodplains, both during normal flows, as well as during flood events. Given this, floodplains are characterized by a suite of geomorphological features associated with fluvial processes, such as point bars on the inside bends of channels, scroll bars on the banks of the inside bends of channels, and oxbow lakes or abandoned channels. Although inputs of water from lateral sources do occur, floodplains are shaped hydrologically and geomorphologically by streams.

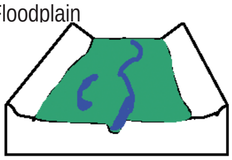
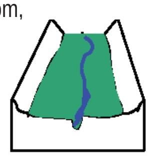
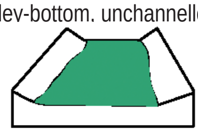
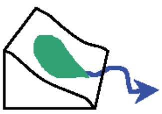
Valley-bottom wetland systems may be channelled or unchannelled. Although such systems are sites of sediment accumulation or temporary storage, fluvial deposition is not nearly as important a process in these systems as it is in floodplains. Therefore, there are few (if any) depositional features present that can be related to current fluvial processes. These systems are thus not as strongly driven as floodplains are by streams. In the case of channelled valley-bottom wetlands, water inputs are from both the stream and adjacent slopes, and the same is generally true for unchannelled valley-bottom wetlands, although the stream entering the wetland will disappear so that flow through the wetland is primarily diffuse.

There are cases where channels are weakly developed in valley-bottom wetlands. Channels may in fact be present in one part of a wetland and disappear. In some cases it may thus be difficult to decide on whether a valley-bottom wetland is channelled or not. The decision to allocate an HGM type should be informed by an understanding of flow patterns within the wetland. If the channel is so weakly developed that low flows still continue to flow across the valley-bottom, rather than all being contained within the channel, then the HGM unit would be taken as an unchannelled valley-bottom. If on the other hand, most low flows are confined to a defined channel, the wetland would be taken as a channelled valley-bottom.

Hillslope seepage zones are a consequence of diffuse groundwater flow from upslope such that groundwater inputs dominate. Where the surface water disappears below surface again or is lost mainly to evapotranspiration, the seep will not feed a stream, but where surface flow exceeds the rate of groundwater recharge or evapotranspiration, it is likely to feed a stream.

Depression wetlands occur where the groundwater rest level intercepts the land surface, such as along the coastal plains of KwaZulu-Natal and the Eastern and Western Cape, or they occur in semi-

Table 1.2: Wetland hydrogeomorphic (HGM) types typically supporting inland wetlands in South Africa (modified from Brinson, 1993; Kotze, 1999; and Marneweck & 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, channelled 	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, unchannelled 	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 	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

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 are complicated, particularly for wetlands such as those occurring on the coastal plain. Depression wetlands on the coastal plain are in direct contact with the regional water table and they are fed by both their local topographically-defined catchment as well as by the regional water table. The relative contribution of these two sources will thus vary from wetland to wetland. Outside of the coastal plain, these wetlands are characteristically inward draining.

arid settings where insufficient rainfall prevents their connection with the open drainage network and surface water runoff dominates the water inputs and evaporation dominates the outputs. In semi-arid settings the concentration of dissolved solids varies in relation to the balance between inputs and losses to evaporation. In semi-arid settings electrical conductivity thus varies dramatically over the wet and dry seasons. However, for wetlands on the coastal plain where reworked marine sediments typically have a very high hydraulic conductivity, depression wetlands are hydrologically more open due to rapid groundwater inflow to the wetland (groundwater discharge) and surface flow to groundwater from the wetland (groundwater recharge). Thus, they are fed by both their local topographically-defined catchment as well as by a much larger regional water table such that electrical conductivity will not vary seasonally as much as might be expected from variation in water level. The relative contribution of local and regional water sources is likely to vary from wetland to wetland, making it difficult to determine the extent of the 'catchment' for such wetlands. Users will need to use their discretion.

The HGM units described above focus on geomorphic setting and the inputs of water to a wetland, as well as the pattern of water flow through and out of a wetland. Other geomorphological features that may be encountered and are worth mentioning here are alluvial fans and deltas. Alluvial fans are features that are created when valleys lose confinement or streams suddenly reduce their slope as they enter a plain from a region of steeper slope. Given these circumstances, such streams deposit much of their sediment load, giving rise to an alluvial fan. Such systems may be channelled or the channels may disappear as water and sediment flow out across the fan. Such features should be classified as channelled or unchannelled valley-bottom wetlands depending on the degree of channel development present, and on the quantity of low flow they capture relative to the total water flow. Deltas are not features present in southern Africa since they are either coastal features or associated with lakes. There are no appreciable lakes and a combination of small rivers and longshore processes prevent the accumulation of sufficient sediment to form deltaic features along the South African coastline.

In *WET-Health*, wetlands are divided into HGM units, which are then assessed individually. It should be noted however that there may be scenarios where it is appropriate to group HGM units to prevent unnecessarily complicating the assessment. This may for example apply to an extensive valley bottom wetland that changes from a channelled to an unchannelled valley bottom at regular intervals. Under such a situation, the wetland should be classified according to the dominant HGM type. Once HGM units have been identified, results of each assessment unit are then combined to obtain an indication of the health of the wetland as a whole.

1.2.4 Quantification of impacts

The overall approach is to quantify the impacts of human activity or clearly visible impacts on wetland health, and then to convert the impact scores to a Present State score.

The tool attempts to standardise the way that impacts are calculated and presented across each of the modules. This takes the form of assessing the spatial *extent* of impact of individual activities and then separately assessing the *intensity* of impact of each activity in the affected area. The extent and intensity are then combined to determine an overall *magnitude* of impact. Extent, intensity and magnitude of impact are defined as follows:

- **Extent:** The proportion of the wetland and/or its catchment affected by a given activity (expressed as a percentage).
- **Intensity:** The degree to which wetland characteristics have been altered within the affected area. Throughout the module, intensity of impact is measured on a scale of 0-10, with a score of 0 representing no impact or deviation from natural, and a score of 10 representing complete transformation from natural.
- **Magnitude:** The overall impact of a particular activity or suite of activities on the component of wetland health being evaluated. This is determined by calculating an area-weighted impact score such that the intensity of impact is scaled by its extent. The magnitude of impact is expressed on a scale of 0-10 by multiplying intensity by extent of impact as follows:

Magnitude = Extent / 100 x Intensity

For example: If a given activity was affecting 25% of the wetland and its intensity was 4 (on a scale of 0-10) then the magnitude of the impact would be 25 / 100 x 4 = 1.0. However, if the same activity (intensity of 4) was affecting 75% of the wetland, then the magnitude of impact would be 75 / 100 x 4 = 3.0.

GIS is a useful tool for mapping the extent of activities and impacts in the wetland and its catchment. However, extent can be measured using traditional mapping methods such as the cut-and-weigh method or by tracing polygons of activities onto graph paper and calculating area by counting squares of known area that are covered by more than 50% by the polygon. Area is simply calculated as the number of squares thus counted multiplied by their area.

Once magnitudes of impact of individual activities and/or indicators have been calculated, these are combined in a structured way to provide a measure of overall impact on a scale of 1-10, which is scaled into six categories as shown and described in Table 1.3.

Table 1.3: Guideline for assessing the magnitude of impact on wetland integrity

Impact category	Description	Impact score range
None	No discernible modification or the modification is such that it has no impact on wetland integrity.	0-0.9
Small	Although identifiable, the impact of this modification on wetland integrity is small.	1-1.9
Moderate	The impact of this modification on wetland integrity is clearly identifiable, but limited.	2-3.9
Large	The modification has a clearly detrimental impact on wetland integrity. Approximately 50% of wetland integrity has been lost.	4-5.9
Serious	The modification has a clearly adverse effect on this component of habitat integrity. Well in excess of 50% of the wetland integrity has been lost.	6-7.9
Critical	The modification is present in such a way that the ecosystem processes of this component of wetland health are totally / almost totally destroyed.	8-10

1.2.5 Quantification of Present State of a wetland

Recall that health is assessed for hydrological, geomorphological and vegetation integrity, and a single Present State score is produced at the end of the assessment process in each case. The impact scores and Present State categories are provided in Table 1.4. Our view is that these scores are best kept separate for each of the three assessments because it helps focus wetland management on relevant activities. For example, if hydrology and vegetation Present States score well but Present Geomorphological State scores poorly, management attention should focus upon restoring geomorphic integrity of the wetland – possibly through rehabilitation interventions. By combining these scores, much of the information that is useful to managers is lost. However, we recognize that some users will want a single score and we thus propose a method whereby hydrological, geomorphological and vegetation Present States are integrated in a single score (Section 1.4).

Table 1.4: Impact scores and categories of Present State used by *WET-Health* for describing the integrity of wetlands

Impact category	Description	Impact score range	Present State category
None	Unmodified, natural.	0-0.9	A
Small	Largely natural with few modifications. A slight change in ecosystem processes is discernable and a small loss of natural habitats and biota may have taken place.	1-1.9	B
Moderate	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact.	2-3.9	C
Large	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	4-5.9	D
Serious	The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9	E
Critical	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10	F

1.2.6 Assessing the anticipated Trajectory of Change

Here, the question is posed: "*is the current state of the wetland likely to change in the future, by how much and in which direction?*" This appraisal of likely future trends is dealt with in much less detail than for assessing the Present State, and for the purposes of the assessment, five potential situations exist depending upon the direction and likely extent of change, as outlined in Table 1.5 (p.31). In order to determine the appropriate Trajectory of Change symbol for the wetland each HGM unit is assigned a change score.

Table 1.5: Trajectory of Change classes and scores used to evaluate likely future changes to the present state of the wetland

Change Class	Description	HGM change score	Symbol
Substantial improvement	State is likely to improve substantially over the next 5 years	2	↑↑
Slight improvement	State is likely to improve slightly over the next 5 years	1	↑
Remain stable	State is likely to remain stable over the next 5 years	0	→
Slight deterioration	State is likely to deteriorate slightly over the next 5 years	-1	↓
Substantial deterioration	State is expected to deteriorate substantially over the next 5 years	-2	↓↓

As is the case with the Present State, future threats to the state of the wetland may arise from activities in the catchment upstream of the unit or from within the wetland itself or from processes downstream of the wetland. In each of the individual sections for hydrology, geomorphology and vegetation, potential sources of change for each component of assessment are listed and the user is expected to assess future trends.

1.3 The Assessment Procedure

1.3.1 Define objectives and scope for assessment

The requirements for assessing wetland health may be very diverse. It is important therefore that before any assessment is undertaken, the specific objective for undertaking the assessment should be clearly defined. State how you intend to use the results of the assessment (e.g. to prioritise the allocation of limited resources for managing, rehabilitating or protecting the wetland). Also, clearly define the geographical boundaries of your study area and your available resources. In most cases, all three modules will be required but some assessments may have very specific objectives requiring information from only one or two modules.

Setting the objectives of the study will affect the choice of geographical area for which the assessment is best undertaken. Some aspects of the assessment require consideration of the wetland as a whole – such as the analysis of factors that determine the physical location of the wetland (geological or geomorphological controls). For other aspects of the assessment it may be appropriate to consider just a portion of the wetland – such as the portion of a larger wetland that is on an individual farmer's land such that the farmer can manage it appropriately. Alternatively, rehabilitation may wish to focus on the upper part of a wetland and use *WET-Health* as a diagnostic tool for assessing a portion of the wetland. The geographic scope of the study may vary from assessment to assessment, bearing in mind that some aspects need to be undertaken for the wetland as a whole.

1.3.2 Determine most appropriate level of assessment

Depending on the particular requirements of the assessment, the appropriate level of assessment (i.e. desktop or field-based) should be chosen. It is important to decide the degree of accuracy you would like to obtain considering your available resources. This will influence whether you do a desktop-based assessment only, or how much field time you allocate to each HGM unit.

1.3.3 Basic mapping and identification of HGM units

After setting the scope of the assessment and defining the geographic extent of the study, the assessor is required to generate a basic map of the wetland and its associated catchment. A Geographic Information System (GIS) is particularly useful during this process, since it can be used to generate a substantial amount of information necessary to inform the assessment. Where these facilities are not available, orthophotos (1: 10 000) may be used for small wetlands while topo-cadastral maps (1: 50 000) may be used for large wetland systems. A brief description of the basic mapping requirements are outlined below.

- Delineate the wetland boundary. Here, the wetland boundary is defined as the outer edge of the temporary zone (DWAF, 2005). Where a Level 1 assessment is undertaken, wetlands may simply be mapped at a coarse level from aerial photographs. For a Level 2 assessment, ground-truthing is required to more accurately define the wetland boundary.
- Divide the wetland into hydrogeomorphic (HGM) units. Once the wetland has been defined, it needs to be sub-divided into HGM units for further assessment (See section 1.2.3). A wetland may consist of several different hydrogeomorphic units. Illustrated in Figure 1.3 are a floodplain that is linked to smaller valley-bottom (channelled) and hillslope seepage wetlands (a), and a combination of channelled and unchannelled valley-bottom wetlands (b). The boundary between one unit and another may be unclear and in order to locate the boundary in a sensible manner, users will need to read the descriptions of the types in Table 1.2 carefully. Remember that the transition is often, but not always, associated with a change in slope. For example, a transition from hillslope to floodplain, as in Figure 1.3, is usually associated with a decrease in slope.
- Delineate the catchment boundary. This needs to be done for each HGM unit being assessed and may therefore necessitate the delineation of a number

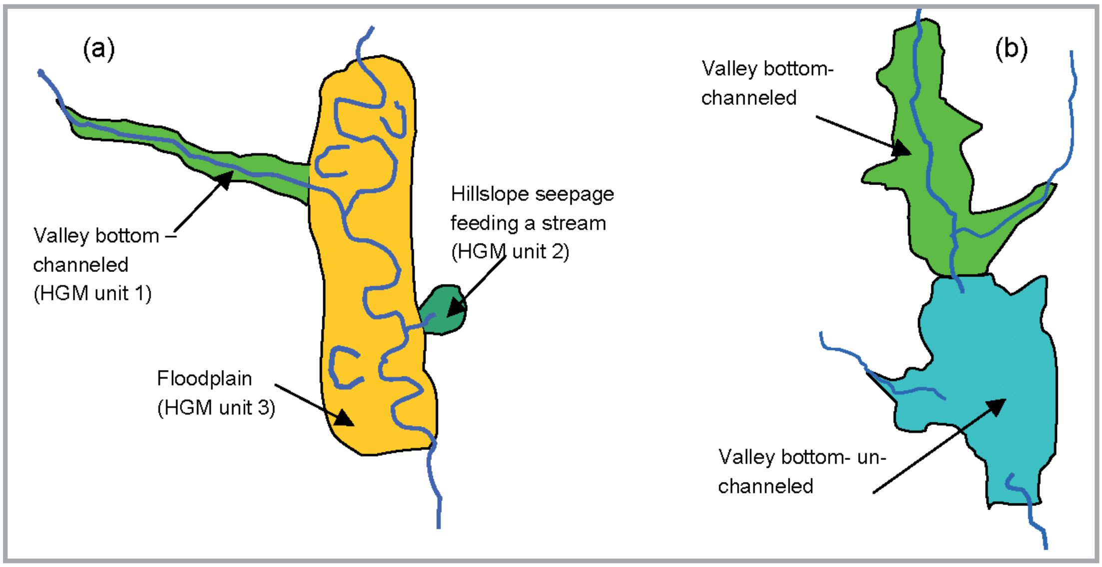


Figure 1.3: Two wetlands, the first comprising three different hydro-geomorphic units and the second comprising two units (see Table 1.2 for definitions of the HGM unit types)

of sub-catchments relevant to each HGM unit. Contours are typically used to help map these catchments since runoff flows perpendicularly to contour lines. This is typically a simple task for small wetland systems but may be onerous where wetlands are located on river systems with extensive catchment areas.

- Determine the extent of HGM units and their catchments. Once HGM units and catchments have been defined, the extent needs to be estimated to obtain an indication of catchment size relative to that of the wetland. While this can be done using hard-copy maps, the process is considerably easier where GIS tools are available.

1.3.4 Identify information sources of key wetland and catchment characteristics

A range of wetland and catchment information needs to be collected in undertaking an assessment of wetland health. Data that are necessary for various assessments can be obtained from two main sources:

- *in the office* using a desktop investigation of maps, aerial photographs, Google Earth;
- *through a field investigation* by visiting the wetland; or
- in some cases a *combination* of the above sources may be necessary.

Sources of information for each assessment are indicated in tables in the three modules using a superscript symbol as follows:

^{D} = Data to be obtained in the office through desktop investigation prior to field assessment

^{R} = Data may be available through desktop investigation but may be revised/refined in the field

^{F} = Data should be obtained in the field.

1.3.5 Desktop identification of key wetland and catchment characteristics

Using 1:10000 orthophotographs, available GIS coverages, 1:50000 topocadastral maps and where possible, aerial photographs[1], the following should be mapped and/or recorded based upon a desktop investigation, prior to going into the field:

- Catchment boundary and catchment area (units should preferably be in hectares)
- Wetland boundary and HGM unit boundaries and area of each HGM unit (in hectares)
- The quaternary catchment in which the wetland is situated should be identified and Mean Annual Precipitation (MAP) and Potential Evapotranspiration (PET) should be obtained from the Appendices 1 and 2
- As far as possible the land uses in the catchment and the wetland, and their approximate extent (in hectares)
- Presence of any drains, dams, erosion features in the catchment or the wetland and their extent (in hectares).

1.3.6 Field procedure for conducting a Level 2 assessment

While the field work requirements vary for Level 1 and Level 2 assessments, both require some degree of field work The first logical step in undertaking the fieldwork required is to be familiar with the descriptors that need to be measured in the field in order to assess the health of the wetland. Examples include the depth of artificial drainage channels, presence of obstructions in channels, width of gullies

1 Maps, orthophotographs and aerial photographs can be obtained from the Surveyor General, Chief Directorate: Surveys and Mapping, Rhodes Avenue, Mowbray, 7700: Private Bag X10, Mowbray 7705: Tel 021 658 4300: Fax 021 686 9884

etc. You do not want to get back after the fieldwork and find that you have forgotten to describe some important descriptors. For Level 2 assessments, refer to Sections 2 to 4. Where a Level 1 assessment is planned, refer to Section 5.

Next, it is important to remember that each of the HGM units making up the wetland must be examined individually. Being a rapid assessment, there will not be time to examine the entire HGM unit thoroughly in the field. Instead, specific parts of the HGM unit need to be identified for particular attention. The aerial photograph interpretation and the initial stratification of the wetland into individual HGM units serve as a useful guide in directing where to focus the field examination.

Some obvious features (notably, areas where the indigenous vegetation has been totally lost, e.g. where flooded by dams or under annual tillage) are easily visible on aerial photographs and do not need close inspection in the field. For most other features, however, it is usually valuable to take a closer look at the wetland in the field. To ensure that no key features are omitted it is recommended that the assessor completes the data tables for each module in a step-wise and systematic manner. Standardized data sheets have been developed for each module to assist practitioners in working through the different assessments. Data sheets are contained in the CD enclosed in the back cover of this manual.

1.3.7 Evaluate each component of Present State and Trajectory of Change separately for each HGM unit

Separate techniques have been developed for the assessment of each component of wetland health (hydrology, geomorphology and vegetation). For the Level 2 assessment, each component of health is presented as a separate module (Sections 2 to 4), and the assessments should be done for each HGM unit. Each component is assessed for each HGM unit as separate steps for Level 1 assessment (Section 5). Once all necessary information has been collected, each component of wetland health is evaluated by completing the Excel datasheets developed for each module. This is used to obtain the Present State category, likely Trajectory of Change score and Health for each HGM unit.

1.3.8 Summarise the overall health of the wetland

Once all HGM units have been assessed, a summary of health for the wetland as a whole needs to be calculated. This is achieved by calculating a combined score for each component by area-weighting the scores calculated for each HGM unit (Table 1.6). Recording the health assessments for the hydrology, geomorphology and vegetation components provides a summary of impacts, Present State, Trajectory of Change and Health for individual HGM units and for the entire wetland.

For the wetland illustrated in Figure 1.3a with three HGM units, HGM unit 1 has a large hydrological impact score, but moderate geomorphological and vegetation impact scores. Based on the Trajectory of Change scores hydrology and vegetation are likely to deteriorate slightly, while geomorphology should remain stable. HGM unit 2 has a serious impact score for hydrology and geomorphology and a moderate impact score for vegetation. In this case the Trajectory of Change for hydrology and geomorphology appear to be deteriorating slightly while vegetation is likely to deteriorate substantially. HGM unit 3 has a small impact score for hydrology, a moderate impact score for geomorphology and a large impact score for vegetation. Based on the Trajectory of Change scores hydrology, vegetation and geomorphology are all likely to deteriorate slightly. Based on a weighted average for the overall wetland, hydrological and geomorphological impacts are moderate and deteriorating slightly, and vegetation is in the worst state with a large impact score and deteriorating substantially.

These health profiles provide a useful basis for management and/or rehabilitation, where hydrological factors should be the focus of intervention in HGM units 1 and 2, vegetation composition and structure in HGM units 2 and 3, and geomorphology in HGM unit 2.

Table 1.6: Summary of the overall Present State impact scores and Trajectory of Change scores for the wetland represented in Figure 1.3a, consisting of three HGM units

HGM Unit	Ha	HGM Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact score	Change score	Impact score	Change score	Impact score	Change score
1	4	20	5.0	-1	2.5	0	2.5	-1
2	2	10	7.5	-1	6.0	-1	5.0	-2
3	14	70	1.0	-1	2.5	-1	5.0	-1
Area weighted scores*			2.5	-1	3.6	-0.7	4.5	-1.1
Present State category and likely Trajectory of Change**			C	↓	C	↓	D	↓↓

* The area-weighted scores for each component are calculated by first calculating an area-weighted impact /change score for each HGM unit (Proportion of wetland as a percentage/100 x impact/change score) and then summing the area-weighted scores across all HGM units.

** The Present State category ranges from A to F (see Table 1.4), and for Trajectory of Change, the symbol is assigned to the overall wetland based on the class range below (e.g. if the overall weighted change score = 0.7 then the symbol = ↑)

Class Range	Symbol
1.1 to 2.0	↑↑
0.3 to 1.0	↑
-0.2 to +0.2	→
-0.3 to -1.0	↓
-1.1 to -2.0	↓↓

1.4 Inter-relationships between the three components of health: Integration of hydrological, geomorphological and vegetation scores

Although *WET-Health* deals with health in three discrete components, it is recognized that the three components are closely inter-linked (Figure 1.4). A loss in hydrological integrity will usually result in a loss of vegetation integrity, although the vegetation may be very slow to respond, particularly where the ratio between mean annual precipitation and potential evapotranspiration (MAP: PET ratio) is relatively high and/or vegetation is dominated by one or two species. However, loss in hydrological integrity will sometimes result in a loss of geomorphological integrity, depending on the nature of the particular hydrological change and on local conditions such as wetland slope and soil type.

A loss in geomorphological integrity will almost always result in a loss of hydrological integrity, but the magnitude of the effect will depend on local features, notably slope of the wetland and the texture of its soils. The effect of reduced geomorphological health on vegetation may be direct (e.g. through the deposition of sediment on existing vegetation) or indirect (e.g. through desiccation, caused by the drainage effect of an erosion gully).

The effect of a loss in the integrity of vegetation on hydrology will depend very much on the structural and compositional changes that take place, primarily through the effect of vegetation on surface roughness and transpiration rates. The most important aspect of vegetation affecting geomorphological integrity is vegetation cover. If this is reduced, erosion risk of a wetland may be considerably increased, particularly where the geological and geomorphological setting render the wetland susceptible to erosion.

Many of the inter-linkages described above are contained within *WET-Health*. For example, erosion gullies are considered as one of the features that may potentially alter the distribution and retention of water in a wetland. However, it must be recognized that much of the complexity of these different interrelationships cannot be fully captured by *WET-Health*.

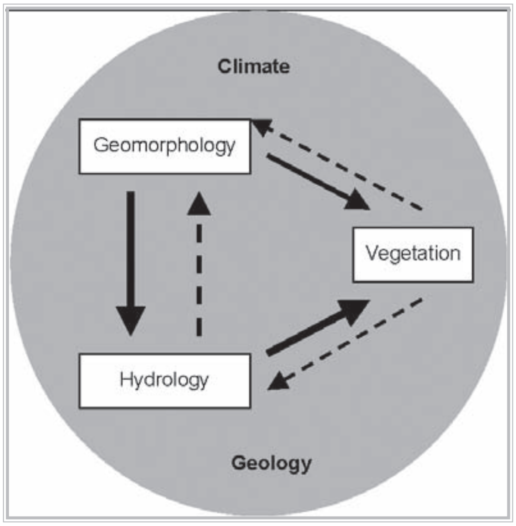


Figure 1.4: Interrelationships with respect to magnitude of impact between hydrological, geomorphological and vegetation state of wetlands. The width of the lines indicates the likely strength of interactions

Users are not encouraged to aggregate the scores for the three components (hydrology, geomorphology and vegetation). However, if a user has a specific requirement to do so, then this should be based on the following formula:

Health = ((Hydrology score) x3 + (Geomorphology score) x 2 + (Vegetation score) x 2)) ÷ 7, which gives a score ranging from 0 (pristine) to 10 (critically impacted in all respects). The rationale for this is that hydrology is weighted by a factor of 3 since it is considered to have the greatest contribution to health as explained in Section 2.1. If the user considers that the weightings should be adjusted then this can be done, provided that written justification is given.

In the example given in Table 1.6, the overall score for impacts would be ((2.5 x 3) + (3.6 x 2) + (4.5 x 2)) ÷ 7 = 3.39 and for Trajectory of Change it would be ((-1 x 3) + (-0.7 x 2) + (-1.1 x 2)) ÷ 7 = -0.94. According to Tables 1.4 and 1.5 this would be represented as a Health score of C (↓). Please note that a C (↓) does not represent a wetland half way between a C and a D class – it indicates that, if no remedial action is taken, the wetland could deteriorate from a category C to a category D.

SECTION 2: HYDROLOGY MODULE

Introduction

For the purpose of this assessment, hydrology refers to the movement of both surface and sub-surface water into, through and out of a wetland. Hydrology is the defining feature of wetlands and therefore forms a key component of the assessment of wetland health. The hydrological conditions in a wetland affect many important processes, including the development of anaerobic conditions in the soil (waterlogging), availability of nutrients and other solutes, and sediment fluxes. These factors strongly influence which fauna and flora will inhabit a wetland, and this in turn has a feedback effect on hydrological conditions (e.g. through transpiration by plants; Mitsch and Gosselink, 1993). Clearly therefore, the consequences of altering the hydrological conditions in a wetland may be enormous in terms of overall wetland structure and the biophysical processes taking place in a wetland.

The hydrology of a wetland can be altered through:

1. human modifications to the wetland's catchment that change the quantity and timing of water inputs to the wetland
2. modifications taking place within the wetland that alter the distribution and retention patterns of water within that wetland (Figure 2.1).

To simplify the evaluation of the hydrology of a wetland, separate assessments are undertaken for the respective components, which are then integrated into an overall health score. The general assessment process involves a number of steps outlined in Figure 2.2 (opposite).

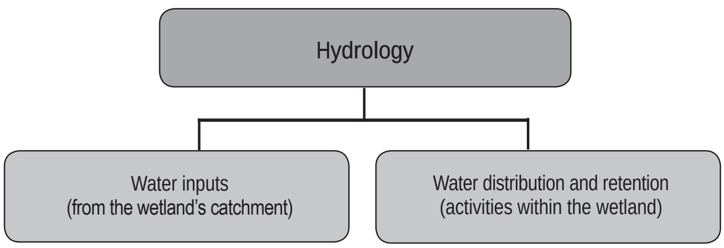


Figure 2.1: The primary components included in an evaluation of hydrological impacts that may affect a wetland

Step 1: Identify HGM units in the wetland and describe the local climate
- Step 1A: Divide the wetland into HGM units (see Section 1.3.3)
- Step 1B: Assess the vulnerability of the HGM unit to altered water inputs, based on local climate

↓

Step 2: Water inputs:
For each HGM unit, assess impacts of changes in quantity and pattern of water inputs to the unit from its **upstream catchment**

↓

Step 2A:
Identify, map and assess impact of land-use activities that reduce the *inflow quantity* to the HGM unit

Step 2B:
Assess the intensity of impact of factors potentially altering *flow patterns (timing)* to the HGM unit

↓

Step 2C: Assess the combined magnitude of impact of altered *quantity and pattern* of inputs, accounting for the wetland's vulnerability

↓

Step 3: Water distribution and retention
Assess the degree to which natural water distribution and retention patterns within the HGM unit have been altered as a result of **on-site activities**
- Step 3A: Assess magnitude of impact of *canalization* and *stream modification*
- Step 3B: Assess magnitude of impact of *impeding features*
- Step 3C: Assess magnitude of impact of altered *surface roughness*
- Step 3D: Assess the impact of *direct water losses*
- Step 3E: Assess the impact of *recent deposition, infilling or excavation*
- Step 3F: Determine the combined magnitude of impacts of *on-site activities*

↓

Step 4: Determine the Present Hydrological State of each HGM unit based on integrating the scores from Steps 2 and 3

↓

Step 5: Determine overall Present Hydrological State for the wetland by integrating the assessments from the individual HGM units

↓

Step 6: Assess the anticipated Trajectory of Change of wetland hydrology

↓

Step 7: Describe the overall Hydrological Health of the wetland based on Present Hydrological State and Trajectory of Change

Figure 2.2: Outline of the steps involved in the hydrology module

STEP 1: Identify HGM Units in the wetland and describe the local climate

Step 1A: Identify the HGM Types in the wetland and divide the wetland into HGM units

As highlighted in Section 1, each HGM unit in the wetland is assessed separately, based on the assumption that different HGM types are likely to be affected in different ways by hydrological impacts. In the example in Section 1 (Figure 1.3), the hillslope seepage, channelled valley bottom and floodplain portions of the first wetland would each be assessed as individual units. See Section 1.3.3 for a detailed description of the HGM types and how to identify them.

Step 1B: Assess the vulnerability of the HGM unit to altered water inputs based on local climate

One of the most important aspects of climate affecting a wetland's vulnerability to altered water inputs is the ratio of Mean Annual Precipitation (MAP) to Potential Evapotranspiration (PET). These data are presented for all catchments in South Africa in Appendix 1. Over most of South Africa, the MAP is lower than the PET, and there is a general trend of decreasing MAP and increasing PET from east to west across the country. The lower the MAP:PET ratio, the smaller will be the contribution of direct precipitation falling onto the wetland and the more dependent the hydrology of the wetland will be on inflows from its upstream catchment, and therefore the more vulnerable it will be to reduced inflows. This ratio is used in Table 2.1 to score the contribution of climate to amplifying or dampening the effects of flow-reducing activities in the HGM unit's catchment.

Table 2.1: Hydrological vulnerability factor based on the MAP:PET ratio

MAP to PET ratio[D]	>0.6	0.50-0.59	0.40-0.49	0.30-0.39	<0.3
Vulnerability factor	0.9	0.95	1.0	1.05	1.1

Note: The vulnerability factor is used later (e.g. in Table 2.2) as a multiplier in the calculation of impact intensity of land-uses in the catchment that reduce flow (e.g. tree plantations). Where the vulnerability factor is <1, it decreases the intensity score, but where >1 it increases the intensity score.

The symbols [D, R and F] used in tables throughout this module refer to where data is best acquired.

- [D] = Data should be obtained in the office through desktop investigation prior to the field assessment
- [R] = Data may be available through desktop investigation but are likely to be revised/refined in the field
- [F] = Data should be obtained in the field

The hydrology of South African wetlands and the factors affecting the vulnerability of individual wetlands to reduced inflows are largely still poorly understood and are in need of further investigation.

The vulnerability of a wetland to altered water inputs is also affected by the HGM type of the wetland, which is accounted for in Step 2C. Within a given HGM setting, several other factors may also affect the vulnerability of a wetland to altered inflows, which includes the underlying geology and the ratio of the area of the wetland to the area of its upstream catchment. *WET-Health* does not include explicit guidelines on how to account for these additional factors. However, if you have an understanding of some of these factors, and data for the HGM unit, then you may use these to adjust the score, provided that you document your justification.

STEP 2: Assess the impact of changes in the quantity and pattern of water inputs to the wetland

Both the quantity and pattern of inflows of water into a wetland from its catchment may be altered (timing and magnitude of peak flows and low flows; Figure 2.3). The quantity of water entering a wetland may either be increased or decreased depending on land-use in the catchment. Given the high demand for water in South Africa, which in global terms has low rainfall, decreased water inputs are far more widespread than increased inputs, except in urban areas where discharges (e.g. from sewage treatment plants) often increase inflows to wetlands.

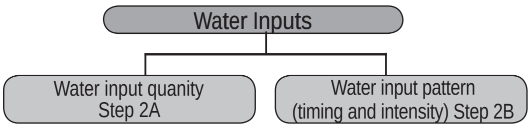


Figure 2.3: The components evaluated as part of an assessment of impacts on water inputs to a wetland

The evaluation in Step 2 is undertaken at the scale of the wetland's catchment and therefore reflects impacts from altered catchment characteristics. The key focus of the evaluation is to understand the changes to water inputs that result from catchment changes and to evaluate what effect these changes are likely to have on wetland health. Not all wetlands are affected equally by changes in quantity and timing of inputs. Some wetlands (e.g. floodplains) may be particularly sensitive to reduced floodpeaks, while other wetlands are more sensitive to reduced overall quantity of inputs. Thus, to assess the effect of altered inputs it is necessary not only to determine how the water input quantity and pattern to a wetland has been altered (Steps 2A and 2B), but to also determine the impact of these alterations on the ecological state of the wetland, taking into account the particular features of the wetland (Step 2C).

Step 2A: Identify, map and assess the impact of land-use activities that reduce the water inflow quantity to the HGM unit

In this step, the catchment of each of the HGM units must be delineated and dealt with individually. Note that for the purpose of estimating the extent of each land-use type in the HGM unit's catchment, land-use activities upstream or upslope of the HGM unit are examined. Land-use activities taking place in the HGM unit itself are therefore excluded from this assessment. Water losses from on-site activities are explicitly addressed in Step 3.

The effects of land-use activities on the water inflow from a wetland's catchment are dependant on several factors. For the purposes of this assessment, the following factors are considered:

- local climate (MAP:PET ratio)
- land use type and the particular activities associated with the land-use
- the extent of the area under the respective land-use types.

The main land-use activities considered here, which reduce the quantity of water flowing into a wetland, are (a) abstraction of water for irrigation and other purposes, (b) timber plantations, (c) sugarcane and other evergreen crops, (d) woody alien plants and (e) dams. Increases in the quantity of water flowing into a wetland commonly result from sewage discharges and inter-basin transfer schemes.

Map the areas in the HGM unit's upstream catchment under the different land-use types given in Table 2.2 and record their extent in column 9 of Table 2.2 as a proportion of the total area of the HGM unit's upstream catchment.

Determine the intensity of the impacts associated with each of the land-use types by scoring the relevant descriptors given in Table 2.2 and record this in column 8 of Table 2.2. Note that the vulnerability factor from Table 2.1 forms part of this intensity record. Calculate the magnitude of impact of each land-use in reducing water inflows by multiplying the scores for extent and intensity (see Table 2.2). The overall magnitude of reduction in quantity of inflows to the HGM unit is the sum of all the magnitudes for all of the different land-use types.

Mapping must be undertaken carefully as there may be different types of irrigation (year-round *vs.* seasonal *vs.* *ad hoc*), different types of timber plantations (pine *vs.* gum) and different types of alien woody plants (trees *vs.* shrubs) etc. – all of which have different impacts on inflow reduction to the wetland. Here you should come to a sensible estimate of the average conditions for the portion of the catchment being considered.

Table 2.2: Different land-use types and activities potentially altering inflow quantities to the HGM unit from its upstream catchment, and the magnitude of their collective effect[1]

Reduced flows:

	Land-use activity descriptors	Low				High	Intensity of waterloss[2]	Extent(%)	Magnitude[3]
		0	-2	-5	-8	-10			
Irrigation	(1) Duration of irrigation[R]			*Ad hoc*, supplementary	Seasonal	Year-round			
Irrigation	(2) Prevalence of water conserving practices[R]		High	Intermediate	Low				
Other abstractions not used for irrigation in the catchment [R4]:									
Alien plants	1. Plant type[R]			Shrubs	Trees				
Alien plants	2. Distribution of alien woody plants in riparian areas[R]		Confined to non-riparian areas	Occur across riparian & non-riparian areas	Occur mainly in riparian areas				
Plantations	1. Tree type[R]				Wattle & pine	Eucalyptus			
Plantations	2. Distribution of tree plantations in riparian areas[R]		Confined to non-riparian areas	Occur across riparian & non-riparian areas	Occur mainly in riparian areas				
Sugar[5]	1. Crop type[R]		Sugar						
Sugar[5]	2. Distribution in riparian areas[R]		Confined to non-riparian areas	Occur across riparian & non-riparian areas	Occur mainly in riparian areas				
	Dams: specific allowance for releasing low flows within the operating rules of the dam[R]		Allowance made	No allowance made					
Overall magnitude of reduction in water inputs to the HGM unit as the sum of all the above impact magnitudes (following page):									

Increased flows:

Description of the level of increase	Magnitude score
Additional flows are more than equal to the natural situation (e.g. as a result of an inter-basin transfer scheme or major discharge from sewage treatment plants).	+10
Additional flows are approximately equal to the natural situation (e.g. as a result of moderate discharge from a sewage treatment plant); i.e. if there are no factors reducing flows then the natural flows will be doubled.	+7
Additional flows are approximately a third of the natural situation (e.g. as a result of minor discharge from a sewage treatment plant).	+3
No increase, or flow is increased by a negligible amount.	0

Combined score: Increased flows score + Decreased flows score The combined score will range from -10 to +10, depending on the magnitude of the factors causing an increase or decrease in flow respectively	

[R] = Data may be available through desktop investigation but are likely to be revised and refined in the field.

[1] Many coastal plain wetlands, such as those occurring on the Cape Flats and the Maputaland coastal plain 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. The relative contribution of these two sources is likely to vary from wetland to wetland. This complicates the assessment of catchment alterations to water inputs. Thus, the application of the catchment assessment scheme given in Table 2.2 of *WET-Health* is problematic for these wetlands. Instead, it is probably best that assessors base their assessment of catchment effects on best professional judgment and seek local knowledge on the extent to which the regional water table may have been altered (e.g. extensive planting of eucalyptus trees lowering the water table).

[2] Intensity= Mean of (1) & (2) x vulnerability factor from Table 2.1. For example, if alien woody plants are predominantly shrubs occurring mainly in riparian areas, and the MAP:PET ratio is 0.45 then the intensity of reduced inflows resulting from the alien plants will be as follows: (-5 + -8)/2) x 1.0 = -6.5.

[3] Magnitude=Intensity x Extent (%)/100. For example, if the total extent of the alien woody plants in the HGM units upstream catchment is 25% then the magnitude of inflow reduction from the catchment will be as follows: 25/100 x -6.5 = -1.6

[4] Abstraction may also take place for purposes other than irrigation, e.g. for domestic purposes. The magnitude score for these abstractions is determined relative to abstractions for irrigation within the catchment. Take for example, where the overall magnitude as a result of irrigation within the wetland's catchment is -4 (on a scale of 0 to -10) and the amount abstracted for domestic use is approximately half that used for irrigation in the wetland's catchment. The magnitude for other abstractions would therefore be -2.

[5] Other evergreen crops such as tea.

Rationale for Table 2.2

Irrigation

The abstraction of water from a catchment for irrigation and other purposes has a direct impact on water flows as it involves the removal of water from the catchment to sustain the evapotranspiration of crops. There is thus significant loss of water to the atmosphere through irrigation.

The duration of irrigation is particularly important as year-round irrigation is likely to have a higher impact than seasonal irrigation. Irrigation practices vary considerably, from inefficient methods such as overhead irrigation, to much more efficient methods such as drip irrigation. If the efficiency with which water is transported to the fields is low (e.g. as a result of high leakages) then losses are further increased. Appropriate scheduling of irrigation may further affect irrigation efficiency. Cultivation practices may also influence water losses as cultivation practices such as mulching and minimum tillage reduce evaporative loss and therefore reduce the required application rate. Conversely, practices such as conventional tillage leave soil exposed, causing high evaporative-loss and leading to increased irrigation requirements.

Other forms of water abstraction may also take place within a wetland's catchment (e.g. for domestic purposes) and these need to be accounted for by estimating their magnitude in relation to abstractions used for irrigation in the catchment (see Table 2.2).

Alien plants, timber and sugarcane plantations

Different plant species have different rates of water consumption. As a general rule eucalyptus trees reduce catchment water yield more than do wattle and pine trees (Gush *et al.*, 2002). Water-use by sugarcane is considered to be intermediate, as is the use of water by alien species (depending on growth form). In riparian areas (much of which often consists of wetland) the soil water is generally much more readily available to trees than it is in the upland portions of the catchment, as the water table is close to the soil surface. Thus, species with a high water-use requirement would have their greatest impact in depleting water if they are located in riparian areas.

Dams

Dams present in the wetland's catchment have the effect of retaining water, which is then subject to evaporation and delayed releases. The larger the collective surface-area of dams, the greater would be the area over which evaporation can take place and therefore the greater the potential reduction of water inputs to the wetland. The greater the MAP:PET ratio the greater will be the evaporative loss. A specific allowance for releasing low flows would reduce the impact of a dam.

Inadequacies in the catchment assessment

It must be emphasized that the above assessment of land use impacts on the quantity of inflow provides only a very coarse-level indication of reduced water inputs to a wetland based on different land-uses. Additional information about the catchment may be available (e.g. the type and depth of the soil) which could be incorporated into this assessment to enhance the rapid assessment conducted in this step. If resources and the data are available, consider modelling the water inputs (e.g. with the ACRU or SCS models) as an alternative to the rapid assessment approach used here. Although the modelling approach requires more resources and time, it provides a more accurate assessment.

Note also that examining flow reductions over the whole year may mask more subtle impacts (e.g. abstraction may be concentrated in the early growing season or during low flow periods). The low resolution of the *WET-Health* assessment mitigates against such finer-level distinctions, but if you as the assessor have an understanding of these factors then you may make an adjustment to the assessment in Table 2.2 provided that your justification is documented.

Step 2B: Assess the intensity of the impact of factors potentially altering the pattern of water delivery to the HGM unit

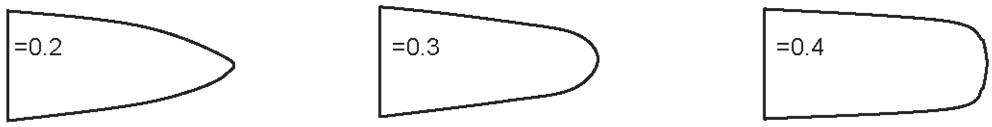
The pattern of water inputs has a number of dimensions, but for the purposes of this relatively low-resolution assessment, water input patterns have been reduced to a single dimension, the magnitude and/or frequency of floodpeaks. The floodpeak magnitude and/or frequency can either increase or decrease, depending upon the type of activity being conducted in the catchment (Table 2.3). Factors contributing to decreases and factors contributing to increases counteract each other's effects, and under certain circumstances, these effects may cancel each other out. Their overall effect is described with reference to Table 2.3.

Table 2.3: Factors potentially contributing to a decrease or increase of floodpeak magnitude and/or frequency received by the HGM unit

Level of reduction	Low				High	Score
	0	-2	-5	-8	-10	
1. Collective volume of dams in the wetland's catchment in relation to mean annual runoff (MAR)^{R*}	<20%	20-35%	36-60%	60-120%	>120%	
2. Level of abstraction from the dams^{R}	Low	Moderately low	Intermediate	Moderately high	High	
3. Specific allowance for natural floods within the operating rules of the dam^{R} **	Good allowance made	Moderate allowance	Limited allowance	Poor allowance	No allowance	
Level of increase***	Low				High	Score
	0	+2	+5	+8	+10	
4. Extent of hardened surfaces in the catchment^{R}	<5%	5-20%	21-50%	50-70%	>70%	
5. Extent of areas of bare soil in the wetland's catchment including that associated with poor veld condition^{R***}	<10%	11-40%	41-80%	>80%		
Combined score: [Average of (1), (2) and (3)] + [(4) + (5)] Adjusted**** The combined score will be in the range from -10 to +10 depending on whether the increases in peak flow are greater or smaller than the decreases.						

* Refer to Appendix 1 to obtain the median annual simulated runoff given in millimeters for the particular quaternary catchment in which the wetland falls. Convert this to metres (÷ 1000) and multiply this by the area of the catchment (converted from ha to m^2 by multiplying by 10 000). For example, if the wetland is in quaternary catchment B60B then the simulated runoff given in Appendix 1 is 251 mm. Assuming in the example that the wetland's catchment is 500 ha, then the MAR = 251 ÷ 1000 X 500 X 10 000 = 1 255 000 m^3.

The volume of a dam is calculated roughly based on the following formula.
Q=FLOD, Where Q=capacity (m^3)
F= Dam shape factor



L= Wall length at full supply level (m); O= Throwback (m); D= Maximum water depth (m)

** This is only applicable where the collective volume of dams is >120% of MAR.

*** Excluding very sandy soils with clay contents too low for crusting to occur

**** Two factors that may potentially further increase floodpeaks are gullies and roads in the catchment, which serve to increase the delivery of stormflows to the wetland, and inter-basin transfers. If either of these are present then adjust accordingly, with written justification. For example, the extent of hardened surfaces may be only 10% of the catchment (i.e. a score of +2) but an extensive network of roads may act to effectively deliver stormflows to the wetland, and the score is adjusted to +4. Inter-basin transfers are common in urban settings, where water is often transferred into a catchment for industrial and domestic purposes.

Rationale for Table 2.3

Factors resulting in decreased floodpeaks

The greater the collective volume of dams in relation to the MAR from the wetland's catchment, the greater the potential flood storage, in particular where dams remain at low levels for much of the year. For example, the storage capacity of the Pongolopoort Dam immediately upstream of the Pongolo Floodplain, is 224% of the MAR, which is exceedingly high. In simple terms, therefore, if the dam was emptied, it would take more than two years to refill it under average conditions, even if no water was released. Thus, the potential impact of the impoundment on downstream flows is considerable. If an estimate of dam volume is not available, then use the outcome of the descriptors for dams in Table 2.2.

The greater the level of water abstraction from the dams, the greater is the likelihood that dams will be well below their capacity when potential flood events arrive, thereby greatly dampening floods downstream, unless specific mechanisms for release are being followed.

Large dams in particular have the potential to eliminate natural flooding downstream of the dam unless specific allowance is made for natural floods within the operating rules of the dam so as to simulate natural flooding. In this regard, it is important to note that some dams do not have the structural capacity for releasing sufficiently large floods to simulate natural flooding.

Factors resulting in increased floodpeaks

The greater the extent of hardened surfaces (e.g. roofs, parking lots etc.) or areas of bare soil in the wetland's catchment, the lower is the infiltration of storm-waters and therefore the greater the surface runoff and increase in floodpeaks. The infiltration capacity of bare soils is characteristically lower than well-vegetated soil, owing to factors such as the development of surface crusting. It must be added, however, that very sandy soil has too little clay for crusting to develop. It should also be noted that hardened surfaces will have lower infiltration capacities than will bare soil, even that with a high clay content, and hence there is different scaling used for factors (4) and (5) in Table 2.3.

A further impact of reduced infiltration of water in a wetland's catchment, is reduced and less sustained sub-surface water inputs to a wetland. This is of course dependent on there being no transfer of water into the wetland's catchment from another catchment (i.e. inter-basin transfer).

Alteration classes are provided in Table 2.4, for comparison with the combined score in Table 2.3. Motivated adjustments can be made if necessary.

Table 2.4: Level of alteration of the natural pattern of floods delivered to the HGM unit

Combined score	Alteration classes	Description
>6	Large increase	Floodpeaks have been substantially increased, resulting in the marked reduction of sub-surface water inputs.
4 to 6	Moderate increase	Floodpeaks have been moderately increased, often resulting in the noticeable reduction of sub-surface water inputs
1.6 to 3.9	Small increase	Discernable but small increase in floodpeaks that may not necessarily have resulted in the discernable reduction of sub-surface water inputs.
-1.5 to 1.5	No effect	No discernable effect on floodpeaks.
-1.6 to -3.9	Small decrease	Discernable but small reduction in floodpeaks.
-4 to -6	Moderate decrease	Floodpeaks have moderately decreased .
<-6	Large decrease	Floodpeaks greatly reduced, such that in the case of a floodplain, no further flooding out of the main channel across the wetland takes place unless during major floods (i.e. >1 in 20 year flood events).

Step 2C: Assess the combined magnitude of impact of altered quantity and pattern of inputs, accounting for the HGM unit's vulnerability

The magnitude of impact on both the quantity (Table 2.2) and the pattern (Table 2.3) of inflows to the HGM unit has been scored. These two scores need to be integrated to obtain a combined measure of the magnitude of impact of altered inflows on the HGM unit's catchment, taking into account the vulnerability of the HGM unit. This is achieved using Table 2.5. If the HGM unit is driven largely by overbank flooding, it is assumed to be particularly vulnerable to reduced floodpeaks and relatively resilient to small to moderate reductions in quantities of inflows, and Table 2.5a is used. However, if the HGM unit is driven primarily by lateral inputs it is assumed to be relatively resilient to reduced floodpeaks but vulnerable to reduced quantity of inputs and Table 2.5b is used.

Table 2.5: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of hydro-geomorphic type, altered quantity of water inputs and the altered pattern of water inputs.

a. Floodplains and channelled valley bottoms driven primarily by over-bank flooding

Change in quantity of **water inflows (Score** from Table 2.2)	**Alteration to floodpeaks** (Score from Table 2.3)						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	7	6	5	4	5	6	7
4-9	5	4	3	3	4	6	7
1-3.9 (Increase)	3	2	1	1	2.5	4.5	7
-0.9- +0.9 (Negligible)	1	1	0	0	1	5	7.5
-1- -1.9 (Decrease)	2	1.5	1	1	2.5	5	7.5
-2- -3.9	3	2.5	2	2	4	6	8
-4- -5.9	4	3.5	3	3	5	7	8.5
-6- -7.9	-**	-**	-**	4	6	8	9
-8- -9	-**	-**	-**	-**	-**	9	9.5
< -9	-**	-**	-**	-**	-**	-**	10

b. Other hydrogeomorphic settings, including floodplains and channelled valley bottoms driven primarily by lateral inputs (e.g. from tributaries)

Change in quantity of **water inflows (Score** from Table 2.2)	**Alteration to floodpeaks** (Score from Table 2.3)						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	6	5	4	3	3	3.5	4
4-9	4.5	4	3	2	3	3	3
1-3.9 (Increase)	3	2	1	1	1	2	2.5
-0.9- +0.9 (Negligible)	2.5	1.5	0.5	0	0.5	1	1.5
-1- -1.9 (Decrease)	3.5	2.5	1.5	1	1.5	2	2.5
-2- -3.9	4.5	3.5	2.5	2	2.5	3	3.5
-4- -5.9	6	5	4	3.5	4	4.5	5
-6- -7.9	-**	-**	-**	5	5.5	6	6.5
-8- -9	-**	-**	-**	-**	-**	7.5	8
< -9	-**	-**	-**	-**	-**	-**	10

**These classes are unlikely, given that when there is a high level of reduction of quantity of inputs then there would be insufficient water to maintain unaltered or increased floodpeaks (i.e. a decrease in floodpeaks would be inevitable).

Magnitude of impact based on the joint consideration of hydro-geomorphic type, altered quantity of water inputs and the altered pattern of water inputs:	
Magnitude of impact adjusted to account for any change in seasonality:***	

***If seasonality has been changed moderately then increase the magnitude of impact score by 1 and if it has been changed greatly then increase the magnitude of impact score by 2.

Rationale for Table 2.5

The HGM setting of a wetland is considered to have an important influence over the wetland's vulnerability to reduced inflows and altered flow patterns. As highlighted in the introduction to Table 2.5, floodplains are particularly vulnerable to reduced floodpeaks. This is because floodplains are typically supplied with water during flood events. The negative consequences of an artificial reduction in flooding are well documented (e.g. Heeg and Breen, 1994; Heeg *et al*., 1989). Besides the primary effect of floodplain desiccation, there are also secondary effects such as inadequate flushing of floodplain pans leading to unnaturally-high salinity levels (Heeg *et al*., 1989). The linkages between altered flows and hydrological integrity on non-floodplain wetlands are less well understood than for floodplains. However, there is evidence to show that these systems, particularly hillslopes and valley bottoms without a channel are not dependent on flood events but are maintained by low flows and sub-surface water inputs, the decline of which will have potentially major consequences for the wetland. It is important to note, however, that a wetland of low vulnerability can still be highly impacted upon if the reduction in inflows is very high, which is shown in Step 2C.

For all HGM settings, it is assumed that although serious impacts may result from increased water inputs (e.g. from inter-basin transfers), reduced inputs are generally of greater consequence than increased inputs. Dramatic increases in inputs may completely alter the plant species composition of a wetland, but some characteristic wetland hydrological features will still remain. Conversely, extreme reductions in inputs may result in the complete loss of any wetland hydrological features.

Although a change in seasonality of inputs (e.g. perennial flow is altered to flow in the wet season only) is considered to have a potentially important impact on hydrological integrity, it is assumed to have a lesser impact than either a change in the quantity of inputs or a change in floodpeaks. However, there may be particular circumstances where seasonality is of greater prominence, and further adjustment can be made by the user to account for this, provided that written justification is provided.

Checking the impact score against your own understanding

The total impact score derived from Table 2.5 will fall into one of the six categories given in Table 2.6 (this is similar to Table 1.3 from Section 1 but Table 2.6 has a specific focus on hydrological integrity). Bearing in mind the difficulty in attempting to capture knowledge about complex systems with a tool such as *WET-Health*, it is essential at this point to reflect on the score you have calculated. Consider whether or not this score and its associated description match your understanding thus far and if the score reflects any direct observations of altered hydrology. If not, does this mean that the tool is missing key factors that you consider to be affecting the impact of catchment activities on the HGM unit's hydrological integrity? If you are able to provide a sound, documented justification, then an adjustment may be made.

For example, a factor not accounted for in the tool (i.e. in Table 2.2 and 2.3) is the proximity of the HGM unit to the flow-modifying activities in the HGM unit's catchment. You may choose to adjust the impact score down if, for example, a given area of hardened surfaces is located well away from the HGM unit, or adjust the score up if the hardened surface is located immediately adjacent to the wetland.

Table 2.6: Guideline for interpreting the magnitude of impact on the hydrological integrity of an HGM unit

Impact category	Description	Impact score range
None	No discernible modifications, or the modifications are of such a nature that they have no impact on the hydrological integrity.	0 – 0.9
Small	Although identifiable, the impact of the modifications on the hydrological integrity is small.	1 – 1.9
Moderate	The impact of the modifications on the hydrological integrity is clearly identifiable, but limited.	2 – 3.9
Large	The impact of the modifications is clearly detrimental to the hydrological integrity. Approximately 50% of the hydrological integrity has been lost.	4 – 5.9
Serious	Modifications clearly have an adverse effect on the hydrological integrity. 51% to 79% of the hydrological integrity has been lost.	6 – 7.9
Critical	Modifications are so great that the hydrological functioning has been drastically altered. 80% or more of the hydrological integrity has been lost.	8 – 10

In addition, changes to catchment inflows are scored in *WET-Health* based on two aspects, namely the reduction in quantity of inflows and the alterations to floodpeaks. Provided that written justification is provided, users may also score it based on additional aspects, e.g. reduced low flows, or an increase in the extent and frequency of zero flows.

STEP 3: Assess the degree to which natural water distribution and retention patterns within the HGM unit have been altered as a result of on-site activities

The focus of this section of the module is the evaluation of the degree to which human activities have affected the distribution and retention patterns of water within the wetland. This explicitly excludes the impacts of catchment changes on the wetland and therefore assumes a natural supply of water.

In South Africa, the formation of a wetland and the maintenance of wetland habitat are largely dependent on the input of water from the wetland's upstream catchment. Once the water has reached a wetland, the hydrology of the wetland is potentially also impacted upon by on-site (within wetland) factors. One of the key factors impacting on wetland hydrology is the way in which water is distributed and retained within the wetland system. A change in water distribution generally results in altered wetness regimes, which in turn affect the biophysical processes and the vegetation patterns. The retention of water within a wetland is a pre-requisite for the maintenance of wetland habitat and function. Some activities (e.g. canalisation) within the wetland may reduce the extent to which water is both distributed across the wetland surface and retained within the wetland. Other activities within wetlands may increase the retention times or result in deep flooding, which ultimately destroys wetland habitat.

For practical purposes, on-site impacts on water distribution and retention have been grouped into five components according to the primary mode of impact (Figure 2.4).

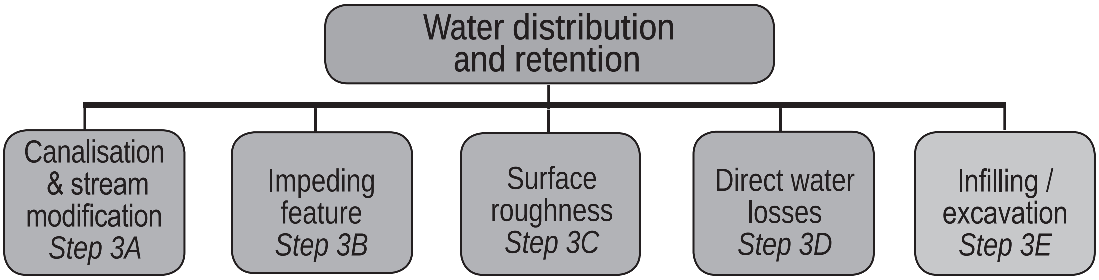


Figure 2.4: The components evaluated as part of the assessment of impacts on water distribution and retention in a wetland.

Step 3A: Assess the magnitude of impact of canalisation and stream modification

There are three components to this assessment: canalisation (including artificial drainage channels and erosion gullies); modifications to existing stream channels; and assessment of the combined magnitude of these factors.

Canalisation

Canalisation includes both the creation of artificial drains and the incision caused by erosion gullies, both of which have a potentially high impact on the distribution and retention of water within a wetland. Canalisation does not include the modification of existing natural channels (straightening, deepening and reduced roughness) as this is dealt with in the following section, 'stream channel modification'. However, if channel modification cannot be spatially separated from an artificial drainage network, then the analysis of channel modification should be included as part of the assessment of canalization, in which an analysis of channel modification for the area of overlap is omitted (Figure 2.5).

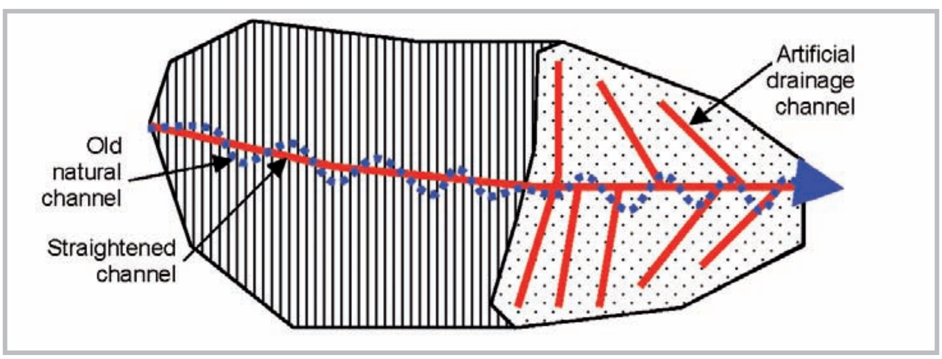


Figure 2.5: Representation of an HGM unit where the natural channel through the wetland (flowing from left to right in the diagram) has been straightened along its entire length and artificial drainage channels have been introduced in the lower (stippled) portion. Analysis of the impact of channel straightening is only conducted upstream above the main network of drains (in the hatched portion). Downstream where the altered natural channel is integrated in the system of drains (the stippled portion), the impact is included in the analysis of the impact of canalisation.

Drainage channels are common in wetlands that have been used for agricultural purposes. Erosion gullies are commonly associated with overgrazing and other poor land-management practices but they may also arise due to climate change or other natural factors. Although the underlying cause of erosion gullies may vary, gullies have a similar impact on water distribution and retention patterns. Erosion gullies and drainage channels tend to reduce diffuse surface-flow and retention of water in favour of more concentrated flow. The effect of canalization on sub-surface flow should also be considered because it is influenced strongly by the hydraulic conductivity of the wetland sediments. This refers to the ease with which water moves through the sediments. If the hydraulic conductivity is high (i.e. water moves easily through the soil) then the effect of the drains is potentially great. If it is very low, then even large drains will have little effect on sub-surface flow within the wetland.

To assess the impact of canalisation, begin by estimating the extent of the HGM unit affected by artificial canalisation, and express this as a proportion of the total area of the HGM unit (Table 2.7). If there is a fairly extensive network of drains, then encircle the drains on your map (the stippled area in Figure 2.5). If there is only a single drain or gully, determining its sphere of influence will be more difficult. Here it is recommended that a preliminary assessment of the extent of the affected area be reviewed and revised if necessary once the intensity of impact has been assessed (Table 2.7); this will provide an indication of the sphere of influence of the drain or gully.

Assess the magnitude of impact by completing Table 2.7. You will notice that the calculation of intensity in Table 2.7 is not the simple mean value for factors, but involves several steps to account for the relative importance of the different factors and how they interact. Once you have calculated the intensity of impact from canalization, reflect on the final score in the light of any direct evidence you can see of the effect of the canalization (e.g. water moving rapidly out of a drain or a decline in hydric vegetation) and, if necessary, adjust the score and document your justification for the adjustment. Remember, however, that vegetation may be very slow in responding to the effects of artificial drainage, particularly where it is naturally dominated by a single species with high cover (see Section 4).

Further comments to Table 2.7 opposite

For organic soils, if the soil consists of large (>5 mm) fragments of identifiable plant material (e.g. of leaves, wood fibres etc.) then soil is very fibrous. If it consists predominantly of small fragments (<5 mm) of plant material but these are still identifiable then soil is somewhat fibrous. If it consists of a mixture of identifiable plant fragments and amorphous material (which has the feel of humus or clay), but neither predominates, it is intermediate. If it consists of a mixture of fibrous and amorphous material, with amorphous material predominating then it is somewhat amorphous. If no fibres can be identified and the material feels like humus or clay, then soil is amorphous.

**In some circumstances, a wetland may be artificially drained by tilling the soil and piling it up onto raised beds rather than digging a drainage channel down below the soil surface. Both methods, however, serve to dry out the area. In the case of raised beds, the height of the bed above the low ground between the beds is taken as the “Depth of the drains”.

Table 2.7: Characteristics affecting the impact of canalization on the distribution and retention of water in the HGM unit

Factors	Low				High	Score
	0	2	5	8	10	
	Characteristics of the wetland					
1. Slope of the wetland[R]	<0.5%	0.5-0.9%	1-1.9%	2-3%	>3%	
2. (a) Texture of mineral soil, if present[F]*	Clay	Clay loam	Loam	Sandy loam	Sand/loamy sand	
2. (b) Degree of humification of organic soil, if present[F]*	Completely amorphous (like humus)	Somewhat amorphous	Intermediate	Somewhat fibrous	Very fibrous	
3. Natural level of wetness[F]	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%	Seasonal & permanent zone both present & collectively 30-60%	Seasonal & permanent zone both present & collectively >60% of total HGM unit area	
	Characteristics of the drains/gullies					
4. Depth of the drains/ gullies[F]**	<0.20 m	0.20-0.50 m	0.51-0.80 m	0.81-1.10 m	>1.10 m	
5. Density of drains (metres of drain per hectare of wetland)[R]	<25 m/ha	26-100 m/ha	101-200 m/ha	201-400 m/ha	>400 m/ha	
6. Location of drains/ gullies in relation to flows into and through the wetland[R]. Drains/ gullies are located such that flows are:	Very poorly intercepted	Moderately poorly intercepted	Intermediate	Moderately well intercepted	Very well intercepted	
7. Obstructions in the drains/ gullies[F]	Complete obstruction	High obstruction	Moderate obstruction	Low obstruction	No obstruction	
Calculate the mean score for factors 1, 2a or 2b, 3, 4 and 5						
Multiply the score for factor 6 by the vulnerability factor (Table 2.1)						
Mean score for above two scores						
Intensity of impact for canalization: divide the score for factor 7 by 10 and multiply this by the mean score derived in previous row						
Magnitude of impact of canalisation: extent of impact/100 × intensity of impact calculated in the row above						

*Soil texture in mineral soils or humification in organic soils are used as coarse surrogates for hydraulic conductivity, with 0=low conductivity, through to 10=high conductivity.

For mineral soil, take a teaspoon-size piece of soil and add sufficient water to work it in your hand to a state of maximum stickiness, breaking up any lumps that may be present. Now try to form the soil into a coherent ball. If this is impossible or very difficult (i.e. the ball collapses easily) then soil is sand or loamy sand. If the balls forms easily but collapses when pressed between the thumb and the fore-finger then soil is sandy loam. If the soil can be rolled into a thread but this cracks when bent then soil is loam. If the thread can be bent without cracking and it feels slightly gritty then soil is clay loam, but if it feels very smooth then soil is clay.

Rationale for Table 2.7

The logic of the above scoring system is as follows. Canalisation can act to desiccate an area of wetland by draining the wetland more quickly than would naturally occur i.e. by reducing the retention of water in a wetland (accounted for by factors 1 to 4), and by intercepting flow entering the wetland (accounted for by factor 5). The vulnerability factor is included because the impact of intercepted flow is likely to increase with an increased vulnerability factor. Both the draining and intercepting effects of canalisation may be negated to varying degrees by obstructions in the canals, such as rehabilitation plugs (accounted for by factor 6). At one extreme, a minimum score, there are no obstructions and at the other extreme, a maximum score, the obstructions are completely negating the effect of the canalisation.

For example, where the factors score as follows, factor 1: 2, factor 2: 5, factor 3: 5, factor 4: 2, factor 5: 8, factor 6: 5, factor 7: 5 and the vulnerability factor is 0.9, and the canalised area occupies 60% of the wetland,

- the mean score for factors 1 to 5 would be ((2+5+5+2+8)/5) = 4.4
- factor 6 (score of 5) multiplied by the vulnerability factor (0.9) is (5 X 0.9) = 4.5
- the mean score for the two above factors is ((4.4+4.5)/2) = 4.45
- to account for obstructions, the above mean score (4.45) is multiplied by the score of factor 7 divided by 10 and gives an impact intensity of (4.45 X (5/10)) = 2.23
- the magnitude of the impact is 60/100 X 2.23 = 1.34

Slope of the wetland

The steeper the slope of the wetland, the more efficiently the water drains from the wetland through the drains.

Texture of mineral soil and the degree of humification of organic soil

The greater the hydraulic conductivity of the wetland soils, the more effective the drains are in removing sub-surface water from the wetland. If the wetland has mineral soil then the hydraulic conductivity is approximated based on soil texture. If the HGM unit has peat (organic) soil, then the hydraulic conductivity is based on the degree of humification of the soil. The finer the texture of the soil, the smaller the pore spaces between the particles, and the slower the water moves through the soil. Similarly, the more humified the peat, the finer the particles of organic matter, and the slower the water moves through the soil.

Natural level of wetness

The greater the natural level of wetness of the wetland prior to any artificial drainage or gully erosion, the greater the potential for the area to be rendered much drier by artificial drains or erosion gullies. The natural level of wetness can generally be estimated by referring to a comparable unaltered wetland, but this may sometimes be impossible.

Depth of drains

The deeper the drains and gullies in the affected area, the greater is the potential of the drain and gully network to intercept sub-surface flow and to lead intercepted flow (sub-surface and surface) out of the wetland.

Drain density

The greater the density of drains, the more likely they are to effectively desiccate the section of wetland in which they occur.

Location of drains and gullies in relation to flows into and through the wetland

The interception of water in the wetland, by drains is affected by the location of the drains relative to the location of water inputs. To calculate the level of interception of water by the drains, it is necessary to examine how the flow naturally enters and passes through the wetland, and in particular where the flow is entering the wetland. In situations where water enters the wetland diffusely from the surrounding catchment, cutoff drains, constructed around the margins of the wetland, may successfully intercept a large proportion of flow that would have naturally entered the wetland. Note that it cannot be assumed that because a drain extends around the entire margin of the wetland that all of the inflow will be intercepted. In high rainfall events, the capacity of the channel may well be exceeded. In addition, some subsurface inflows may pass beneath the channel or some water may seep through the walls of the channel.

The lower the MAP:PET ratio, the more dependent is the wetland on inflows from its upstream catchment (as explained in Step 1B), and therefore the more vulnerable is the wetland to any interception of these flows.

It is important to note that a dam wall may work together with an artificial drainage channel to effectively intercept flow through an HGM unit. This applies particularly to situations where the dam wall spans the width of the unit and the outlet of the dam feeds directly into an artificial drainage channel.

Obstructions in drains and gullies

Obstructions (e.g. rehabilitation 'plugs') reduce the speed of through-flows and the ability of the drains to effectively function. Obstructions may override the effect of all other features of a drain, and substantially reduce their ability to re-direct water through the wetland.

Stream channel modification

Having considered canalization and drains (Table 2.7), we now consider the impact caused by the artificial modification of streams within wetlands. Here we assume that modifications of a natural channel are spatially separated from the areas dominated by artificial drains (see Figure 2.5).

The first step is to estimate the extent of the HGM unit affected by the modifications to the natural channel. This should be expressed as a percentage of the length of the HGM unit. In the example given in Figure 2.6, 6 km of a 17 km long HGM unit has been affected by channel straightening and upstream, a further 5 km has been affected by increased cross-sectional area as a result of channel incision. Therefore the total percentage of the HGM unit affected by stream channel modification is $(6 + 5)/17 \times 100 = 65\%$.

It can be difficult to establish if a change in channel cross-sectional area of a natural channel has occurred. Examine historical and recent aerial photographs for evidence of a change in channel width. Examine features on the ground for evidence of mounds of sediment piled up adjacent to the channel that may have been removed during channel widening or deepening. As elaborated upon in the geomorphology section, because straightening a channel increases the slope on the bed of the channel, there will generally be headward erosion resulting in a deepening of the channel immediately upstream of the straightened portion. A general assumption can be made that if the sediment is clay, then deepening will extend 5 km upstream along the valley floor and if sandy, deepening will extend 20 km upstream. This is elaborated on in the geomorphology section.

The next step is to determine the intensity of impact in the affected area by scoring the factors given in Table 2.8. Calculate the

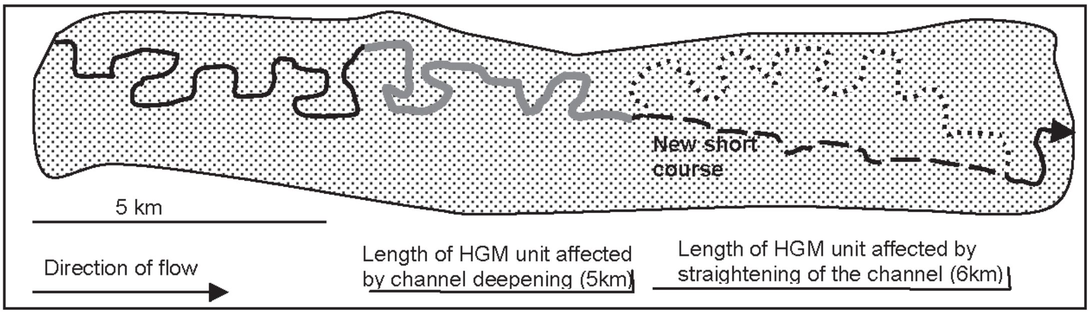


Figure 2.6: An example of an altered stream channel in a floodplain with clay sediment showing the effect of straightening of the channel

reduction in stream length by identifying the section of the river that has been straightened, and measuring its length along the old natural course. Next, measure the length of the straightened section, and calculate the difference between this and the old, natural section. Finally, express this difference as a percentage of the old natural course. In the example in Figure 2.6, the old course was 13 km long and following diversion the new course is 6 km long. Thus, the difference expressed as a percentage is (13 – 6)/13 x 100 = 53%. Altered roughness will be most appreciably altered by the removal of vegetation from the channel, which can best be assessed from aerial photography or by interviewing local landholders.

Table 2.8: Characteristics affecting the impact on the distribution and retention of water in the HGM unit **through the modification of a stream channel**

Extent of HGM unit affected by stream channel modification[R]	%

Characteristics of stream channel	Low				High	Score
	0	2	5	8	10	
1. Reduction in length of stream*[D]	<5%	5-25%	25-50%	50-75%	>75%	
2. % increase in cross sectional area of the stream[F]	<5%	5-25%	26-50%	51-75%	>75%	
3. Change in surface roughness in relation to the surface roughness of the channel in its natural state (see Table 2.9 for description of roughness classes)[F]	Roughness is increased or is unchanged[1]	Decrease in roughness is moderate (i.e. by one class)	Decrease in roughness is high (i.e. by two classes)	Decrease in roughness is very high (i.e. by three or more classes)		
Intensity of impact: use the maximum score of factors 1 to 3 x HGM weighting factor*						
Magnitude score of impact of stream channel modification: extent of impact/100 × intensity of impact						

*HGM weighting factor

The intensity of the hydrologic impact of modified stream channels is dependent on the extent to which the HGM unit is naturally dependent on bank overspill for maintaining the wetland's hydrology. To account for this, apply the following weighting factors:

- If entirely dependent on bank overspill as may be the case for some floodplains = 1
- If fed by a combination of inputs from the main channel and lateral inputs = 0.6
- If fed predominantly by lateral inputs = 0.3

Rationale for Table 2.8

Reduction in the length of stream (sinuosity, expressed as a percentage of the length of the valley)

For a given slope on the valley bottom, the greater the length of stream channel passing through the valley bottom, the gentler is the gradient on the bed of the stream channel. The more gentle the slope, the lower is the velocity of flow in the channel, which in turn results in increased retention of water in the channel. This in turn, increases the possibility of bank overspill as the capacity of the channel is exceeded. A less-straight channel (i.e. one which is more sinuous) has more bends and this contributes to the slowing down the flow of water in the channel (Ward and Trimble, 2004; see Figure 2.6).

Increased cross-sectional area

The greater the cross-sectional area of a stream, the greater is the flood volume that the channel will be able to accommodate before its capacity is exceeded and bank overspill occurs. There are several ways in which channel cross-sectional area can be increased. This includes deepening, widening and/or the creation of berms or dykes (Figure 2.7).

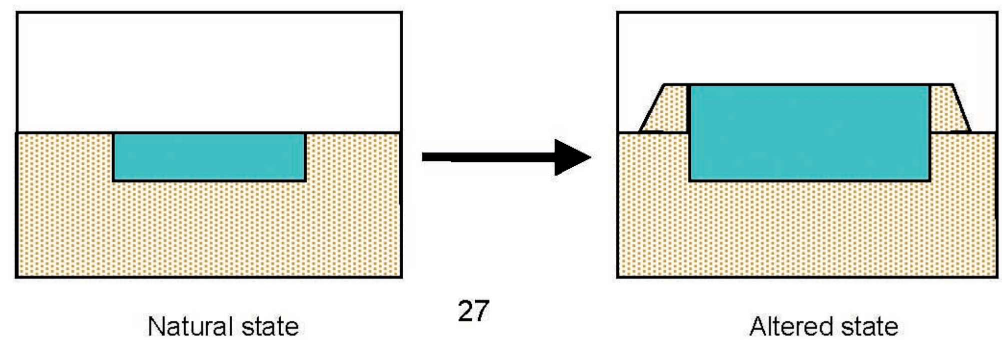


Figure 2.7: An example of increased stream cross sectional area resulting from the construction of berms that were built from material removed from the channel to widen the channel. In this case the cross-sectional area has been **doubled at bank full-flows.**

Roughness within a natural channel

The greater the degree of roughness (Table 2.9) within the channel, offered principally by vegetation growing in the channel, the slower is the flow rate in the channel. The greater the reduction in roughness, the greater is the impact on flow rate.

Table 2.9: Estimate of wetland surface roughness for a channel of the HGM unit

Class	Descriptor
Low	Smooth surface with little or no vegetation to offer resistance to water flow
Moderately low	Vegetation is present but short (i.e. < 500 mm) and not robust (e.g. rye grass)
Moderate	Vegetation offering slight resistance to water flow, generally consisting of short plants (i.e. < 1 m 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 with a dense understorey) and offering high resistance to water flow.

Note: Where roughness varies across the channel or HGM unit, take the average condition, and where roughness varies over time (e.g. areas which are regularly cut short) take the average condition during the wet season.

Now, integrate the scores for canalisation and stream channel modification as described in Table 2.10 to produce a combined magnitude-of-impact score.

Table 2.10: Calculation of the magnitude of impact of canalisation and modification of a stream channel on the distribution and retention of water in a wetland HGM unit

Overall magnitude-of-impact score: canalisation and stream channel modification	Score
Calculate the sum of scores from Tables 2.7 and 2.8.	

Step 3B: Assess the magnitude of impact of impeding features

Activities within the wetland can also slow down water flow and result in increased water- retention times within the wetland. This section examines the on-site impacts of dams, weirs and road crossings.

Dams and weirs are the most common impeding features causing unnatural water retention that occurs behind the structure. Poorly constructed road crossings can also result in back-flooding, in an upstream direction. Back-flooding may be caused by the embankments along the road or through an insufficient number of culverts to accommodate stream flow. In all of these scenarios, the extent of water retention is taken as the flooded area upstream of the impeding feature. This increased flooding leads to changes, above the obstruction, to the hydrological integrity of the wetland.

Impeding features may also result in the localized desiccation downstream of the obstruction. Here, factors such as water abstraction, and the relative importance of catchment inflows to lateral inputs below the structure should be considered. For example, road culverts may confine through-flow, thereby exposing some sections of the wetland to reduced flows. This typically occurs below the road on either side of the culvert, leading to the localized desiccation of the wetland.

Note: Trenches dug during road construction remove water from a wetland in the same way that artificial drains do and this often results in the localized desiccation of the wetland, particularly if the base level has been lowered. The desiccating effects of drains associated with road crossings are covered in Step 3A (canalization; Tables 2.7 and 2.8).

Within the HGM unit, identify the extent to which the area upstream and downstream of the impeding structure/s is affected. Express this as a proportion of the total area of the HGM unit (Table 2.11). Then, assess the magnitude of impact by completing the rest of Table 2.11.

Table 2.11: Typical changes in water distribution and retention patterns within an HGM unit as a result of impeding structures

1. **Upstream impact of flooding**		
Extent of HGM unit affected by flooding *upstream* of the impeding structure[R]	ha	%

Descriptor	Low				High	Score
	0	2	5	8	10	
1. Representation of different hydrological zones prior to flooding by the dam[R]	-	Seasonal and permanent zone both present and collectively >30%	Permanent and seasonal zones both present but collectively <30%	Seasonal zone present but permanent zone absent	Permanent and seasonal zones lacking (i.e. only the temporary zone present)	
Intensity of impact: score of (1) X 0.8*						
Magnitude of impact score: extent of impact /100 × intensity of impact						

2. **Downstream impact on quantity and timing of flows to downstream portion of the HGM unit**		
Extent of HGM unit affected *downstream* of the impeding structure[R]	ha	%

Descriptor	Low				High	Score
	0	2	5	8	10	
Extent to which dams or roads interrupt low flows to downstream areas[R]	No interruption (e.g. many culverts through a road embankment)	Slight interruption (e.g. a moderate number of culverts through a road embankment)	Intermediate interruption (e.g. earth dam with very high seepage or road embankment with no/ very limited culverts)	Moderately high interruption (e.g. earth dam with some seepage/ flow releases)	High interruption (e.g. a concrete dam with no seepage and no low flow releases)	
Level of abstraction from the dam/s[R]	Low	Moderately low	Intermediate	Moderately high	High	
Proportion of catchment flows intercepted[D]	Dam intercepts <20% of the affected area's catchment	Dam intercepts 21-40% of the affected area's catchment	Dam intercepts 41-60% of the affected area's catchment	Dam intercepts 61-80% of the affected area's catchment	Dam intercepts >80% of the affected area's catchment	
Collective volume of dam/s in relation to MAR of the affected area[D]	<20%	20-35%	36-60%	60-120%	>120%	
Intensity of impact: mean score of the THREE highest scoring factors x 0.8						
Magnitude-of-impact score: extent of impact /100 × intensity of impact						
* 0.8 is the weighting factor. This is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.						

3. Combined impact	
Combined impact: Magnitude of impact for upstream + Magnitude of impact for downstream	

Rationale for Table 2.11

The impact that the flooded area behind an impeding feature has on water distribution and retention patterns is related to the original wetness patterns in the flooded area. The alteration caused by flooding is therefore larger for previously non-flooded (e.g. temporary wetlands) areas than for permanently flooded wetlands.

An impeding structure within an HGM unit may impact on that portion of the HGM unit lying downstream of the structure through its effect on (1) reducing the quantity of flow to this portion and (2) through altering flow patterns to this portion. The rationale provided for Tables 2.2 and 2.3 also applies here.

Step 3C: Assess the magnitude of impact of altered surface roughness

The critical role played by surface roughness (as expressed in terms of Manning's Roughness Coefficient) in reducing the velocity of water movement and therefore in increasing the residence time of water in wetlands has been well-demonstrated (Ward and Trimble, 2004). The greater the surface roughness of a wetland, the greater is the frictional resistance to the flow of water and the more effective is the reduction of flow velocity through the wetland (Reppert *et al*., 1979; Adamus *et al*., 1987). The reduced flow-velocity, in turn, increases the retention of water in the wetland and potentially influences the distribution of water through the wetland.

Reduced flow velocity also reduces the capacity of the flow to erode sediment particles and is therefore of significance to the geomorphic integrity of wetlands. The surface roughness of a wetland is usually determined primarily by vegetation, but hummocks can also significantly contribute to roughness. Hummocks are small earth mounds covered in vegetation. They are usually about 20-50 cm in diameter and 50 cm high, and are commonly found in high altitude (>1500 m) wetlands in South Africa.

Be warned that there is a high degree of variation in roughness between seasons due to die-back of vegetation in winter and the occurrence of fires. In applying this tool, it is important to be aware of such variability. The wet season is the most important season to describe roughness because it is during the wet season that peak flows are likely to be highest and the effect of the roughness in reducing flow velocity is potentially the most significant.

Assessing the altered surface roughness of a wetland is a three step process. Within the HGM unit: a) assess current surface roughness; b) estimate historical surface roughness under natural conditions; and c) compare current roughness with historical, natural conditions.

a. Assess current surface roughness: based on observation of the wetland in its current state, and thinking particularly in terms of the resistance offered to water flow by the vegetation during the wet season, assign the wetland unit to one of the classes in Table 2.9.
b. Estimate historical surface roughness under natural conditions: obtain information about what the wetland looked like in its historical, natural state before it was impacted on by human intervention, and then using the average state, assign the wetland to one of the five classes in Table 2.9. If historical information on the wetland is not available it will be necessary to infer what the wetland is likely to have looked like, based on observation of a reference wetland (i.e. another wetland that is in a natural state and with the same hydro-geomorphic setting and a similar climate to the wetland being assessed).

c. Compare current roughness with historical natural conditions: within the HGM unit, identify the extent of the area that is affected by change in surface roughness and express it as a proportion of the total area of the HGM unit (Table 2.12). Then, assess the magnitude of impact by comparing the assigned class for the current state with that for the historical state (Table 2.12).

Table 2.12: Comparison of surface roughness of an HGM unit in its current state compared with its natural state

Extent of HGM unit affected by change in surface roughness[R]	ha	%

Descriptor	Low				High	Score
	0	2	5	8	10	
Change in surface roughness in relation to the surface roughness of the wetland in its natural state[F]	Roughness increased or is unchanged[1]	Decrease in roughness is low (i.e. by one class)	Decrease in roughness is moderate (i.e. by two classes)	Decrease in roughness is high (i.e. by three or more classes)		
Intensity of impact: score for the above row x 0.6*						
Magnitude of impact score: extent of impact /100 x intensity of impact						

[1]It is considered to be of greater consequence to water retention and distribution if the surface roughness of a wetland is decreased than if it is increased, therefore the focus of this assessment is primarily on a decrease in surface roughness.

* The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.

Step 3D: Assess the magnitude of impact of direct water loss

Direct water loss from a wetland may result in localized drying-effects and reduced water availability in downstream areas. Common direct water loss is associated with dams, alien plants, commercial afforestation, and sugarcane within the wetland boundary. Direct water abstraction from a wetland may take place from a dam, well or borehole in the wetland. The loss associated with evaporation from dams is dealt with in Step 3B (Table 2.11). Here, we consider the other land-use and -cover types.

Within the HGM unit, identify the extent of the area affected by each of alien plants, commercial afforestation (separate pines, wattle and eucalyptus), and sugarcane. Express this extent as a proportion of the total area of the HGM unit and assess the magnitude of impact by completing Table 2.13. Extent of wetland affected by the direct abstraction of water is most difficult to assess.

Table 2.13: Evaluating the effect of alien woody plants, commercial plantations and sugarcane growing in the HGM unit on water loss

Land-use activity descriptors	Low				High	Intensity of water loss*	Extent (%)	Mag-nitude **
	0	2	5	8	10			
1. Alien woody plant type[F]			shrubs	trees				
2. Plantation tree type[F]				Wattle & pine	Eucalyptus			
3. Sugarcane growth[F]		Poor growth	Good growth					
4. Direct water abstractions***		Low	Moderately low	Moderately high	High			
Overall magnitude of increased water loss: (sum of (1), (2), (3) and (4)) X 0.8****								

* Intensity= Score x Vulnerability factor (from Table 2.1)

** Magnitude=Intensity x Extent (%)/100

*** See "Rationale" below for guidance in assessing the extent and intensity of direct water abstractions from the wetland

**** The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and is therefore assigned a weighting factor of 1.

Note: When assessing the extent of water loss, remember that the impact may extend beyond the direct area in which the alien woody plants or plantations occur in the HGM unit to also include a downstream portion subject to reduced flows. If this is the case, adjust the score accordingly with documented justification.

Rationale for Table 2.13

It is assumed that alien woody plants use more water than native wetland plants, particularly when they have direct access to the water table within the wetland. High densities of alien woody plants can significantly reduce the amount of water within a wetland.

Timber plantations are recognized as reducing stream flow. With all other factors being equal, the greater the extent of timber plantations in a wetland, the greater is the reduction in quantity of water supplied downstream of the plantation. Different tree types have different rates of water consumption, and as a general rule, eucalyptus trees reduce water yield more so than do wattle and pine trees (Gush *et al*., 2002). Sugarcane is increasingly being recognized as reducing stream flow (Cheesman, 2004) when planted within wetlands.

The extent of the area affected by direct abstractions from the wetland depends on the location in the HGM unit. If it is located at the upstream end of the wetland, it will potentially affect a greater extent of the wetland than if it was located near the downstream end of the wetland (i.e. near the wetland outlet). Similarly, several abstraction points are likely to affect a greater extent than only one abstraction point. The intensity of abstraction relates to the volume of water abstracted, which may depend on the following.

- Duration of abstraction (e.g. abstraction throughout the year will have a greater impact than supplementary irrigation that occurs only occasionally during the year).
- Depth of abstraction. The deeper the abstraction, the greater will be the potential lowering of the water table

in the wetland, unless the wetland is maintained by a perched water table and the abstraction is from a deeper water table below.

- Means of abstraction. Abstraction by hand with buckets will potentially have the lowest intensity of impact, followed by hand- or treadle-pumps. Motorized pumps, especially larger pumps, will potentially have the highest intensity of impact.

Step 3E: Assess the magnitude of impact of recent deposition, infilling or excavation

The recent deposition of sediment includes sediment from sources within the HGM unit's upstream catchment (e.g. erosion gullies or poorly managed construction sites) that has been carried by water and deposited in the HGM unit. It also includes the direct deposition by humans of fill material in the HGM unit (e.g. in order to prepare a site for construction or for a sports field). Excavation refers to the direct removal of sediment by humans from the HGM unit (usually with heavy machinery). Excavation is commonly associated with mining and sand winning.

Two key questions should be addressed for both deposition and excavation.

1. To what extent is the upper soil layer (50 cm) rendered more free-draining than it was in its natural state? (i.e. how is the vertical movement of water through the surface layer of the soil affected?). In the case of deposition, a new surface layer of soil is created through the addition of material on top of the existing soil-surface layer. In the case of excavation the soil is removed with some of the original soil potentially being replaced. In both cases the new material is likely to have different drainage properties from the original material.
2. To what extent has the horizontal movement of water through the HGM unit been altered? This alteration generally takes place through alteration to the morphometry (the shape of the ground surface) of the HGM, which in turn affects flow patterns across the wetland.

The effects of deposition or excavation on the vertical and horizontal movements of water are assessed separately and then integrated (Table 2.14).

Table 2.14: Magnitude of impact of recent deposition, infilling or excavation

Extent of HGM unit affected by deposition/infilling or excavation[R]	ha	%

Descriptor	Low High					Score
	0	2	5	8	10	
Effect on vertical drainage properties of the uppermost soil layer[F]	No effect	Rendered somewhat free draining	Intermediate	Rendered free draining	Rendered very well drained*	
Effect on the horizontal movement of water[F]	No effect	Moderate modification	Large modification	Serious modification		
Intensity of impact: use the highest score for the above two factors						
Magnitude of impact score: extent of impact (%) /100 x intensity of impact x 1**						

* i.e. drainage is so free that the area no longer has any wetland characteristics

** The weighting factor is given relative to the impact of drainage channels, which are considered to have the greatest potential impact on hydrological integrity out of all the on-site factors considered, and drainage channels are therefore assigned a weighting factor of 1.

08 WET - Health - Final for Prin63 63 24/07/2009 10:35:33 AM

Rationale for Table 2.14

Effects on the vertical movement of water

Wetlands are generally characterized by naturally-impeded vertical drainage, resulting in the prolonged saturation of the soil at, or very close to (within 50 cm), the soil surface. A key factor affecting the intensity of impact of excavation or deposition on the vertical movement of water relates to the extent to which the upper soil-layer is rendered more free-draining. In the case of infilling, the deeper the fill and the coarser the fill material, the greater is the impact. If, for example, 1 m of very free-draining fill material is added, with the saturated zone remaining in its former position, the surface of the soil is raised by 1 m relative to the saturated zone, and the impact intensity is very high. In the case of excavation, the most vulnerable situations are where a poorly-drained soil layer lies on top of a more freely-drained layer, resulting in a 'perched' zone-of-saturation, which would be lost if the upper soil layers were removed.

Effects on the horizontal movement of water

Assuming that the depth of the saturated-zone material is not unduly affected by deposition or excavation, water distribution and retention within the HGM unit may nonetheless be strongly affected by the altered morphometry of the wetland surface, influencing flow patterns through the wetland. Excavation or deposition may, for example, cause flow to be much more concentrated than it would be naturally.

STEP 3F: Determine the combined magnitude of the impact of on-site activities

Tables 2.10 to 2.14 provide an estimate of the magnitude of on-site activities on natural distribution and retention patterns within the HGM unit. These must be added together to get a combined magnitude score for the HGM unit, as shown in Table 2.15.

Table 2.15: Overall magnitude of impacts of on-site activities on water distribution and retention patterns n the HGM unit

Activity	Magnitude of impact
1. Calculated magnitude of impact of canalization and stream channel modification from Table 2.10	
2. Calculated magnitude of impact of impeding features from Table 2.11	
3. Calculated magnitude of impact of altered surface roughness from Table 2.12	
4. Calculated magnitude of impact of aliens, timber and/or sugarcane in the wetland from Table 2.13	
5. Calculated magnitude of impact of recent deposition/excavation from Table 2.14	
Total score of magnitude of on-site activities in the HGM unit (sum of the above scores)*	

* If score is > 10, then magnitude of impact = 10

Making sense of the combined magnitude-of-impact score of the assessment

The total-impact score derived here falls into one of six categories given in Table 2.6. This is a useful opportunity to compare the total magnitude-of-impact score for on-site activities (Table 2.15) with the description of impact categories provided in Table 2.6. Does your impression of the score for the impact of on-site activities you have calculated match the impact category and description provided in Table 2.6? If not, consider where the tool is underestimating or overestimating impact, and consider modifying your score. Document any justification you have for modifying your score.

STEP 4: Determine the Present Hydrological State of the HGM unit through integrating the assessments from Steps 2 and 3

This final assessment is based on the joint consideration in Table 2.16 of the impacts on catchment inputs (assessed in Step 2) and the impacts of on-site activities on water distribution and retention patterns in the wetland (assessed in Step 3). Refer back to the score in Table 2.5 for the magnitude of impacts of catchment activities. Similarly, refer to Table 2.15 for the magnitude of impacts of on-site activities. The intersection of the respective column and row in Table 2.16 gives a score for the overall magnitude-of-impact for the HGM unit being considered. For example, if the score for the catchment activities altering water inputs is 3 and the score for the on-site activities altering water distribution and retention patterns is 5, then according to Table 2.16, the score for the overall magnitude-of-impact is 6.5.

All that remains to be done is to establish into which health category the HGM unit falls based on its impact score (Table 2.17). If, for example, the overall magnitude-of-impact score was 6.5 then the health category would be E.

Table 2.16: Derivation of overall magnitude-of-impact scores through combining the scores obtained from the catchment and within-wetland assessments. The colour codes correspond to the impact categories given in Table 2.17.

			Water Inputs (Step 2 - Table 2.5)					
			None	Small	Moderate	Large	Serious	Critical
			0-0.9	1-1.9	2-3.9	4-5.9	6-7.9	8-10
Water distribution & retention patterns (Step 3, Table2.15)	None	0-0.9	0	1	3	5	6.5	8.5
	Small	1-1.9	1	1.5	3.5	6	7	9
	Moderate	2-3.9	3	3.5	4	6.5	7.5	9
	Large	4-5.9	5	6	6.5	7	8	9.5
	Serious	6-7.9	6.5	7	7.5	8	9	10
	Critical	8-10	8.5	9	9	9.5	10	10

08 WET - Health - Final for Prin65 65 24/07/2009 10:35:33 AM

Table 2.17: Health categories used by *WET-Health* for describing the integrity of wetlands

Impact score range	Description	Health category
0-0.9	Unmodified, natural.	A
1-1.9	Largely natural with few modifications. A slight change in ecosystem processes is discernable and a small loss of natural habitats and biota may have taken place.	B
2-3.9	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	C
4-5.9	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	D
6-7.9	The change in ecosystem processes and the loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	E
8-10	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	F

STEP 5: Determine the overall Present Hydrological State for the wetland by integrating the scores of individual HGM units in the wetland

Now, calculate the overall magnitude-of-impact for the wetland as a whole, based on the area weighted average of the HGM units in the wetland. The proportional area of the HGM unit within the entire wetland (expressed as a percentage) is multiplied by the overall magnitude of impact score for that HGM unit (Table 2.18). An illustrative example is provided in Figure 2.8 and Table 2.19.

Table 2.18: Derivation of the overall Present Hydrological State score for the wetland being considered.

HGM unit number	Area (ha)	HGM unit extent (%)	Overall impact score for HGM unit	Area weighted impact score*	Present Hydrological State category
1					
2					
3					
4					
5					
Total		100	Overall area weighted Impact score**		

*Area weighted impact score = HGM extent /100 x impact score

**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

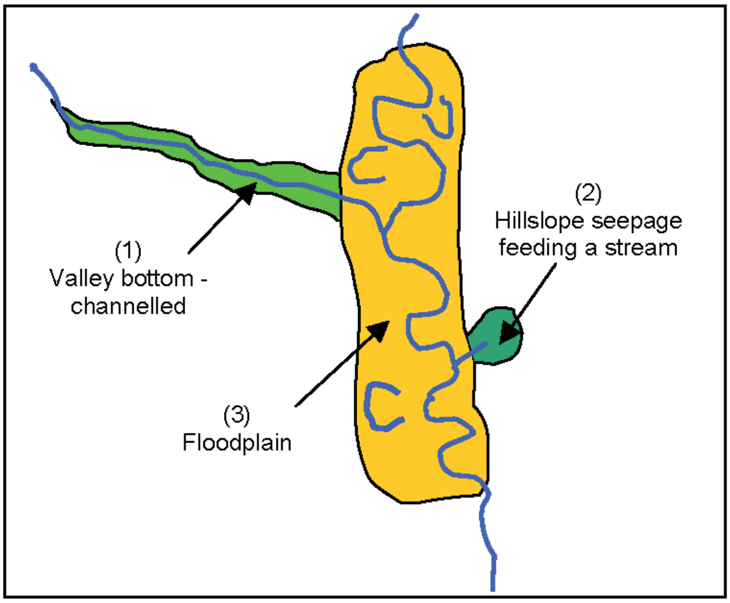


Figure 2.8: Wetland (depicted in Figure 1.3a) for which the overall impact scores have been calculated for each of the three HGM units, as shown in Table 2.19.

Establish into which health category the wetland falls based on its impact score by referring to Table 2.17. For the example in Table 2.19, this is a Health Category C given the overall area weighted impact score of 3.8.

Table 2.19: Illustrative example of the calculation of the Present Hydrologic State a score for the example-wetland presented in Figure 2.8.

HGM unit number	Area (ha)	HGM unit extent (%)	Overall impact score for HGM unit	Area weighted impact score*	Present Hydrological Statecategory
1	4	20	4	0.8	
2	2	10	2	0.2	
3	14	70	4	2.8	
Total	20	100	Overall weighted mean impact score**	3.8	C

*Area weighted impact score = HGM extent /100 x impact score

**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

STEP 6: Assess the anticipated Trajectory of Change of wetland hydrology

Here, the following question must be addressed: Is the current hydrological health of the HGM unit likely to change in the future? Four potential situations for the assessment are outlined in Table 2.20.

As is the case with the current situation, future threats to the health of the HGM unit may arise from upstream in the catchment of the HGM unit or from within the HGM unit itself.

Table 2.20. Trajectory class, change scores and symbols used to evaluate Trajectory of Change to wetland hydrology

Trajectory Class	Description	Change Score	Class Range	Symbol
Improve	Hydrological condition is likely to improve over the over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Hydrological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Slight deterioration	Hydrological condition is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Substantial deterioration	Substantial deterioration of hydrological condition is expected over the next 5 years	-2	-1.1 to -2.0	↓↓

It is important to note whether an increase in the extent and intensity of any of the factors given in Table 2.2 is anticipated within the catchment. Some typical examples may include: an anticipated increase in the extent of alien plants, increased irrigation volumes or increased area of plantations of gum or pine trees.

As highlighted in Section 1, the three components of wetland health, namely hydrology, geomorphology and vegetation are closely linked. Thus, when considering future changes likely to take place that affect one particular component, in this case hydrology, it is important to consider the potential changes in the other two components; and whether these may affect the hydrological health of the wetland. The most common geomorphological change likely to affect future hydrological health is advancing gully erosion (see Section 3 to see if this is predicted), which has the potential to dry out the area into which it advances. The most common change in vegetation integrity likely to result in a change in hydrological integrity is the invasion of alien woody plants or trees, which would lead to an increase in the direct water loss from the wetland.

Once the various threats to the hydrological health of the wetland have been considered, a change-score (column 3 of Table 2.20) is assigned to each HGM unit and an area weighted threat-score is calculated to represent the overall threat to the wetland's hydrological health (Table 2.21, column 5). This threat-score is used to assign the wetland to one of four classes, based on column 4 and 5 of Table 2.20.

Table 2.21: Derivation of the overall likely Trajectory of Change to the hydrology for the wetland being considered.

HGM Unit	Description of sources of change	HGM unit extent (%)	Change Score*	Area-weighted score**
1				
2				
3				
4				
5				
Overall weighted change score***:				

* Refer to Table 2.20 for a description of change scores
**Area weighted change score = HGM extent /100 x change score
***Overall area weighted change score = sum of individual area weighted scores for each HGM unit

For example, the wetland shown in Table 2.19 consists of three HGM units that occupy 20% 10% and 70% respectively of the area of the wetland. Assuming that the first HGM is remaining stable, the second is rapidly deteriorating and the third is slowly deteriorating, the weighted average would be (0 x 20/100) + (-2 x 10/100) + (-1 x 70/100) = -0.9. According to columns 4 and 5 of Table 20 the hydrological health of the wetland would be assigned a symbol of (↓) as it falls in the range of -0.3 to -1.0.

STEP 7: Describe the overall Hydrological Health based on the Present Hydrological State and Trajectory of Change

Now that both the Present Hydrological State of the wetland and anticipated Trajectory of Change have been assessed these can now be used together to describe the overall hydrological health of the wetland. This is done by documenting the Present Hydrological State of the wetland, followed by the change symbol.

In the example given in Table 2.19, where the wetland scores a C for its Present Hydrological State, if the hydrological state continues to decline as a result of the slowly-advancing gully erosion which is drying out a progressively larger proportion of the HGM unit, then the health of the HGM unit is represented as C (↓). However, if the situation is stable (i.e., there is no advancing erosion gully) then it is represented as C (→). Note that a C (↓) does not represent a wetland half way between a C and a D class. Indeed, if no remedial action is taken, the wetland could deteriorate all the way to an E or F class.

SECTION 3: GEOMORPHOLOGY MODULE

Introduction

Users of this tool should be familiar with the document "Wetland origin and evolution" (Ellery *et al*., 2009) published as part of the "Wetland Rehabilitation and Management Series". Factors that lead to wetland formation and degradation are described. The tool recognizes that wetlands are subject to both inputs and outputs of sediment such that under natural reference conditions, inputs that occur are generally stored in the wetland over short (decades to centuries) to long (thousands to tens of thousands of years) time periods. Input is generally equal to or greater than output. Wetlands are thus generally characterised by the temporary storage or net accumulation of sediment. An increase in sediment output from a wetland threatens a wetland's natural structure and functioning, particularly as this invariably takes place through incision by gullying. We would describe erosion as one of the most serious problems facing South African wetlands, which makes this module particularly important.

The intention here is to focus on geomorphic health alone, not on the hydrological or ecological consequences of unnatural rates of deposition or erosion. Nevertheless, it needs to be recognized that there are strong feedback effects between geomorphology, hydrology and vegetation, with geomorphic processes controlling and shaping wetland structure and dynamics, which strongly affect water distribution and therefore ecosystem structure and function.

Two types of sediment that accumulate within and/or leave a wetland are of interest to users of this module:
1. *clastic* sediment (mineral particles);
2. *organic* sediment (organic material).

The accumulation or loss of these materials within a wetland fundamentally affects the three-dimensional structure of the wetland surface, particularly its longitudinal and lateral slopes. Thus, geomorphic processes fundamentally control how water flows through the wetland.

The deposition or erosion of sediments also creates variation in substratum characteristics and a disturbance regime that in their own right affect the biota and biotic heterogeneity. In this module it is necessary to distinguish between natural channels and erosion gullies, which is generally easy to do. However, there are cases where natural channels can be incorrectly interpreted as erosional gullies or where unnatural erosion of a natural watercourse is taking place. The challenge is to recognize these alternative situations so that a sensible evaluation can be made with respect to wise management and/or rehabilitation interventions.

Natural channels within wetlands and/or floodplains are typically features that exist for long periods and can be recognized from the fact that they are characterized by a combination of deposition and erosion in approximately equal quantities or with deposition being greater on average than erosion. These processes lead to the formation of depositional features:

- Along the length of the bed of the watercourse as sand bars that are generally visible at low flows,
- Locally on the convex side or bank of the channel as point bars or scroll bars respectively, in which case they will be visible at low and normal flows respectively, or,
- On the banks of the entire length of the channel such that the banks become elevated relative to the surrounding wetland or floodplain surface, including levees or alluvial ridges.

In contrast to natural channels that typically have erosion and deposition taking place, **gullies tend to be primarily erosional features**. Therefore, they are dominated by bank slumping and headcut and side wall collapse that is not accompanied by sediment deposition on the same or a similar scale.

From the above brief description of sediments and their erosion and deposition, it is clear that an understanding of wetland geomorphic processes and dynamics is important for assessing health. In this module we focus on clastic and organic sediment as these are generally most prevalent in wetland systems. Given the lack of readily available literature on wetland geomorphology, the module provides more theoretical material than other modules (and than we would have liked to include in a technical manual of this nature).

This wetland-based geomorphological module focuses on wetlands that are connected to the drainage network in some way, and it therefore excludes endorheic pans. While such pans are not uncommon in South Africa, they are seldom subjected to geomorphological impacts. Therefore, they are not dealt with explicitly in this module.

The present module is divided into seven separate steps (Figure 3.1):

- Step 1 requires that the wetland be subdivided into HGM units.
- For each HGM unit Present Geomorphic State is assessed by evaluating:
  - activities and impacts which are known to commonly influence geomorphic processes such as sediment erosion and/or deposition (diagnostic analysis, Step 2)
  - direct on-site impacts which provide clear clues of changes to geomorphic processes (indicators-based analysis, Step 3).

  The extent of such activities and impacts, and their intensity, are combined to give a magnitude of impact score and these are combined in a structured way for each HGM unit (Step 4).
- Step 5 requires that the overall Present Geomorphic State of the wetland as a whole be determined by combining scores on an area-weighted basis.
- The vulnerability and Trajectory of Change due to erosion are evaluated in Step 6.
- Overall Geomorphic Health is represented based on a combination of Present Geomorphic State and the likely Trajectory of Change (Step 7).

The above-mentioned assessment may be done for many reasons, including for assessing Present Geomorphic State and anticipated Trajectory of Change, for the identification or prioritisation of wetlands for conservation or rehabilitation, or for an assessment of mitigation in the event of wetland degradation or destruction through development. The diagnostic component of the assessment should provide insight into those factors that reduce geomorphic integrity such that management might focus on the likely causes of past or future degradation.

Erosional headcuts are one of the most important threats to the Present Geomorphic State of South African wetlands, and have particular relevance to wetland management and structural rehabilitation. It is for this reason they have been included in this analysis, and may provide insights into appropriate interventions for rehabilitation.

Step 1: Map and determine the extent of each HGM unit

↓

Step 2: Conduct individual assessments based on diagnostic features

- Step 2A: Impact of dams upstream of or within floodplains
- Step 2B: Impact of channel straightening
- Step 2C: Impact of artificial wetland infilling
- Step 2D: Impact of changes in runoff

↓

Step 3: Conduct individual assessments based on indicators

- Step 3A: Impact of erosion or deposition
- Step 3B: Impact of loss of organic sediment

↓

Step 4: Determine the Present Geomorphic State of each HGM unit by combining diagnostic (Step 2) and indicator-based (Step 3) analyses

↓

Step 5: Determine overall Present Geomorphic State for the wetland by integrating scores of individual HGM units

↓

Step 6: Assess vulnerability and Trajectory of Change due to erosion

- Step 6A: Assess vulnerability to erosion of each HGM unit
- Step 6B: Describe the increased extent of gullies in relation to any external controls
- Step 6C: Assess the likely Trajectory of Change of Geomorphic State

↓

Step 7: Describe overall Geomorphic Health of the wetland based on the Present Geomorphic State and the Trajectory of Change

Figure 3.1: An outline of the steps involved in the geomorphology module

STEP 1: Map and determine extent of each HGM unit

As highlighted in Section 1, each HGM unit in the wetland is assessed separately, based on the assumption that different HGM types are likely to be affected in different ways by hydrological impacts. See Section 1.3.3 for a detailed description of the HGM types and how to identify them.

Not all HGM types are assessed for all activities or indicators (Table 3.1). The first 4 activities increase the likelihood of erosion and are included for **diagnostic** purposes to help identify likely causes of geomorphic changes. These are addressed in Step 2. The last 3 features represent visible indicators of negative impacts on **geomorphic** integrity. These are addressed in Step 3.

Floodplains need to be assessed for dams upstream of or within the wetland, while floodplain and channelled valley-bottom wetlands should be assessed for channel straightening and infilling of any kind, such as in the construction of bridges across wetlands or for ‘reclamation’ of wetlands for developments (buildings, parking areas, sports fields etc.). Changes in runoff characteristics may impact erosional processes in all non-floodplain HGM types. Non-floodplain systems also need to be assessed for the presence of erosional features, depositional features or the loss of organic sediment.

Table 3.1: Guideline for assessing the impacts of activities according to HGM type

HGM type to assess	Activity/Indicator
Diagnostic component	
Floodplain	Dams upstream of or within floodplains
Floodplain, channelled valley bottom	Stream shortening or straightening
Floodplain, channelled valley bottom	Infilling that leads to narrowing of the wetland
All non-floodplain HGMs	Changes in runoff characteristics
Indicator-based component	
All non-floodplain HGMs	Erosional features
All non-floodplain HGMs*	Depositional features
All non-floodplain HGMs	Loss of organic sediment

*Consider floodplains if there are large alluvial fans impinging laterally onto them

STEP 2: Conduct individual assessments based on diagnostic features

The focus of the diagnostic component of each assessment is to identify activities that impact on geomorphological processes since the impact of these activities may be very difficult to measure – such as erosion in an existing channel in a floodplain or valley bottom wetland, which will only be detected with careful measurement and comparison of channel cross-section and longitudinal slope. It also helps identify factors that may be leading to loss of health, which is not easily done if only the indicator based assessment is done.

Recall, Table 3.1 should guide which of the steps should be completed in the diagnostic component – based on HGM unit-type. If it is a floodplain, Steps 2A-C are followed. If it is a channelled valley bottom, Steps 2B -D are completed, and if it is a non-floodplain HGM unit then Step 2D is completed.

Step 2A: Impacts of dams upstream of and/or on floodplains

If the HGM unit is a floodplain, this step should be completed (see Table 3.1). Floodplain wetlands have internal mechanisms by which sediment is dealt with, since these systems are dominated by fluvial processes and are characterised by the accumulation of some sediment. Therefore, these systems are generally reasonably resilient (low vulnerability) to changes in sediment inputs. This is true even if there are visible signs of localized erosion or deposition within the floodplain, since these are generally simply a consequence of localised adjustments to variation in slope. However, erosion may be occurring that is harmful and a distinction needs to be made between erosion that is part of the natural dynamic and erosion that is detrimental. The main threat to floodplains is damming of streams upstream of or located within the floodplain. This is due to the ability of dams to trap sediment and release water that is effectively starved of sediment. This reduction in sediment load deprives floodplains of sediment required for floodplain construction and commonly leads to floodplain degradation.

Dams in the floodplain catchment

The extent of impact of dams upstream of floodplains is assumed to be 100% since the entire floodplain will be starved of sediment (Table 3.2). The intensity of impact of impoundments above the floodplain is dependent upon the size of the impoundment in relation to the size of the stream and the nature of sediment supply, as well as its distance upstream of the floodplain and its position relative to the main trunk stream leading into the floodplain (Table 3.2). Therefore, our assessment of the magnitude of impacts of impoundments on floodplains initially involves consideration of sediment and impoundment characteristics. Here we focus on those streams that connect to the floodplain stream, which usually involves a single trunk stream. Where there are inputs of sediment from tributary streams these need to be borne in mind in the determination of extent and intensity of impact.

Base the determination of the sediment load in the stream by looking at how clear the water is. Often the name of a stream in the catchment is useful (e.g. 'Modder', 'Vaal' (suspended load) and 'Sand', 'Klip' (bedload)). The nature of the catchment is also useful, in that sandstone or quartzite catchments, or even unconsolidated sediments on the coastal plain will produce bedload sediments, whereas those on igneous rocks or shale and mudstone will produce fine sediment that is transported in suspension.

Table 3.2: Extent, intensity and magnitude of impacts of impoundments in the catchment

Extent of impact of dams situated above floodplains						
Extent: For dams upstream of floodplains extent is assumed to be 100%. If a dam is also situated on the floodplain, extent of impact for the dam above the floodplain is determined as the length of the floodplain above the dam / total floodplain length, expressed as a percentage						%
Intensity of impact score: size of dams and nature of sediment transported						
Determine the size of dam/s on the stream[D] and the nature of sediment load being transported[F]						
	Small (<10 % MAR)	Modest (10-20% MAR)	Medium (20-40% MAR)	Large (40-80% MAR)	Very large (>80% MAR)	Score
Suspended load dominated	1	2	3	4	5	
Mixed load	2	4	6	8	10	
Bedload dominated	4	6	8	10	10	
Intensity of impact score: location of dams in the catchment						
Score	0	2	5	8	10	Score
Location of dam/s[D]	Dams on minor tributary stream or on trunk stream far upstream of floodplain	Intermediate between descriptions for scores 0 and 5	Dams on major tributary or on trunk stream a moderate distance upstream of floodplain	Intermediate between descriptions for scores 5 and 10	Dam on trunk stream immediately above floodplain	
Overall intensity of impact score for dams situated above floodplains: mean of above 2 scores						
Magnitude of impact score for dams situated above floodplains: (extent of impact score/ 100) x overall intensity of impact score						

The symbols [D, R] and [F] refer to where data is best acquired or summarised as follows:
[D] = Data should be obtained in the office through desktop investigation prior to the field assessment
[R] = Data may be available through desktop investigation but are likely to be revised/refined in the field
[F] = Data should be obtained in the field

Dams on the floodplain

For dams within floodplains the extent of impact depends upon the proportion of the floodplain length that is flooded plus the length of floodplain below the dam (Table 3.3). The intensity of impact of impoundments along the floodplain stream within a floodplain is dependent upon the size of the dam and the arrangement of spillways from the dam in relation to the floodplain stream. The spillway may be designed to deal with base flows and peak flows in the same way – either into the course of the dammed floodplain stream below the dam or into the backswamp away from the floodplain stream below the dam. Alternatively, base flows and peak flows may be diverted into separate regions of the wetland such that either

- base flows are diverted into the course of the floodplain stream below the dam and peak flows are diverted into the backswamp away from the floodplain stream below the dam, or
- base flows are diverted into the backswamp away from the floodplain stream below the dam and peak flows are led into the course of the floodplain stream below the dam (Table 3.3).

Table 3.3: Extent, intensity and magnitude of impact of impoundments within the floodplain

Extent of impact of dams situated within floodplains						
Extent: The percentage of the floodplain valley length flooded by the dam plus that occurring below the dam wall[D]						%
Intensity of impact of dams situated within floodplains						
SCORE	2	4	6	8	10	Score
Size of dam[D]	Small (<10 % MAR)	Modest (10-20% MAR)	Medium (20-40% MAR)	Large (40-80% MAR)	Very large (>80% MAR)	
Configuration of spillway/s[D]			Baseflows to floodplain stream: peak flows to backswamp	Baseflows and peak flows to floodplain stream OR baseflows to backswamp and peak flows to floodplain stream	Baseflows and peak flows to backswamp	
Overall intensity of impact score for dams situated within floodplains: mean of above 2 scores						
Magnitude of impact score for dams situated within floodplains: (extent of impact score / 100) x overall intensity of impact score						

Combining impacts of dams in the catchment and on the floodplain

The impacts of dams in the catchment and in the wetland have been determined separately. These assessments need to be combined to produce an overall score that assesses the magnitude of impact of dams on floodplain systems. If a dam is only present in the catchment or on the floodplain, the magnitude of impact score for this activity describes the impact of dams on the floodplain Present Geomorphic State. If dams are present in the catchment and the wetland, the scores for these need to be combined (Table 3.4). Use the score for dams in the floodplain (Table 3.3) plus the score for dams in the catchment (Table 3.2).

Table 3.4: Combining the magnitude of impact scores of impoundments in the catchment and on the floodplain.

Magnitude of impact score for dams upstream of and on the floodplain	
Magnitude of impact score for dam/s located in the catchment (Table 3.2)	
Magnitude of impact score for dam/s located within the floodplain (Table 3.3)	
Overall magnitude of impact for floodplain wetlands with dams upstream of and on the floodplain = sum of above two rows	

Rationale for Tables 3.2 to 3.4

The impacts of dams on floodplain systems are a result of the dams trapping sediments that are necessary for floodplain functioning such as building of alluvial ridges, channel aggradation, and maintaining natural dynamics that make foodplains what they are. The extent of impact of dams upstream of floodplains is downstream of the dam, while the intensity of impacts depends on the nature of sediment being transported and on the size of the impoundment relative to the size of the stream. Large dams result in most of the incoming sediment settling out of the water column such that when the water leaves the dam it is starved of sediment and erodes the stream bed, even if the sediment is predominantly fine (clay and silt) and transported in suspension (suspended load). However, if the stream is dominated by bedload sediment (rolled or bounced along the channel bed), then even small dams will trap most sediment, with similar effects.

The impact of dams upstream of floodplains also depends on their position in the catchment since this will affect the amount of sediment normally reaching the floodplain, which is partly mitigated by the presence of tributary streams or erosion of the stream bed between the dam and the floodplain.

For dams within floodplains size is important as it affects the extent to which sediment is trapped (we assume here that within floodplains sediment will tend to be either mainly suspended load or a mixture of suspended load and bedload). The manner in which water is released from the dam back onto the floodplain also affects its intensity of impact. Forcing base and peak flows into a backswamp is equivalent to a forced channel avulsion with a high intensity of impact, while leading base flows into the channel and peak flows onto the floodplain most closely resembles the natural condition with lowest intensity of impact of all options. The alternatives to these ways of dealing with overspill from the dam have intermediate impacts.

Combining scores for dams above and on floodplains recognizes that impacts for dams upstream of the floodplain will only extend as far downstream as a dam within the floodplain, below which the dam within the floodplain will have further impacts downstream of the point of flooding.

Step 2B: Impacts of channel straightening

If the HGM unit is a floodplain or a channelled valley bottom, this step should be completed (see Table 3.1). Many South African floodplain and valley-bottom wetlands with channels have had their channels straightened for purposes of drainage, flow diversion and/or flow improvement. Channel straightening potentially has an appreciable impact on Present Geomorphic State in that it steepens channel slope and thus promotes headward erosion (erosion that proceeds upstream along the channel), lowering the elevation of the channel bed. This erosion will extend upstream beyond the upper limit of straightening and the impacts thus extend far beyond the location of the excavation. However, the effect of headward erosion will be attenuated gradually as it proceeds such that over a sufficient distance upstream of the modification its effect will be gradually diminished and ultimately lost. The distance upstream over which this happens will depend upon local circumstances, including the magnitude of the initial straightening activity and the nature of the substratum. Calculations are based on the linear measurement of the length of the activity or wetland distance.

Extent is calculated as the proportion of the wetland length over which stream straightening took place plus a distance upstream of the head of the excavation based on the nature of the channel bed (Table 3.5). For the purposes of this assessment we assume that the impact of headward erosion will be attenuated over a distance of 10 km if the channel bed is sandy, and over 5 km if it is clayey or silty. If the distance to the head of the wetland is less than the distance stated above, the distance to the head of the floodplain is added to the length of the excavation, and if there is a dam on the floodplain upstream of the head of the excavation, the distance to the dam wall is added to the length of the excavation. Road crossings may have a similar effect depending upon how flow beneath the road has been dealt with.

Table 3.5: Extent, intensity and magnitude of impacts of channel straightening

Extent of impact of channel straightening.						
Extent: the length of modification plus THE LESSER OF 10 km for sandy stream beds OR 5 km for silty/clayey stream beds OR the distance to the head of the floodplain OR to a dam wall (if present), expressed as a percentage of wetland length[R]						%
Intensity of impact of channel straightening						
	0	2	5	8	10	Score
Reduction in stream length per unit valley length[R]	<5%	6-25%	26-50%	51-75%	>75%	
Magnitude of impact of channel straightening: (extent of impact score/ 100) x intensity of impact score						

In the example illustrated below (Figure 3.2), if the sediment is clayey then the length of wetland affected would be the length of excavation (6 km) + the distance over which headward erosion will take place (5 km), giving an overall extent of impact of 11 km, which is 65% given that the wetland is 17 km long. If sediment on the bed of the channel is sandy then the impact will be the distance over which straightening took place (6 km) plus the valley distance to the head of the wetland (10 km), giving a total extent of impact of 16 km or 94%.

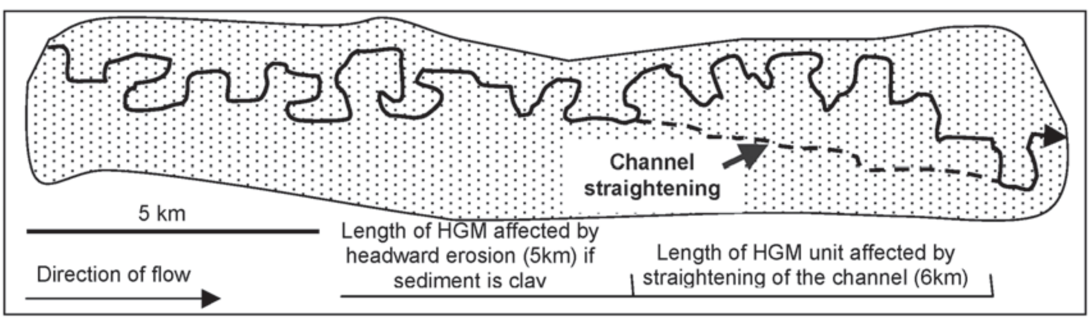


Figure 3.2:Illustration of the calculation of extent of impact of channel straightening if the channel bed is silt or clay.

Intensity of impact of channel straightening is related to the degree of steepening (Table 3.5), which is proportional to the degree of channel shortening since slope is the difference in elevation divided by the distance over which elevation is measured. If distance is shorter for a given difference in elevation, slope is steeper.

Step 2C: Impacts of artificial wetland infilling

If the HGM unit is a floodplain or a channelled valley bottom, this step should be completed (see Table 3.1). The presence of bridges or any other earthen or other fill in a wetland has an impact on wetland geomorphology that is dependent upon many factors, particularly on the location of the fill in the wetland in relation to other confining features and the degree of confinement of the wetland associated with this activity. The fill confines flow and geomorphic activity to a local portion of the wetland and therefore reduces the extent, frequency and/or rate of erosion and/or deposition to those areas closer to the stream than would occur naturally.

In order to assess extent we suggest that in addition to the area filled, the area of the wetland within 45 degrees of the filled area should be determined as far as the wetland boundary – both in an upstream and downstream direction (Figure 3.3). Berms that are oriented parallel to the floodplain boundary will affect areas behind the berm. If there are any other physical features upstream or downstream of the impacted area that may confine flow to a portion of the wetland, such as a resistant dolerite dyke that extends into the wetland or another area of wetland infilling, then the user may modify the calculation of extent in an appropriate way to reflect any areas that may become geomorphologically inactive (Figure 3.3). Extent of impact is then estimated as the proportion of the wetland area filled plus the area of the wetland that is geomorphologically inactivated by flow confinement (Table 3.6).

Intensity of impact is determined by expressing the extent of infilling (measuring from the wetland boundary towards the channel) of the wetland as a proportion of total wetland width.

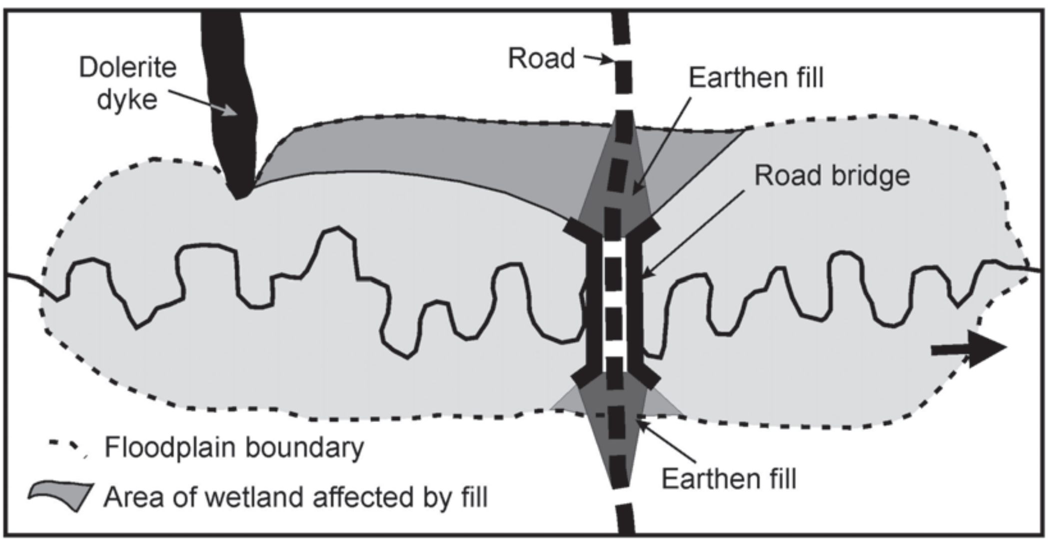


Figure 3.3: Illustration of the method for determining the extent of impact of infilling on floodplains and channelled valley bottom wetlands.

Table 3.6: Extent, intensity and magnitude of impact of infilling of floodplains and channelled valley bottom wetlands.

Extent of impact of infilling.						
Extent of impact of infilling as determined by establishing the area of wetland that will not be subjected to normal erosion and / or deposition, as a percentage of wetland area.						%
Intensity of impact of infilling						
	0	2	5	8	10	Score
Reduction in active wetland width at point of infilling[R]	<5%	6-25%	26-50%	51-75%	>75%	
Magnitude of impact of infilling: (extent of impact score / 100) x intensity of impact score.						

It should be noted that in order to enable some activities associated with infilling (such as road construction), the stream bed may be straightened and/or deepened as there is considerable modification of wetland morphology during the process of infilling. Such impacts are assessed in the sections dealing with channel straightening (Step 2B) and/or erosion (Step 3A).

Extent is calculated as the proportion of the floodplain area affected as a percentage. Where there is more than one area of infilling in an HGM unit, extent will need to be considered jointly depending on their proximity to each other.

Step 2D: Impacts of changes in runoff characteristics

If the HGM unit is a non-floodplain, this step should be completed (see Table 3.1). Changes in runoff characteristics alter the ability of water to lift, transport and deposit sediment, leading to erosion (increased discharge relative to sediment yield from catchments) or deposition (increased sediment yield relative to discharge) in the wetland. This is one of the most significant factors giving rise to geomorphological damage in wetlands, and is assessed by considering those factors described in the hydrology module. In particular, those factors that increase water yield and peak flows are most likely to threaten geomorphic integrity.

Changes in runoff characteristics are the outcome of decreases and increases in water inputs and Steps 2A to 2C of the hydrology module are relevant here. They are not repeated here in detail since the analyses are likely to have been completed. Here the impact of interbasin transfers into the catchment being considered is particularly important, such as for domestic use, irrigation or treatment of domestic sewage, and we draw this to the attention of users in this section. Here, you need to assess these carefully and summarise your analysis in Table 3.7 by using scores from the hydrology module. If there is an increase in water yield from the catchment, then use the score from Table 2.2. If there is an increase in flood peak flows, then use the score from Table 2.3. If there is a reduction in flood peaks, there is likely to be no geomorphological impact on the HGM unit.

The impact is likely to affect the entire wetland below the point at which the increased volumes of water enter the wetland. Thus the extent should be calculated based on length of wetland affected by increased flow as a proportion (%) of the entire wetland length. Thus, if the entire wetland experiences increased water inputs, then extent is 100%.

Table 3.7: Effect of altered water inputs (increased flows and floodpeaks) on wetland geomorphological integrity

Extent of impact of altered water inputs					
Extent calculated based on length of wetland affected by increased flow as a proportion (%) of the entire wetland length.					%
Intensity of impact of altered water inputs					
		Increased floodpeaks (combined score in Table 2.3)			
		No effect (0-2)	Small increase (2.1-4)	Moderate increase (4.1-7)	Large increase (>7)
Increased **flows** (increased **flow score in** Table 2.2)	No increase (0-2)	0	2	4	7*
	Small increase (2.1-4)	2	3	6	8
	Moderate increase (4.1-7)	4	6	8	9
	Large increase (>7)	7*	8	9	10
Magnitude of impact score: (extent of impact score/100) x intensity of impact score (from above rows)					

* Unlikely to occur

STEP 3: Conduct individual assessments based on indicators

This section of the assessment focuses on directly visible impacts of activities – such as erosion gullies, depositional fans or peat fires or peat harvesting. The following steps are only undertaken if it is a non-floodplain HGM (see Table 3.1).

Step 3A: Impacts of erosion and/or deposition

The purpose of this step is to establish the impacts of recent large-scale erosional and/or depositional features. Erosion in wetlands typically takes place through gullying, which is easily visible (Figure 3.4). Large-scale deposition of sediment in a wetland may be associated with erosion in the catchment or the wetland, such that obvious signs of erosion in the catchment or wetland should be the point of departure for investigating excessive deposition of sediment in the wetland. A useful starting point should be a superficial investigation of erosion in the catchment using aerial photography or a broad-scale, superficial field investigation. The deposition of a fan-like lobe of sediment in the wetland at the point of entry of tributary streams (Figure 3.5) or catchment gullies (Figure 3.6) into the wetland is not uncommon.

Figure 3.4: Gully **erosion in a wetland reflecting excessive** sediment loss during a single storm event (in this case).
Photo: Japie Buckle

Figure 3.5: Fan like deposits of clastic sediment at the **head of a wetland reflecting excessive sediment input** during a single storm event (in this case).
Photo: Japie Buckle

In the case of the Blood River Vlei (Figure 3.6) two large fans of sediment are associated with erosion of gullies in the catchment. In this case the cone of sediment in the wetland is neither easily visible in aerial photography nor in the field, but the presence of these large gullies in the catchment made us inspect the wetland more closely for an associated depositional feature, which once pointed out, is clearly visible. Aerial photography and use of Google Earth are extremely useful aids in wetland assessments.

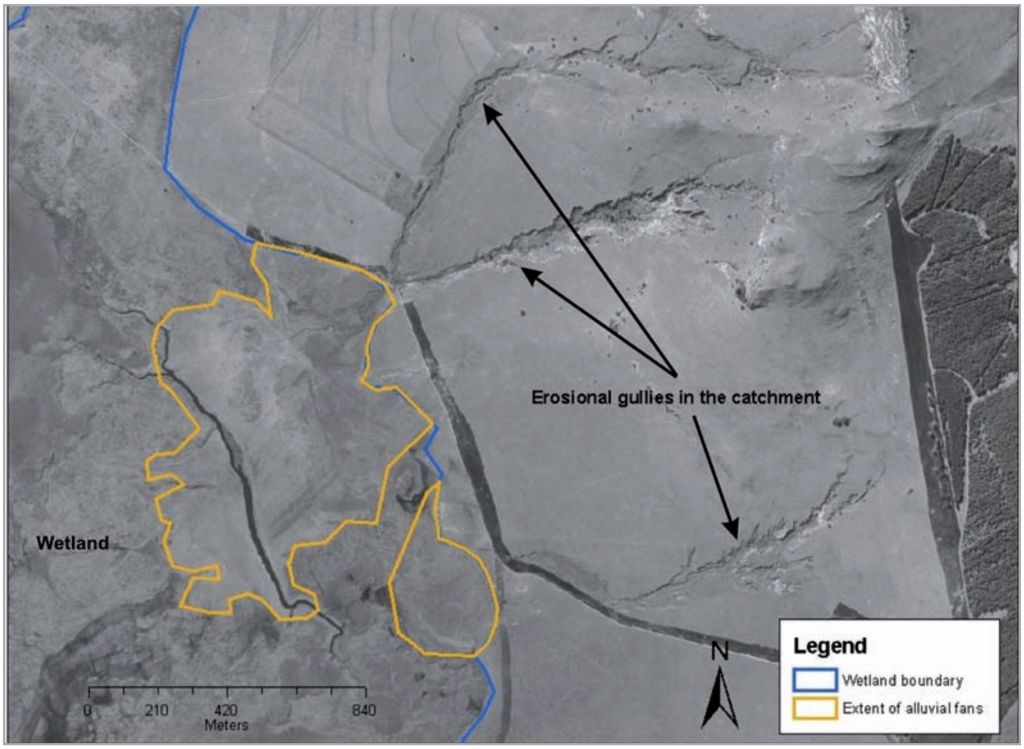


Figure 3.6: Two fan-like cones of sediment associated with gullies in the catchment of the Blood River Vlei, KwaZulu-Natal.

Erosional features

Begin by determining the extent of the wetland affected by erosion gullies. This is based on the length and width of the gully/ies in relation to the length and width of the wetland. Estimate the extent of the HGM affected by erosion gullies as described in Table 3.8.

Table 3.8: Estimation of extent of impact of erosional features

		Length of wetland occupied by gully/ies as a percentage of the length of HGM[R]				
		0-20%	21-40%	41-60%	51-80%	>80%
Average gully width (sum of gully widths if more than 1 gully present) in relation to wetland width[R]	< 5%	5%	10%	15%	20%	25%
	5-10%	10%	15%	25%	35%	45%
	11-20%	15%	25%	40%	55%	65%
	21-50%	20%	30%	50%	70%	80%
	>50%	25%	40%	60%	80%	100%

The rate of sediment loss from a wetland is related to the size of gullies, particularly their depth and width, and these are assessed. Scale the score calculated in the first part of Table 3.9 by the mean of the scaling factors described in the second part of Table 3.9 in order to adjust the intensity of impact in proportion to the current activity of the gully and the extent to which sediment generated by erosion is exported from the wetland.

Table 3.9: Intensity and magnitude of impact of erosional features. The scores for rows 2 and 3 are unscaled for any natural recovery that may have taken place. Factors to use to scale the intensity of impact of erosional features for natural recovery are presented in rows 7 and 8.

Factor	2	4	6	8	10	Unscaled Score
Mean depth of gullies[F]	<0.50 m	0.50-1.00 m	1.01-2.00 m	2.00-3.00 m	>3.00 m	
Mean width of gullies[F]	<2 m	2-5 m	5.1-8 m	8.1-16 m	>16 m	
Number of headcuts present[F]	1	2	3	4	>4	
Unscaled intensity of impact score: mean score of above 3 rows						
Scaling factor	0.4	0.5	0.7	0.9	1.0	Factor
Extent to which sediment from the gully is deposited within the HGM or wetland downstream of the HGM unit (as opposed to being exported)[F]	Entirely deposited	Mainly deposited	Intermediate	Mainly exported	Entirely exported	
Extent to which the bed and sides of the gully have been colonized by vegetation and/or show signs of natural recovery[F]	Complete	High	Moderate	Low	None	
Scaling factor score: mean of above 2 rows (value is between 0 and 1)						
Scaled intensity of impact score = unscaled intensity of impact score x scaling factor score						
Magnitude of impact score for erosional features: (extent of impact score (see Table 3.8)/100) × scaled intensity of impact score						

Rationale for Tables 3.8 and 3.9

Calculation of the extent of erosional features (Table 3.8) is not simply related to their physical extent as their impact on wetland geomorphology is non-linear. This is recognized in the way that extent has been scaled.

Erosion may take different forms in a wetland depending upon flow patterns through the wetland, basin morphology and substratum conditions. Indicators of the rate of sediment loss (intensity) are the width, depth and number of headcuts present (Table 3.9), since a broad gully indicates sediment loss over a broad front, whereas a narrow gully indicates sediment loss over a narrow front. Width is included in both the determination of extent and intensity since the width used in establishing extent does not consider the actual width of gullies, but simply the proportion of HGM width (and length) with gullies. Gully width will determine the rate of sediment loss with other things equal. Similarly, for a gully of given area, gully depth is proportional to the rate of sediment loss. The number of headcuts is important as most sediment loss takes place at the headcut.

The mean of the intensity score in Table 3.9 is scaled by the mean value of factors that indicate natural recovery of the gully, to produce a scaled intensity of impact score. Features that mitigate against active erosional impacts are gully stabilisation and the deposition of some or all of the sediment generated by erosion within the HGM unit. Gullies that arise and terminate within the HGM unit result in little or no sediment being exported, which is not as serious a threat to Present Geomorphic State as gullies that connect to the stream network and thus export sediment from the wetland.

Revegetation of the bed and side walls of the gully suggests that erosion is no longer active. In contrast, the absence of any vegetation suggests ongoing active sediment erosion and transport.

Depositional features

We are only interested here in recent depositional features. Depositional features are difficult to spot, and even people with a basic training in geomorphology may have difficulty spotting depositional features in the field, on aerial photographs or even from a low-level aerial survey. Given this we have taken both direct and indirect approaches to estimating the extent of impact for depositional features. If the user feels confident in being able to map depositional features that can be attributed directly to recent human activity, then extent should be established directly using Table 3.10, but if they are not confident that they can do this, indirect indicators can be used as outlined in Table 3.11. Users may wish to use a combination of approaches by using the indirect indicators to assist in the location and mapping of depositional features in the wetland of interest, following which they may map depositional features directly, but ideally, one would only map these features directly.

Score the factors in Table 3.12 describing the intensity of impact of depositional features in a wetland and calculate magnitude of impact score.

Table 3.10: Estimation of the extent of impact of depositional features for known depositional features in the HGM unit. Complete either this table or Table 3.11 to calculate extent

Extent of depositional features in relation to area of HGM unit being considered[R]	0.2-1.9%	2-10%	11-25%	26-50%	>50%
Score for 'extent' to be used in the estimation of magnitude of impacts	5%	20%	50%	75%	100%

Table 3.11: Estimation of extent of depositional features based on indirect indicators of recent anthropogenic activity leading to excessive deposition. Complete either Table 3.10 or this table to calculate extent

Indicator	0	2	5	8	10	Score
Presence, size and distribution of gullies or active erosion of drains within the catchment or wetland[D]	None or very small	Limited extent and size	Moderate size and distribution	Large size or widespread distribution	Very large size or widespread distribution	
Presence / extent of dirt roads in the catchment[D]	None/ few	Moderate	Many/ extensive			
Breaching of upstream dams in the catchment or wetland[R]	None	Very small earthen dams	Small earthen dams	Large earthen dams		
Extent of decreased vegetation cover in the catchment[F]	Slight	Moderate	High			
Mean of two highest scores from the above						
Extent of impact score of depositional features as a percentage is calculated as the score from the above multiplied by 10.						%

Table 3.12: Intensity and magnitude of impact of depositional features

Indicator	0	2	5	8	Score
The position of fan-like deposits within the wetland[R]		Toe	Middle	Upper	
Impact of depositional features on existing wetland features[D]	Not evident	Minor destruction of features	Moderate destruction of features	Large impact on existing features	
Intensity of impact score of depositional features: mean of two rows above					
Magnitude of impact score of depositional features: (extent of impact score (Table 3.10 or 3.11) / 100) x intensity of impact score					

Rationale for Tables 3.10 to 3.12

The extent of depositional features in Table 3.10 is converted to a different scale because their impact on steepening gradient is nonlinear and greater than is suggested by their physical extent in the wetland. Extent of sediment deposition is likely to be related to the presence, size, distribution, activity or extent of gullies in the catchment or wetland, dirt roads in the catchment, dam breaching or decreased vegetation cover in the catchment that generates sediment during rainfall events (Table 3.11).

The best indicator of intensity of impact of depositional features is the extent to which existing wetland features are destroyed by their presence, such as the disappearance of deeply flooded habitat in a wetland, or of a channel in a valley-bottom wetland with a channel – or even the disappearance of a floodplain. The location of depositional features within the wetland is also important (Table 3.12), as their occurrence lower down in the wetland from tributary streams whose catchments are undergoing erosion, may have a desirable effect on wetland development in that they may have a damming effect that enhances flooding and sediment deposition in the main wetland upstream. Conversely, excessive deposition at the head of the wetland will steepen the longitudinal slope of the wetland, thereby increasing the risk of erosion within the entire wetland.

Step 3B: Impacts of the loss of organic sediment

Apart from erosional and depositional features, a third feature to consider is the loss of organic sediment through human extraction (peat mining) and subsurface peat fires. Such fires completely destroy plant communities in the wetland, and the presence of ash deposits or stands of ruderal ('pioneer') species in localized areas of the wetland may indicate recent burning of peat. These fires are a sign that the integrity of organic sedimentation is threatened through desiccation of existing peat deposits. Tillage also causes oxidation and loss of organic sediment. Peat deposits may also undergo invisible loss through decomposition as a consequence of drying or changes in land use in the wetland or its catchment. This will not be visible in a brief survey such as this, and is best assessed by considering factors that cause the peat to dry out, which causes oxidation (indirect indicators).

Begin by measuring the aerial extent of the direct (Table 3.13A) and indirect (Table 3.13B) indicators of organic sediment loss and express these as a proportion of the extent of the total area of the HGM unit. Although they may be related to each other, we calculate the extent of impact of direct impacts as a proportion of the area of the HGM unit, and then the **additional** area of impact of indirect impacts, in order to avoid counting the same area of the HGM unit twice.

To determine the intensity of impact in the affected area of the wetland, see Tables 3.14 and 3.15 for direct and indirect indicators respectively.

Direct indicators

Activities that impact directly on organic sediment loss include peat fires, peat mining and tillage of organic soils (Table 3.14).

Intensity of impact of activities on peat deposits will depend upon the depth of burning or extraction relative to the depth of the peat. For a given extent, the greater the depth, the greater will be the volume that is lost. In the case of mining, burning or cultivation of a peatland, the greater the duration of these activities, the greater will be the intensity of impact.

Table 3.13: Extent of impact of the loss of organic sediment for direct indicators (A) and indirect indicators (B). Express results as a proportion of the total area of the HGM unit.

A. Extent of impact score based on direct indicators (if present)[F]	%
B. Additional extent of impact score based on indirect indicators (if present)[F]	%

Table 3.14: Macroscopic features (clearly visible direct indicators) determining the intensity of impact of the loss of organic sediments

Activity	1	2	5	8	10	Score
Depth of the peat fires or extraction of peat relative to the depth of the peat deposit[F]	<5%	5-15%	16-30%	31-60%	>60%	
If tillage is practiced, duration of tillage[F]	1-2 yrs	3-5 yrs	6-10 yrs	>10 yrs		
Intensity of impact score: maximum score of above scores						
Magnitude of impact score of loss of organic sediments: (extent of impact score (Table 3.13A) /100) × intensity of impact score						

Indirect indicators

The central issue is to assess any reduction in water inputs to, or residence time of water within, the area of the HGM unit with peat. Therefore, it is relevant to refer to your scores from the hydrological module, where reduced inputs were assessed in Table 2.2 and reduced residence time was assessed in Table 2.15. Consideration of these scores is useful in evaluating indirect indicators of a diminished state of organic sediments (Table 3.15).

The ability of a wetland to store organic sediments is related primarily to its ability to maintain permanently saturated sediments. Thus, if a wetland is desiccated, the more oxic soil conditions are likely to lead to diminished organic matter accumulation and even to oxidation of peat. Therefore, the maintenance of the water table at an elevation above the land surface is critical to preservation of peat.

Table 3.15: Indirect indicators (not clearly visible) reflecting the intensity of diminished integrity of organic sediments in the HGM unit.

	0	2	5	8	10	Intensity score
Level of desiccation of the region of the HGM unit in which peat accumulation is taking place*	Unmodified	Largely natural	Moderately modified	Largely modified	Serously / critically modified	
Magnitude of impact score: extent of impact score (Table 3.13B)/100 × intensity of impact score						

08 WET - Health - Final for Prin86 86 24/07/2009 10:35:43 AM

Table 3.16: Magnitude of impact score for organic sediments expressed as a proportion of the area of the entire HGM unit

	Overall magnitude of impact score: organic sediments
Sum of magnitude scores in Tables 3.14 and 3.15	

Overall magnitude of impact: Organic sediment

In order to determine the magnitude of impact of the loss of organic soils, direct and indirect indicators need to be combined as indicated in Table 3.16.

STEP 4: Determine the Present Geomorphic State of each HGM unit by combining diagnostic (Step 2) and indicator-based (Step 3) analyses

We have considered several components of Present Geomorphic State – impoundments, stream shortening, infilling, erosional features, depositional features and loss of organic sediment. Scores for these should be recorded in Table 3.17 (where relevant). This information is integrated as described in the last row of Table 3.17.

For each HGM unit, compare the overall magnitude of impact score with the scores and descriptions provided in Table 3.18. If your score corresponds with the description given in the table, keep the score, but if you feel that the magnitude of impact score for your HGM unit does not correspond with the score in Table 3.18, then consider the reasons for this (either you have made a mistake or the assessment is poorly suited to the wetland you are examining). Revisit the data or the score; in the latter case you need to justify your modified score.

STEP 5: Determine overall present geomorphic state for the wetland by integrating scores of individual HGM units

It is now opportune to calculate the overall magnitude of impact for the wetland as a whole. This is the sum of the area-weighted impact scores for each HGM unit in the wetland being considered (Table 3.19). The proportional area of each HGM unit within the entire wetland (expressed as a value between 0 and 1) is multiplied by the overall magnitude of impact score for that HGM unit (Table 3.17). The sum of values for each HGM unit is taken to give the overall area-weighted wetland impact score and Present Geomorphic State Category (from Table 3.18).

Table 3.17: Derivation of overall magnitude-of-impact scores through combining the scores obtained from individual assessments

Impact category	Score
1. Magnitude of impact of dams (Table 3.4)	
2. Magnitude of impact of channel straightening (Table 3.5)	
3. Magnitude of impact of infilling (Table 3.6)	
4. Magnitude of impact of changes in runoff characteristics (Table 3.7)	
5. Magnitude of impact for erosional features (Table 3.9)	
6. Magnitude of impact for depositional features (Table 3.12)	
7. Magnitude of impact for loss of organic sediment (Table 3.16)	
Overall Present Geomorphic State = Sum of three highest scores	

Table 3.18: Description of Present Geomorphic State in relation to Impact Scores and Present Geomorphic State Categories for each HGM.

Impact score	Description	Present Geomorphic State category
0-0.9	Unmodified, natural.	A
1-1.9	Largely natural. A slight change in geomorphic processes is discernable but the system remains largely intact.	B
2-3.9	Moderately modified. A moderate change in geomorphic processes has taken place but the system remains predominantly intact.	C
4-5.9	Largely modified. A large change in geomorphic processes has occurred and the system is appreciably altered.	D
6-7.9	Greatly modified. The change in geomorphic processes is great but some features are still recognizable.	E
8-10	Modifications have reached a critical level as geomorphic processes have been modified completely.	F

Table 3.19: Derivation of the overall Present Geomorphic State for the wetland being considered.

HGM unit number	Area (ha)	HGM unit extent (%)	HGM unit impact score (Table 3.16)	Area weighted impact score*	Present Geomorphic State Category
1					
2					
3					
4					
5					
Total		100	Overall area weighted impact score**		

*Area weighted impact score = HGM extent /100 x impact score
**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

The overall area-weighted impact score for the wetland as a whole is assigned a Present Geomorphic State category based on Table 3.18. If users wish to do so, they can assign Present Geomorphic State categories for each HGM unit based on the overall impact scores in column 4 of Table 3.19.

An illustrative example of calculating the area-weighted impact score in the determination of Present Geomorphic State for the wetland as a whole is provided in Figure 3.7 and Table 3.20.

For the example wetland in Figure 3.7 and Table 3.20, the impact score is 4.0. Based on the Present Geomorphic State categories presented in Table 3.18, this translates to Category D, where the geomorphic processes have been largely modified such that the system is appreciably altered.

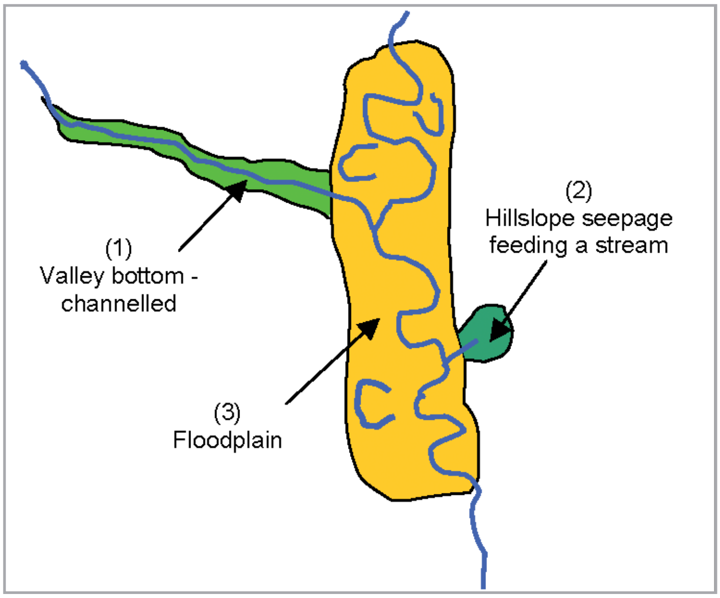


Figure 3.7: Example wetland for which impact scores have been calculated for each of the three HGM units, illustrating the calculation of overall wetland impact score and Present Geomorphic State (see Table 3.20).

Table 3.20: Illustrative example of the calculation of the overall Present Geomorphic State for the example wetland illustrated in Figure 3.7.

HGM unit number	Area (ha)	HGM unit extent (%)	HGM unit impact score	Area weighted impact score*	Present Geomorphic State Category
1	4	20	2	0.4	
2	2	10	8	0.8	
3	14	70	4	2.8	
Total	20	100	Overall weighted impact score**	4.0	D

*Area weighted impact score = HGM extent /100 x impact score

**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

STEP 6: Assess vulnerability and Trajectory of Change due to erosion

Here we assume that the user has become familiar with our approach and philosophy, and that we can expect sensible judgements regarding the Trajectory of Change. Thus, this section of the module is not as detailed as the preceding sections. The user is expected to determine vulnerability (Step 4A), increased extent of gullies (Step 4B), and based on these the Trajectory of Change (Step 4C).

Many factors and activities may threaten Present Geomorphic State, such as overgrazing in catchments leading to increased runoff intensity, the construction of dams in the catchment or the wetland leading to sediment-hungry inflow, or the infilling of floodplains leading to flow confinement. Impacts of these activities generally lead to erosion by gullying in wetlands. Headcuts are a major threat to the health/integrity of South African wetlands. However, assessing the vulnerability of a wetland to erosion is a very difficult task owing to the range of different factors that may potentially influence headcut advance and the erosion resulting from this advance. A very large and ugly headcut is not necessarily a major threat to a wetland. It may, for example, be located such that it can only advance through a small part of the wetland, leaving most of the wetland unaffected. Conversely, a modest sized headcut may be located such that it could advance through most of the wetland given particular circumstances at the site such as a steep slope, erodible soils and a high level of on-site disturbance.

Step 6A: Assess vulnerability to erosion of each HGM unit

In this part of the assessment of geomorphic health/integrity we consider the inherent vulnerability of each HGM unit to geomorphological change. Our assessment focuses on features of the wetland itself and not on features of the catchment that make it vulnerable.

Erosion, and rate of headcut erosion, is dependent upon many factors (such as soil type, vegetation cover and type, rainfall events etc.) but one of the most critical and overriding factors is slope. For any given discharge, the steeper the slope the more likely a headcut will erode. It is this relationship between longitudinal slope and discharge of a wetland that is used here to assess vulnerability to erosion. For the purposes of this assessment wetland area (ha) is used as a proxy for discharge. Therefore, for a given discharge, which is approximated in Figure 3.8 by wetland size (ha), an estimate of wetland vulnerability is obtained based upon longitudinal slope.

The method of measuring longitudinal slope is described in *WET-Origins* (Ellery *et al*., 2009).

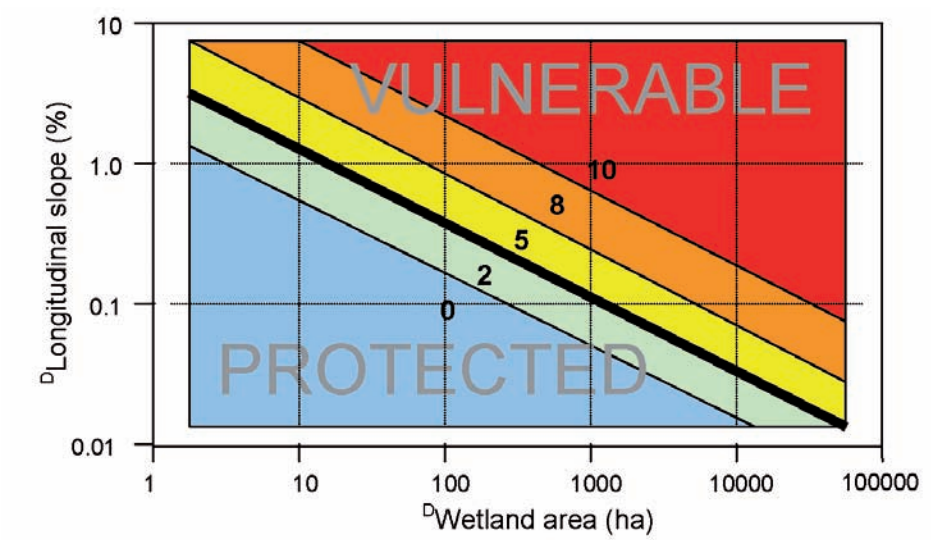


Figure 3.8: Vulnerability of HGM units to geomorphological impacts based on wetland size (a simple surrogate for mean annual runoff) and wetland longitudinal slope. The line between scores 2 and 5 approximates the equilibrium slope for a wetland of a given size

In interpreting the figure you need to be aware that both area and slope are plotted logarithmically. In other words, for each interval on the x- and y-axes the values increase by a factor of 10. Therefore, points between the plotted intervals need to be plotted on the same scale. Thus, if the area is 20 ha and slope is 0.5%, the location of the area measurement is roughly midway between the 10 ha and 100 ha marks on the x-axis, and the slope measurement is about ¾ of the way between the 0.1% and 1% marks on the y-axis. Users also need to be aware that the relationship plotted in Figure 3.8 is based on ongoing research into the relationship between discharge (area) and slope in various HGM types.

For the moment it is necessary to record the vulnerability of each HGM unit (Table 3.21). A score of 0 suggests that no change is likely, a score of 2 or 5 indicates that change may proceed slowly and dissipate a relatively short distance upstream, while a score of 8 or 10 suggests that headcut advance will be rapid and lead to substantial deterioration. Having assessed vulnerability of the wetland to erosion, we suggest that users evaluate the circumstances that have given rise to the observed vulnerability. Is the wetland oversteepened for its size (high vulnerability score) because of excessive input of sediment at the head of the wetland, and can the source of sediment be identified? Is understeepening (low vulnerability score) due to lateral input of sediment to the toe of the wetland? Is there more than a single control on the HGM unit being considered, and what is the effect of each? Such interrogation of the relationship between controls and slope will provide insight that is well worth the effort, and can be recorded in the 'comments' column of Table 3.21.

Table 3.21: Tabulation of the geomorphic vulnerability of each HGM unit of the wetland

HGM unit no.	HGM unit type	Vulnerability score	Extent of predicted headcut advancement (%)	Comments (optional)
1				
2				
3				
4				
5				

Step 6B: Describe the increased extent of gullies in relation to any external controls

At this point we suggest that the geological and/or geomorphological controls on each HGM unit and/or the wetland as a whole should ideally be determined. However, this is a lengthy process and is not essential for the estimation of geomorphological vulnerability. For those interested in going this route, the procedure is outlined in *WET-Origins* (Ellery *et al*., 2009).

For the purposes of this assessment, the headcuts and geological/ geomorphological features (or other man-made features) that may control erosion in the wetland should be mapped, and the extent of potential headcut advancement needs to be determined. This is done by considering the headward advance of the headcut/s in relation to factors that may accelerate or retard it. Extent is determined by considering the length, width and number of gullies in relation to the extent of the wetland. We assume that the number of branches and their width will be the same as presently exist, but length will increase in an upstream direction until an obstacle to erosion is encountered. If the headward advance is likely to be halted by a fault, dyke or road, the situation will not be substantially worsened. However, if advance is likely to be substantial, the increased extent of impact is great. This is illustrated in the example wetland in Figure 3.9 where the dolerite dyke extending down the eastern side of the main north-south portion of the wetland will limit the advance of the headcut into the eastern branch of the wetland, but the headcut in the main portion of the wetland will likely proceed all the way up to its head. Based on these considerations, estimate the final extent of headcut advancement in the wetland using Table 3.8, and record the values in column 4 in Table 3.21.

Step 6C: Assess the likely Trajectory of Change of geomorphic state

Floodplain wetlands

Since no attempt was made in the assessment of floodplain Present Geomorphic State to locate the physical location of any erosional nick point/s that may have arisen from channel straightening, the assessment of floodplain Present Geomorphic State is really an analysis of the potential headward erosion along the trunk stream (see the first paragraph in the section on 'Dams in the floodplain catchment', that refer to Table 3.2). This is equivalent to estimating the likely Trajectory of Change and no assessment of floodplain systems is undertaken here.

Non-floodplain wetlands

In order to establish the likely Trajectory of Change of headcut/s present within or below each non-floodplain HGM unit the analysis is based firstly on the vulnerability score from Step 6A. Secondly, consider the presence of controls that may affect the extent of headcut advance (refer to Table 3.21 for the predicted extent of headcuts). Thirdly, the overall Trajectory of Change will be worsened if there is any likelihood of increased water flows or peak flows due to activities in the catchment because these will increase the likelihood of erosion. Given these three factors, assign a change score to each HGM unit based on categories presented in Table 3.22.

Based on the sum of the area weighted change scores for each HGM unit the overall Trajectory of Change for the wetland is determined (Table 3.23), making it possible to determine an overall health score for the wetland. If for example, the HGM Trajectory of Change scores for the

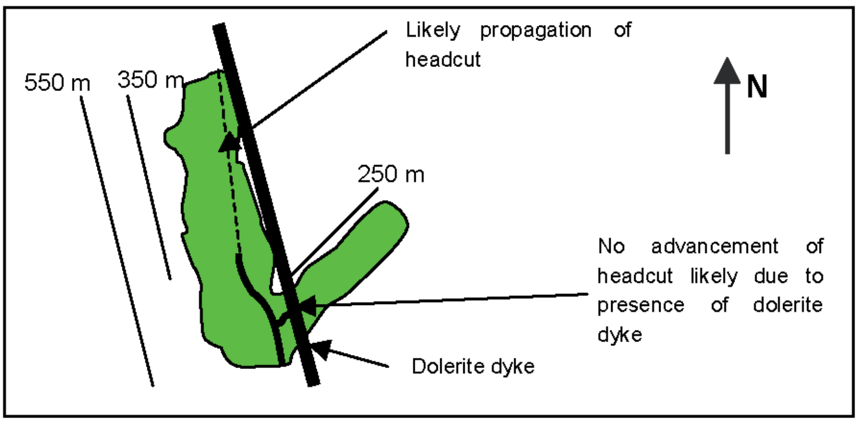


Figure 3.9 An example wetland with two headcuts and a significant geological control in one of the arms of the wetland, which is likely to limit headcut advancement

Table 3.22: Trajectory class, change score and symbol used to evaluate Trajectory of Change to the geomorphology of each HGM unit

Trajectory class	Description	HGM unit change score	Class Range	Symbol
Improve slightly	Geomorphological condition is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Geomorphological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deteriorate slightly	Geomorphological condition is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deteriorate greatly	Geomorphological condition is likely to deteriorate greatly over the next 5 years	-2	-1.1 to -2.0	↓↓

three HGM units depicted in Figure 3.7 and Table 3.20 were assigned values of -1 (geomorphological state is likely to change slightly), -2 (geomorphological state is likely to change greatly) and 0 (geomorphological state is not likely to change) respectively, the overall Trajectory of Change score for the wetland would be (20/100 x -1) + (10/100 x -2) + (70/100 x 0), which translates to a Trajectory of Change score of for the wetland of -0.4. Refer to the Class Range in Table 3.22 and assign the relevant symbol, which for our example suggests that geomorphological state is likely to deteriorate slightly and the symbol is ↓.

STEP 7: Describe the overall Geomorphological Health of the wetland based on Present Geomorphic State and Trajectory of Change

Now that both the Present Geomorphic State and Trajectory of Change have been assessed, these can be represented together to describe Geomorphic Health. This is done simply by documenting the Present Geomorphic State category (Table 3.19) followed by a Trajectory of Change symbol (Table 3.23).

In the example given in Table 3.20:

- The impact score for the wetland is 4.0, which translates to a Present Geomorphic State Category of D (Table 3.18) and
- The Trajectory of Change symbol is ↓, suggesting that the wetland Geomorphological State is likely to deteriorate slightly
- The Geomorphic Health of the wetland would thus be presented as D (↓).

Table 3.23: Evaluation of likely Trajectory of Change of geomorphic condition of the entire wetland.

HGM Unit	Description of relevant sources of change	HGM unit extent (%)	HGM unit change score*	Area-weighted change score**
1				
2				
3				
4				
5				
Overall weighted change score and symbol***				

*Refer to Table 3.22

**Area weighted change score = HGM extent /100 x change score

***Overall area weighted change score = sum of individual area weighted scores for each HGM unit. Assign a symbol to the HGM unit based on Table 3.22.

SECTION 4: VEGETATION MODULE

Introduction

Wetland vegetation has compositional and structural characteristics that provide specialised habitats for a range of important wetland dependent species such as the red chested flufftail and wattled crane. Wetland vegetation may also provide a range of locally important goods for local communities such as reeds for weaving, and services to downstream users such as flood attenuation and nutrient retention. It is therefore important to be in a position to assess vegetation health.

In order to assess vegetation wetland health, the user is required to undertake a joint assessment of the Present Vegetation State and threats to wetland vegetation. The methodology unfolds in a stepwise fashion that begins by subdividing the wetland into hydrogeomorphic (HGM) units (Step 1, Figure 4.1). Present Vegetation State (Step 2) is then assessed by evaluating the degree to which current vegetation composition has deviated from perceived natural or reference conditions. Assessing this deviation is based on what 'should not be there' (e.g. invasive alien species or a high abundance of ruderal (weedy) species) rather than on the composition of indigenous plants that 'should be there'.

Undertaking an assessment for an entire HGM unit may prove difficult in situations where vegetation is highly variable as a result of different parts of the HGM unit being subject to different disturbances (cultivation, dams etc.). The evaluation is simplified by defining 'disturbance classes' which represent areas of similar vegetation characteristics and disturbance history. These classes may consist of a number of 'disturbance units' or individual land parcels, which when mapped, portray the spatial distribution of disturbance classes in the HGM unit. The extent of each disturbance class identified is then estimated and the intensity of impact in each disturbance class assessed based on a qualitative assessment of vegetation transformation. The *magnitude of impact score* for each disturbance class is then calculated as extent x intensity and these scores for each disturbance class are combined to produce an area-weighted *HGM magnitude of impact score* for the HGM unit. A Present Vegetation State score (Step 3) is then calculated for the wetland as a whole as the sum of the area-weighted scores of each HGM unit.

Manifest threats to wetland vegetation are also assessed for each HGM unit and combined using an area-weighted approach to obtain a score for the wetland as a whole that reflects the anticipated Trajectory of Change of wetland vegetation (Step 4). This, together with the Present Vegetation State score is used to describe the vegetation health of the wetland being assessed (Step 5).

Step 1: Map and determine the extent of each HGM unit

Step 2: Determine the Present Vegetation State of each HGM unit
- Step 2A: Familiarisation with the general structure and composition of wetland vegetation in the area
- Step 2B: Identify and estimate the extent of each disturbance class in the HGM unit
- Step 2C: Assess the intensity and magnitude of impact for each disturbance class
- Step 2D: Determine Present Vegetation State for each HGM unit

Step 3: Determine the overall Present Vegetation State for the wetland

Step 4: Assess the anticipated Trajectory of Change to wetland vegetation
- Step 4A: Assess the anticipated Trajectory of Change to wetland vegetation within in each HGM unit
- Step 4B: Determine the anticipated Trajectory of Change to wetland vegetation in the wetland as a whole

Step 5: Describe the overall vegetation health of the wetland based on Present Vegetation State and Trajectory of Change

Step 6: Record the alien vegetation that is present in the wetland

Figure 4.1: An outline of the steps involved in the vegetation module

STEP 1: Map and determine the extent of each HGM unit

As for all modules, the first step is to divide the wetland into HGM units and to map them and determine their extent. Separate assessments are then undertaken for each of these HGM units.

STEP 2: Determine the Present Vegetation State of each HGM unit

The aim of this step is to sub-divide each HGM unit into broadly similar disturbance classes for the purpose of further analysis. This requires some initial understanding of the general composition of wetland vegetation of the area and how this changes following disturbance. Disturbance classes are mapped based on their similarity of land use activities or disturbance regimes (both current and historical) within the HGM unit. This step is described in more detail in Steps 2A to 2D below.

Step 2A: Familiarisation with the general structure and composition of wetland vegetation in the area

In order to evaluate changes in vegetation, it is important for the assessor to have a reasonable regional appreciation of the appearance and composition of wetland vegetation under natural conditions. It is also useful to appreciate the response of vegetation to disturbance. Where assessors are not familiar with the vegetation in a particular region they need to familiarise themselves with wetlands in the area before undertaking this assessment. It is important to note, however, that this methodology does not require the assessor to be able to identify all wetland plant species. Rather, the assessor should have a feel for general wetland vegetation characteristics and must be able to identify the alien species, ruderal (weedy) species and common indigenous species, including those that are naturally dominant and those that are invasive or ruderal ('pioneer/weedy species'). Such information can be obtained by undertaking brief field visits to a range of wetlands within the region or working together with a person with a good knowledge of the vegetation of the area. Bromilow (1995) is a useful reference book for identifying alien and ruderal plants and DWAF (2005) provides diagrams of wetland plants common to the summer rainfall areas of South Africa. See also Appendices 4.1 to 4.3 for a listing of common alien, ruderal and invasive indigenous species commonly associated with South African wetland systems.

Step 2B: Identify and estimate the extent of each disturbance class in the HGM unit

Once the wetland has been mapped and HGM units defined, each HGM unit is divided into broadly homogenous areas on the basis of current and historic disturbances. In this methodology, 'disturbance classes' are used to describe the type of disturbance present. Disturbance classes range from completely transformed areas in which the indigenous vegetation has been totally lost or removed (e.g. by a road or a deeply flooding dam: areas of introduced species where no indigenous species are present); to substantial transformation (e.g. current cultivation, dense alien vegetation, or shallow flooding etc.) to historically transformed areas (e.g. areas previously cultivated) and untransformed areas where changes in vegetation composition are limited.

The vegetation in the HGM unit needs to be mapped as different disturbance classes. These can occur as single units or as smaller units as shown in Figure 4.2. Therefore, a wetland may have a small number of disturbance classes (in this case 'untransformed' and 'cultivated lands') but a large number of disturbance units (in this case, 1 unit that is 'untransformed' and 5 units of 'cultivated lands').

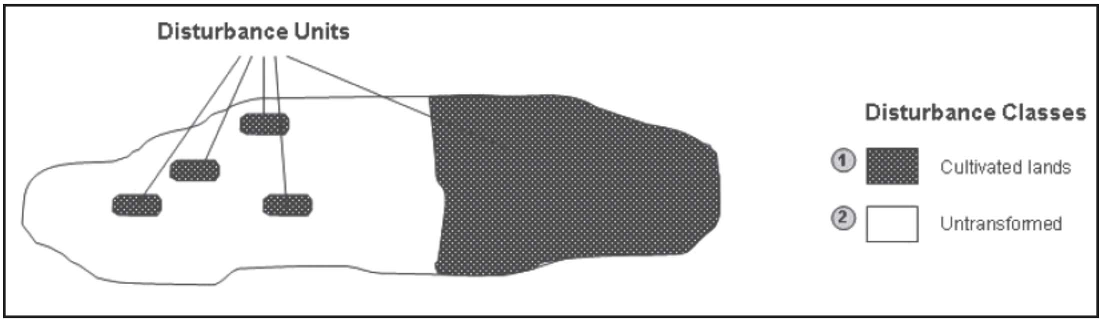


Figure 4.2: Schematic diagram illustrating a wetland with two disturbance classes, 'Class 1' consisting of 5 disturbance units and 'Class 2', present as a single disturbance unit.

Mapping of these disturbance classes should be undertaken initially at a desktop level with the aid of aerial photos or orthophotos where available. This is done by first identifying disturbance classes present in the wetland and then mapping disturbance units. A list of common disturbance classes that may typically be found in wetlands is provided in Table 4.1. This list is by no means exhaustive and the user should refine these classes and provide a brief description of each class for the wetland being assessed (Table 4.2). During the site visit, the user is encouraged to obtain a good vantage point over the wetland to help locate and refine disturbance classes and disturbance units. Further refinements to these classes may then be made during the site visit when each disturbance class is more thoroughly evaluated.

Table 4.1: Description of common disturbance classes in South African wetlands

Disturbance class	Description
Land uses commonly associated with complete transformation of wetland habitat	
Infrastructure	Includes houses, roads and other permanent structures that totally replace wetland vegetation.
Deep flooding by dams	This includes situations where flooding is too deep for emergent vegetation to grow.
Land uses commonly associated with substantial-to-complete transformation of vegetation characteristics	
Crop lands	These lands are still in use and when active are generally characterized by almost total indigenous vegetation removal (predominance of introduced species). Examples include maize lands, tree plantations, sugarcane lands & madumbe fields etc.
Commercial plantations	Common plantations include pine, wattle, gum, poplar. Other land uses such as vineyards and orchards may have a similar impact on wetland vegetation.
Annual pastures	These areas are characterized by frequent soil disturbance with a general removal of wetland vegetation. Some ruderal wetland species may become established but are frequently removed.
Perennial pastures	Although such areas generally include a high abundance of alien terrestrial grasses or legumes, the reduced disturbance frequency may permit the establishment of some wetland species.
Dense alien vegetation	Where dense patches of alien plants can be identified within a wetland system, they should be identified as a separate disturbance class and evaluated as a unit.
Shallow flooding by dams	Such areas can often be identified at the head or tail end or edges of dams.
Sports fields	These include cricket pitches, golf courses and the like, where a species such as Kikuyu have been introduced and are maintained through intensive management. These are often located within areas of temporary wetland where terrestrial species generally dominate.
Gardens	Gardens are generally associated with urban environments.
Sediment deposition/ infilling and excavation	Deposition includes sediment from excessive erosion or human disturbance (e.g. a construction site) upstream of the wetland, which is carried by water and deposited in the wetland. Infilling is the placement by humans of fill material in the wetland (e.g. for a sports field). Excavation is the direct human removal (usually with heavy machinery) of sediment from the wetland, which is commonly associated with mining and sand winning.
Eroded areas	In wetlands this typically occurs as gully erosion.
Land uses commonly associated with moderate transformation of vegetation characteristics	
Old / abandoned lands	These secondary vegetation areas have typically been altered through historic agricultural practices, but are in the process of recovering. They are generally characterized by a high relative abundance of ruderal species, but this abundance may vary greatly depending on time since cultivation ceased. In cases where this varies greatly within an HGM unit, it may be best to distinguish between vegetation classes comprising recently abandoned lands and areas comprising older lands that are at a more advanced successional stage of recovery.
Land uses generally associated with low or no transformation of wetland vegetation	
Seepage below dams	Earthen dams used for agricultural purposes often allow water to leak through the wall, creating artificial wetter areas below the dam wall. Such areas are typically characterized by an increase in hydric species.
Minimal human disturbance	These primary vegetation areas have not been significantly impacted by human activities, but may have been impacted upon by factors such as scattered alien plants. It may include wetland areas within game reserves or extensive grazing management systems. Small pockets of untransformed vegetation may also be set aside as streamside buffers on commercial landholdings.
Note: Scattered alien plants may occur in most of the above disturbance classes. Where this occurs, alien plants are considered as part of the larger disturbance class of which they are part (e.g. scattered bramble occurring within an old land), and the intensity of disturbance score is modified to account for the fine grain disturbances within them.	

Table 4.2: Description and extent of each disturbance class within each HGM unit

Disturbance class	Brief description of disturbance class	Extent (ha)*	Extent(%)
1			
2			
3			
4			
5			
			100

* Extent can simply be estimated as a % if actual extent (ha) is not available or easily calculated

The spatial scale of disturbances within the wetland, referred to as 'grain size', may affect the ability to clearly map separate disturbance classes. This concept is explored and illustrated as two case studies.

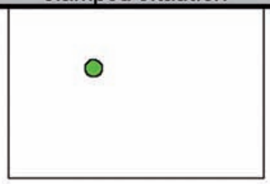
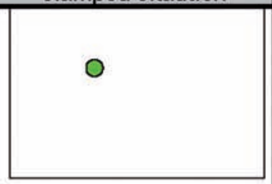
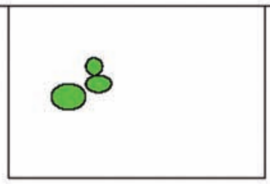
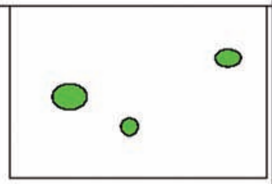
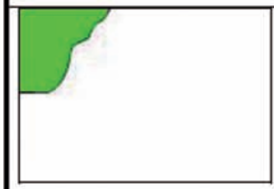
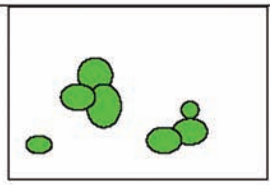
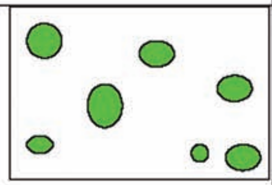
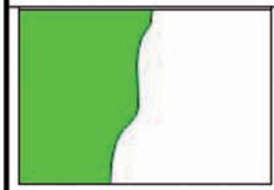
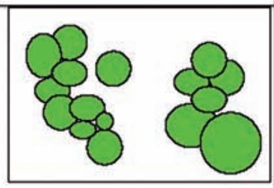
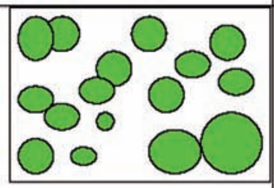
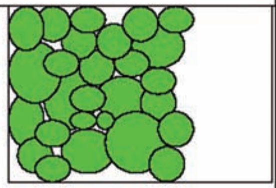
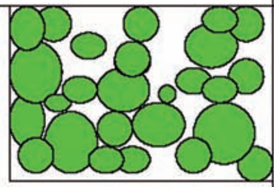
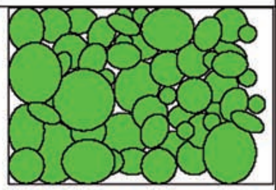
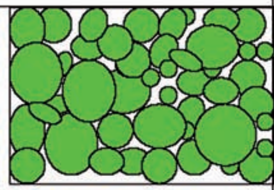
Where the grain size of disturbance is coarse (as is often the case in a large-scale agricultural context) then most disturbance classes can be easily identified and mapped as large units. GIS is a particularly useful tool in such a scenario and may be used to accurately map individual disturbance units. The aerial extent of each class is then estimated by summing the areas of mapped disturbance units. This extent is estimated as a proportion (%) of the HGM unit and recorded in Table 4.2.

Alternatively, where the grain size is fine (such as in a small-scale cultivation context or in the case of scattered patches of alien plants) then each disturbance class may be present as many small fragments which can be distinguished as distinct patches but are practically not possible to map. Under these situations, a sketch-map is drawn and one of two approaches is applied:

1. The cumulative cover (%) of individual patches that form part of the disturbance class is estimated visually using Table 4.3.
2. Patches of fine-scale disturbance units are grouped and mapped as part of a coarse-scale disturbance unit/s (e.g. area dominated by small, active, cultivated fields within a matrix of historically cultivated area) and intensity is treated accordingly.

In either case, the aerial extent of each disturbance class is estimated as a proportion of the HGM unit and recorded in Table 4.2.

Table 4.3: Classes to assist scoring the aerial cover of disturbance classes under fine-grain scenarios

Diagrams of contiguous situation	Diagrams of highly clumped situation	Diagrams of a loosely clumped situation	Extent range
			0-1%
			2-5%
			6-25%
			26-50%
			51-75%
			76-100%

As illustrated in Figure 4.3, Case 1 represents an un-channelled valley bottom wetland within a large-scale agricultural (forestry) context. Six disturbance classes can be identified. These are all coarse-scale disturbance classes and are easily mapped for further evaluation. Unlike the scrub wattle, which occurs as a clearly defined clump and is therefore recognized as a single disturbance class, bramble occurs as scattered plants that cannot be mapped as a disturbance class. Instead, bramble is considered as part of the disturbance class in which it occurs, and the intensity of impact of this disturbance class (assessed in Step

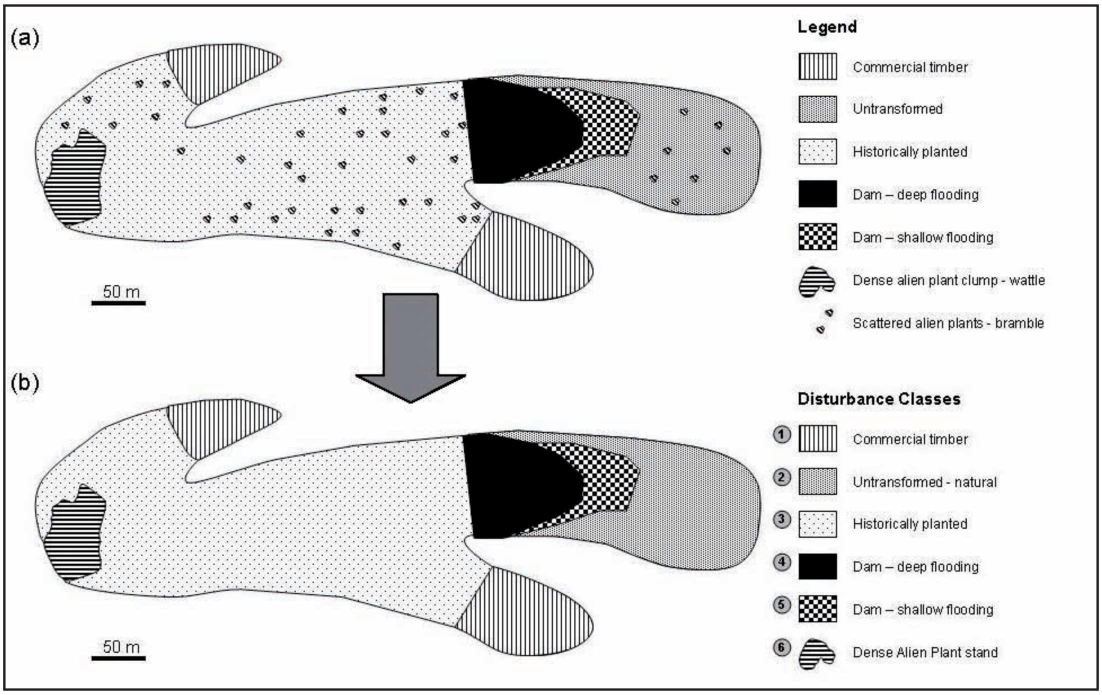


Figure 4.3: Case 1: (a) Land uses and activities affecting vegetation health and (b) mapping of disturbance classes for a wetland in a large-scale commercial forestry context.

2C) is modified (increased) to reflect the presence of bramble within the class.

Case 2 portrays a small-scale cultivation context where disturbance generally occurs at a fine grain (Figure 4.4). Four disturbance classes are portrayed, reflecting a typical subsistence agricultural context. Disturbances are localized and fragment the wetland vegetation into numerous small disturbance fragments. This applies particularly to the "currently cultivated" class, with cultivation occurring as 23 small, raised beds, in a matrix of historically transformed areas between the beds. Mapping of each bed forming part of a disturbance class of this nature would be extremely time consuming and unnecessarily slow down the evaluation process. The first option would be to visually estimate the collective area covered by all of the individual raised beds. Alternatively, the beds can be mapped as a single disturbance class consisting of a mosaic of currently cultivated patches in a matrix of historically cultivated area. Brambles occur as scattered plants and are not identified as a discrete disturbance class but are rather considered as part of the larger disturbance classes in which they occur.

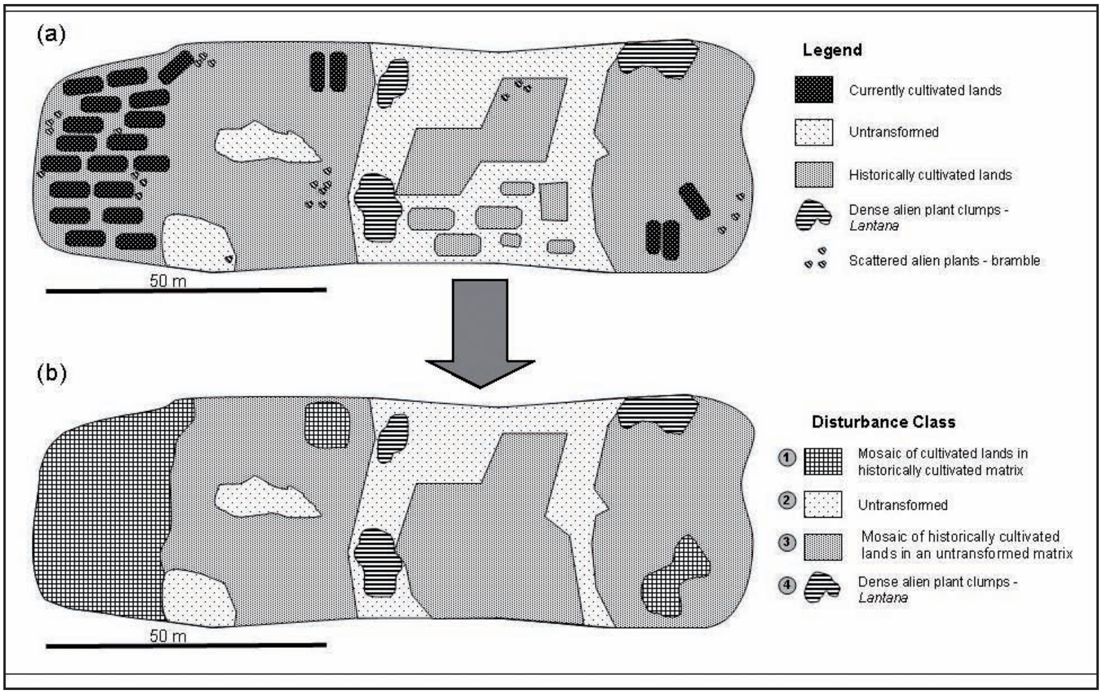


Figure 4.4: Case 2: (a) Disturbance types and (b) mapping of disturbance classes for a wetland in a small-scale agricultural context.

Step 2C: Assess the intensity and magnitude of impact for each disturbance class

Table 4.4 provides an indication of the impact scores typically associated with different disturbance classes, as well as an indication of some specific factors to look out for in assigning an intensity of impact score for each disturbance class.

Table 4.4: Typical intensity of impact scores for disturbance classes that can be used to inform the vegetation assessment

Disturbance class	Typical intensity scores	**Specific factors to consider when assigning the score**
Infrastructure	10	N/A
Deep flooding by dams	10	N/A
Shallow flooding by dams	4-8	The impact on vegetation may be less intense where the dams are shallow and emergent plant species are able to persist. The impacts on vegetation depend on the periodicity of flooding and the extent to which seasonal drying out of dam margin occurs
Crop lands	8-10	Impacts on wetland vegetation is determined largely by disturbance interval. Drains can also dry out these areas, reducing the likelihood of wetland species persisting in them.
Commercial plantations	7-10	Commercial plantations generally result in a gradual suppression of wetland vegetation as indigenous plants become shaded out by commercial species. Pines tend to have a more detrimental impact on wetland vegetation than wattle, gum or poplar due to the slow decaying litter layer that builds up under such plantations.
Annual pastures	9-10	Small scale patches that can be readily colonized by indigenous vegetation are more likely to have at least a little indigenous vegetation present than large, contiguous cultivated patches
Perennial pastures	4-10	The degree of change is largely dependent on the duration between disturbance events and how long ago the area was tilled. The longer the interval between tillage events, and the further back in time the area was tilled, the lower the impact score.
Dense Alien vegetation patches.	5-10	Degree of change is determined largely by the class of plants and their aerial cover. The longer these plants have persisted, the greater the potential impact on wetland vegetation.
Sports fields	7-10	Dependent on the degree of maintenance and species introduced.
Gardens	6-10	The degree of change is largely dependent on landscaping and the introduction of non-native species.
Areas of sediment deposition/ infilling & excavation	4-10	The longer the time since the past disturbance (e.g. from cultivation, infilling or erosion) and the smaller the extent to which the natural hydrology has been altered, the greater the opportunity provided for recovery towards the natural vegetation, unless the area becomes dominated by aggressive invasive alien plants. In addition, the wetter the area, the more readily it generally recovers to its natural vegetation, as the excessive wetness generally exerts an overriding influence on the other factors.
Eroded areas	3-9	
Old / abandoned lands (Recent)	7-9	
Old / abandoned lands (Old)	3-8	
Seepage below dams	1-5	The greater the changes in water balance in the wetland area below the dam, the greater the potential change in vegetation characteristics. Historically temporary wetland zones will therefore be more severely affected than seasonal / permanent wetland zones.
Minimal human disturbances	0-3	Many of South Africa's wetlands evolved under burning and grazing by indigenous grazers, and are well adapted to moderate grazing intensities. A change in wetland vegetation does become apparent under heavy grazing pressure where a decrease in basal cover may even trigger significant erosion. Exclusion of grazing and fire may also have a negative consequence through shading out of grazing tolerant wetland species.

Next, evaluate the changes in vegetation characteristics within each disturbance class by walking through representative sections of each class and comparing vegetation characteristics to those you would expect in a reference site. Table 4.5 is then used to allocate an intensity of impact score that reflects the degree to which each disturbance class deviates from the reference conditions. These scores are then entered in Table 4.6 and used to calculate the vegetation impact score for the HGM unit as a whole.

Users are also encouraged to take fixed point photographs to reflect current vegetation characteristics of each disturbance class. These photos are extremely useful as they not only provide a visual reference of vegetation at the site, but provide an important reference point for follow-up surveys.

It is also important to note that where a high confidence assessment is required (e.g. for a comprehensive reserve determination process), users are encouraged to undertake quantitative sample-based assessments to better inform the intensity scores assigned above. This would entail a detailed assessment and description of species compositions under the current and natural or reference conditions. Suitable approaches would include transect or quadrat assessments designed to specifically enumerate the composition of wetland vegetation at appropriate sites.

Once an intensity score has been assigned, users are encouraged to outline the primary factors that have contributed to the changes in vegetation characteristics in each disturbance class (Table 4.6). Here, users should consider both factors that have a direct impact on vegetation such as cultivation and grazing, along with changes to wetland processes that can indirectly affect vegetation dynamics. Such factors may include changes in hydrology (e.g. drying out from plantations in the catchment or drainage within the wetland), geomorphology (e.g. alluvial deposition), or water quality changes (e.g. increased nutrient input from sewage works). This information is important in situations where management recommendations need to be proposed to improve vegetation integrity.

Table 4.5: Impact categories for assessing the intensity of impacts on vegetation integrity within disturbance classes

Impact category	Description	Intensity of impact score
None	Vegetation composition appears entirely natural.	0.5
Small	A very minor change to vegetation composition is evident at the site (e.g. abundance of ruderal, indigenous invasive slightly higher than would be the case naturally).	1.5
Moderate	Vegetation composition has been moderately altered but introduced, alien and/or increased ruderal species are still clearly less abundant than characteristic indigenous wetland species.	3
Large	Vegetation composition has been largely altered and introduced, alien and/or increased ruderal species occur in approximately equal abundance to the characteristic indigenous wetland species.	5
Serious	Vegetation composition has been substantially altered but some characteristic species remain, although the vegetation consists mainly of introduced, alien and/or ruderal species.	7
Critical	Vegetation composition has been almost totally altered, and in the worst case all indigenous vegetation has been lost (e.g. as a result of a parking lot).	9

Table 4.6: Calculation of the HGM magnitude of impact score based on an area weighted magnitude of impact score for each disturbance class

Disturbance class	Disturbance class extent (%) (from Table 4.2)	Intensity of impact score (from Table 4.5)	Magnitude of impact score*	Factors contributing to impact
1				
2				
3				
4				
5				
HGM Magnitude of impact score**				

* Magnitude of impact score is calculated as extent / 100 x intensity of impact
** Overall magnitude of impact score for the HGM unit = sum of magnitude scores for each disturbance class.

Step 2D: Determine the Present Vegetation State of each HGM unit

Magnitude of impact is now calculated for each disturbance class as an area-weighted magnitude of impact score. The magnitude of impact score is then calculated for the HGM unit as the sum of the magnitude of impact scores for each disturbance class (Table 4.6). This is the Present Vegetation State for the HGM unit.

WET-Health assumes that vegetation composition is reasonably uniform within an HGM unit. In practice however, often quite distinct vegetation communities, each with a different species composition, may occur in a single HGM unit. If the assessor has detailed information on the specific vegetation communities naturally occurring in the wetland, and has evidence that some communities have been greatly transformed, even though the overall transformation may be only small or moderate, then the overall impact on vegetation composition may be increased with documented justification.

STEP 3: Determine the overall Present Vegetation State of the wetland

In order to determine the Present Vegetation State for the wetland it is necessary to combine the impacts for all HGM units into a single impact score for the wetland as a whole. This is done by calculating an area-weighted HGM unit score for each HGM unit and summing them to provide an overall weighted impact score for the wetland as a whole (Table 4.7). This score is then used to place the wetland into a Present Vegetation State category (Table 4.8) that describes the current state of wetland vegetation.

Table 4.7: Summary impact score for each HGM unit and assessment of overall Present Vegetation State of the wetland

HGM Unit	Area (Ha)	HGM unit extent (%)	HGM unit magnitude of impact score (from Table 4.6)	Area weighted impact score*	Present Vegetation State category
1					
2					
3					
4					
5					
		100	Overall weighted impact score**		

*Area weighted impact score = HGM extent /100 x impact score
**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

Table 4.8: Present Vegetation State categories used to define health of wetland vegetation.

Description	Overall impact score	Present Vegetation State category
Vegetation composition appears natural.	0-0.9	A
A very minor change to vegetation composition is evident at the site.	1-1.9	B
Vegetation composition has been moderately altered but introduced alien and/or ruderal species are still clearly less abundant than characteristic indigenous wetland species.	2-3.9	C
Vegetation composition has been largely altered and introduced alien and/or ruderal species occur in approximately equal abundance to the characteristic indigenous wetland species.	4-5.9	D
Vegetation composition has been substantially altered but some characteristic species remain, although the vegetation consists mainly of introduced, alien and/or ruderal species.	6-7.9	E
Vegetation composition has been totally or almost totally altered, and if any characteristic species still remain, their extent is very low.	8-10	F

STEP 4:
Assess the anticipated Trajectory of Change to wetland vegetation

The Present Vegetation State of wetland vegetation provides a snapshot of vegetation condition at a point in time. While this is itself an extremely useful measure, if considered alone, it may mask hidden threats that, if not addressed, could result in rapid deterioration of vegetation condition. A more comprehensive diagnosis of health may therefore be obtained by understanding existing threats and using this as a basis for understanding the likely future changes in vegetation health. The aim of this step is therefore to make an informed assessment of potential future changes to wetland vegetation over the next five years. This involves consideration of the disturbance classes in each HGM unit and an assessment of likely changes in their extent, nature and direction of change from their present status. It also involves consideration of the likely influence of catchment activities and their impacts on the wetland vegetation. Assessments are therefore first undertaken at the HGM unit level and later combined to obtain an indication of the Trajectory of Change to vegetation in the wetland as a whole.

Step 4A: Assess the anticipated Trajectory of Change to wetland vegetation within each HGM unit

Within each HGM unit, the disturbance classes have already been recorded. The assessor needs to take into consideration future management and/or interventions and how these will influence the disturbance classes. For example, wetlands with high weed infestations in the wetland and/or the catchment are likely to deteriorate faster than sites with low weed infestations. Disturbance is also likely to facilitate spread of existing alien plants. However, systematic weed control activities can reduce the impact of alien plants on wetland vegetation. Similarly, a shift to higher intensity utilisation of the wetland will cause disturbance and loss of indigenous vegetation, whereas a shift to lower intensity use could result in improvement of wetland vegetation cover. By the same token, whereas catchment activities that cause the wetland to dry out may result in terrestrial species encroachment, activities that result in increased flow may facilitate recovery of dried out areas.

The influence of on-site and off-site (catchment) factors and activities on each disturbance class in each HGM unit, should therefore be considered. For the purposes of the assessment, five potential trajectory classes with associated change scores have been identified as outlined in Table 4.9. A likely change score is assigned for each disturbance class, and is recorded in column 4 of Table 4.10 and is used to calculate an overall weighted change score for each HGM unit.

Table 4.9: Trajectory classes, change scores and symbols used to evaluate Trajectory of Change of wetland vegetation

Trajectory Class	Description	Change Score	Class Range	Symbol
Improve markedly	Vegetation is likely to improve substantially over the next 5 years	2	1.1 to 2.0	↑↑
Improve slightly	Vegetation is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Vegetation is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deteriorate slightly	Vegetation is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deteriorate markedly	Vegetation is expected to deteriorate substantially	-2	-1.1 to -2.0	↓↓

Table 4.10: Evaluation of Trajectory of Change of vegetation within an HGM

Disturbance class	Source of change	Disturbance class extent (%) (Table 4.6)	Change score (Table 4.9)	Area-weighted change score*
1				
2				
3				
4				
5				
HGM change score**				

*Area weighted change score = Disturbance Class extent /100 x change score
**HGM change score = sum of individual area weighted scores for each disturbance unit

Step 4B: Determine the anticipated Trajectory of Change to wetland vegetation in the wetland as a whole

As with the assessment of Present Vegetation State, threats to wetland vegetation are first assessed at an HGM unit level (as outlined in Table 4.10 above) and then combined to obtain a score that reflects the anticipated Trajectory of Change for the wetland as a whole (Table 4.11 below). The area-weighted change scores for each HGM unit are summed across all HGM units to obtain an overall weighted change score, which represents the anticipated Trajectory of Change of wetland vegetation as a whole (Table 4.11). This score is used to assign the wetland into one of five classes based on Table 4.9, with its associated symbol.

This final trajectory class is particularly useful for decision makers responsible for prioritising rehabilitation initiatives. Wetlands that are likely to remain stable or improve are unlikely to require urgent attention while timely rehabilitation interventions should be seriously considered for wetlands prone to rapid deterioration.

STEP 5: Describe the overall Vegetation Health of the wetland based on Present Vegetation State and Trajectory of Change

Now that both the current state of wetland vegetation and future threats have been assessed, these can be combined to describe the health of wetland vegetation. This is done by documenting the Present Vegetation State class followed by the Trajectory of Change symbol for the wetland. So, referring back to Tables 4.8 and 4.9, if a Present Vegetation State score of 4.5 was obtained along with a threat score of -0.5, wetland health would be represented as D (↓).

Table 4.11: Evaluation of Trajectory of Change of vegetation in the entire wetland.

HGM unit	Description of relevant sources of change	HGM unit extent (%) (Table 4.7)	HGM change score*	Area-weighted change score**
1				
2				
3				
4				
5				
Overall weighted change score***				

*Calculated for each HGM unit – See Table 4.10

**Area weighted change score = HGM extent /100 x HGM change score

***Overall area weighted change score = sum of individual area weighted scores for each HGM unit

Table 4.12: Alien species identified and suspected factors contributing to current infestation levels

HGM unit	List the alien species present	Aerial extent of invasion (%)	Suspected factors contributing to increased abundance
1			
2			
3			
4			
5			
Threat of further invasion, given the current management:			Low □ Medium □ High □

Note: The above table is used to capture the combined extent of all listed alien species in each HGM unit. Where necessary - such as where a detailed weed control strategy must be developed - this table may be expanded to include separate extent estimates for each species present.

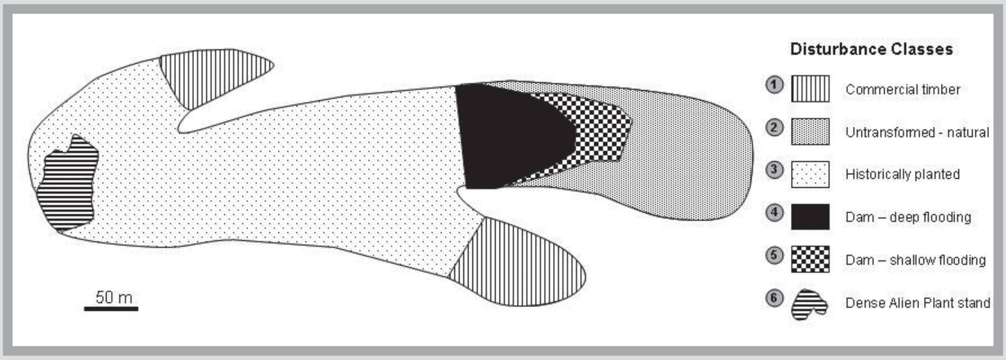
STEP 6: Record the alien vegetation that is present in the wetland

Unlike in the other two modules, a further step has been provided in this module in order to ensure that alien species are recorded in a systematic way. Alien vegetation poses one of the most significant threats to wetland vegetation and is typically a major focus of rehabilitation programs. Where further management intervention is intended, it is useful to identify the problem species and to obtain further insight into their occurrence. A list of common alien plant species present in South African wetlands is outlined in Appendix 4.1. Since alien plant cover may vary significantly across the wetland system, this assessment is undertaken for each HGM unit. Table 4.12 may be used to capture such information and includes a list of alien species present, extent (estimated using Table 4.3 as a guide) along with a description of the factors contributing to increased abundance in each HGM unit.

Case Studies

In order to clarify the procedure outlined in Steps 1-5 above, the methodology has been applied to the two simple cases outlined earlier in the text. Under field conditions, a wetland may well consist of a number of HGM units rather than the single units illustrated in these case studies. Under such a scenario, the same approach would apply, but would include the integration of individual HGM scores into impact and change scores for the wetland as a whole as outlined in Tables 4.7 and 4.11. Details of the case study assessments are given on the following pages.

Case Study 1: Forestry Context



Disturbance class	Brief description of disturbance class	Extent (ha)	Extent (%)
1	Area planted to pine. Indigenous cover very low.	1	13
2	Open area above dam – largely natural vegetation, with localized bramble infestation.	1.2	15
3	Old pine compartment under rehabilitation – dominated by ruderal species, bramble common.	4.4	55
4	Large earth dam – deep flooded with no emergent species.	0.7	9
5	Margin of dam – seasonally flooded with high proportion of hydric species.	0.3	4
6	Old wattle patch – no indigenous vegetation cover.	0.4	5
		8.0	100

In this case study, GIS mapping was used to obtain accurate estimates of the aerial extent of each of the 6 identified disturbance classes. The degree of change from reference conditions is scored below, with details outlining the main factors contributing to the score assigned.

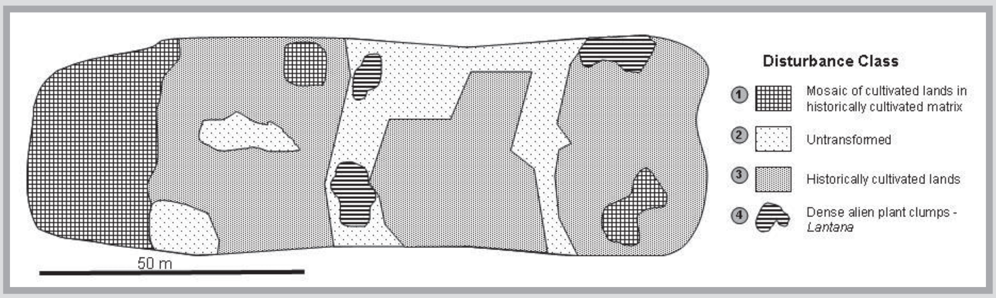
Disturbance Class	Extent (%)	Intensity Score	Magnitude of Impact Score	Factor/s contributing to impact
1	13	9	1.1	Pine plantation suppresses indigenous vegetation through shading and dense pine litter layer. Local desiccation of soil from increased transpiration.
2	15	3	0.5	Despite most species being present, a lack of burning has resulted in a buildup of old grass and suppression of fire-tolerant species. Localized bramble infestation also apparent.
3	55	7	3.9	Plantation trees removed three years ago. Vegetation recovering well but still dominated largely by ruderal species. Bramble infestation also problematic.
4	9	10	0.9	Wetland vegetation totally submerged – no emergent vegetation.
5	4	4	0.2	Back-flooding has resulted in a substantial increase in hydric species over the perceived reference condition.
6	5	10	0.5	Dense wattle patch allowing no light penetration. Local drying out through increased transpiration.
Overall weighted impact score			6.9	

HGM unit	Description of relevant sources of change	Proportion of wetland (%)	Change Score
1	While most of the wetland catchment has been historically planted to timber, measures are now underway to remove trees from streamside zones. Such efforts, along with steps to remove trees within the wetland will improve the hydrological functioning of the system. These changes along with management commitment to improve alien plant control should result in a moderate improvement in vegetation integrity over the next 5 years.	100	1
Overall weighted change score			1

Case Study 2: Small-scale cultivation

The overall weighted impact score obtained for this HGM unit is 6.9. This translates into an E category for Present Vegetation State (Table 4.8), indicating that significant changes to natural vegetation characteristics have occurred. Management interventions both within the wetland and the wetland catchment are likely to result in improvements to vegetation integrity. The current vegetation health is therefore represented as E (↑).

The assessment of this HGM unit is undertaken in a slightly different manner to that presented in Case Study 1. Since the grain of disturbances is very fine, it was not practical to accurately map each disturbance class. A sketch map was therefore used to illustrate disturbance types. In this instance, actively cultivated fields have been grouped and mapped as course-scale disturbance units which include a matrix of historically transformed areas. If the alternate approach had been applied, the extent of madumbe fields would have been estimated on their own by using Table 4.3 as a guide and a higher intensity score allocated to the disturbance class.

Disturbance class	Brief description of disturbance class	Extent (ha)	Extent (%)
			
1	Mosaic of actively cultivated small-scale madumbe fields within a matrix of historically cultivated areas.	N/A	20
2	Uncultivated areas – no sign of historic agricultural activities	N/A	13
3	Old / abandoned fields – historically cultivated areas	N/A	60
4	Dense Lantana infestations – very little indigenous cover	N/A	7
		N/A	100

Disturbance Class	Extent (%)	Intensity Score	Magnitude of Impact Score	Factor/s contributing to impact
1	20	7	1.4	Active maintenance of fields has resulted in the removal of most indigenous vegetation. Some indigenous vegetation persists in historically cultivated areas between the raised beds.
2	13	2	0.3	Cattle use unfenced areas extensively for fodder. While most characteristic species persist, the abundance of ruderal species is somewhat higher than the perceived reference condition.
3	60	6	3.6	Historic agriculture has resulted in a loss of some sensitive wetland species. These areas now have a high abundance of ruderal species with some encroachment by bramble.
4	7	9	0.6	Dense infestations of Lantana have formed – no attempts made to clear areas.
Overall weighted impact score			5.9	

HGM Unit	Description of relevant sources of change	Proportion of wetland (%)	Change Score
1	This wetland is found within a tribal area where overgrazing is causing considerable erosion within the catchment. The resultant reduction in suitable grazing is likely to cause increased pressure on the wetland, particularly during the drier winter months. Discussions with community members also indicate that the areas under cultivation are increasing which is likely to further affect vegetation integrity of the small wetland.	100	-1
Overall weighted change score			-1

The overall weighted impact score obtained for this small wetland is 5.9 and translates into a D category for Present Vegetation State (Table 4.8). Further deterioration is expected in the face of increased reliance by the community on the wetland for cropping and sustained grazing pressure during winter months. The current vegetation health of the wetland is therefore represented as D (↓).

APPENDIX 4.1: Invasive alien plant species commonly found in wetlands

A huge range of alien invasive species occurs across the South African landscape. The prevalence of particular species varies geographically and it is therefore important that assessors become familiar with and are able to identify alien invasive plants within the area in which they are working. A brief list of some of the common invasive alien species found in summer and winter rainfall areas in South Africa is presented in Table 4.13. These species are classified according to their hydric status (Table 4.14).

Table 4.13: Invasive alien plant species commonly found in wetlands in the summer (S) and winter (W) rainfall areas of South Africa

Scientific name	Common name	Region	Hydric status (see Table 4.15)
Terrestrial Species			
Caesalpinia decapetala	Mauritius thorn	S	fd
Chromolaena odorata	Triffid weed	S	fd
Glyceria maxima	Great mann grass	S	o
Japonicum sp.	Privet	S	fd
Pinus elliotti	Slash pine	S	f
Psidium guajava	Guava tree	S	fd
Rubus cuneifolius	American bramble	S	fd
Salix fragilis	Crack willow	S	fw
Sambucus racemosa	Elderberry	S	f
Schinus terebinthifolius	Brazilian pepper tree	S	f
Senna sp.	Cassia	S	fd
Acacia baileyana	Bailey's wattle	W	fd
Acacia dealbata	Silver wattle	W	fd
Acacia elata	Peppertree wattle	W	fd
Ageratina adenophora	Crofton weed	W	fd
Ageratum conyzoides	Invading argeratum	W & S	f
Arauja sericifera	Moth catcher	W	fd
Canna indica	Indian shot	W	f
Canna X generalis	Garden canna	W & S	f
Cirsium vulgare	Scotch thistle	W & S	fd
Cortaderia jubata	Purple pampas	W	fd
Cortaderia selloana	Pampas grass	W	f
Cuscuta campestris	Common dodder	W	fd
Hedychium coronarium	White ginger lilies	W	fd
Hypericum perforatum	St. John's wort	W	fd
Lolium rigidum	Rye grass	W	f
Lythrum salicaria	Purple loosestrife	W	f
Metrosideros excelsa	New Zealand Christmas Tree	W	fd
Paraseriasnthes lopantha	Stink bean	W	fw
Paspalum distichum	Water couch grass	W & S	fw

Paspalum vaginatum	Brak paspalum	W	fw
Ricinus communis	Castor-oil plant	W & S	fd
Rosa rubiginosa	Eglantine, sweetbriar	W	fw
Rubus fruiticosus	European bramble	W	fd
Syzigium paniculatum	Australian water pear	W	fd
Acacia longifolia	Long leafed wattle	W & S	f
Acacia mearnsii	Black wattle	W & S	fd
Acacia melanoxylon	Black wood	W & S	fd
Arundo donax	Spanish reed	W & S	f
Lantana camara	Lantana	W & S	fd
Melia azedarach	Syringa	W & S	fd
Paspalum dilatatum	Common paspalum / Dallis grass	W & S	fw
Paspalum urvillei	Giant paspalum / Vasey grass	W & S	fw
Pennisetum purpureum	Napier fodder	W & S	fd
Populus canescens	Grey poplar	W & S	fw
Salix babylonica	Weeping willow	W & S	fw
Sesbania punicea	Red sesbania	W & S	fw
Solanum mauritianum	Bug weed	W & S	fd
Aquatic Species			
Alternanthera philoxeroides	Alligator weed	W	o
Azolla filiculoides	Red water fern	W & S	o
Azolla pinnata	Red water fern	W & S	o
Eichornia crassipes	Water hyacinth	W & S	o
Myriophyllum aquaticum	Parrot's feather	W & S	o
Nasturtium officinale	Watercress	W & S	o
Pistia stratiotes	Water lettuce	W & S	o
Salvinia molesta	Salvinia	W & S	o

While these listed invasive alien plants are generally favoured by disturbance, they also readily invade areas that have not been disturbed. These plants are perennial and once they are well established they generally persist at the expense of the indigenous vegetation.

The annual species are generally only abundant in the first year or two following a disturbance. However, the perennial species may take longer to reach their greatest abundance and often continue to persist, particularly where they provide tall and dense cover to the exclusion of other species.

Table 4.14: Classification of plants according to occurrence in wetlands, based on U.S. Fish and Wildlife Service Indicator Categories (Reed, 1988)

Obligate wetland species	o	Almost always grow in wetlands (>99% of occurrences)
Facultative wetland species	fw	Usually grow in wetlands (67-99% of occurrences) but are occasionally found in non-wetland areas
Facultative species	f	Are equally likely to grow in wetland and non-wetland areas (34-66% of occurrences)
Facultative dryland species	fd	Usually grow in non-wetland areas but sometimes grow in wetlands (1-34% of occurrences)
Dryland species	d	Almost always grow in drylands (>99% of occurrences)

APPENDIX 4.2: Ruderal species common to wetlands

Ruderal species are typically species that are adapted to rapidly colonized areas with disturbed soils (e.g. in cultivated lands). As such, these species typically increase in abundance in response to disturbance, but are gradually replaced by later successional species as a site recovers. As with alien plants, specific species vary in their hydric status and occurrence between different geographic areas (Table 4.15).

Table 4.15: Some weedy (ruderal) species commonly found in wetlands in the summer rainfall areas of South Africa

Species	Common Name	Region	Hydric status	Alien	Annual/ perennial
Ageratum conyzoides	Blue weed	S	fd	A	
Agrimonia procera	Agrimony	S	fd	A	P
Agrostis eriantha		S	fw		P
Ambrosia artemisiifolia	Common ragweed	S	fd	A	P/A
Asclepias physocarpa	Milkweed	S	fd	A	A
Cardiospermum halicacabum	Balloon vine	S	fd	A	A
Conyza albida	Fleabane	S	fd	A	A
Conyza bonariensis	Flaxpleaf fleabane	S	fd		A
Eriochloa meyeriana	Black footed Water grass	S			
Glinus lotoides	Lotus sweetjuice	S	fd		A
Gnaphalium pensylvanicum	Gnaphalium	S	f	A	A
Helichrysum cooperi	Yellow Everlasting	S	fd		P
Heliotropum indicum	Indian heliotrope	S			A
Heliotropum ovalifolium	Grey leaf heliotrope	S			
Oenothera rosea	Rose evening-primrose	S	fw		P/A
Oxalis obliquifolia	Sorrel	S	fd	A	P
Persicaria hydropiper *	Waterpepper	S	w		A
Phalaris arundinaceae	Reed canary grass	S	w	A	P
Physalis viscose	Wild gooseberry	S	fd	A	P
Rumex crispus	Curly dock	S	fw	A	P
Setaria pallide-fusca	Garden bristle grass	S	fd		A
Sida alba	Spiny sida	S	fd		P/A
Sorghum bicolour	Common wild sorghum	S	fd	A	P/A
Verbena bonariensis	Purpletop vervain	S	fd	A	A
Bidens formosa	Cosmos	S & W	fd	A	A
Bidens pilosa	Common blackjack	S & W	fd	A	A
Centella asiatica	Waternael	S & W	fw	A	P
Circium vulgare	Scotch thistle	S & W	fd	A	A
Commelina africana	Wandering Jew	S & W	fw		P
Commelina bengalensis	Benghal Dayflower	S & W	fw		P
Cyperus dives	Mat sedge	S & W	w		P
Cyperus esculentus	Yellow flowered watergrass	S & W	fd	A	P

Cyperus rotundus	Purple watergrass	S & W	fd	A	P
Eragrostis curvula	Weeping Love Grass	S & W	fd		P
Eragrostis plana	Fan lovegrass	S & W	fd/fw		P
Eragrostis planiculmis	Broom lovegrass	S & W	w		P
Hibiscus trionum	Flower of an hour	S & W	fd	A	A
Holcus lanatus	Common velvetgrass	S & W	fw		P
Hyparrhenia dregeana	Silky thatching grass	S & W	f		P
Imperata cylindrica	Cottonwool grass	S & W	w		P
Ipomea purpurea	Morning glory	S & W	fd	A	A
Ischaemum fasciculatum	Red vlei grass	S & W	w		P
Juncus effusus	Soft rush	S & W	w		P
Juncus tenuis	Wire rush	S & W	w	A	P
Leersia hexandra *	Southern cutgrass	S & W	w		P
Mariscus congestus		S & W	fw		P
Oxalis corniculata	Creeping woodsorrel	S & W	fd	A	P
Panicum maximum	Guinea grass	S & W	d		P
Panicum schinzii	Sweet buffalo grass	S & W	fw		A
Paspalum distichum *	Couch paspalum	S & W	w	A	P
Persicaria aviculare	Knotgrass	S & W	w		P/A
Persicaria lapathifolia *	Pale persicaria	S & W	w		A
Plantago spp	Plantain	S & W	fd	A	P
Pseudognaphalium luteo-album	Jersey cudweed	S & W	fd	A	A
Pycreus polystachyos	Field sedge	S & W	w		P
Ranunculus multifidus	Wild buttercup	S & W	w		P
Ricinus communis	Castorbean	S & W	fd	A	P
Rumex acetosella	Common sheep sorrel	S & W	fw		P
Setaria sphacelata	Common bristle grass	S & W	f		P
Sorgum halapense	Johnson grass	S & W	fd	A	P
Tagetes minuta	Khaki weed	S & W	fd	A	A
Xanthium strumarium	Large cockleburr	S & W	fd	A	A
Ageratina adenophora	Crofton weed	W	fd	A	P
Aizoon canariense		W	fd		A-P
Arauja sericifera	Moth catcher	W	fd	A	?
Centella eriantha		W	fw		P
Cerastium capense	Horingblom	W	f		A
Chenopodium album		W	fw	A	A
Chenopodium ambrosioides		W	f	A	A
Conium chaerophylloides		W	fw		biennial
Conyza pinnata		W	f		P
Conyza pinnatifida		W	f		P
Conyza scabrida		W	fd		P

Echinochloa crusgalli	Barnyard millet	W	o	A	A
Eragrostis cilianensis	Stinkgrass	W	fw		A
Gnaphalium gnaphalodes		W	fw		P
Heliotropium curassavicum		W	o	A	A-P
Heliotropium supinum		W	o	A	A
Leysera tenella	Vaalteebossie	W	fw		A-P
Lolium rigidum	Rye grass	W	f	A	A
Paraseriasnthes lopantha	Stink bean	W	fw	A	P
Phalaris aquatica	Towoomba canary grass	W	fw	A	P
Phalaris minor	Small canary grass	W	f	A	A
Phyllopodium bracteatum Benth.		W	f		A
Phyllopodium cuneifolium		W	f		A
Polypogon monspeliensis	Brakbaardgrass	W	f	A	A
Pucinellia angusta	Vinkbrakgrass	W	f		P
Pucinellia distans		W	f	A	P
Pucinellia fasciculata		W	f	A	P
Ranunculus muricatus	Spiny-fruited buttercup	W	f	A	A
Setaria verticillata	Bur bristle grass	W	fd	A	A
Spergularia media	Perennial sea spurrey	W	fw	A	P
Vulpia bromoides	Squirrel tail fescue	W	fw	A	A
Vulpia myuros	Rats tail fescue	W	fw	A	A

Those species marked with an * are well adapted to colonising shallow open water areas, even where soil disturbance is entirely lacking.

APPENDIX 4.3: Common invasive indigenous plant species in wetlands

While introduced and invasive plants generally have the most obvious impact on wetland vegetation, there are also a variety of indigenous species that tend to increase in abundance in response to disturbance events. Some common species are listed in Table 4.16, along with brief notes outlining some of the common factors affecting their abundance.

It is important to stress that these species, especially *Typha capensis* and *Phragmites australis* occur naturally across many wetlands in South Africa, and many wetland areas are naturally dominated by a single species (e.g. *Phragmites australis*). In the permanently wet portions of a wetland, where only species tolerant of intense waterlogging are able to grow, it is common to find a single species naturally dominating, and pollen analyses from wetland sediment strata show that some wetlands have been dominated naturally by species such as *Phragmites australis* for thousands of years.

Table 4.16: Invasive indigenous plants commonly found in South African wetlands (see Table 4.14 and Appendix 4.1 for a description of different hydric statuses)

Species	Hydric status	Notes
Typha capensis	w	Favoured by increased nutrients, stabilized and increased wetness and/or increased disturbance
Phragmites australis	w	Favoured increased nutrients, stabilized and increased wetness, increased sediment deposition and/or increased disturbance
Phragmites mauritianus	w	Appears to be favoured by increased disturbance and/or increased sediment deposition
Leucosidea sericea	fd	Favoured by exclusion of fire and/or wetland desiccation.
Pteridium aquilinum	fd	Favoured disturbance/or and exclusion of fire

SECTION 5: LEVEL 1 ASSESSMENT MODULE

Introduction

In situations where the time and resources available for a Level 2 wetland assessment are limited, a more rapid approach is required to obtain some understanding of wetland impacts and health. The Level 1 assessment module makes provision for such scenarios by limiting the information and time required to undertake an assessment. A simplified procedure of this nature places more onus on the assessor to make judgment calls on the impacts of various activities and processes on the wetland. As such, it is important that the assessor be familiar with all of the concepts and detail of a Level 2 assessment (e.g. features of artificial drains that potentially contribute to their desiccating impact on a wetland).

The Level 1 procedure follows the same basic approach as the Level 2 assessment but at a lower level of detail. Its use is most appropriate where a large number of wetlands need to be assessed at a low resolution. The procedure for conducting a Level 1 assessment is outlined in Figure 5.1 below.

STEP 1: Divide the wetland into HGM units

In a Level 1 assessment, identifying HGM units is generally based mainly on aerial photographic interpretation with some field verification. As in a Level 2 assessment, the imagery used should be of a high quality and ideally at a scale of 1: 10 000 or higher. Any imagery of a scale less than 1: 30 000 would not be acceptable. As with the Level 2 assessment, users should be cautioned not to overcomplicate the assessment

Step 1: Divide the wetland into HGM units

↓

Step 2: Assess hydrological health of the wetland
- Step 2A: Evaluate changes to water input characteristics from the catchment
- Step 2B: Evaluate changes to water distribution & retention patterns within the wetland
- Step 2C: Determine the hydrological impact score of the HGM unit based on integrating the assessments from steps 2A and 2B
- Step 2D: Determine the overall Present Hydrological State of the wetland based on integrating scores from individual HGM units
- Step 2E: Assess the anticipated Trajectory of Change of the wetland hydrology

↓

Step 3: Assess geomorphological health
- Step 3A: Determine the Present Geomorphic State of the individual HGM units
- Step 3B: Determine the overall Present Geomorphic State of the wetland based on integrating scores from individual HGM units
- Step 3C: Assess the anticipated Trajectory of Change of the geomorphology of the overall wetland

↓

Step 4: Assess vegetation health of the wetland
- Step 4A: Familiarisation with the general structure and composition of wetland vegetation in the area
- Step 4B: Identify and estimate the extent of disturbance classes
- Step 4C: Assess the changes to vegetation composition in each class, and integrate these for the overall HGM unit
- Step 4D: Determine the overall Present Vegetation State based on integrating scores from individual HGM units.
- Step 4E: Assess the anticipated Trajectory of Change of wetland vegetation

↓

Step 5: Represent the health scores for the overall wetland

Figure 5.1: An outline of the steps involved in the Level 1 assessment.

by subdividing the wetland into too many HGM units unless this makes good practical sense. Once HGM units have been defined, they form the basis for further assessment.

STEP 2: Assess Hydrological Health of the wetland

Changes in hydrology are evaluated by assessing (a) changes to water input volumes and pattern (effects of alteration in the upstream catchment), and (b) changes to the water distribution and retention patterns of water passing through the wetland (effects of on-site alterations).

Step 2A: Evaluate changes to water input characteristics from the catchment.

Land use activities within the HGM unit's upstream catchment can affect both the volume of water inputs and the pattern of flood peaks. Both an increase and a reduction in water inputs are evaluated by assessing the type of land use activities in the catchment and assigning an alteration class from Table 5.1. Land-use activities associated with reduction that should be considered include abstraction for irrigation and other purposes, alien plant invasion, forestry and evergreen crop production and dams regulating stream flow. Land-use activities increasing flow are usually associated with discharge from sewage or inter-basin transfer of water.

Table 5.1: Guideline for assessing the reduction and increase in water inputs as a result of catchment activities

Reduced flows	
Alteration Classes	Description
Negligible (0 to -0.9)	None or negligible reduction in flow
Small (-1 to -1.9)	Identifiable but small reduction in flows (e.g. 5% of the catchment under plantation forestry or 2% of the catchment irrigated with good conservation measures being applied)
Moderately small (-2.0 to 3.9)	Moderately small reduction in flows (e.g. 20% of the catchment under plantation forestry, with trees outside of riparian areas or 10% of the catchment irrigated with good conservation measures being applied)
Intermediate (-4 to -5.9)	Intermediate reduction in flows (e.g. approximately 40% of the HGM's catchment under plantation forestry, with trees outside of riparian areas)
Moderately large (-6 to -7.9)	Moderately large reduction in flows (e.g. approximately 55% of catchment planted with eucalyptus trees)
Large (-8 to -9)	Large reduction in flows (e.g. approximately 70% of catchment planted with eucalyptus trees)
Very large (>-9)	Very large reduction in flows, usually >75% reduction (e.g. entire catchment completely planted with eucalyptus trees or a very high level of abstraction of water from the catchment for irrigation)
Increased flows:	
Alteration Classes	Description of the level of increase
> 9	Additional flows are more than equal to the natural situation (e.g. as a result of an inter-basin transfer scheme or major discharge from sewage treatment plants).
4-9	Additional flows are approximately equal to the natural situation (e.g. as a result of moderate discharge from a sewage treatment plant); i.e. if there are no factors reducing flows then the natural flows will be doubled.
1-3.9	Additional flows are approximately a third of the natural situation (e.g. as a result of minor discharge from a sewage treatment plant).
0-0.9	No increase, or flow is increased by a negligible amount.
Alteration Classes (Combined score: **Increased flows score + Decreased flows score)**	**Description of land-use factors influencing water inputs**

Table 5.2: Level of alteration of the natural pattern of floods delivered to the HGM unit

Alteration Classes	Description
Large increase (>6)	Flood peaks have been increased substantially, resulting in a marked reduction in sub-surface water inputs.
Moderate increase (4 to 6)	Flood peaks have been increased moderately, often resulting in a noticeable reduction in sub-surface water inputs.
Small increase (1.6 to 3.9)	Discernable but small increase in flood peaks that may not necessarily have resulted in a discernable reduction in sub-surface water inputs.
No effect (-1.5 to 1.5)	No discernable effect on flood peaks.
Small decrease (-1.6 to -3.9)	Discernable but small reduction in flood peaks.
Moderate decrease (-4 to -6)	Flood peaks have decreased moderately.
Large decrease (<-6)	Flood peaks greatly reduced, such that in the case of a floodplain, no further flooding out of the main channel across the wetland takes place unless in major floods (i.e. >1 in 20 year flood events).
Alteration class	Land-use factors contributing to impacts, and any additional notes

Changes in flood peaks are generally associated with either dams (reduction) or reduced infiltration associated with hardened or eroded areas in the catchment (increase). This impact is scored by assigning an alteration class from Table 5.2.

The magnitude of these alterations on water inputs is affected by the HGM type, with floodplain and channelled valley bottom wetlands being most sensitive to reduced flood peaks and the other HGM units being most sensitive to reduction in input volumes. Table 5.3 is used to combine the scores obtained from Tables 5.1 and 5.2 into a single impact score, while also accounting for differences amongst HGM units.

Table 5.3: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of hydro-geomorphic type, altered quantity of water inputs and the altered pattern of water inputs.

(a) Floodplains and channelled valley bottoms driven primarily by over-bank flooding

Change in quantity of **water inflows (Score** from Table 5.1)	**Alteration to floodpeaks (Score from Table 5.2)**						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	7	6	5	4	5	6	7
4 to 9	5	4	3	3	4	6	7
1 to 3.9 (Increase)	3	2	1	1	2.5	4.5	7
-0.9 to +0.9 (Negligible)	1	1	0	0	1	5	7.5
-1 to -1.9 (Decrease)	2	1.5	1	1	2.5	5	7.5
-2 to -3.9	3	2.5	2	2	4	6	8
-4 to -5.9	4	3.5	3	3	5	7	8.5
-6 to -7.9	-**	-**	-**	4	6	8	9
-8 to -9	-**	-**	-**	-**	-**	9	9.5
< -9	-**	-**	-**	-**	-**	-**	10

(b) Other hydro-geomorphic settings, including floodplains and channelled valley bottoms driven primarily by lateral inputs (e.g. from tributaries)

Change in quantity of **water inflows (Score** from Table 5.1)	**Alteration to floodpeaks (Score from Table 5.2)**						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	6	5	4	3	3	3.5	4
4 to 9	4.5	4	3	2	3	3	3
1 to 3.9 (Increase)	3	2	1	1	1	2	2.5
-0.9 to +0.9 (Negligible)	2.5	1.5	0.5	0	0.5	1	1.5
-1 to -1.9 (Decrease)	3.5	2.5	1.5	1	1.5	2	2.5
-2 to -3.9	4.5	3.5	2.5	2	2.5	3	3.5
-4 to -5.9	6	5	4	3.5	4	4.5	5
-6 to -7.9	-**	-**	-**	5	5.5	6	6.5
-8 to -9	-**	-**	-**	-**	-**	7.5	8
< -9	-**	-**	-**	-**	-**	-**	10

**These classes are unlikely, given that when there is a high level of reduction of quantity of inputs then there would be insufficient water to maintain unaltered or increased floodpeaks (i.e. a decrease in floodpeaks would be inevitable).

Magnitude of impact	Any additional notes

Step 2B: Evaluate changes to water distribution and retention patterns within the wetland

Human activities within wetland systems may also substantially alter hydrological characteristics of wetland systems. A common suite of impacts are outlined in Table 5.4 and are used as the basis for evaluating the impact of these activities on the movement and retention patterns of water within the wetland. This is done by estimating the extent (%) of the wetland affected by each activity (Table 5.4, column 2), estimating an intensity score associated with the affected area (Tables 5.5 to 5.11) and using these two figures to calculate a magnitude score, which represents the effect of the impact when averaged across the entire HGM unit. These scores are then summed to obtain a combined impact magnitude score for the entire HGM unit.

Table 5.4: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of the extent and intensity of different on-site impacts

Type of modification	Extent (%)[1]	Intensity of impact	Magnitude[2]	Land-use factors contributing to impacts, and any additional notes
Gullies and artificial drainage channels		See Table 5.5		
Modifications to existing channels		See Table 5.6		
Reduced roughness		See Table 5.7		
Impeding features (e.g. dams) – upstream effects		See Table 5.8		
Impeding features – downstream effects		See Table 5.9		
Increased on-site water use		See Table 5.10		
Deposition/infilling or excavation		See Table 5.11		
Combined hydrology impact score[3]				

[1] Extent refers to the extent of the HGM unit affected by the modification expressed as a percentage of the total area of the HGM unit
[2] Magnitude = Extent /100 x Intensity
[3] Calculated as the sum of magnitude scores across all modifications

Table 5.5: Guideline for assessing the intensity of impact of erosion gullies and artificial drainage channels on the affected area of the HGM unit

Intensity of impact	Impact category description
None (0.5)	While drainage channels or gullies may be present, they are having no readily discernible impact on water distribution and retention (e.g. because they are completely blocked).
Small (1.5)	Although identifiable, the impact of drainage channels or gullies on water distribution and retention is small (e.g. because the drains are poorly intercepting flow and are very shallow)
Moderate (3)	The impact of drainage channels or gullies on water distribution and retention is moderate (e.g. owing to a moderate density and depth of drains and a gentle slope and fine texture of soil that limit the draining effect).
Large (5)	The impact of drainage channels or gullies on water distribution and retention is large (e.g. because the drain density is high but the moderate depth of the drains and/or the fine texture and gentle slope of the wetland prevent the impact from being serious or critical).
Serious (7)	The impact of drainage channels or gullies on water distribution and retention is serious (e.g. because the drain density is high, drains are deep and very effectively intercept flow through the wetland, but one or more features are present (e.g. fine texture of soil) that prevents the impact being critical).
Critical (9)	The impact of drainage channels or gullies on water distribution and retention is critical (e.g. because the drain density is high, drains are deep and very effectively intercepting flow through the wetland and no features are present which may be limiting the draining effect of the channels.

Factors affecting intensity of impact of artificial drainage channels include:

- Natural features of the site, including the lower the MAP: PET ratio, the steeper the wetland slope and the coarser the texture of the wetland soil, the greater the intensity of impact of any artificial drains present.
- Features of the drains, including: the deeper the drains, the denser the drains, the greater the flow interception by the drains, and the lower the obstructions in the drains, the greater the intensity of impact.
- See Section 2, Step 3A for further guidance if necessary.

Table 5.6: Guideline for assessing the intensity of impact of modifications to an existing channel on the affected area of the HGM unit

Intensity of impact	Impact category description
None (0.5)	No discernible modifications to the natural stream channel.
Small (1.5)	Although identifiable, the impacts of any modifications to the natural stream channel are small (e.g. as a result of slight increase in cross sectional area, decrease in stream length or reduction in surface roughness of the channel).
Moderate (3)	Modifications to the natural stream channel have a moderate impact (e.g. as a result of an intermediate increase in cross sectional area, decrease in stream length or an intermediate reduction in surface roughness of the channel; usually with a low to intermediate dependency of the HGM unit on bank overspill).
Large (5)	Modifications to the natural stream channel have a large impact (e.g. as a result of a moderately high increase in cross sectional area or decrease in stream length or an intermediate to high dependency of the HGM unit on bank overspill).
Serious (7)	Modifications to the stream channel have a serious impact (usually a result of a combination of high modification to 2 or 3 of the factors or a considerable increase in cross sectional area) but some overtopping probably still occurs, although much less frequently than was the case naturally. There should be a high dependency of the HGM unit on bank overspill.
Critical (9)	Modifications to the natural stream channel have a critical impact (i.e., modifications are so great that no over-topping of the channel ever takes place; and with a high dependency of the HGM unit on bank overspill).

Factors affecting the intensity of impact of channel modifications include:

- Dependency of the HGM unit on bank overspill from the channel rather than from lateral inputs
- Extent to which bank overspill is reduced, which is determined by the following three factors given in order of importance: stream cross sectional area, stream length and surface roughness in the stream channel.
- See Section 2, Step 3A for further guidance if necessary.

Table 5.7: Guideline for assessing the intensity of impact of altered surface roughness on the affected area of the HGM unit

Intensity of impact	Impact category description
None (0.5)	No readily discernible impact on surface roughness.
Small (1.5)	Although identifiable, the decrease in roughness is low (e.g. a change from robust sedges of intermediate height (0.5-1 m) to short vegetation (e.g. rye grass) with only a minor impact on water retention).
Moderate (3)	The decrease in roughness is moderate (e.g. a change from tall, robust vegetation (e.g. phragmites reeds) to short vegetation resulting in a clear reduction in water retention).
Large (5)	The decrease in roughness is high (e.g. a change from tall very robust vegetation (e.g. dense swamp forest) to short vegetation resulting in a marked decrease in water retention).

- See Section 2, Step 3C for further guidance if necessary.

Table 5.8: Guideline for assessing the intensity of impact of flow-impeding structures on the affected (flooded) area upstream of the impeding feature

Intensity of impact	Impact category description
None (0.5)	No readily discernible impact on water distribution and retention (e.g. because many culverts present to allow free flow of water)
Small (1.5)	Discernable but small increase in saturation from flooding with seasonal and permanent zones both present and collectively >30% in the flooded area prior to modification.
Moderate (3)	Moderate increase in saturation from flooding with permanent and seasonal zones both present but collectively <30% in the flooded area prior to modification.
Large (5)	Large change in saturation associated with areas where seasonal zone is present but the permanent zone was absent prior to flooding.
Serious (7)	Serious change in saturation associated with wetland areas of temporary wetness i.e. permanent and seasonal zones were lacking prior to flooding.

- See Section 2, Step 3B for further guidance if necessary.

Table 5.9: Guideline for assessing the intensity of impact of flow-impeding structures on the affected area downstream of the impeding feature

Intensity of impact	Impact category description
None (0.5)	No readily discernible impact on water distribution and retention (e.g. because many culverts present to allow free flow of water). Saturation levels remain largely unaltered.
Small (1.5)	Discernable reduction in saturation, but impact is small (e.g. the volume of storage upstream of feature is small relative to MAR and no abstraction takes place from the stored water).
Moderate (3)	Reduction in flow and saturation is moderate (e.g. the volume of storage upstream of the impeding feature is moderate relative to MAR and low abstraction takes place from the stored water).
Large (5)	Reduction in flow and saturation is large (e.g. the volume of storage upstream of impeding feature is large relative to MAR and moderate abstraction takes place from the stored water).
Serious (7)	Reduction in flow and saturation is serious (e.g. the volume of storage upstream of impeding feature is large relative to MAR and high abstraction takes place from the stored water). This results in considerable desiccation of the downstream wetland area.

- See Section 2, Step 3B for further guidance if necessary.

Table 5.10: Guideline for assessing the intensity of impact of direct water losses[1] on the affected area of the HGM unit

Intensity of impact	Impact category description
None (0.5)	Although there may be a change from the natural vegetation, there is no discernable impact.
Small (1.5)	Although identifiable, only minor desiccation occurs (e.g. because plants with a moderately higher water use than the natural vegetation have been introduced into the affected area of the HGM).
Moderate (3)	The impact causes moderate change in wetness regimes in the affected area (e.g. because plants with a moderately higher water use than the natural vegetation dominate the affected area of the HGM unit).
Large (5)	The impact causes significant change in wetness regimes in the affected area (e.g. because plants with a much higher water use than the natural vegetation occur extensively in affected area of the HGM unit, but do not completely dominate the unit, or water abstraction from the unit is moderately high).
Serious (7)	The impact causes a major change in wetness regimes in the affected area (e.g. because plants with a much higher water use than the natural vegetation dominate the affected area or water abstraction from the affected area of the unit is very high).

[1] This excludes direct losses from evaporation from a dam, which would be covered under the impacts from impeding features (Table 5.8)

- See Section 2, Step 3D for further guidance if necessary.

Table 5.11: Guideline for assessing the intensity of impact of recent deposition/infilling or excavation on the affected area of the HGM unit

Intensity of impact	Impact category description
None (0.5)	While some signs of deposition or excavation may be present there are no readily discernible impacts on water distribution and retention.
Small (1.5)	Although identifiable, minor changes to water flow patterns and wetness regimes are apparent (e.g. because flow is concentrated very slightly).
Moderate (3)	The impact is moderate with clear changes in flow patterns and wetness regimes (e.g. owing to the deposition/ infill being somewhat freely drained or concentrating flow to a moderate degree).
Large (5)	The impact causes a large change in flow patterns and wetness regimes (e.g. owing to the deposition/ infill being somewhat freely drained or concentrating flow to a large degree).
Serious (7)	The impact causes a serious change in flow patterns and wetness (e.g. owing to the deposition/ infill being well drained or concentrating flow to a high degree, but some slight wetland hydrological features are distinguishable at the surface).
Critical (9)	The modifications result in a near complete change in wetland hydrological processes (e.g. owing to the deposition/ infill being deep (>1 m) and very well drained to the extent that that no wetland hydrological features are present on the surface and the “wetland” is effectively completely buried).

Factors affecting the intensity of impact of channel modifications include:

- Vertical drainage properties of the uppermost soil layer, with the more free draining the soil becomes, the greater the impact.
- Horizontal movement of water, with the greater the concentration of flow, the greater the impact.
- See Section 2, Step 3E for further guidance if necessary.

Step 2C: Determine the hydrological impact score of the HGM unit based on integrating the assessments from Steps 2A and 2B

This assessment is based on the joint consideration in Table 5.12 of the impacts on catchment inputs (assessed in Step 2A) and the impacts of on-site activities on water distribution and retention patterns in the wetland (assessed in Step 2B). The score obtained reflects the hydrological impact score for the HGM unit evaluated.

Table 5.12: Derivation of magnitude of impact scores by combining scores obtained from catchment and within-wetland assessments

			Water Inputs (score from Table 5.3)					
			None	Small	Moderate	Large	Serious	Critical
			0-0.9	1-1.9	2-3.9	4-5.9	6-7.9	8-10
Water distribution & retention patterns(score from Table 5.4)	None	0-0.9	0	1	3	5	6.5	8.5
	Small	1-1.9	1	2	3.5	6	7	9
	Moderate	2-3.9	3	3.5	4	6.5	7.5	9
	Large	4-5.9	5	6	6.5	7	8	9.5
	Serious	6-7.9	6.5	7	7.5	8	9	10
	Critical	8-10	8.5	9	9	9.5	10	10

Combined magnitude of impact of catchment and within-wetland effects	Any additional notes

Step 2D: Determine the overall Present Hydrological State of the wetland based on integrating scores from the individual HGM units

The Present Hydrological State is summarised for hydrology at the end of this module (Step 5). This is done by calculating the overall magnitude of hydrological impacts for the wetland as a whole based on the area weighted average of the HGM units in the wetland (Table 5.25). For example, if HGM unit 1 comprising 40% of the wetland had a score of 4, and HGM unit 2 comprising 60% of the wetland had a score of 7, then the weighted average score would be (4 x 40/100) + (7 x 60/100) = 5.8. All that remains is to establish into which health category the wetland falls based on its hydrological impact score (Table 5.26). The above wetland example would be a D.

Step 2E: Assess the anticipated Trajectory of Change of the wetland hydrology

The final step is to determine the probable Trajectory of Change of the wetland's hydrological integrity and present the results in Table 5.25. This is done by first assigning a change score to each HGM unit (by referring to the first three columns of Table 5.27). Remember that the hydrology of an HGM unit may be threatened by changes in the catchment (e.g. increased levels of water abstraction) and changes in the wetland (e.g. the further advance through the wetland of an erosion gully, which increases the desiccation of the system). Next, calculate an area-weighted change score for the entire wetland, and then assign the final Trajectory of Change symbol by referring to columns 4 and 5 of Table 5.27. Record the individual HGM unit change scores and weighted average in Table 5.25, which summarises the health of the wetland.

Take for example, HGM unit 1, comprising 40% of the wetland, which is considered likely to improve and is therefore assigned a score of "1" and HGM unit 2, comprising 60% of the wetland, which appears to be deteriorating substantially over the next 5 years and is therefore assigned a score of -2. The weighted average of this would be (1 x 40/100) + (-2 x 60/100) = -0.8, which according to column 4 and 5 of Table 5.27 would be assigned a symbol of (↓) because it falls in the range -0.3 to -1.0. The overall Hydrological Health of the example wetland given in Step 2D would therefore be represented as D (↓).

STEP 3: Assess Geomorphic Health of the wetland

Step 3A: Determine the Present Geomorphic State of the individual HGM units

The assessment of geomorphic integrity is conducted as a

- diagnostic assessment that considers factors affecting geomorphological integrity, followed by an
- indicator-based assessment that considers the visible indicators of reduced geomorphic integrity.

These assessments are combined to provide an overall assessment of impacts and Present Geomorphic State score. Vulnerability and threat of erosion are assessed to provide a measure of the likely Trajectory of Change and this is combined with Present Geomorphic State to give overall Geomorphic Health.

Diagnostic assessment

Different HGM types vary according to their susceptibility to different impacts (Table 5.13, column 2). Floodplains, for example, are susceptible to the first three impact types listed. The impact assessment is therefore dictated by the type of HGM unit being assessed.

Table 5.13: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of different on-site impacts

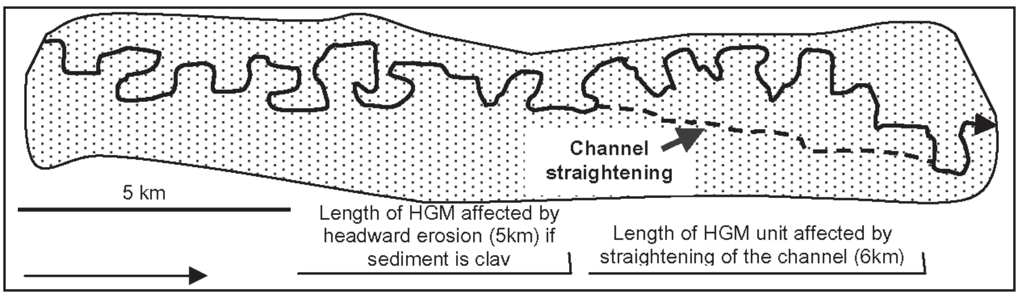
Impact type	Applicability to HGM type	Extent (%)[1]	Intensity of Impact	Magnitude[2]	Land-use factors contributing to impacts, and any additional notes
Diagnostic component					
1. Upstream dams	Floodplain	See below [3]	See Table 5.14		
2. Stream diversion/ shortening	Floodplain, Channelled valley bottom	See below [4]	See Table 5.15		
3. Infilling	Floodplain, Channelled valley bottom	See below [5]	See below[5]		
4. Increased runoff	Non-floodplain HGM units	See Table 5.16	See Table 5.16		
Indicator-based assessment					
5. Erosional features	All non-floodplain HGM units	See Table 5.17	See Table 5.18		
6. Depositional features	All non-floodplain HGM units	See Table 5.19	See Table 5.20		
7. Loss of organic matter	All non-floodplain HGM units with peat	See below [6]	See Table 5.21		
Combined impact score based on a sum of all magnitude scores					

1 Extent refers to the extent of the HGM unit affected by the modification, expressed as a percentage of the total area of the HGM unit.

2 Magnitude = Extent (%)/100 x Intensity.

3 Extent is determined based upon the area of the HGM unit that is flooded (in the case of a dam in the HGM unit) and the area of the HGM unit area downstream of the dam (for a dam upstream of the HGM unit, this will be 100% of the HGM unit).

4 Extent of area affected by stream straightening is expressed by measuring the length of the wetland affected by stream straightening and expressing this as a percentage of the overall length of the HGM unit. Extent of the wetland affected by stream diversions is determined based upon a distance upstream of the point of diversion along the channel of 20 km if the sediment is sandy and 5 km if it is clayey (or to the upstream end of the HGM unit if this is less than the specified distance). The specified distances are given based on the fact that headward erosion in the stream channel advances much more readily through sand than through clay. Assume that in the example given below the sediment was clayey, then the length of wetland affected by diversion and straightening would be 5 + 6 km, which, expressed as a proportion of the total length of the wetland, would be 11/17 km= 65%.



5 Extent of area affected by infilling is based on the following guideline: for a small stream (i.e., 1st to 2nd order stream), filled area + 1 km upstream and downstream, and for a large stream (i.e. > 3rd order) 2 km upstream and downstream. Intensity of impact is based on the extent to which flow is blocked by embankments given as a percentage of the HGM unit width, divided by 10 to give a score ranging from 0 to 10. For example, if embankments block flow across 1.4 km of an HGM unit that is 2 km wide (70% of width) then intensity of impact is 70 ÷ 10=7.

6 Extent of the area affected by organic matter reduction is based on the extent of peat subject to desiccation, ground fires or extraction, expressed as a percentage of the HGM unit.

Dams above or on floodplains deprive the floodplain of sediment, with the extent of impact depending upon the location of the dams upstream of or on the floodplain and the intensity of impact depending upon the location of the dam/s and relationship between the size of the dam and mean annual discharge, as well as the nature of sediment being transported (Table 5.14).

Stream shortening leads to an increased stream slope that leads to headward erosion that extends upstream of the location of the impact. The degree of steepening is related to the degree of stream shortening (Table 5.15).

Table 5.14: Guideline for assessing the intensity of impact of upstream dams on the integrity of the affected area of the HGM unit

Intensity of impact*	Impact category description
None (0.5)	No discernible modification or the modification is such that it has no impact on wetland geomorphic integrity because dams are absent or very far upstream.
Small (1.5)	Although identifiable, the impact of this modification on geomorphic integrity of the affected area is small (e.g. a few small dams occur far upstream of the floodplain on a few tributaries interrupting the supply of sediment only slightly).
Moderate (3)	The impact of this modification on geomorphic integrity of the affected area is clearly identifiable, but limited (e.g. a few small dams occur a moderate distance upstream of the floodplain and therefore impact moderately on the supply of sediment).
Large (5)	The modification has a clearly detrimental impact on geomorphic integrity of the affected area. Approximately 50% of the integrity of the affected area has been lost (e.g. a large dam occurs a moderate distance from the floodplain still allowing significant introduction of sediment from tributaries entering between the dam and the end of the HGM unit).
Serious (7)	The modification has a clearly adverse effect on geomorphic integrity of the affected area. Well in excess of 50% of the integrity of the affected area has been lost (e.g. a large dam occurs a short distance upstream of the affected area such that a small amount of sediment is introduced by tributaries downstream of the dam).
Critical (9)	The modification is present in such a way that the geomorphic integrity of the affected area is almost totally destroyed (e.g. a large dam immediately upstream of the affected area and no sediment introduced by tributaries downstream of the dam).

* Intensity increases by a single class if the sediment being transported is largely bedload

Table 5.15: Guideline for assessing the intensity of impact of stream shortening on the integrity of the affected area of an HGM unit

Intensity of impact	Impact category description
None (0.5)	No discernible modification or the modification is such that it has no impact on wetland geomorphic integrity.
Small (1.5)	Although identifiable, the impact of this modification on geomorphic integrity of the affected area is small (e.g. the new stream course is 10% shorter than the natural course).
Moderate (3)	The impact of this modification on geomorphic integrity of the affected area is clearly identifiable, but limited (e.g. the new stream course is 20% shorter than the natural course).
Large (5)	The modification has a clearly detrimental impact on geomorphic integrity of the affected area. Approximately 50% of the integrity of the affected area has been lost (e.g. the new stream course is 50% shorter than the natural course)
Serious (7)	The modification has a clearly adverse effect on geomorphic integrity of the affected area. Well in excess of 50% of the integrity of the affected area has been lost (e.g. the new stream course is 70% shorter than the natural course)
Critical (9)	The modification is present in such a way that the geomorphic integrity of the affected area is almost totally destroyed (e.g. the new stream course is 90% shorter than the natural course).

Note: The score selected from this table (Table 5.15) applies to the area where the shortening takes place as well as to the affected area upstream, given that the greater the level of shortening, the greater will be the intensity of headward erosion upstream of the diversion.

08 WET - Health - Final for Prin129 129 24/07/2009 10:35:53 AM

Table 5.16: **Effect of increased water yield and floodpeaks on wetland geomorphological integrity**

Extent of impact of altered water inputs					
Extent (based on length of wetland affected by increased flow as a proportion (%) of the entire wetland length)					%
Intensity of impact of altered water inputs					
		Increased floodpeaks (score in Table 5.2)			
		No effect (0-2)	Small increase (2.1-4)	Moderate increase (4.1-7)	Large increase (>7)
Increased **flows (score** in Table 5.1)	No increase (0-2)	0	2	4	7*
	Small increase (2.1-4)	2	3	6	8
	Moderate increase (4.1-7)	4	6	8	9
	Large increase (>7)	7*	8	9	10
Magnitude of impact score: (extent of impact score /100) x intensity of impact score (from above rows)					

Increased water yield and flood peaks of water flowing into a wetland leads to increased capacity to transport sediment, and the intensity of impact is therefore related to the increased flood volumes (Table 5.16). Extent is calculated based on length of wetland affected by increased flow as a proportion (%) of the entire wetland length. Thus, if the entire wetland experiences increased water inputs, then extent is 100%.

Indicator-based assessment

The results from the indicator-based analysis should be recorded in Table 5.13. The extent of impact of gullies depends upon their number and overall width and length as depicted in Table 5.17. The intensity of impact depends upon gully depth, whether or not sediment is exported, and the extent of revegetation on the gully bed and side walls (Table 5.18).

Table 5.17: Estimation of extent of impact of erosional features in the wetland to be used in the calculation of magnitude of impact

		Length of wetland occupied by gully/ies as a percentage of the length of HGM unit				
		0-20%	21-40%	41-60%	51-80%	>80%
Average gully width (sum of gully widths if more than 1 gully present) in relation to wetland width	< 5%	5%	10%	15%	20%	25%
	5-10%	10%	15%	25%	35%	45%
	11-20%	15%	25%	40%	55%	65%
	21-50%	20%	30%	50%	70%	80%
	>50%	25%	40%	60%	80%	100%

Table 5.18: Guideline for assessing the intensity of impact of erosion gullies on the affected area of an HGM unit

Intensity of impact	Impact category description
None (0.5)	No discernible modification or the modification is such that it has no impact on wetland geomorphic integrity.
Small (1.5)	Although identifiable, the impact of this modification on geomorphic integrity of the affected area is small (e.g. gully 0.5 m, the sediment from the gully has been deposited in the HGM unit and the bed and sides of the gully are now well vegetated).
Moderate (3)	The impact of this modification on geomorphic integrity of the affected area is clearly identifiable, but limited (e.g. gully 1.0 m deep, most of the sediment from the gully has been deposited in the HGM unit and the bed and sides of the gully are now moderately vegetated).
Large (5)	The modification has a clearly detrimental impact on geomorphic integrity of the affected area. Approximately 50% of the integrity of the affected area has been lost (e.g. gully 1.5 m deep, the sediment from the gully has been deposited in the HGM unit and the bed and sides of the gully are poorly vegetated)
Serious (7)	The modification has a clearly adverse effect on geomorphic integrity of the affected area. Well in excess of 50% of the integrity of the affected area has been lost (e.g. gully 2.0 m deep, the sediment from the gully has been mainly exported from the HGM unit and the bed and sides of the gully are poorly vegetated).
Critical (9)	The modification is present in such a way that the geomorphic integrity of the affected area is almost totally destroyed (e.g. gully 4.0 m deep, the sediment from the gully has been mainly exported from the HGM unit and the bed and sides of the gully are completely un-vegetated).

Factors affecting the intensity of impact:
- Depth of the gully
- Extent of which material is exported from the HGM unit and wetland
- Extent to which vegetation is absent from the gully

Table 5.19: Estimation of the extent of depositional features in the wetland HGM unit

Extent of depositional features in relation to area of HGM unit being considered[R]	0.2-2%	2-10%	11-25%	25-50%	>50%
Score for 'extent' to be used in the estimation of magnitude of impacts	5%	20%	50%	75%	100%

Table 5.20: Guideline for assessing the intensity of impact of depositional features on the affected area of an HGM unit

Intensity of impact	Impact category description
None (0.5)	No discernible modification or modification is such that it has no impact on wetland geomorphic integrity.
Small (1.5)	Although identifiable, the impact of this modification on geomorphic integrity of the affected area is small (e.g. deposition confined to the margin and toe of the wetland).
Moderate (3)	The impact of this modification on geomorphic integrity of the affected area is clearly identifiable, but limited (e.g. deposition extending somewhat in from the margin).
Large (5)	The modification has a clearly detrimental impact on geomorphic integrity of the affected area. Approximately 50% of the integrity of the affected area has been lost (e.g. extends well into the wetland and has a large effect on wetland features)
Serious (7)	The modification has a clearly adverse effect on geomorphic integrity of the affected area. Well in excess of 50% of the integrity of the affected area has been lost (e.g. complete destruction of features and location in the head of the HGM unit).

Factors affecting the intensity of impact:
- Location along the length of the unit, with the head having the greatest impact followed by the middle and then the toe
- Extent of destruction of existing features, ranging from complete destruction to very limited destruction because confined to the margins.

The extent used to determine the impact of depositional features is based upon their aerial extent (Table 5.19) while intensity is affected by their location in the wetland (Table 5.20).

Table 5.21: Guideline for assessing the intensity of impact of loss of organic sediment on the affected area of an HGM unit

Intensity of impact	Impact category description
None (0.5)	No discernible modification or the modification is such that it has no impact on wetland geomorphic integrity.
Small (1.5)	Although identifiable, the impact of this modification on geomorphic integrity of the affected area is small (e.g. resulting from slight desiccation of the area as a result of upstream catchment abstractions).
Moderate (3)	The impact of this modification on geomorphic integrity of the affected area is clearly identifiable, but limited (e.g. resulting from resulting from slight desiccation of the area as a result of upstream catchment abstractions together with infrequent ground fires to depths of 10% of the peat deposit).
Large (5)	The modification has a clearly detrimental impact on geomorphic integrity of the affected area. Approximately 50% of the integrity of the affected area has been lost (e.g. resulting from intermediate desiccation and frequent ground fires to 25% of the depth of the peat deposit)
Serious (7)	The modification has a clearly adverse effect on geomorphic integrity of the affected area. Well in excess of 50% of the integrity of the affected area has been lost (e.g. resulting from moderately high desiccation and frequent ground fires to 50% of the depth of the peat deposit).
Critical (9)	The modification is present in such a way that the geomorphic integrity of the affected area is almost totally destroyed (e.g. resulting from high desiccation and frequent ground fires to 80% of the depth of the peat deposit or resulting from extraction of 80% of the depth of the peat deposit through peat mining).

Organic sediment may be lost directly by harvesting peat or by combustion in peat fires, or indirectly by oxidation through desiccation or repeated tillage (Table 5.21).

Step 3B: Determine the overall Present Geomorphic State of the wetland based on integrating scores for individual HGM units

Now calculate the overall magnitude of geomorphic impact for the wetland as a whole based on the area weighted average of the HGM units in the wetland, e.g. if HGM unit 1 is 40% of the wetland and scores 4 and HGM unit 2 is 60% of the wetland and scores 8 then the weighted average score would be (4 x 40/100) + (8 x 60/100) = 6.4. Record the scores and weighted average in Table 5.25, which summarizes of the health of the wetland.

All that remains is to establish into which health category the wetland falls based on its geomorphological impact score (Table 5.26). The above wetland with an impact score of 6.4 would be an E.

Step 3C: Assess the anticipated Trajectory of Change of the wetland geomorphology

The final step involves an assessment of threats to the current geomorphology of the wetland in order to obtain an indication of the anticipated Trajectory of Change, recorded in Table 5.25. Here, it is worth noting that the greatest threat facing the geomorphic integrity of wetlands is typically that posed by erosion gullies through their headward advance. Once you have identified any active headcuts in the wetland, you should consider the area of the HGM unit upstream of the headcut that could be affected. At this point you should also look out for any controls that may limit the advance of the headcut. These include volcanic dykes and sills, which often resist erosion where they cross a valley. Finally consider the level of activity of the headcut/s, since this is likely to provide an indication of the future rate of headcut advance.

Once potential causes of change for each HGM unit have been considered, assign a change score to each HGM unit (by referring to the first three columns of Table 5.27). Remember that as is the case for hydrology, the geomorphology of an HGM unit may be affected by changes in the catchment (e.g. increased levels of sediment trapping by new dams in the upstream catchment) and changes in the wetland (e.g. increased levels of excavation). Next, calculate an area weighted change score for the entire wetland using area-weighted scores, and then assign the final symbol by referring to column 4 and 5 of Table 5.27. Record the individual HGM change scores and weighted average in Table 5.25. For a detailed example on how to do this, see Steps 2D and 2E of this section.

STEP 4: Assess Vegetation Health of the wetland

Step 4A: Familiarisation with the general structure and composition of wetland vegetation in the area

In order to evaluate changes in vegetation, it is important for the assessor to have a reasonable regional appreciation of the appearance and composition of wetland vegetation under natural conditions. It is also useful to appreciate the response of vegetation to disturbance.

This is particularly important for a Level 1 assessment, where little time is generally available for field verification. Where assessors are not familiar with the vegetation in a particular region they need to familiarize themselves with wetlands in the area before undertaking this assessment. This can be done by undertaking brief field visits to a range of wetlands within the region or working together with a person with a good knowledge of the vegetation of the area.

Step 4B: Identify and estimate the extent of disturbance classes

Disturbance classes are used to apportion the wetland into areas with similar levels of transformation. These classes range from infrastructure where wetland vegetation has been totally removed to areas with no visible signs of transformation. A list of common disturbance classes that may typically be found in wetlands is outlined in Table 5.22.

Table 5.22: Description of common disturbance classes in South African wetlands.

Disturbance class	Description
Land uses commonly associated with complete transformation of wetland habitat	
Infrastructure	This includes houses, roads and other permanent structures that have totally replaced wetland vegetation.
Deep flooding by dams	This includes situations where flooding is too deep for emergent vegetation to grow.
Land uses commonly associated with substantial to complete transformation of vegetation characteristics.	
Crop lands	These lands are still in use and when active are generally characterised by almost total indigenous vegetation removal (predominance of introduced species). Examples include maize lands, sugarcane lands & madumbe fields etc.
Commercial plantations	Common plantations include pine, wattle, gum, poplar. Other land uses such as vineyards and orchards may have a similar impact on wetland vegetation.
Annual pastures	These areas are characterized by frequent soil disturbance with a general removal of wetland vegetation. Some ruderal wetland species may become established but are removed on a frequent basis.
Perennial pastures	Although such areas generally include a high abundance of alien terrestrial grasses or legumes, the reduced disturbance frequency may permit the establishment of some wetland species.
Dense alien vegetation patches.	Where dense patches of alien plants can be identified within a wetland system, they should be identified as a separate disturbance class and evaluated as a unit.
Shallow flooding by dams	Such areas can often be identified at the head or tail end or edges of dams.
Sports fields	These include cricket pitches, golf courses and the like, where a species such as Kikuyu have been introduced and are maintained through intensive management. These are often located within areas of temporary wetland where terrestrial species generally dominate.
Gardens	Gardens are generally associated with urban environments.
Sediment deposition/ infilling and excavation	Deposition includes sediment from excessive erosion or human disturbance (e.g. a construction site) upstream of the wetland, which is carried by water and deposited in the wetland. Infilling is the placement by humans of fill material in the wetland (e.g. for a sports field). Excavation is the direct human removal (usually with heavy machinery) of sediment from the wetland, which is commonly associated with mining and sand winning.
Eroded areas	In wetlands this typically occurs as gully erosion.
Land uses commonly associated with moderate transformation of vegetation characteristics.	
Old / abandoned lands	These secondary vegetation areas have typically been altered through historic agricultural practices, but are in the process of recovering. They are generally characterised by a high relative abundance of ruderal species, but this abundance may vary greatly depending on time since cultivation ceased. In cases where this varies greatly within an HGM unit, it may be worthwhile to distinguish between vegetation classes comprising recently abandoned lands and vegetation classes comprising older lands that are at a more advanced successional stage of recovery.
Land uses generally associated with low transformation of wetland vegetation.	
Seepage below dams	Earthen dams used for agricultural purposes often allow water to leak through the wall, creating artificial wetter areas below the dam wall. Such areas are typically characterized by an increase in hydric species.
Untransformed areas	These primary vegetation areas have not been significantly impacted by human activities. This may include wetland areas within game or extensive grazing management systems. Small pockets of untransformed vegetation may also be set aside as streamside buffers on commercial landholdings.

For the Level 1 assessment, the user is simply required to work through the list of disturbance classes provided (with their typical intensity scores) in Table 5.23 and provide an estimate of the extent of each disturbance class as a proportion of the HGM unit. This is typically estimated by roughly mapping the extent of each disturbance class on a sketch map or by using GIS to obtain a more accurate estimate. The extent is recorded in Table 5.24.

Step 4C: Assess the changes to vegetation composition in each class, and integrate these for the overall HGM unit

Now that disturbance classes have been identified and their extents determined, the degree of change within each disturbance class should be estimated and recorded in Table 5.24. There is typically little time for field verification during the Level 1 assessment, so the evaluation is based primarily on aerial photograph interpretation and the typical impact scores associated with different disturbance classes as provided in column 3 of Table 5.24.

Table 5.23: Typical intensity of impact scores for disturbance classes to be used to inform the vegetation assessment.

Disturbance class	Typical intensity scores	**Specific factors to consider when assigning the score**
Infrastructure	10	N/A
Deep flooding by dams	10	N/A
Shallow flooding by dams	4-8	The impact on vegetation may be less intense where the dams are shallow and emergent plant species are able to persist. The impacts on vegetation depend on the periodicity of flooding and the extent to which seasonal drying out of dam margin occurs.
Crop lands	8-10	Impact wetland vegetation is determined largely by disturbance interval. Drains can also dry out these areas, reducing the likelihood of wetland species persisting in them.
Commercial plantations	7-10	Establishment of commercial plantations generally results in a gradual suppression of wetland vegetation as indigenous plants become shaded out by commercial species. Pines tend to have a more detrimental impact on wetland vegetation than wattle, gum or poplar due to the slow decaying litter layer that builds up under such plantations.
Annual pastures	9-10	Small scale patches that can be more readily colonized by indigenous vegetation are more likely to have at least a little indigenous vegetation present than large, contiguous cultivated patches.
Perennial pastures	6-10	The degree of change is largely dependent on the duration between disturbance events and how long ago the area was tilled. The longer the interval between tillage events, and the further back in time the area was last tilled, the lower the impact score.
Dense alien vegetation patch.	5-10	Degree of change is determined largely by the class of plants and aerial cover. The longer these plants have persisted, the greater the impact.
Sports fields	7-10	Dependant on the degree of maintenance and species introduced.
Gardens	6-10	Degree of change is dependent on landscaping and introduction of non-native species.
Areas of sediment deposition/ infilling & excavation	4-10	The longer the time since the past disturbance (e.g. from cultivation, infilling or erosion) and the smaller the extent to which the natural hydrology has been altered, the greater the opportunity provided for recovery towards the natural vegetation, unless the area becomes dominated by aggressive invasive alien plants. In addition, the wetter the area, the more readily it generally recovers to its natural vegetation, as the excessive wetness generally exerts an overriding influence on the other factors.
Eroded areas	3-9	
Old / abandoned lands (Recent)	7-9	
Old / abandoned lands (Old)	3-8	
Seepage below dams	1-5	The greater the changes in water balance in the wetland area below the dam, the greater the potential change in vegetation characteristics. Historically temporary wetland zones will therefore be more severely affected than seasonal / permanent wetland zones.
Minimal human disturbances	0-3	Many of South Africa's wetlands evolved under burning and grazing by indigenous grazers, and are well adapted to moderate grazing intensities. A change in wetland vegetation does become apparent under heavy grazing pressure where a decrease in basal cover may even trigger significant erosion. Exclusion of grazing and fire may also have a negative consequence through shading out of grazing tolerant wetland species.

Where time permits, users are encouraged to visit some of the disturbance classes to obtain a better indication of the changes that have taken place and to adjust their scores accordingly. Preference should generally be given to visiting those disturbance classes with a wide range in scores (e.g. 4-10). An overall score for the HGM unit is calculated based on an area-weighted average of the impact scores for each disturbance class (Table 5.24). Record the overall weighted score for each HGM unit in the summary table (Table 5.25).

Table 5.24: Calculation of the magnitude of impact score for each disturbance class in each HGM unit based on extent and intensity of impact scores

Disturbance class	Extent (%)	Intensity Score*	Magnitude of Impact**	Additional notes
Infrastructure		10		
Deep flooding by dams		10		
Shallow flooding by dams		6		
Crop lands		9		
Commercial plantations		9		
Annual pastures		9		
Perennial pastures		8		
Dense alien vegetation patches		7		
Sports fields		9		
Gardens		8		
Areas of sediment deposition/infilling & excavation		8		
Eroded areas		7		
Abandoned croplands (recent)		7		
Abandoned croplands (old)		5		
Seepage below dams		3		
Untransformed areas		1		
Overall weighted impact score***				

* Default scores are provided which should be adjusted based on field investigations or local knowledge

** Magnitude of impact score is calculated as extent / 100 x intensity of impact.

*** The overall magnitude of impact score for the HGM unit is the sum of magnitude scores for each disturbance class

Step 4D: Determine the overall Present Vegetation State of wetland based on integrating scores from individual HGM units

Now calculate the overall vegetation magnitude of impact for the wetland as a whole based on the area weighted average of the HGM units in the wetland, and record this in the summary Table 5.25. For details on how to do this see Step 2D in this section.

Step 4E: Assess the anticipated Trajectory of Change of wetland vegetation

The final step is to determine the probable Trajectory of Change of the wetland's vegetation integrity and present the results in Table 5.25. This is done by first assigning a change score to each HGM unit (by referring to the first three columns of Table 5.27). Remember that the integrity of wetlands vegetation in an HGM unit may be affected by both on-site factors (e.g. alien clearing or encroachment) and off-site (catchment) factors (e.g. changes in water inputs). Next, calculate an area-weighted change score for the entire wetland, and then assign the final Trajectory of Change symbol by referring to columns 4 and 5 of Table 5.27. Record the individual HGM change scores and weighted average in Table 5.25, which summarizes the health of the wetland.

Table 5.25: Summary of the overall health of the wetland based on impact score and change score.

HGM unit	ha	HGM unit extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact score	Change score	Impact score	Change score	Impact score	Change score
1								
2								
3								
4								
5								
Area weighted scores*								
PES Category**								

Table 5.25: Summary continued

HGM Unit	Threat descriptions		
	Hydrology	Geomorphology	Vegetation
1			
2			
3			
4			
5			

* The area weighted scores for the wetland as a whole are calculated by (i) calculating an area-weighted score for each HGM unit and then (ii) summing the area-weighted HGM unit scores to obtain a score for the wetland as a whole.
**For impacts, this ranges from A to F (see Table 5.26), and for change it is ↑, →, ↓ or ↓↓ (see Table 5.27)

08 WET - Health - Final for Prin137 137 24/07/2009 10:35:55 AM

STEP 5: Represent the overall Health Scores for the wetland

Once the health assessments for the hydrology, geomorphology and vegetation components and have been completed and recorded in Table 5.25, a complete summary of the health of the wetland will exist.

Users are not encouraged to aggregate the scores for the three components of hydrology, geomorphology and vegetation. However, if a user has a specific requirement to do so, then this is based on the following formula: ((Hydrology score) x 3 + (geomorphology score) x 2 + (Vegetation score) x 2) ÷ 7, which gives a score ranging from 0 (pristine) to 10 (critically impacted in all respects). The rationale for this is that hydrology is considered to have the greatest contribution to health.

Table 5.26: Impact scores and Present Ecological State categories used by *WET-Health* for describing the integrity of wetlands

Description	Combined impact score	PES Category
Unmodified, natural.	0-0.9	A
Largely natural with few modifications. A slight change in ecosystem processes is discernable and a small loss of natural habitats and biota may have taken place.	1-1.9	B
Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	2-3.9	C
Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	4-5.9	D
The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9	E
Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10	F

Table 5.27: Trajectory of Change classes, scores and symbols used to represent anticipated changes to wetland integrity

Trajectory class	Description	Change score	Class Range[1]	Symbol
Improve markedly	Condition is likely to improve substantially over the next five years	2	1.1 to 2.0	↑↑
Improve	Condition is likely to improve over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deterioration slight	Condition is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deterioration substantial	Condition is likely to deteriorate substantially over the next 5 years	-2	-1.1 to -2.0	↓↓

[1] Used when determining a trajectory score for a wetland comprising several HGM units

SECTION 6: A LEVEL 2 CASE STUDY - NORTHINGTON ARM OF THE HLATIKULU VLEI

Local climate

The wetland is situated in the Drakensberg foothills and receives a mean annual rainfall of 954.3 mm that occurs mainly in the summer months. Average annual potential evapotranspiration is approximately 1677 mm. Daily temperatures range between a maximum of about 30 degrees centigrade in summer and a minimum of -5 degrees centigrade in winter.

The HGM types in the wetland (Step 1 for all Modules)

All modules require that the HGM units of the wetland be identified and mapped. The wetland is a single type of HGM unit – unchanneled valley bottom. However a significant difference in gradient was found between two sections of wetland. Based on this difference in gradient, the wetland was divided into two separate HGM units. HGM 1, situated in the south at the head of the wetland system, forms the steeper sloping section of the wetland system, whereas HGM 2, which comprises the middle and lower sections of the wetland is significantly less steep. These two sections of wetland are separated by a dolerite dyke, which is believed to be part of the reason for this marked difference in slope. Figure 6.1 shows the wetland boundary and HGM units.

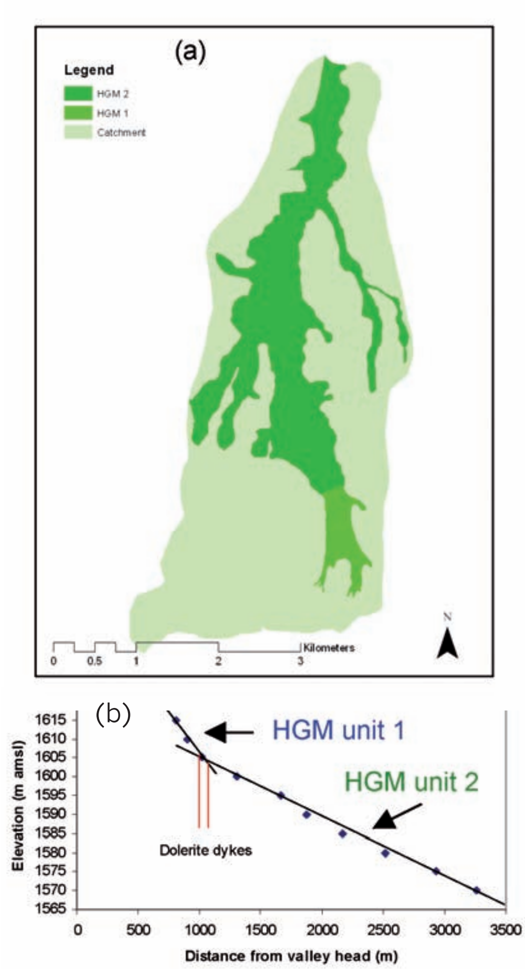
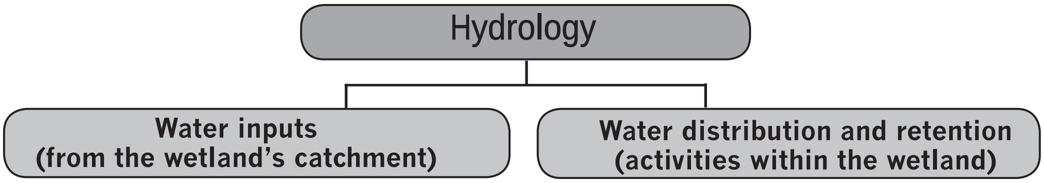


Figure 6.1: Map showing (a) the catchment and wetland boundaries of the 2 HGM units and (b) longitudinal slope of the Northington Wetland

1. Hydrology

The hydrology module starts with an assessment of vulnerability based upon the ratio of mean annual precipitation (MAP) to potential evapotranspiration (PET). The Northington Wetland is situated in Catchment V20C with mean annual precipitation of 954.3 mm and mean annual potential evapotranspiration of 1677.0 mm. Thus the ratio between MAP and PET is 0.57, which means that the vulnerability factor is 0.95.

The hydrology module is divided into ‘Water inputs’ and ‘Water distribution and retention’. The water inputs section deals with the catchment and tries to assess its condition and land use, and how these affect the amount of water inputs. The water distribution and retention section looks at factors occurring within the wetland itself that influence the pattern of water flow.



Water inputs

Step 2A: Changes in water input quantity

HGM unit 1 has a limited extent of wattle encroachment (2%) that is distributed in both riparian and non-riparian areas, while HGM unit 2 has extensive plantations of gum (10%) and pine (12%) in non-riparian areas and some wattle encroachment (2%) in riparian and non-riparian areas (Table 6.1)

Step 2B: Changes in the pattern of water delivery

The timing and pattern of water inputs is assessed using Table 6.2. Neither HGM unit is affected in any way by dams in the catchment, and hardening of surfaces and the presence of bare soils is minor. The relevant tables have therefore been ignored.

Step 2C: Combined impact of altered quantity and timing of water inputs

The combined impact is assessed by selecting the appropriate column and row from Table 6.2, which jointly considers hydro-geomorphic type, altered quantity of water inputs and the altered pattern of water inputs.

From Table 6.2, which integrates the scores for quantity of inputs and alteration of floodpeaks, HGM unit 1 has an overall score of 0, whereas HGM unit 2 has a score of 1. These scores, when applied to Table 6.3, show that HGM 1 falls under the fist impact category of no impact, whereas HGM 2 falls under the category of small impact.

Table 6.1: Activities and extent in the HGM unit's upstream catchment, of different land-use types potentially **reducing inflow quantities, and the magnitude of their effects**

Land-use activity descriptors	Extent (%)	Intensity	Magnitude HGM 1	Extent (%)	Intensity	Magnitude HGM 2
Irrigation			-			-
Alien plants	2	(-8+-5)/2 *0.95	-0.12	2	(-8+-5)/2 *0.95	-0.12
Plantations			-	10 12	(-10+2)/2 *.95 (8+2)/2 *.95	-1.14
Sugar			-			-
Dams: specific allowance for releasing low flows within the operating rules of the dam			-			-
Overall magnitude of reduction in water inputs to the HGM unit as the sum of all the above impact magnitudes			-0.12			-1.26

Table 6.2: Guideline for assessing the magnitude of impact on the HGM unit based on the joint consideration of hydro-geomorphic type, altered quantity of water inputs and the altered pattern of water inputs. The table is for non-**floodplain HGM units.**

Change in quantity **of water inflows** (Score from Table 2.2)	**Alteration to floodpeaks (Score from Table 2.3)**						
	Large increase (>6)	Moderate increase (4-6)	Small increase (1.6-3.9)	No effect (-1.5 to 1.5)	Small decrease (-1.6 to -3.9)	Moderate decrease (-4 to -6)	Large decrease (<-6)
> 9	6	5	4	3	3	3.5	4
4-9	4.5	4	3	2	3	3	3
1 to 3.9 (Increase)	3	2	1	1	1	2	2.5
-0.9 to +0.9 (Negligible)	2.5	1.5	0.5	0	0.5	1	1.5
-1 to -1.9 (Decrease)	3.5	2.5	1.5	1	1.5	2	2.5
-2 to -3.9	4.5	3.5	2.5	2	2.5	3	3.5
-4 to -5.9	6	5	4	3.5	4	4.5	5
-6 to -7.9	-**	-**	-**	5	5.5	6	6.5
-8 to -9	-**	-**	-**	-**	-**	7.5	8
< -9	-**	-**	-**	-**	-**	-**	10

**These classes are unlikely, given that when there is a high level of reduction of quantity of inputs then there would be

Table 6.3: Guideline for interpreting the magnitude of impact on hydrological integrity

Impact category	Description	Score
None	No discernible modifications, or the modifications are of such a nature that they have no impact on hydrological integrity.	0-0.9
Small	Although identifiable, the impact of modifications on hydrological integrity are small.	1-1.9
Moderate	The impact of modifications on hydrological integrity is clearly identifiable, but limited.	2-3.9
Large	Modifications have had a clearly detrimental impact on hydrological integrity. Approximately 50% of hydrological integrity has been lost.	4-5.9
Serious	Modifications have had a clearly adverse effect on hydrological integrity. Well in excess of 50% of the hydrological integrity has been lost.	6-7.9
Critical	Modifications are so great that hydrological functioning has been drastically altered. 80% or more of the hydrological integrity has been lost.	8-10

STEP 3: Water distribution and retention within the wetland

Step 3A: Impact of canalisation and stream modification

The wetland has been drained (canalised) but there has been no modification of streams since this is a unchannelled valley bottom wetland. The extent and character of drains in a portion of HGM 2 is shown in Figure 6.2, and the extent, intensity and magnitude of canalisation of both HGM units is shown in Table 6.4.

In this case neither HGM unit had any stream channels modified. The relevant table has not been presented and a final score of 0 was given.

Table 6.5 combines the scores of Table 6.4 and the impact of stream channel modification.

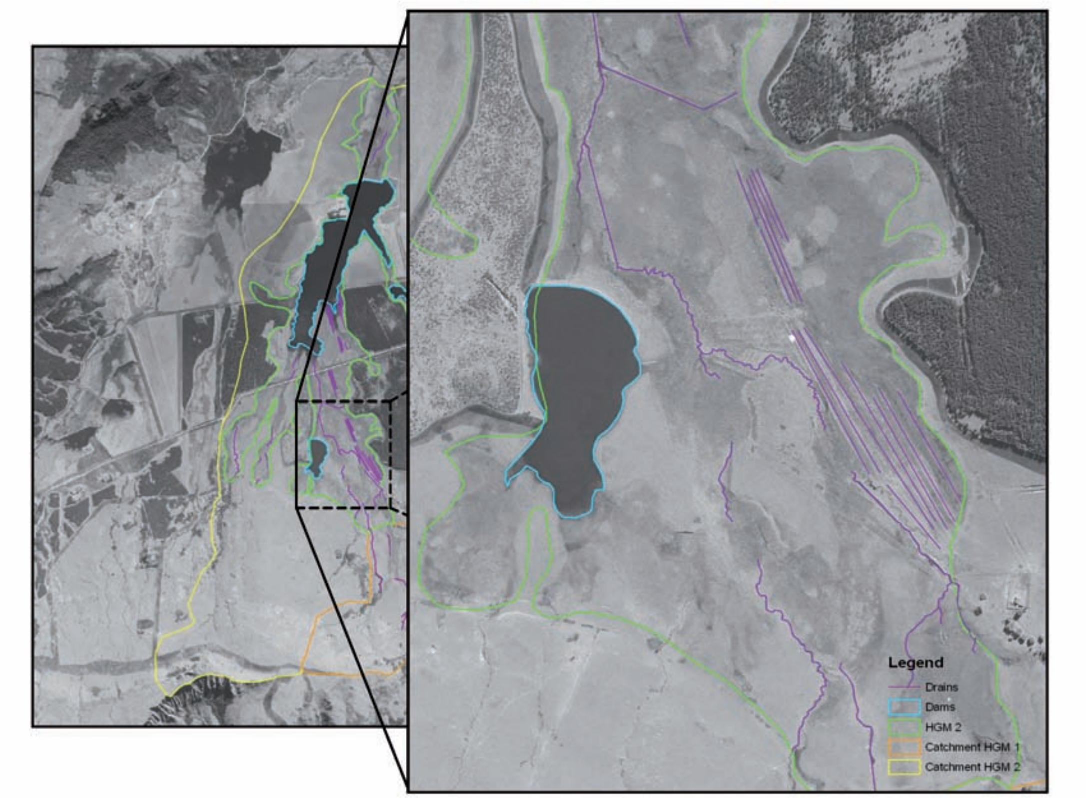


Figure 6.2: Map showing the extent of canalisation and abandoned ridge & furrow agriculture in a portion of the Northington arm of the Hlatikulu vlei

Table 6.4: Characteristics affecting the impact of canalisation on the distribution and retention of water in the HGM unit

Extent of HGM unit affected by canalisation	HGM 1	8.2 ha	20.25%
	HGM 2	43.2 ha	11.2 %

Factors	Score HGM 1	Score HGM 2
1. Slope of the wetland	8	5
2.(a) Texture of mineral soil, if present	2	2
2.(b) Degree of humification of organic soil, if present	-	-
3. Natural level of wetness	2	8
Characteristics of the drains/gullies		
4. Depth of the drains/gullies	10	10
5. Density of drains (meters of drain per hectare of wetland)	2	2
6. Location of drains/gullies in relation to flows into and through the wetland. Drains/gullies are located such that flows are: Moderately well intercepted (see Table 2.7)	8	8
7. Obstructions in the drains/ gullies	10	8
Calculate the mean score for factors 1, 2a or 2b, 3, 4 and 5	4.8	5.4
Multiply the score for factor 6 by the vulnerability factor (0.95 in this case)	7.6	7.6
Mean score for above two scores	6.2	6.5
Intensity of impact for canalization: divide the score for factor 7 by 10 and multiply this by the mean score derived in previous row	6.2	5.2
Magnitude of impact of canalisation: Extent of impact/100 × intensity of impact calculated in the row above	1.26	0.58

Table 6.5: Calculation of magnitude of impact of canalisation and modification of a stream channel on the distribution and retention of water in a wetland HGM unit

Overall magnitude of impact score: canalisation and stream channel modification	Score HGM 1	Score HGM 2
Calculate the sum of scores from Table 6.4 and impact of stream channel modification	1.26	0.58

Step 3B: Magnitude of impact of impeding features

HGM unit 1 did not have any impeding features and was thus not assessed for this. HGM unit 2 has 3 dams which flood a significant area of the wetland, as can be seen in Figure 6.3. The extent and magnitude of these areas upstream and downstream of each dam wall are presented in Table 6.6.

Step 3C: Impact of altered surface roughness

For this section no significant areas of either of the HGM units had their surface roughness changed and the score of 0 was given.

Step 3D: Impact of direct water losses

There were no alien woody plants, commercial plantations or stands of evergreen crops growing in the wetland and final scores of 0 were assigned to each HGM unit.

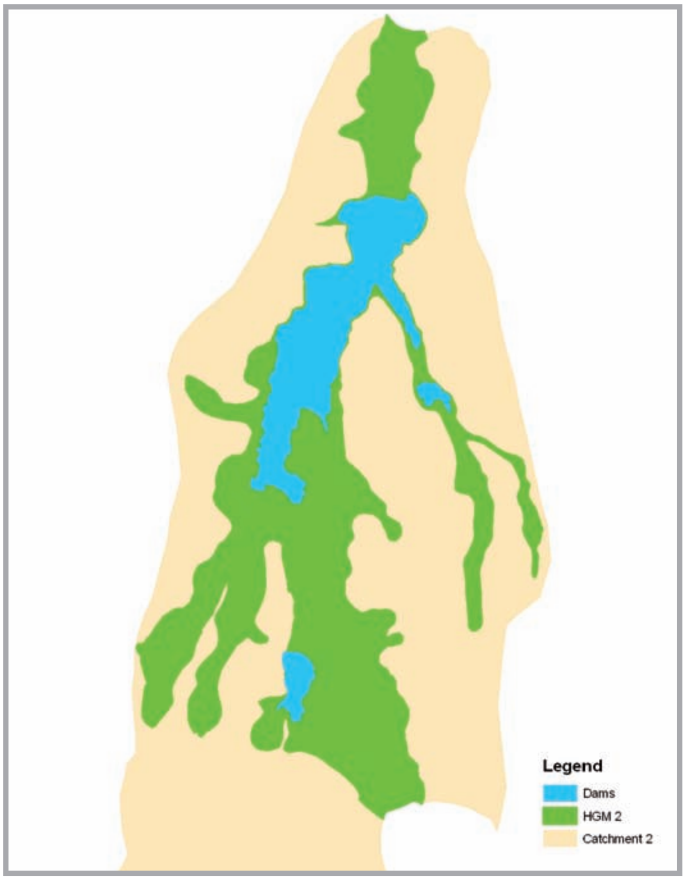


Figure 6.3: Map of HGM unit 2 showing the dams in the wetland.

Table 6.6: Typical changes in water distribution and retention patterns within an HGM unit as a result of impeding features

(a) Upstream impact of flooding

Extent of HGM unit affected by flooding upstream of the impeding structure	HGM 1	0	0
	HGM 2	88,7 ha	23%

Descriptor	Score HGM 1	Score HGM 2
Representation of different hydrological zones prior to flooding by the dam	-	2
Intensity of impact: score of (1) X 0.8	-	1.6
Magnitude of impact score: extent of impact /100 × intensity of impact	-	0.37

(b) Downstream impact on quantity and timing of flows to downstream portion of the HGM unit

Extent of HGM unit affected downstream of the impeding structure	HGM 1	0 ha	0%
	HGM 2	53.4 ha	13.8%

Descriptor	Score HGM 1	Score HGM 2
Extent to which dams or roads interrupt low flows to downstream areas	-	8
Level of abstraction from the dam/s	-	5
Location of dam/s relative to affected area's catchment- proportion of catchment flows intercepted	-	8
Collective volume of dam/s in relation to MAR of the affected area	-	5
Intensity of impact: mean score of the two highest scoring factors x 0.8*	-	6.4
Magnitude of impact score: extent of impact /100 × intensity of impact	-	0.88

(c) Combined impact

Combined impact: Magnitude of impact for upstream + magnitude of impact for downstream	0	1.25

Step 3E: Impact of recent deposition, infilling or excavation

There were signs of recent deposition in both of the HGM units (see assessment of Geomorphic Health) and the scores for this section are presented in Table 6.7.

Step 3F: Impact of on-site activities

The scores calculated in the preceding tables were combined (Table 6.8) to produce an overall score for the distribution and retention of water within the HGM units.

08 WET - Health - Final for Prin145 145 24/07/2009 10:35:59 AM

Table 6.7: Magnitude of impact of recent deposition/infilling or excavation

Extent of HGM unit affected by deposition/excavation or excavation[R]	HGM 1	2%
	HGM 2	8%

Descriptor	HGM unit 1 Score	HGM unit 2 Score
Effect on vertical drainage properties of the uppermost soil layer	5	5
Effect on the horizontal movement of water	2	2
Intensity of impact: use the highest score for the above two factors	5	5
Magnitude of impact score: extent of impact (%) /100 × intensity of impact x 1*	0.1	0.4

Table 6.8: Overall magnitude of impacts of on-site activities on water distribution and retention patterns in the HGM unit

Activity	Magnitude of impact HGM 1	Magnitude of impact HGM 2
1. Calculated magnitude of impact of canalization and stream channel modification (Table 6.5)	1.26	0.58
2. Calculated magnitude of impact of impeding features (Table 6.6)		1.25
3. Calculated magnitude of impact of altered surface roughness (N/A)		
4. Calculated magnitude of impact of direct water losses (N/A)		
5. Calculated magnitude of impact of recent deposition/excavation (Table 6.7)	0.1	0.4
Total score of magnitude of on-site activities in the HGM unit (sum of the above scores)	1.36	2.23

STEP 4: Present Hydrological State of the HGM Unit

From the scores calculated for water inputs (Step 2) and water distribution and retention within the wetland (Step 3), the score for the overall magnitude of impacts can be calculated from Tables 6.9 and 6.10. The health category is determined from Table 6.11.

STEP 5: Present Hydrological State for the Overall Wetland

In order to determine the overall Present Hydrological State of the wetland, the health scores of the two HGM units are combined on an area weighted basis (Table 6.12)

Table 6.9: Summary of Water inputs score and Water Retention within the wetland

	HGM 1	HGM 2
Water inputs (Table 6.2)	0	1
Water distribution and retention within the wetland (Table 6.8)	1.36	2.23

Table 6.10: Derivation of overall magnitude of impact scores by combining scores obtained from catchment and within-wetland assessments. Colour codes correspond to impact categories as expressed in Table 6.11.

			Water Inputs (Table 6.2)					
			None	Small	Moderate	Large	Serious	Critical
			0-0.9	1-1.9	2-3.9	4-5.9	6-7.9	8-10
Water distribution & retention patterns (Table 6.9)	None	0-0.9	0	1	3	5	6.5	8.5
	Small	1-1.9	1	2	3.5	6	7	9
	Moderate	2-3.9	3	3.5	4	6.5	7.5	9
	Large	4-5.9	5	6	6.5	7	8	9.5
	Serious	6-7.9	6.5	7	7.5	8	9	10
	Critical	8-10	8.5	9	9	9.5	10	10

Table 6.11: Health categories used by *WET-Health* for describing the Present Hydrological State of the wetland

Description	Impact score	Present state category
Unmodified, natural.	0-0.9	A
Largely natural with few modifications. A slight change in ecosystem processes is discernable and a small loss of natural habitats and biota may have taken place.	1-1.9	B
Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	2-3.9	C
Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	4-5.9	D
The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9	E
Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10	F

Table 6.12: Derivation of the overall Present Hydrological State score for the wetland being considered.

HGM unit number	Area (ha)	HGM unit extent (%)	Overall impact score for HGM (Table 6.10)	Area weighted impact score*	Present Hydrologic State category
1	40.5	9	1	0.09	
2	385.9	91	3.5	3.19	
Total	426.4	100	Overall weighted mean impact score**	3.28	C

*Area weighted impact score = HGM extent /100 x impact score

**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

STEP 6: Anticipated Trajectory of Change of wetland hydrology

Threats to wetland hydrology are assessed in order to evaluate future trends. On the basis of an interview with the landowner, land use will not change in the catchment and wetland rehabilitation is being undertaken in both HGM units with the explicit purpose of promoting diffuse flow and reducing confined flow in dongas and drains. Therefore, we anticipate that the hydrological characteristics of the wetland will improve (Tables 6.13 and 6.14).

Overall Hydrological Health

This wetland was found to have an overall hydrology impact score of 3.28, which, when applied to Table 6.11 shows this wetland's present health class is a C. Add to this the change score and the wetland's health is represented as C(↑). Thus we might expect the wetland to change to having a health of a B class in the next 5 years from the perspective of its hydrology.

Table 6.13. Trajectory classes, change scores and symbols used to represent likely Trajectory of Changes to wetland hydrology

Trajectory Class	Description	Change Score	Class Range	Symbol
Improve	Hydrological condition is likely to improve over the over the next 5 years	+1	0.3 to 1.0	(↑)
Remain stable	Hydrological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	(→)
Slowly deteriorate	Hydrological condition is likely to slowly deteriorate over the next 5 years	-1	-0.3 to -1.0	(↓)
Rapidly deteriorate	Rapid deterioration of hydrological condition is expected over the next 5 years	-2	-1.1 to -2.0	(↓↓)

Table 6.14: Evaluation of overall Trajectory of Change for the wetland hydrology

HGM unit	Threat Description	HGM unit extent (%)	Change Score	Area-weighted change score*
1	Hydrological condition is likely to improve over the next 5 years	9	1	0.09
2	Hydrological condition is likely to improve over the next 5 years	91	1	0.91
Overall weighted change score:**				1

*Area weighted change score = HGM extent /100 x change score

**Overall area weighted change score = sum of individual area weighted scores for each HGM unit

2. Geomorphology

Although there are minor channels present that have a meandering fluvial style in HGM unit 1, these are largely inactive due to their presence on an alluvial ridge. As such flow is generally diffuse in both HGM units and they have thus been classed as unchannelled valley bottom wetlands. Furthermore, the wetland had limited development of organic soils. Given these circumstances the following sections of Geomorphic Health were assessed according to Table 6.15:

- Changes in runoff characteristics
- Erosional features
- Depositional features.

STEP 2: Assessment based on diagnostic features

The diagnostic component for the HGM units in the present study relate to increased water inputs to the wetland in terms of both the quantity and pattern of floodpeaks. There is no increase in either of these variables and score of 0 was assigned.

STEP 3: Assessment based on Indicators

Erosional features

There are many gullies in the wetland that arise in the catchment or in the wetland and terminate within the wetland (Figure 6.4). Based on their width and length these features are estimated to have an extent of 30% for each HGM unit (Table 6.16), while intensity and magnitude of impact are rated in Table 6.17.

Table 6.15: Guideline for assessing the impacts of activities according to HGM type

HGM type to assess	Activity/Indicator that should be assessed
Diagnostic component	
Floodplain	Dams upstream of or within floodplains
Floodplain, channelled valley bottom	Stream shortening or straightening
Floodplain, channelled valley bottom	Infilling that leads to narrowing of the wetland
All non-floodplain HGM units	Changes in runoff characteristics
Indicator-based component	
All non-floodplain HGM units	Erosional features
All non-floodplain HGM units*	Depositional features
All non-floodplain HGM units	Loss of organic sediment

08 WET - Health - Final for Prin149 149 24/07/2009 10:36:00 AM

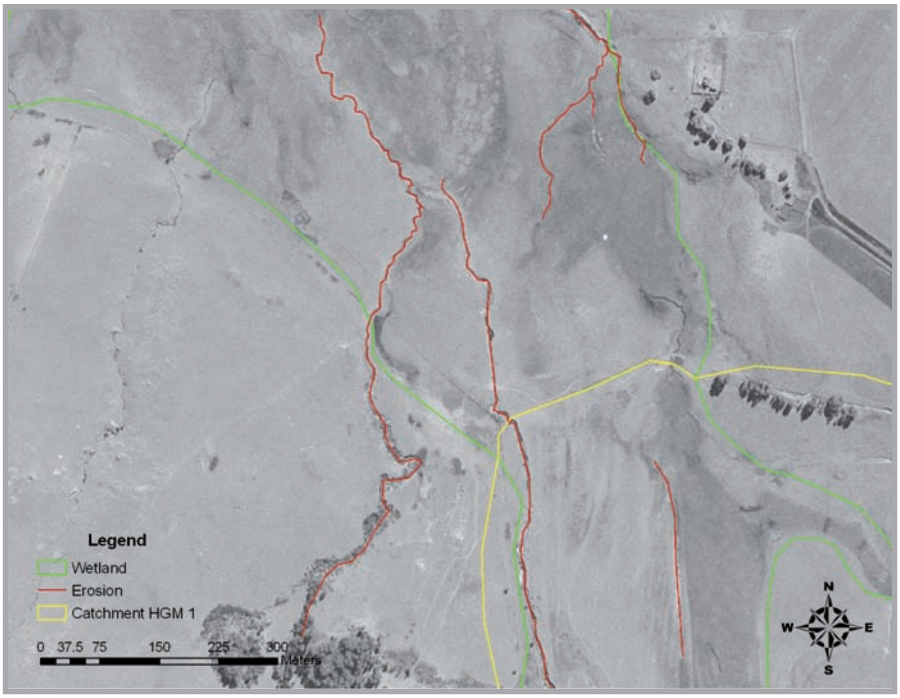


Figure 6.4: Orthophoto of a portion of the Northington Wetland showing examples of erosion gullies

Table 6.16: Estimation of extent of impact of erosional features. Both HGM units were found to have the same extent for gullies

		Length of wetland occupied by gully/ies as a percentage of the length of HGM				
		0-20%	21-40%	41-60%	51-80%	>80%
Average gully width (sum of gully widths if more than 1 gully present) in relation to wetland width	< 2%	5%	10%	15%	20%	25%
	2.1-5%	10%	15%	20%	25%	30%
	5.1-10%	15%	15%	25%	35%	45%
	10.1-20%	25%	25%	40%	55%	65%
	20.1-50%	25%	30%	50%	70%	80%
	>50%	30%	40%	60%	80%	100%

Table 6.17: Intensity and magnitude of impact of erosional features

Factor	HGM unit 1 score	HGM unit 2 score
Mean depth of gullies	10	6
Mean width of gullies	8	6
Number of headcuts present	6	10
Unscaled intensity of impact score: mean score of highest 2 scores in above 3 rows	9.0	8.0
Scaling factor	HGM unit 1 factor	HGM unit 2 factor
Extent to which sediment from the gully is deposited within the HGM or wetland downstream of the HGM unit (as opposed to being exported)	0.4	0.4
Extent to which the bed and sides of the gully have been colonized by vegetation and/or show signs of natural recovery	0.9	0.9
Scaling factor score: mean of above 2 rows (value is between 0 and 1)	0.65	0.65
Scaled intensity of impact score = unscaled intensity of impact score x scaling factor score	5.9	5.2
Magnitude of impact score: extent of impact (see Table 6.16)/100 x scaled intensity of impact score	1.6	1.4

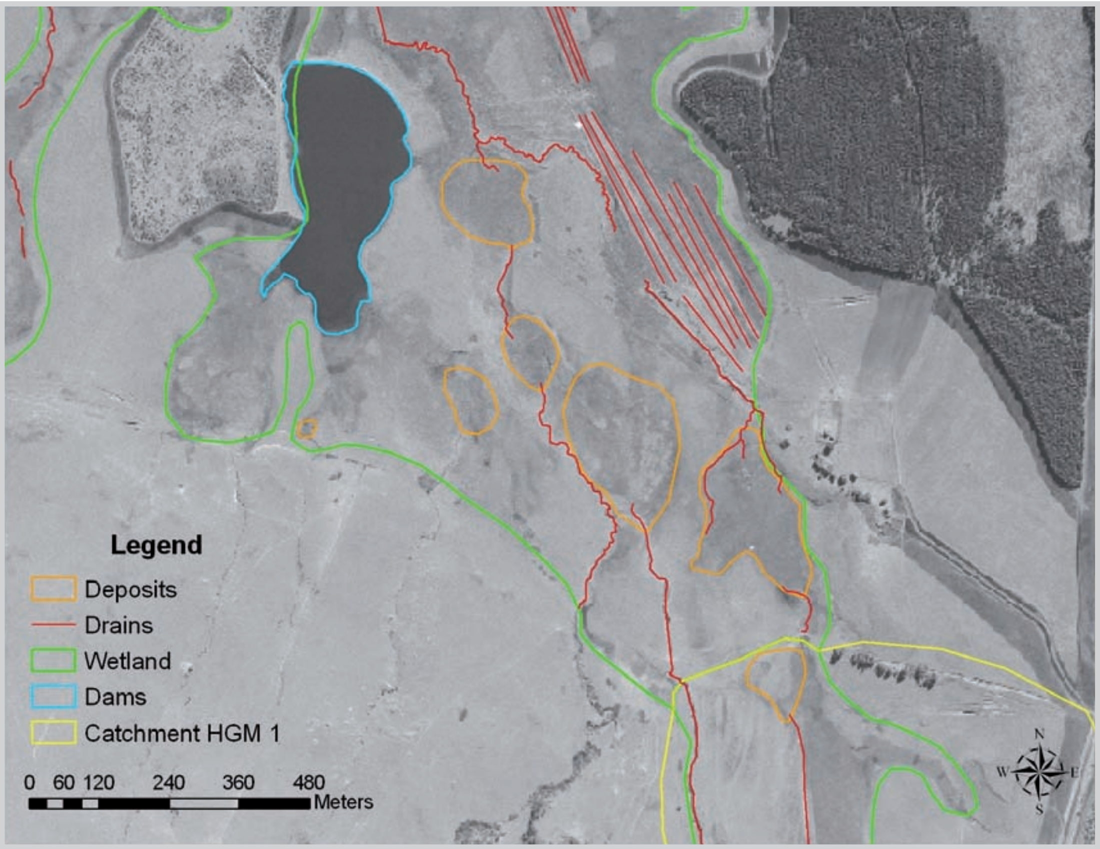


Figure 6.5: Orthophoto of a portion of the Northington Wetland showing the location of some of the depositional features found in HGM unit 2

Depositional features

Gullies that arise in the catchment all terminate within the wetland where they generally form fan-like depositional features (Figure 6.5). Downstream of these features further gullies often arise, which also terminate within the wetland. The extent, intensity and magnitude of impact of depositional features are provided in Tables 6.18 and 6.19.

Since the deposition of sedimentary deposits has been mapped directly there is no need to consider the indirect indicators of deposition that result from gullies. Thus, the intensity and magnitude of impact of depositional features can be calculated as shown in Table 6.19.

Organic sediment

There is no organic sediment in the Northington wetland, so this assessment has been omitted.

STEP 4: Determine Present Geomorphic State of each HGM unit

Results of the assessment of geomorphic health are now summarised as the Present Geomorphic State (PGS; Table 6.20). Since both wetlands were classified as unchannelled valley bottom wetlands and no organic soils are present, only erosional and depositional features were examined.

Table 6.18: Estimation of the extent of depositional features for known depositional features in the HGM unit.

Extent of depositional features in relation to area of HGM unit being considered	0.2-2%	2.1-10%	10.1-25%	25.1-50%	>50%
Score for “extent” to be used in the estimation of magnitude of impacts	5%	20%	50%	75%	100%

Table 6.19: Intensity and magnitude of impact of depositional features

	HGM unit 1 score	HGM unit 2 score
The position of fan-like deposits within the wetland	2	8
Impact of depositional features on existing wetland features	8	8
Intensity of impact score: mean of two rows above	5	8
Magnitude of impact score = extent of impact (Table 6.18)/100 x intensity of impact score	1.0	1.6

Table 6.20: Derivation of overall magnitude-of-impact scores through combining the scores obtained from individual assessments

Impact category	HGM unit 1	HGM unit 2
1. Magnitude of impact of dams		
2. Magnitude of impact of channel straightening		
3. Magnitude of impact of infilling		
4. Magnitude of impact of changes in runoff characteristics		
5. Magnitude of impact for erosional features (Table 6.17)	1.8	1.6
6. Magnitude of impact for depositional features (Table 6.19)	1.0	1.6
7. Magnitude of impact for loss of organic sediment		
Overall Present Geomorphic State = Sum of three highest scores	2.8	3.2

STEP 5: Assess Present Geomorphic State of the wetland

In order to assess the overall present geomorphic state of the wetland as a whole, the health scores of the two HGM units need to be combined on an area weighted basis (Table 6.21).

The score from Table 6.21, which is 2.96, is then applied to Table 6.22, which reveals that the wetland belongs to Category C. This indicates that the wetland's Present Geomorphic State is moderately modified.

Table 6.21: Derivation of the overall Present Geomorphic State score for the wetland being considered.

HGM unit number	Area (ha)	HGM unit extent (%)	Overall impact score for HGM (Table 6.20)	Area weighted impact score*	Present Geomorphic State category
1	40.5	9	2.8	0.25	
2	385.9	91	3.2	2.91	
Total	426.4	100	Overall area weighted impact score**	3.16	C

*Area weighted impact score = HGM extent /100 x impact score
**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

Table 6.22: Description of Present Geomorphic State in relation to Impact Scores and PGS Categories

Description	Impact score	PGS category
Unmodified, natural.	0-0.9	A
Largely natural. A slight change in geomorphic processes is discernable but the system remains largely intact.	1-1.9	B
Moderately modified. A moderate change in geomorphic processes has taken place but the system remains predominantly intact.	2.-3.9	C
Largely modified. A large change in geomorphic processes has occurred and the system is appreciably altered.	4-5.9	D
Greatly modified. The change in geomorphic processes is great but some features are still recognizable.	6-7.9	E
Modifications have reached a critical level. Geomorphic processes have been modified completely.	8-10	F

08 WET - Health - Final for Prin153 153 24/07/2009 10:36:02 AM

STEP 6:
Vulnerability posed by headcut erosion and Trajectory of Change

Step 6A:
Assessing vulnerability to erosion: hydrogeomorphic setting

For interest's sake the controls of the two HGM units are described and illustrated in Figures 6.6 and 6.7. The HGM unit in the upper part of the valley (HGM unit 1; Figure 6.6) is controlled by a dolerite dyke, while HGM unit 2 is controlled by deposition of sediment on the river floodplain (Figure 6.7). The slope along the Northington Wetland is shown in Figure 6.8, together with the location of dolerite dykes and the Nsonge River floodplain. Notice the distinct reduction in slope at the boundary between HGM 1 and HGM 2, that is coincident with the presence of two dolerite dykes oriented across the valley. Longitudinal slopes are provided in Figure 6.8.

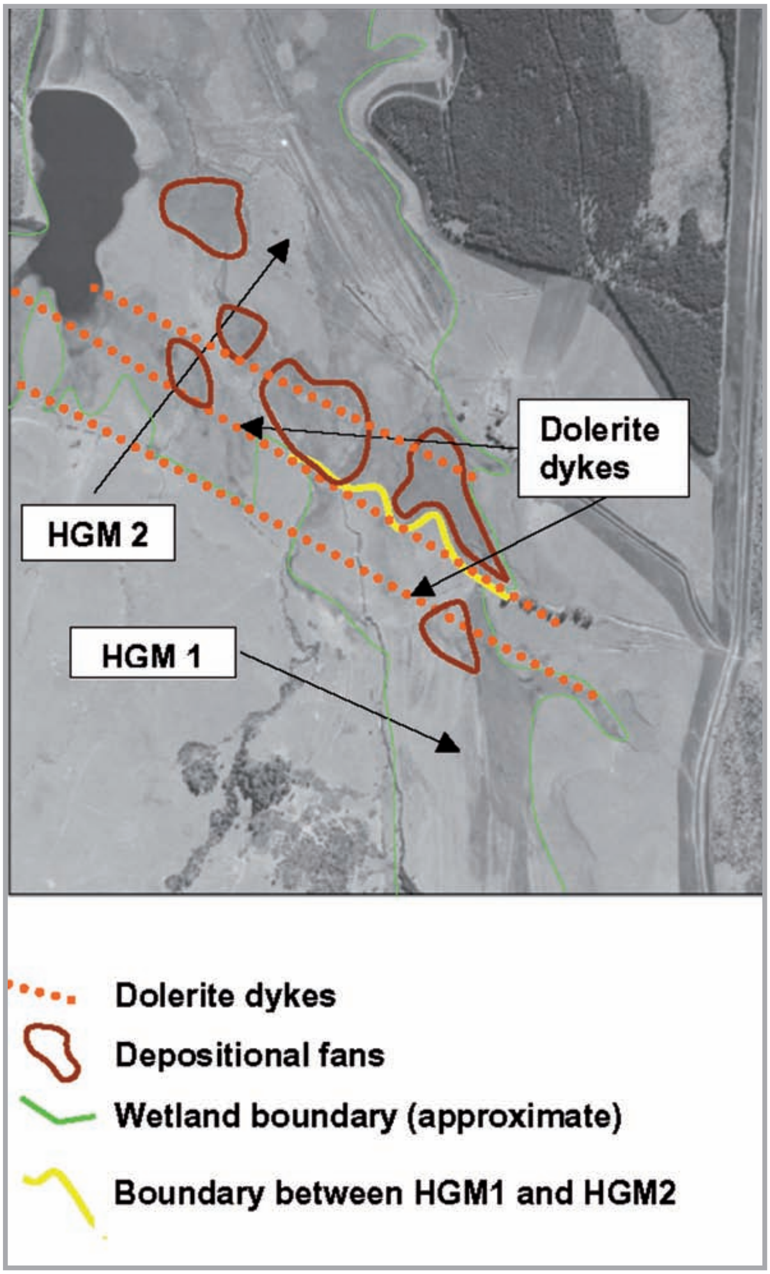


Figure 6.6: Orthophotograph of the boundary between HGM unit 1 and HGM unit 2, showing the location of 2 dolerite dykes and the approximate location of the boundary between these HGM units

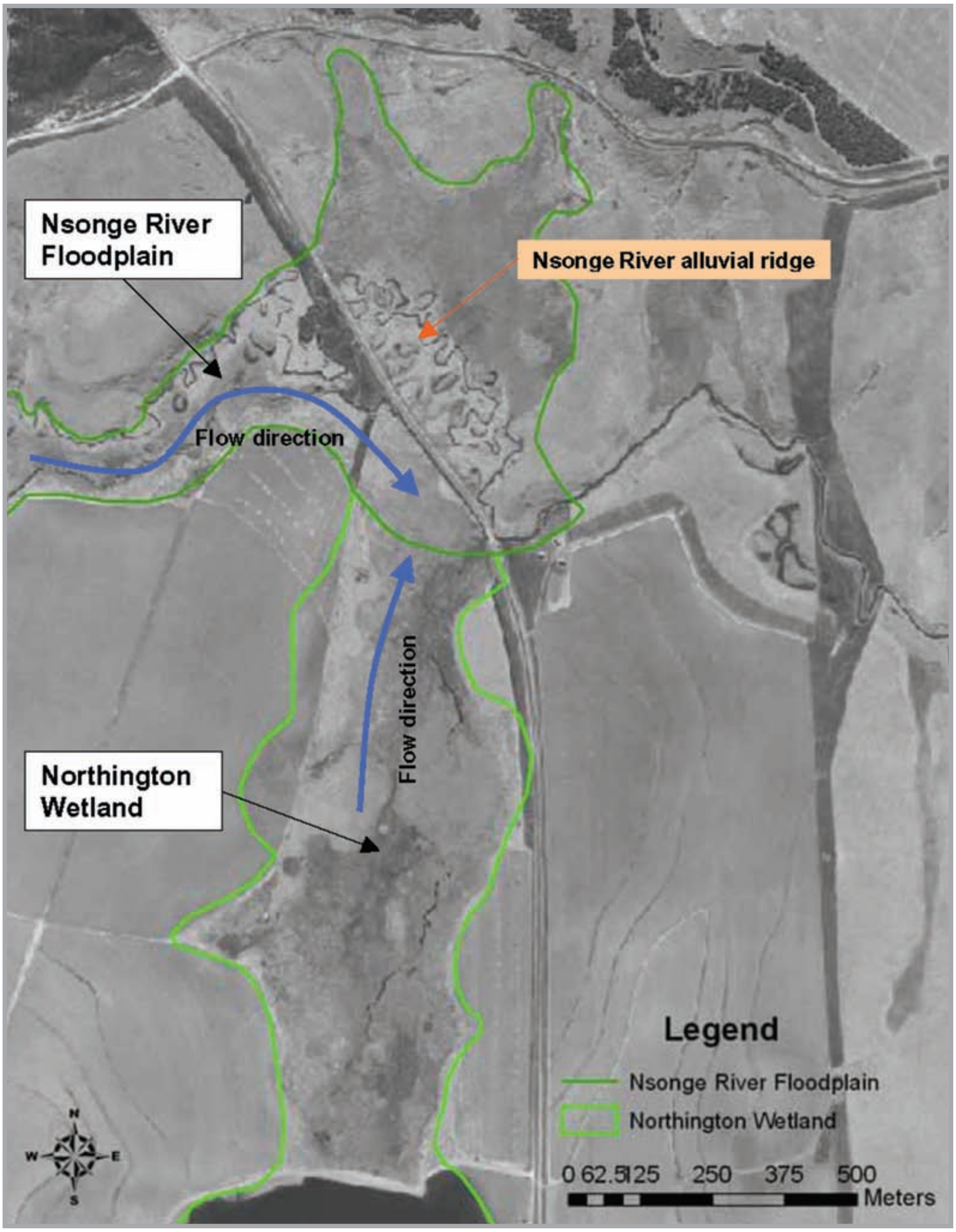


Figure 6.7: The confluence of the Northington Wetland and Nsonge River, showing the alluvial ridge associated with the Nsonge River floodplain

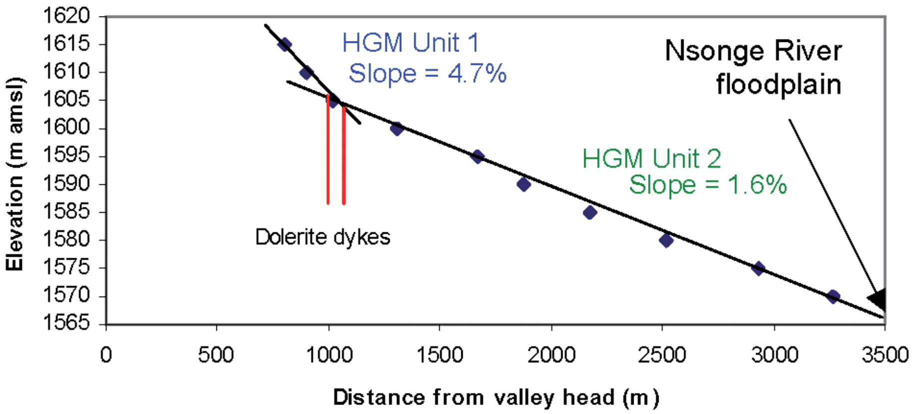


Figure 6.8: Longitudinal profiles of the HGM units in the Northington Wetland, showing the presence of dolerite dykes across the wetland and the location of the Nsonge River floodplain.

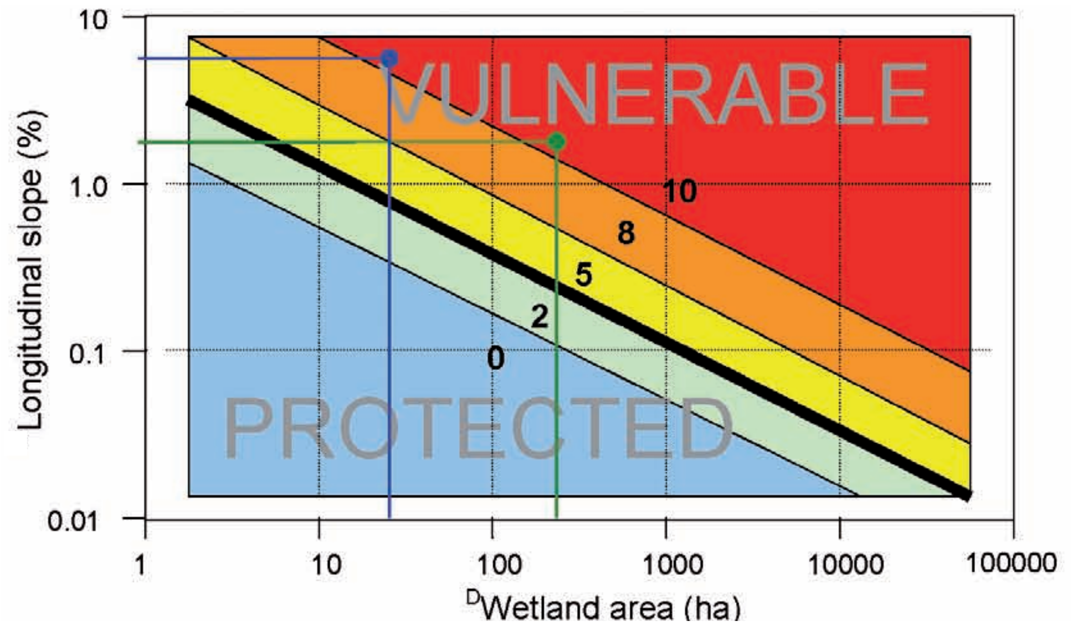


Figure 6.9: Vulnerability of HGM units to geomorphological impacts based on wetland size and wetland longitudinal slope. The line between scores 2 and 5 approximates the equilibrium slope for a wetland of a given size.

The longitudinal slope of each HGM unit is plotted in relation to its area on Figure 6.9 in order to obtain its score for vulnerability (Table 6.23). Recall that in placing the HGM unit on the vulnerability diagram, the axes are plotted on a logarithmic scale! Although these HGM units have vastly different sizes and slopes, their vulnerability is similar.

Table 6.23: Tabulation of the vulnerability of each HGM unit of the wetland

HGM unit no.	Vulnerability score	Comments
1	10	An exceptionally steep longitudinal slope at nearly 5%
2	10	A steep slope for a wetland of this size at 1.6%

Table 6.24: Trajecory class, change scores and symbols used to represent Trajectory of Change to wetland geomorphology

Trajectory Class	Description	Change score	Class Range	Symbol
Improve slightly	Geomorphological condition is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Geomorphological condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Deteriorate slightly	Geomorphological condition is likely to deteriorate slightly over the next 5 years	-1	-0.3 to -1.0	↓
Deteriorate greatly	Geomorphological condition is likely to deteriorate greatly over the next 5 years	-2	-1.1 to -2.0	↓↓

Steps 6B and C: Likely increased extent of gullies and Trajectory of Change

This wetland was found to have a series of erosion channels with associated alluvial fans, all of which could be related to the presence of dolerite dykes. The gullies are narrow in comparison to the wetland's width, but extend along its entire length. Based on field investigations and on past trends gleaned from aerial photographs it seems that the length of wetland eroded by gullies will increase headward in HGM unit 1, but that in HGM unit 2 erosion will be into the oversteepened toes of depositional features. However, erosion in HGM unit 2 will be limited by the presence of dolerite dykes running across the wetland such that it will not run away and threaten the entire wetland. As such the threat of headward erosion is noteworthy but unlikely to lead to great deterioration that might be expected at first glance. The width of gullies is not likely to change appreciably in either HGM unit despite localized incision of depositional features. Change scores as presented in Table 6.24 can thus be assigned to these HGM units accordingly to determine the likely Trajectory of Change for the wetland as a whole (Table 6.25).

The overall threat for the wetland as a whole is determined using area weighted Trajectory of Change scores, giving a score for the wetland as a whole of -1 (Table 6.25), which shows that the geomorphic state is likely to deteriorate slightly over the next 5 years (Table 6.24).

The present assessment of Trajectory of Change ignored any rehabilitation work taking place on the site, but this could (at best) stabilise the deterioration that is expected following this Trajectory of Change analysis such that the Trajectory of Change would be less than 1. Rehabilitation initiatives at the time of writing were largely focusing on HGM unit 1 such that the Trajectory of Change score is unlikely to change much since the greatest source of future change is a product of what is happening in HGM unit 2.

Table 6.25: Derivation of the overall Trajectory of Change to wetland geomorphology.

HGM unit number	Area (ha)	HGM unit extent (%)	Change Score (Table 6.24)	Area weighted Change score*
1	40.5	9	-1	-0.09
2	385.9	91	-1	-0.91
Total		100	Overall area weighted change score**	-1.0

*Area weighted change score = HGM extent /100 x change score

**Overall area weighted change score = sum of individual area weighted scores for each HGM unit

STEP 7: Describe Overall Geomorphological Health of the wetland

Table 6.24 shows that the Trajectory of Change score for geomorphology is towards slight deterioration with a symbol of (↓). This symbol is combined with the Present Geomorphic State category to give the final, overall score for this wetlands Geomorphic Health of C(↓).

This situation provides a fairly robust indication that if rehabilitation is not undertaken to at least stabilize the current situation the geomorphic state should decline. It also illustrates the importance of focusing on HGM unit 2.

3. Vegetation

STEP 2: Present state of wetland vegetation

The Northington Wetland was divided into five disturbance classes with distributions shown in Figure 6.10 and extents shown in Table 6.26.

The intensity and magnitude of impact scores for vegetation disturbance classes is shown in Tables 6.27a and b.

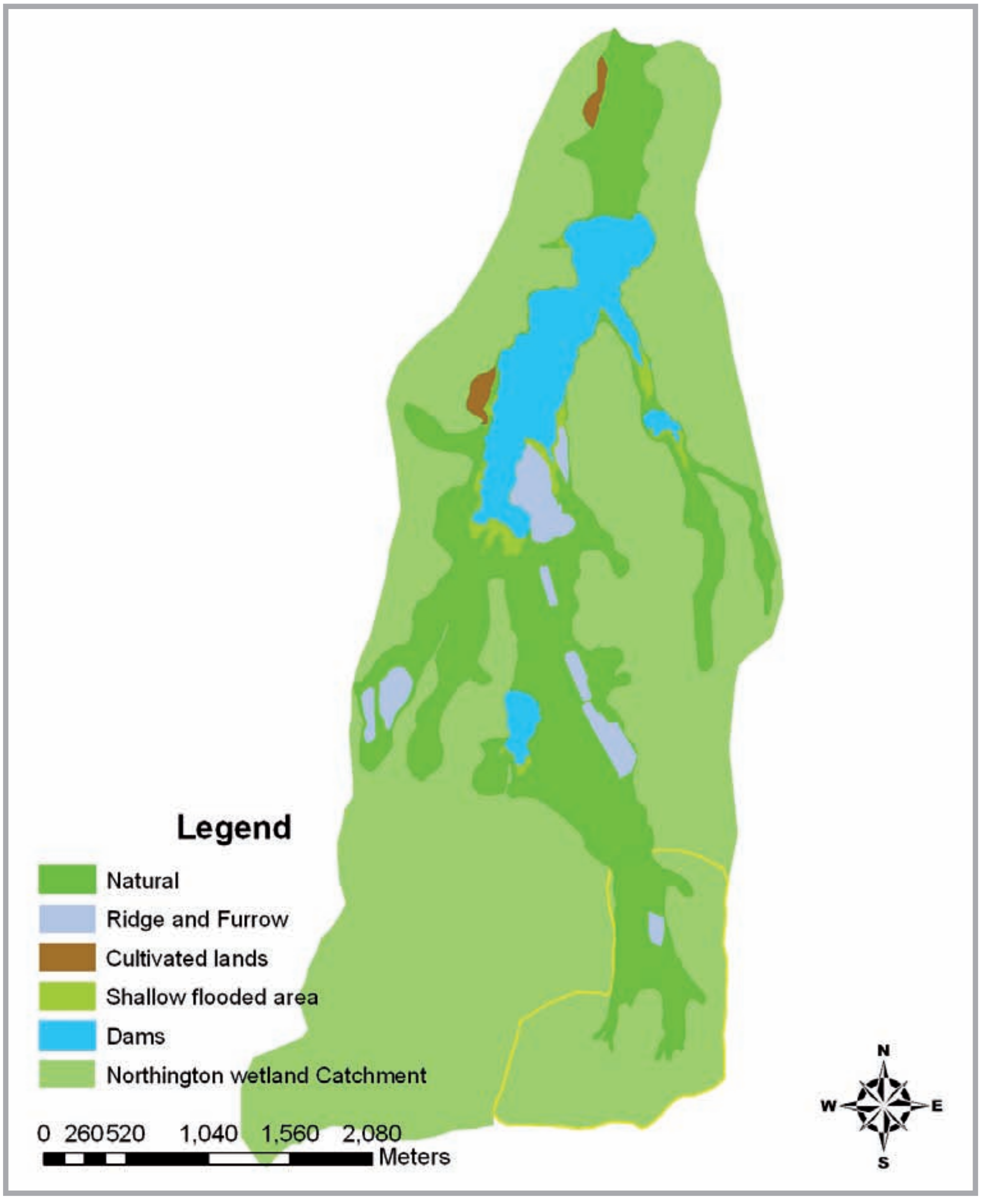


Figure 6.10: The vegetation disturbance classes of each HGM unit of the Northington Wetland

Table 6.26: Description and extent of each disturbance class within each HGM unit

Disturbance class	Brief description of disturbance class	HGM unit 1		HGM unit 2	
		Extent (ha)	Extent (%)	Extent (ha)	Extent (%)
1	Abandoned ridge and furrow agriculture	1.6	3.9	31.8	8.2
2	Cultivated lands	0	0	6.2	1.6
3	Dams (shallow flooded areas)	0	0	13.5	3.5
4	Dams (deep water)	0	0	88.7	22.9
5	Natural	38.9	96.1	245.7	63.7

Table 6.27a: Calculation of the magnitude of impact score for each disturbance class based on extent and intensity of impact scores (HGM unit 1)

Disturbance class	Disturbance class extent (%) (Table 6.26)	Intensity Score (cf Table 4.4)	Magnitude of impact score	Factors contributing to impact
Ridge and furrow	3.9	4	0.16	Abandoned ridge and furrow
Natural	96.1	1	0.96	Wetland vegetation largely intact – although impacted by desiccation and minor inavasion of bramble
Overall weighted impact score			1.12	

Table 6.27b: Calculation of the magnitude of impact score for each disturbance class based on extent and intensity of impact scores (HGM unit 2)

Disturbance class	Disturbance class extent (%) (Table 6.26)	Intensity Score (Table 4.4)	Magnitude of impact score	Factors contributing to impact
Ridge and furrow	8.2	4	0.33	Abandoned ridge and furrow
Cultivated lands	1.6	10	0.16	Currently cultivated land (potatoes)
Shallow flooded areas	3.5	6	0.21	Shallow flooding on the margin of dams in the wetland
Deep water	22.9	10	2.29	Deep flooding by dams in the wetland
Natural	63.7	1	0.64	Wetland vegetation largely intact – although impacted by desiccation and minor inavasion of bramble
Overall weighted impact score			3.63	

STEP 3: Determine overall Present Vegetation State for wetland

The overall vegetation impact scores are provided in Table 6.28, which reflects largely altered vegetation and a Present State category of C (Table 6.29).

Table 6.28: Derivation of overall Present Vegetation State score for the wetland

HGM Unit	Area(Ha)	HGM unit extent (%)	HGM impact score (from Table 6.27)	Area weighted impact score*	Present Vegetation State category
1	40.5	0.09	1.12	0.10	
2	385.9	0.91	3.63	3.30	
		100	Overall area weighted impact score**	3.40	C

*Area weighted impact score = HGM extent /100 x impact score
**Overall area weighted impact score = sum of individual area weighted scores for each HGM unit

Table 6.29: Categories used by *WET-Health* for describing the Present Vegetation State of wetland vegetation

Description	Impact score	Vegetation state category
Vegetation composition appears natural.	0-0.9	A
A very minor change to vegetation composition is evident at the site.	1-1.9	B
Vegetation composition has been moderately altered but introduced, alien and/or increased ruderal species are still clearly less abundant than characteristic indigenous wetland species.	2-3.9	C
Vegetation composition has been largely altered and introduced, alien and/or increased ruderal species occur in approximately equal abundance to the characteristic indigenous wetland species.	4-5.9	D
Vegetation composition has been substantially altered but some characteristic species remain, although the vegetation consists mainly of introduced, alien and/or ruderal species.	6-7.9	E
.Vegetation composition has been totally or almost totally altered, and if any characteristic species still remain, their extent is very low.	8-10	F

STEP 4: Assess Trajectory of Change

Trajectory of change classes and change scores are indicated in Table 6.30. In view of the landowner attempting to rehabilitate the abandoned ridge and furrow fields in the wetland, to remove all cultivated fields in the wetland from agriculture, and to eradicate alien plants from naturally vegetated areas, the Trajectory of Change can be assessed as presented in Table 6.31a and b. The dams in the wetland will remain but no new ones will be constructed.

Table 6.30: Trajectory classes, change scores and symbols used to represent likely Trajectory of Change to wetland vegetation

Trajectory Class	Description	Change Score	Change Class Range	Symbol
Improve markedly	Vegetation condition is likely to improve markedly over the next 5 years	2	1.1 to 2.0	↑↑
Improve slightly	Vegetation condition is likely to improve slightly over the next 5 years	1	0.3 to 1.0	↑
Remain stable	Vegetation condition is likely to remain stable over the next 5 years	0	-0.2 to +0.2	→
Slowly deteriorate	Vegetation is likely to slowly deteriorate over the next 5 years	-1	-0.3 to -1.0	↓
Rapidly deteriorate	Rapid deterioration of vegetation condition is expected	-2	-1.1 to -2.0	↓↓

Table 6.31a: Evaluation of Trajectory of Change within HGM unit 1.

Disturbance class	Source of change	Disturbance class extent (%) (Table 6.27a)	Change score (Table 6.30)	Area-weighted change score*
1	Ridge and furrow	0.04	+2	+0.08
2	Agricultural lands	0	0	0
3	Shallow flooding from dams	0	0	0
4	Deep flooding	0	0	0
5	Natural	0.96	+1	+0.96
HGM change score**				**+1.04**

*Area weighted change score = Disturbance Class extent /100 x change score

**HGM change score = sum of individual area weighted scores for each disturbance unit

Table 6.31b: Evaluation of Trajectory of Change within HGM unit 2

Disturbance class	Source of change	Disturbance class extent (%) (Table 6.27b)	Change Score (Table 6.30)	Area-weighted change score
1	Ridge and furrow	0.08	+2	+0.16
2	Agricultural lands	0.02	+2	+0.04
3	Shallow flooding from dams	0.04	0	0
4	Deep flooding	0.23	0	0
5	Natural	0.64	+1	+0.64
HGM change score				**+0.84**

*Area weighted change score = Disturbance Class extent /100 x change score

**HGM change score = sum of individual area weighted scores for each disturbance unit

The scores for each HGM unit from Tables 6.31a and 6.31b are then used to calculate the overall Trajectory of Change score for the wetland (Table 6.32). The overall score for the wetland, of 0.77, shows that the vegetation of the wetland should improve slightly over the next 5 years (Table 6.30). This is assigned a symbol of ↑.

STEP 5: Describe overall Vegetation Health

In representing the overall vegetation health of the wetland, the Present Vegetation State is assigned a class of C (Tables 6.28 and 6.29), and the Trajectory of Change is given a symbol of ↑, which means that the overall wetland Vegetation Health should be represented as C(↑).

STEP 6: Record the alien vegetation that is present in the wetland

A number of declared weeds occur in the wetland with relatively low cover, and the threat of further invasion given current management is considered low (Table 6.33).

Table 6.32: Evaluation of overall Trajectory of Change for the wetland.

HGM unit	HGM unit extent (Table 6.28) (%)	HGM Change score* (Table 6.31)	Area-weighted change score**
1	9	1.04	0.01
2	91	0.84	0.76
Overall weighted threat score***			0.77

*Calculated for each HGM unit – See Table 6.28

**Area weighted change score = HGM extent /100 x HGM change score

***Overall area weighted change score = sum of individual area weighted scores for each HGM unit

Table 6.33: Alien species identified and suspected factors contributing to current infestation levels.

Disturbance class	List the alien species present	Extent (%)	Suspected factors contributing to increased abundance
1	Bramble (Rubus cuneifolius)	1-5	Stable, except along footpath and other areas of disturbance
2	Wattle (Acacia mearnsii)	1-5	Currently being removed from gully
3	Annual weeds (Bidens, thistle)	<1	Mostly found along the edges of cultivated land
Threat of further invasion, given the current management:			Low ■ Medium □ High □

4. Combined final scores

Although combining scores for hydrology, geomorphology and vegetation health is not advised, there may be some circumstances where it is necessary to do this. This is done using the formula: (Hydrology Score * 3) + (Geomorphology Score * 2) + (Vegetation Score * 2) / 7.

The same formula applies to determining the Trajectory of Change: (Hydrology Score * 3) + (Geomorphology Score * 2) + Vegetation Score * 2) / 7.

Table 6.34: A summary of the scores calculated for each module, combined to give an overall score for the Health of the wetland

Module	Impact Score	Category	Change Score	Change Symbol	Health Class
Hydrology	3.28	C	+1	↑	C(↑)
Geomorphology	2.96	C	-1	↓	C(↓)
Vegetation	3.40	C	+0.77	↑	C(↑)
Overall Health Score for entire wetland	3.22	C	0.36	↑	**C(↑)**

SECTION 7: WATER QUALITY

The term water quality is used to describe in a general way the concentration of dissolved salts (solutes) and of particulate (clastic) sediment. In these guidelines we only wish to deal with dissolved load since clastic sediment is dealt with as part of the geomorphological health assessment. This material offers very coarse guidelines for a qualitative assessment of wetland health with respect to water quality.

It is recognized from the outset that the nature and level of solutes found in wetlands varies considerably from one wetland area to the next. Variation over time within a given wetland area may also be considerable, particularly in areas subject to high climatic variation. This makes generalizations and standards for determining the health of a wetland from the perspective of water quality very difficult. Nonetheless, it is proposed that a very coarse assessment of water quality impacts in wetlands is possible using an impacts-based approach rather than a detailed description of the biotic response to altered water quality.

Solutes can be nutrients, but a variety can have toxicant effects (e.g. xenobiotic compounds such as arsenic and salts such as sodium chloride or sodium carbonate). Solutes can be elevated unnaturally in wetlands through two principal means:

1. Importation from an external source into the wetland's catchment
2. Concentration as a result of decreased throughflows in a wetland that would otherwise have naturally flushed solutes out of the wetland.

Imported solutes include those from both non-point sources (e.g. areas of fertilized crop or pasture land and areas where the density of houses with septic tanks or pit latrines exceeds 6 houses per ha) and point sources (e.g. industrial outfalls, dairies, piggeries or feedlots).

WET-Health does not have a specific module for assessing impacts of altered water quality on wetlands and their biota . However, the same approach can be used as applied in the other modules, whereby the extent of the wetland affected by increased solute levels and the intensity of the impact on the affected area would be assessed.

Extent is based on the location of potential sources of increased solutes in relation to catchment runoff paths into the wetland and the nature of the flow through the wetland (i.e. whether channelled or diffuse). A solute source entering at the upstream end of a wetland is likely to affect a much greater extent of the wetland than a source entering at the downstream end of the wetland. Similarly, increased solutes carried in flow that is spread diffusely across the wetland's surface will affect a much greater extent than solutes carried in channelled flow contained in a small portion of the wetland.

Intensity of impact is based on:

1. the sensitivity of the wetland to increased pollutants (see Table 7.1) and
2. the amount and type of solute, taking into account interception within the wetland's catchment.

If, for example, the outfall from a large piggery entered directly into a wetland of intermediate sensitivity then the intensity of impact is likely to be large. However, if the outfall passed first through a series of ponds, then through an artificial wetland, following which it traveled a distance of several hundred meters along a vegetated waterway, it is assumed that a large proportion of the pollutants would be intercepted and the impact would be small to moderate. Refer to Table 7.2 as a guide in deciding on an intensity score.

Table 7.1: Some key factors affecting the sensitivity of a wetland to imported solutes

Characteristics of a wetland with potentially high sensitivity	Characteristics of a wetland with potentially low sensitivity
Wetlands in catchments that are naturally nutrient-poor (e.g. with a sandstone-derived catchment)	Wetlands in catchments that are naturally intermediate or high in solutes
Naturally short, heterogeneous vegetation	Tall, dense, uniform stands of Phragmites, Typha or Cyperus spp.
Open water areas are present	Open water areas are lacking
The wetland is undisturbed and the vegetation is close to natural	The wetland is already disturbed and dominated by weedy (ruderal) species
MAP:PET ratio is high	MAP:PET ratio is low
Drainage of the wetland is closed (i.e. endhorheic)	Drainage of the wetland is open (i.e. exhoreic)

Table 7.2: Guideline for assessing the intensity of impact of altered water quality on the affected area of an HGM unit

Impact category	Description	Score
None	No discernible modification, or the modification is such that it has no impact on wetland integrity.	0- 0.9
Small	Although identifiable, the impact of this modification on the affected area is small (e.g. resulting from slightly elevated nutrients as a result of leaching from fields some distance from the affected area of the HGM unit).	1-1.9
Moderate	The impact of this modification on integrity of the affected area is clearly identifiable, but limited (e.g. resulting from somewhat elevated nutrients as a result of leaching from fields close to the wetland or from toxicants as a result of regular spraying of biocides adjacent to the wetland).	2-3.9
Large	The modification has a clearly detrimental impact on integrity of the affected area (e.g. resulting from resulting from point source pollution from a piggery entering directly into the affected area).	4- 5.9
Serious	The modification has a highly adverse effect on the integrity of the affected area, but the most tolerant biota are still able to persist (e.g. resulting from leaching of acid mine drainage directly into the wetland, with the resilient Phragmites australis still able to persist, although at reduced levels of growth).	6-7.9
Critical	The modification has an extremely adverse effect on the integrity of the affected area (e.g. resulting from discharge of effluent of very high toxicity directly into the affected area, where even the most resilient plants are unable to persist).	8-10

REFERENCES

Adamus PR, Clarain EJ, Smith RD and Young RE, 1987. *Wetland evaluation technique (WET).* Technical Report T-87. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg.

Brinson MM, 1993. *A hydro-geomorphic classification for wetlands.* Wetland Research Programme Technical Report WRP-DE-4. US Army Corps of Engineers, Vicksburg,

Bromilow C, 1995. *Problem plants of South Africa.* Briza, Aracadia.

Cheesman OD, 2004. *Environmental impacts of sugar production*. CABI Publishing, Wallingford.

Cowardin LM, Carter V, Golet FC and Laroe ET, 1979. *Classification of wetlands and deepwater habitats of the United States*. US Department of Interior, Fish and Wildlife Services Report FWS/UBS 79-31.

Davis MA and Slobodkin LB, 2004. The science and values of restoration ecology. *Restoration Ecology,* 12: 1-3.

Dickens C, Kotze D, Mashigo S and Graham M, 2003. *Guidelines for integrating the protection, conservation and management of wetlands into catchment management planning*. WRC Report No. TT220/04. Water Research Commission, Pretoria.

DWAF, 1994. *Quaternary catchments.* Department of Water Affairs and Forestry, Pretoria.

DWAF 2005. *A practical field procedure for identification and delineation of wetlands and riparian areas.* Department of Water Affairs and Forestry, Pretoria.

Ellery WN, Grenfell MC, Grenfell S, Kotze DC, McCarthy TS, Tooth S, Grundling P-L, Beckedahl H, le Maitre D and Ramsay L, 2009. *WET-Origins: Controls on the distribution and dynamics of wetlands in South Africa.* WRC Report No TT 334/09. Water Research Commission, Pretoria.

Erwin J, 2003. *WWF: Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) Methodology*. World Wide Fund for Nature, Gland, Switzerland.

Ewart-Smith JL, Ollis DJ, Day JA, and Malan HL, 2006. *National Wetland Inventory: development of a wetland classification system for South Africa*. WRC Report No. KV 174/06. Water Research Commission, Pretoria.

Gush MB, Scott DF, Jewitt GPW, Schulze RE, Lumsden TG, Hallowes LA and Görgens AHM, 2002. *Estimation of streamflow reductions resulting from commercial afforestation in South Africa.* WRC Report No. TT173/02. Water Research Commission, Pretoria.

Heeg J, Ackhurst EGJ and Breen CM, 1989. Water quality and the need for water releases. In: Walmsley RD and Roberts CPR (eds.) *Changing patterns of resource use on the Pongolo River Floodplain.* FRD Occasional Report Series No 36. Ecosystem Programmes, Foundation for Research and Development, CSIR, Pretoria.

Heeg J and Breen CM, 1994. Resolution of conflicting values on the Pongola River and Floodplain (South Africa). In: Patten BC (ed.) *Wetlands and shallow continental water bodies, Volume 2*. p303-359. SPB Academic Publishing, The Hague, Netherlands.

Howe CP, Claridge GF, Hughes R and Zuwendra, 1991. *Manual of guidelines for scoping EIA in tropical wetlands.* PHPA/Asian Wetland Bureau, Sumatra Wetland Project Report No. 5, Bogor.

Kotze DC, 1999. *A system for supporting wetland management decisions*. Ph.D. Thesis. School of Applied Environmental Sciences, University of Natal, Pietermaritzburg.

Kotze DC, Marneweck GC, Batchelor AL, Lindley DS and Collins NB, 2009. *WET-EcoServices: A technique for rapidly assessing ecosystem services supplied by wetlands.* WRC Report No TT 339/09. Water Research Commission, Pretoria.

Lackey RT, 2001. Values, policy and ecosystem health. *Bioscience*, 51: 437-443.

Marneweck GC and Batchelor AL, 2002. Wetland classification, mapping and inventory. In: Palmer RW, Turpie J, Marneweck GC and Batchelor AL (eds.) *Ecological and economic evaluation of wetlands in the upper Olifants River Catchment, South Africa.* WRC Report No. 1162/1/02. Water Research Commission, Pretoria.

McCartney MP, Neal C and Neal M, 1998. Use of deuterium to understand runoff generation in a headwater catchment containing a dambo. *Hydrol. Earth Syst. Sci.* 5: 65-76.

McCartney MP, 2000. The influence of a headwater wetland on downstream river flows in sub-Saharan Africa. In: *Land-Water Linkages in Rural Watersheds*. Electronic Workshop. 18 September - 27 October. Food and Agriculture Organization of the United Nations, Rome.

Mitsch WJ and Gosselink JG, 1993. *Wetlands,* 2nd edition. Van Nostrand Reinhold, New York

Reed PB, 1988. *National list of plant species that occur in wetlands.* Biological Report 88. US Fish and Wildlife Services, Washington DC.

Reppert RT, Sigleo W, Srackhiv E, Messman L and Meyers C, 1979. *Wetland values: concepts and methods for wetlands evaluation*. IWR Research Report 79-R-1, U.S. Army Corps Engineers, Fort Belvoir, VA.

Ward AD and Trimble SW, 2004. *Environmental Hydrology,* 2nd edition. Lewis Publishers. Boca Raton.

Working for Wetlands, 2005. *Working for wetlands strategy.* Working for Wetlands, Pretoria.

GLOSSARY

Abiotic	Non-living components of the environment
Aerobic	Having molecular oxygen (O_2) present
Aggradation	To raise the elevation of a river bed or valley floor by the deposition of sediment
Alien	Plant or animal species that does not occur naturally in the area
Alluvial fan	Gently sloping conical accumulation of coarse alluvium deposited by a stream upon emergence from an area of confined flow or due to a sudden loss of slope
Alluvium	Sedimentary materials deposited by flowing water as velocity slows
Anaerobic	Having no molecular oxygen (O_2) present
Anthropogenic	Of, relating to, or resulting from the influence of human beings on natural objects
Assessment	The process of arranging into classes based on careful analytical evaluation
Avulsion	Event where stream flow naturally changes its course, usually as a result of a difference in elevation between the old and new stream course
Backswamp	Extensive, marshy or swampy, low-lying areas of floodplains between natural levees or alluvial ridges and valley sides or terraces
Base flow	The minimum discharge in a stream or river that occurs as a result of deep percolation of water; not through surface runoff (also known as perennial flow)
Base level	The lowest level to which a stream can erode its bed
Bedload	Sediment that is transported by being rolled or bounced along the bed of a stream
Berm	A mound or bank of earth used as a barrier against flooding of land
Biophysical	The biological and physical components of the environment
Biotic	Living components of the environment
Braided channel	A stream with multiple channels that interweave as a result of repeated division and rejoining of flow around interchannel bars, resembling the strands of a complex braid
Canalization	The creation of artificial drains or the incision caused by erosion gullies where no visible confined flow path existed previously
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]).
Channel	The part of a river-bed containing its main current, naturally shaped by the force of water flowing within it
Clastic sediment	The particles of minerogenic material (clay, silt, sand, cobbles and boulders) that are moved by running water
Concave bank	Outer bank of a river bend
Convex bank	Inner bank of a river bend
Cut-off drain	An artificially created ditch that is intended to intercept runoff before or shortly after entering a wetland and promote its efficient flow downstream, in order to dry out he wetland in order to cultivate the land

Depression wetland	A basin shaped area with a closed elevation contour that is associated with inward drainage of surface water
Desiccation	The loss of moisture from material
Discharge	The quantity of water flowing in a stream per unit time, typically in units of cubic meters per second ("cumecs")
Disturbance	Any activity (human or natural) that disrupts natural processes
Disturbance unit	A vegetation unit of relatively similar disturbance history
Drain	An artificially created ditch that is intended to promote the efficient flow of water from a region where flow is diffuse or non-existent
Dyke	Thin layer of intrusive igneous rock, often near vertical, typically cutting across older rock planes
Ecology	The science which deals with the relationship between plants and animals, and their environment
Ecophysical	The ecological and physical components of the environment
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".
Endorheic	Basin or region from which there is little or no outflow of water (either on the surface as rivers, or underground by flow or diffusion through rock or permeable material).
Environmental conditions	Features of the environment that affect the distribution of plants or animals
Erosion	Physical and chemical processes that remove and transport soil and weathered rock.
Evaporation	The physical process of molecular transfer by which a liquid is changed into a gas.
Evapotranspiration	The loss of moisture from the terrain by direct evaporation plus transpiration from vegetation
Extent of impact	The proportion of a site affected by a given activity
Fault	A surface of fracture or rupture of strata, involving permanent dislocation and displacement within the earth's crust, as a result of the accumulation of strain.
Fauna	A collective term for the animal life characteristic of a particular region
Flood attenuation	The holding or slowing of water flow such that it is slowly released to streams
Floodpeaks	The highest discharges that occur in streams following a rainfall event
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.
Flora	A collective term for the plant life characteristic of a particular region or environment.
Fluvial	Related to running water (e.g. a river).
Geology	The study of the composition, structure and processes of the rock layers of the earth.
Geomorphological evolution	Systematic change in landscape features that result from processes of weathering, erosion and deposition
Geomorphology	The study of the origin and development of landforms of the earth

Gully	A well defined, channel carved by water on a hillside.
Head cut	The upper-most entrance into an erosion gully. The point where the headward extension of a gully is actively eroding into undisturbed soil.
Headward erosion	Extension of a stream, gully or canal up the regional slope of erosion
Hillslope seepage wetland	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.
Humification	Formation of organic component of soil through gradual decomposition of organic matter
Hydraulic conductivity	A measure of the rate at which water can move through a permeable medium such as soil or rock.
Hydrogeomorphic unit	Recognizable physiographic wetland-unit based on geomorphic setting, water source and water flow patterns
Hydrology	The study of the properties, distribution, and circulation of water on the earth.
Indicator	Visible sign of human-induced impact
Indigenous	Species that have originated naturally in a particular region or environment
Intensity of impact	The degree to which the component has been altered within the affected area
Introduced species	Has the capacity to out-compete and dominate the naturally occurring species
Invasive species	Has the capacity to out-compete and dominate the naturally occurring species
Levee	Broad, low embankment built up along the banks of a channel during floods
Lithology	Study of the nature and composition of stones and rocks
Magnitude of impact	The actual impact of a particular activity or suite of activities on the component of wetland health being evaluated.
Manning's Roughness Coefficient	A measure of roughness that is used to determine flow velocity in streams for which dimensions and slope are known
Meander ridge	An elevated mound of sediment adjacent to a meandering river built by the progressive deposition of sediment during periods of high flow
Natural reference condition	A system in which natural inputs of resources or toxins has not been modified by recent human intervention, and which experiences levels of disturbance that are regarded as natural
Nick point	The point where the headward extension of a stream or gully is actively eroding headward into undisturbed soil or sediment.
Organic soil	See Peat
Oxidation	Combining with oxygen, typically involving the breakdown of organic matter to produce CO_2 and H_2O
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.
Precipitation	The deposition of moisture on the earth's surface from the atmosphere, including dew, hail, rain, sleet and snow.

Present state	The state of a system in which natural inputs of resources or toxins have been modified by recent human intervention, and which experiences levels of disturbance that are unnatural
Quaternary Catchment	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]).
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).
Ruderal plant	Short-lived, weedy plants (in this case) that typically invade disturbed ground
Runoff	Total water yield from a catchment including surface and sub-surface flow.
Scroll bar	A mound of sediment that occurs on the convex bank of a meandering stream, resulting from deposition of sediment on the inner bank of the channel.
Sediments	Solid material transported by moving water, which typically comprises sand, silt and clay sized particles.
Solute	Dissolved substance
State	The condition of a system with regard to its composition, structure or function
Threat	An indication of likely danger or harm
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.
Trajectory of change	The predicted nature of change in the state of a wetland from its present state given threats and vulnerability
Transformed areas	Areas where wetland habitat has been completely destroyed
Valley-bottom wetland	Valley-bottom areas with or without a clearly defined stream channel, usually gently sloped and characterized by sediment deposition.
Water quality	The purity of the water, determined by the combined effects of its physical attributes and its chemical constituents.
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.

Appendix 1:
Guide to contents of CD

The CD contains the following information:

- Interactive catchment map
- Clickable catchment map
- Hydrological Health assessment data sheet
- Geomorphic Health assessment data sheet
- Vegetation Health assessment data sheet
- Level 1 assessment data sheet.

Interactive Catchment CD User Guide

Introduction

The Catchment CD allows Primary, Secondary, Tertiary and Quaternary river catchments in South Africa to be displayed and explored interactively. This is done by presenting the catchments in the form of maps that very quickly allow the user to locate specific catchments, and to examine their location with respect to neighbouring catchments. Users are also provided with options for displaying rivers, towns and provincial boundaries. These additional datasets serve to orient the user with respect to known geographical landmarks, thereby facilitating the process of locating specific catchments. The catchment and river datasets are also available for download in GIS format.

System Requirements

To run the CD a computer with a CD player and a Web Browser is required. To use the interactive map it is necessary to have Java installed on your computer. Java can be installed by visiting the website http://www.java.com and following the download instructions.

Starting the Interactive Catchment CD

To start the program insert the CD into the CD player. The program should load automatically if Microsoft Windows is installed on the computer. Follow these steps if the program does not start automatically when the CD is inserted:

1. Open a window to browse the contents of the CD.
2. Double-click on the file ***index.html*** to launch the program in your browser.

Instructions for using the Interactive Catchment CD

The catchments can be explored using a clickable map, or by means of an interactive map that requires Java to be installed on your computer. Use the clickable map if Java is not installed, or if it is not possible to download Java from the Internet.

(a) Interactive Catchment Map

The interactive map presents a GIS-style interface that will be familiar to users who have used a GIS. Four different layers of information are shown:

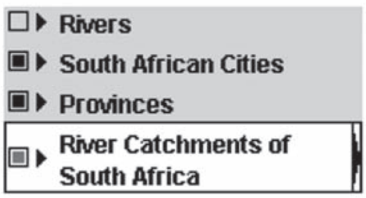
1. Rivers
2. South African Cities
3. Provinces
4. River Catchments of South Africa - *these are colour coded and labelled to show the primary catchments. The borders of the quaternary catchments within the primary catchments are shown in grey*.

Making layers visible

The Rivers, Cities and Provinces layers can be switched on or off by clicking the check box next to the layer name. The Catchments layer is always visible and cannot be switched off. In the example below the Rivers Catchments layer is switched on (i.e. visible) while all other layers are switched off.

Setting the active layer

A layer can be made active by clicking on the layer name. When this is done the active layer is highlighted in white as shown in the following example:



Navigating the map

A number of tools are provided for navigating round the map. The purpose of each of these tools is explained below:

	Zoom to the extent of the active map layer
	Zoom to the extent of all the map layers, i.e. zoom out and show the entire map
	Zoom in by clicking on the map or by dragging a rectangle to define the area to zoom in to
	Zoom out by clicking on the map
	Drag the map around within the map window

Latitude and Longitude Coordinates

As the mouse is moved over the map the current latitude and longitude coordinates are displayed in the bottom right-hand corner of the map. The coordinates are shown in decimal degrees with the longitude reading first, followed by the latitude reading. In South Africa the longitude reading will always be positive while the latitude reading will always be negative.

Querying the map

There are a number of different ways of querying the map data:

	Click on a feature of the active map layer to display the attributes of that feature
	Hover the mouse over a feature in the active layer to display a label identifying that feature
	Search the database for a particular feature. The layer must be turned on (visible) and active

When the catchments are queried using the tool a table showing the following columns will be displayed:

PRIMARY	Primary catchment in which the quaternary catchment is located
SECONDARY	Secondary catchment in which the quaternary catchment is located
TERTIARY	Tertiary catchment in which the quaternary catchment is located
QUATERNARY	Name of the quaternary catchment
AREA_KM^2	Area of the quaternary catchment (km2)
MAP_mm	Mean Annual Precipitation (mm)
PE_mm	Potential Evaporation (mm) Mean Annual A-pan Equivalent
MASR_mm	Median Annual Simulated Runoff (mm)

(b) Clickable Catchment Map

The clickable map can be used if Java is not installed on your computer. When this option is chosen a map showing the primary and quaternary catchments of South Africa is displayed. The primary catchments are colour coded and labelled while the quaternary catchments within the primary catchments are outlined in grey.

Making layers visible

It is possible to overlay a latitude-longitude grid and the outline of the provinces. This will aid the user in locating the desired catchment on the map. These layers can be switched on or off by clicking the check box next to the relevant layer name:

☐	Provinces
☐	Latitude / Longitude Grid

Zooming in to the Primary Catchments

Click on a primary catchment to view details of the secondary, tertiary and quaternary catchments that fall within the primary catchment. The quaternary catchments are labelled and are also colour-coded according to the secondary catchment within which they are located. A latitude-longitude grid is shown at half-degree intervals.

Zooming out to the main map

To return to the main map showing all the South African catchments click on the browser's Back button.

GIS Datasets

The GIS Datasets section of the interactive CD provides access to the Catchments and Rivers data in GIS format. These datasets are in ESRI shape file format and have been compressed into a zip archive. The datasets can be viewed by unzipping the relevant archive and then loading them into a GIS program that can read shape files.

Working for Wetlands

Working for Wetlands
South African National Biodiversity Institute
Private Bag X101
Pretoria, 0001
Tel: 012 843 5191
Fax: 012 843 5250
wetlands@sanbi.org
http://wetlands.sanbi.org

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.

The Water Research Commission

Water Research Commission
Private Bag X03
Gezina, 0031
Tel: 012 330 0340
Fax: 012 331 2565
info@wrc.org.za
www.wrc.org.za

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.

University of KwaZulu-Natal

School of Environmental Sciences
University of KwaZulu-Natal
Durban, 4041
Tel: 031 260 1278
Fax: 031 260 1391
www.ukzn.ac.za

William (Fred) Ellery and Donovan Kotze of the University of KwaZulu-Natal (UKZN) managed the programme that supports the production of this component of the *WET-Management* Series. They can be contacted at:
f.ellery@ru.ac.za
kotzed@ukzn.ac.za

The institutions whose logos appear on this page have made a substantial contribution to the production of this document.

Titles in the Wetland Management Series

WET-RoadMap: A Guide to the Wetland Management Series – TT 321/07

WET-Origins: Controls on the distribution and dynamics of wetlands in South Africa – TT 334/09

WET-ManagementReview: The impact of natural resource management programmes on wetlands in South Africa – TT 335/09

WET-RehabPlan: Guidelines for planning wetland rehabilitation in South Africa – TT 336/09

WET-Prioritise: Guidelines for prioritising wetlands at national, regional and local scales – TT 337/09

WET-Legal: Wetland rehabilitation and the law in South Africa – TT 338/09

WET-EcoServices: A technique for rapidly assessing ecosystem services supplied by wetlands – TT 339/09

WET-Health: A technique for rapidly assessing wetland health – TT 340/09

WET-RehabMethods: National guidelines and methods for wetland rehabilitation – TT 341/09

WET-RehabEvaluate: Guidelines for monitoring and evaluating wetland rehabilitation projects – TT 342/09

WET-OutcomeEvaluate: An evaluation of the rehabilitation outcomes at six wetland sites in South Africa – TT 343/09

9781770056398