Updated Manual for the Identification and Delineation of Wetlands and Riparian Areas

water & forestry
Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

Republic of South Africa

Updated Manual for the Identification and Delineation of Wetlands and Riparian Areas

Department of Water Affairs and Forestry
Sub-Directorate: Stream Flow Reduction Activities

September 2008

Second Edition

September 2008

Published by:

Department of Water Affairs and Forestry
Sub-Directorate: Stream Flow Reduction Activities
Private Bag X313
Pretoria
0001
Republic of South Africa

Co-ordinated by: DWAF: SD Stream Flow Reduction Activities

This document should be cited as:

DWAF (2008) *Updated Manual for the Identification and Delineation of Wetlands and Riparian Areas,* prepared by M. Rountree, A. L. Batchelor, J. MacKenzie and D. Hoare. Report no. **XXXXXXXXX**. Stream Flow Reduction Activities, Department of Water Affairs and Forestry, Pretoria, South Africa.

DOCUMENT STATUS AND APPROVAL

WORKING TITLE: Updated Manual for the Identification and Delineation of Wetlands and Riparian Areas

AUTHORS: M. Rountree, A. L. Batchelor, J. MacKenzie and D. Hoare

EXTERNAL REVIEWER: Awaiting

REPORT STATUS: draft

REPORT NUMBER: **XXXXXXXXXXXXXXXXXXX**

DATE: September 2008

Recommended for the Department of Water Affairs and Forestry:

____

Ms Naomi Fourie
Acting Director: SD: SFRA

Approved for the Department of Water Affairs and Forestry:

____

ACKNOWLEDGEMENTS

This document represents an update of a previous identification and delineation manual. The origins thereof were a product of widespread collaboration between environmental managers, hydrologists and wetland ecologists, drawn from non-government organisations, the private sector, universities and national and provincial government. The major contribution made by the technical committee of the Land-use and Wetland/Riparian Habitat Working Group is gratefully acknowledged. Valuable contributions and guidance were also provided by the steering committee for this project, as well as through advice and suggestions obtained from regional DWAF and other government staff who were trained as part of the 2007 and 2008 series of the DWAF: SFRA "Wetland and Riparian identification and delineation" courses.

This document is a draft. Please kindly direct further suggestions for improvements or comments on the current draft to: mark.rountree@iburst.co.za

STEERING COMMITTEE MEMBERS		AFFILIATIONS
Steering committee:	Naomi Fourie	DWAF: SFRA
	David Lindley	Mondi Wetlands Project
	David Kleyn	Department of Agriculture
	Corrie Swanepoel	Agricultural Research Council

CONTENTS

GLOSSARY

Active channel bank: the bank of the channel(s) that has been inundated at sufficiently regular intervals to maintain channel form and to keep the channel free of established terrestrial vegetation.

Aeolian: wind-blown.

Alluvial soil: a deposit of sand, mud, etc. formed by flowing water, or the sedimentary matter deposited thus within recent times, especially in the valleys of large rivers.

Bar: accumulations of sediment associated with the channel margins or bars forming in meandering rivers where erosion is occurring on the opposite bank to the bar.

Base flow: long-term flow in a river that continues after storm flow has passed.

Biodiversity: the number and variety of living organisms on earth, the millions of plants, animals, and micro-organisms, the genes they contain, the evolutionary history and potential they encompass, and the ecosystems, ecological processes, and landscapes of which they are integral parts.

Buffer: a strip of land surrounding a wetland or riparian area in which activities are controlled or restricted, in order to reduce the impact of adjacent land uses on the wetland or riparian area.

Catchment: the area contributing to runoff at a particular point in a river system.

Channel section: a length of river bounded by the banks and the bed.

Coastal aquifer: groundwater systems found adjacent to the sea.

Chroma: the relative purity of the spectral colour, which decreases with increasing greyness.

Deflational (hollow): a depression in the ground resulting from loss of material due to wind action.

Delineation (of a wetland or riparian zone): to determine the boundary of a water resource (wetland or riparian area) based on soil and vegetation (wetland) or geomorphological and vegetation (riparian zone) indicators.

EIA: Environmental Impact Assessment

Ephemeral stream: a stream that has transitory or short-lived flow.

Fault line: a geological fault resulting from differential movement in the earth's crust

Facultative species: species usually found in wetlands (67% – 99% of occurrences) but occasionally found in non-wetland areas.

Flood bench: area between active and macro-channel, usually vegetated (inundated by annual flood).

Floodplain: a relatively level alluvial (sand or gravel) area lying adjacent to the river channel, which has been constructed by the present river in its existing regime.

Fluvial: resulting from water movement.

Footslope: the lowest portion of a hill-slope.

Geological control: the control over fluvial processes that results from the character of the geological structures in the area.

Gleying: a soil process resulting from prolonged soil saturation, which is manifested by the presence of neutral grey, bluish or greenish colours in the soil matrix.

Groundwater: subsurface water in the saturated zone below the water table.

Habitat: the natural home of species of plants or animals.

High terrace: relict floodplains which have been raised above the level regularly inundated by flooding due to lowering of the river channel (rarely inundated).

Hue (of colour): the dominant spectral colour (e.g. red).

Hydromorphic soil: a soil that, in its undrained condition, is saturated or flooded long enough to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).

Hydrology: the study of the occurrence, distribution and movement of water over, on and under the land surface.

Hydromorphy: a process of gleying and mottling resulting from the intermittent or permanent presence of excess water in the soil profile.

Hydrophyte: any plant that grows in water or on a substratum that is at least periodically deficient in oxygen as a result of soil saturation or flooding; plants typically found in wet habitats.

Intermittent flow: flows only for short periods.

Macro channel bank: the outer bank of a compound channel.

Metamorphosed zone: an area in which sedimentary rocks have been altered by heat and gasses associated with intrusions of magma.

Mid-channel bar: single bar(s) formed within the middle of the channel; flow on both sides.

Midslope: that portion of a terrain unit, which occurs below a crest and/or scarp and above a footslope and/ or valley bottom.

Mire: peat-containing wetlands also referred to as peatlands.

Mottles: soils with variegated colour patterns are described as being mottled, with the “background colour” referred to as the matrix and the spots or blotches of colour referred to as mottles.

Munsell colour chart: a standardized colour chart, which can be used to describe hue (i.e. its relation to red, yellow, green, blue and purple), value (i.e. its lightness) and chroma (i.e. its purity). Munsell colour charts are available which show that portion commonly associated with soils, which is about one fifth of the entire range.

NEMA: National Environmental Management Act, Act 107 of 1998.

Obligate species: species almost always found in wetlands (> 99% of occurrences).

Organic carbon: carbon derived from or associated with the breakdown of vegetative material.

Peat: a dark brown or black organic soil layer, composed of partly decomposed plant matter, and formed under permanently saturated conditions.

Pedology: a branch of soil science dealing with soils as a natural phenomenon, including their morphological, physical, chemical, mineralogical and biological constitution, genesis, classification and geographical distribution.

Perched water table: the upper limit of a zone of saturation that is perched on an unsaturated zone by an impermeable layer, hence separating it from the main body of ground water (the saturated zone).

Permanent zone of wetness: the inner zone of a wetland that is permanently saturated.

Podzolization: the mobilization in and removal from an A and/or E soil horizon of organic matter and/or sesquioxides.

Preferential recharge: area in which a substantial proportion of recharge to groundwater takes place.

Redoxymorphic soil features: physic-chemical changes in the soil due to (1) in the case of gleying, a change from an oxidizing (aerated) to reducing (saturated, anaerobic) environment; or (2) in the case of mottling, due to switching between reducing and oxidizing conditions (especially in seasonally waterlogged wetland soils).

Riparian habitat (as defined by the National Water Act): includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils (deposited by the current river system), 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.

Runoff: stream channel flow.

Saturation zone: the zone in which the soils and rock structure are saturated with water.

Scree Pan: a collection of rocks and coarse debris that accumulates at the foot of a steep slope.

Seasonal zone of wetness: the zone of a wetland that lies between the Temporary and Permanent zones and is characterized by saturation for three to ten months of the year, within 50cm of the surface.

Sedges: grass-like plants belonging to the family Cyperaceae, sometimes referred to as nutgrasses. Papyrus is a member of this family.

Sesquioxides: a general term to describe free iron, aluminium and manganese oxides in the soil.

Soil family: a hierarchical level within the S.A. Soil Classification System, below soil form.

Soil form: a hierarchical level within the S.A. Soil Classification System, above soil family.

Soil horizons: layers of soil that have fairly uniform characteristics and have developed through pedogenic processes; they are bounded by air, hard rock or other horizons (i.e. soil material that has different characteristics).

Soil matrix: the soil framework consisting of the spatially arranged solid particles, which enclose soil air, soil water and biological components.

Soil morphology: pertaining to the form and structure of the soil.

Soil profile: the vertically sectioned sample through the soil mantle, usually consisting of two or three horizons.

Soil survey: the systematic examination, description, clarification and mapping of soils in an area for a specific purpose.

Soil wetness factor: an index indicating the period of wetness of a soil horizon; W1, W2 and W3 being short, long and all year round wetness respectively (correlated to the Forestry Soils Database).

Temporary zone of wetness: the outer zone of a wetland characterized by saturation within 50cm of the soil surface for less than three months of the year.

Terrace: area raised above the level regularly inundated by flooding (infrequently inundated).

Terrain unit morphological classes: areas of the land surface with homogenous form and slope. Terrain may be seen as being made up of all or some of the following units: crest (1), scarp (2), midslope (3) footslope (4), and valley bottom (5).

Value (of colour): the lightness of colour of a soil.

Watercourse (as defined by the National Water Act): means

a) a river or spring;
b) a natural channel in which water flows regularly or intermittently;
c) a wetland, lake or dam into which, or from which, water flows; and
d) any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes where relevant, its bed and banks.

Water table: The upper surface of groundwater or that level below which the soil is saturated with water. The water table feeds base flow to the river channel network when the channel bed is in contact with the water table.

Wetland (as defined by the National Water Act): 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 under normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

Wetland delineation: the determination and marking of the boundary of a wetland. In terms of the delineation procedure described in this document, delineation means marking the outer edge of the temporary zone of wetness.

WULA: Water User Licence Application – relating to Section 21 Water Uses in the National Water Act

1. INTRODUCTION

Rivers, their associated riparian areas, and wetlands play important functions in the landscape, and provide society with a wide variety of ecosystem goods and services, including:

- Flood attenuation;
- Sediment stabilisation and trapping;
- Biodiversity support; and
- Water quality improvement.

In South Africa, the National Water Act [i] aims to achieve a balance between the use and protection of the country's water resources, where the entire aquatic ecosystem - not merely the water it provides – is recognised as 'the water resource'. This legislation has redefined the concept of water resource use and protection to include not only water but the full range of goods and services that aquatic ecosystems provide.

Under this legislation all water resources are an indivisible natural asset under the custodianship of national government. There is "no ownership of water but only a right (for environmental and basic human needs) or an authorisation for its use" [ii]. Thus both wetlands and riparian zones are specified as water resources; and thus these resources are under the custodianship of the DWAF and subject to the relevant authorisations governing use and protection.

In the National Water Act, a wetland is described as "*land which is transitional between terrestrial and aquatic systems where the water table is 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 soil*." [i]

Riparian zones are described as "*the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to and extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent areas*." [i]

In order to give effect to the protection and regulation measures encompassed within the National Water Act and other legislation affording protection or regulation of use of wetlands and riparian zones, it is necessary to be able to translate the legal (verbal) definitions of the resources into practicable approaches which enable one to identify and define the extent of these various water resources on the ground.

Purpose and background of this document

Due to the level of legal protection provided to wetland and riparian zones through the National Water Act, as well as other legislation related to the protection and regulation of use of the country's water resources, the delineation of wetland and riparian zones are generally required as part of the Department of Environmental Affairs and Tourism's Environmental Impact Assessment (EIA) studies and the Department of Water Affairs and Forestry's Water User Licence Applications (WULA's). The purpose of this document is to provide the guidelines and methods to enable to identification and detailed spatial definition and delineation of wetland and riparian area water resources which are described in the National Water Act – effectively to translate the legal, "wordy" definitions of wetlands and riparian areas into a practical approach that can be applied in the field. This manual thus describes:

1) the ways in which wetlands (Section 4 of this document) and riparian zones (Section 6 of this document) can be identified by means of a series of indicators, and
2) the methods for delineating the boundary of a wetland (Section 5 of this document) or riparian zone (Section 7 of this document) at a site.

The suite of wetland or riparian indicators can be used at a screening or desktop level to predict or indicate the possible presence of a wetland or riparian area at a site, and thus for authorising agencies to evaluate whether a detailed wetland or riparian delineation study should be requested for specific EIA's or WULA's (Figure 1). The delineation methods themselves are the detailed field-based methods required to determine the boundary of the relevant water resource.

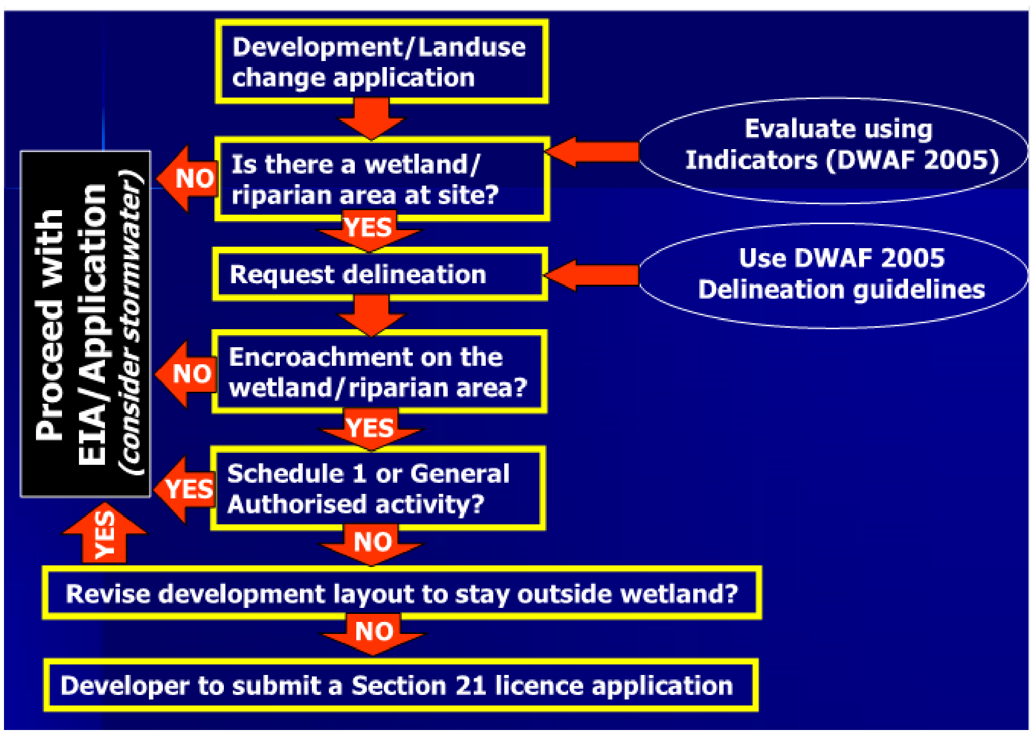


Figure 1: Wetland/Riparian Indicators and Delineation methods within the EIA process

The indicators can thus be used to predict if a wetland or riparian zone is likely to be present at a site, but they are not diagnostic; nor can they be used to map the wetland or riparian area. In order to determine the boundaries of (i.e. to map) a wetland or riparian zone as defined by the National Water Act, it is necessary to apply the delineation guidelines for the relevant water resource type.

The delineation guidelines described for wetlands and riparian areas have been tested and refined under a wide range of conditions, and have proved consistent enough for use across South Africa. These methods are scientifically robust, simple to apply and, most importantly, provide authorities with a standardised, affordable and auditable method of spatially defining these protected water resources.

Although the manual will provide the user with good technical information, the accuracy of delineation is directly dependent upon the training and experience of the user. A good delineator is a person who:

- has extensive field experience,
- has an understanding of wetland or riparian ecology,
- is knowledgeable of the region in which they are working and
- exercises sound and unbiased scientific and professional judgment.

It is also important to recognise that some wetlands will be more difficult to delineate than others and that all data collected must be used in conjunction with the knowledge and experience of the delineator. Those geologies or special cases where additional information or expertise may be required are described in more detail in Appendices A and B of this document.

In order to ensure that accurate delineations can be done under a range of conditions, some form of training in the basics of wetland delineation is recommended. A wide variety of training courses are provided privately as well as through various tertiary institutions. The Department of Water Affairs and Forestry has recently developed a short course for wetland and riparian delineations based on this manual. Further information can be obtained from the National Department of Water Affairs and Forestry: Sub-Directorate Stream Flow Reduction Activities.

This document represents an update of a previous identification and delineation manual and specific note should be made of the vastly updated riparian delineation methods contained herein. The origins of this manual were a product of widespread collaboration between environmental managers, hydrologists and wetland ecologists, drawn from non-government organisations, the private sector, universities and national and provincial government. The major contribution made by the technical committee of the Land-use and Wetland/Riparian Habitat Working Group is gratefully acknowledged.

The difference between wetlands and riparian zones

Both rivers and wetlands are listed as types of watercourses and are afforded appropriate protection under the National Water Act. This is to be expected, since both rivers and wetlands are forms of drainage lines in the landscape. Whereas wetlands generally display more diffuse flow and are lower energy environments, riparian areas are commonly found along streams and rivers that reflect the high-energy conditions associated with the water flowing in a strongly defined channel.

Wetlands have many distinguishing features, the most notable being

- the presence, either permanently, seasonally or temporarily, of water at or near the surface,
- distinctive redoxymorphic features in the soils, and
- vegetation which is adapted to or tolerant of saturated soils.

Wetlands are also often pound in specific topographic settings within the landscape, and are often associated with specific soil types or forms.

Identifying these distinguishing features, by means of indicators, has become widely accepted as a valid way to identify wetlands. The indicators described in section 4 have been developed through the study of wetland characteristics and can be considered accurate if used and interpreted correctly.

Riparian zones can similarly be distinguished from adjacent terrestrial areas by observing the presence or absence of a few key indicators. Although very wet riparian areas may display some wetland indicators, in the generally semi-arid climate of southern Africa, the riparian zones are usually not saturated for a long enough duration for wetland indicators to develop. Whereas wetland vegetation and soils adapt to, and indeed are determined by, prolonged or even permanent periods of saturation; riparian zones are adapted to the physical disturbances due to frequent overbank flooding from the associated river or stream channel.

Thus wetlands reflect the very low energy forms of drainage lines and riparian areas are representative of the fast-flowing, higher energy forms of drainage lines or rivers. For the purposes of this document, we will treat wetlands and riparian zones as separate entities (as indicated in the National Water Act). However it is important to note that there are some situations, such as in floodplains, where both wetlands *and* riparian zones may be expected to be associated with the drainage line. These special cases are described in Appendix B.

2. WETLANDS

What is a wetland?

The word "wetland" is a family name given to a variety of ecosystems, ranging from springs, seeps and mires in the upper catchment, to marshes, pans and floodplains and finally coastal lakes, mangrove swamps and estuaries at the bottom of the catchment. These ecosystems all share a common primary driving force: water. Its prolonged presence in wetlands is a fundamental determinant of soil characteristics and the associated plant and animal species composition. Any part of the landscape where water accumulates for long enough and often enough to influence the soils, plants and animals occurring in that area is thus a wetland.

For the purpose of this manual, wetlands are considered as those ecosystems defined by the National Water Act:

> "*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 land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil*."

According to the National Water Act definition, wetlands must:

- have a water table which is usually at or near the soil surface (or which is periodically above the level of the soil);

  and

- under normal circumstances, be characterised by wetland vegetation.

Why are wetlands important?

Wetland systems provide a variety of ecosystem goods and services, including:
- Temporary storage of floodwaters and attenuation of flood peaks;
- Water quality improvement;
- Baseflow maintenance downstream of large wetlands;
- Erosion control (through sediment trapping and storage);
- Biodiversity support;
- Fishing, grazing and land for subsistence agriculture; and
- Reed and medicinal plant harvesting.

In fact, the economic value of the goods and services which society derives from rivers and wetlands has been estimated at 4.95 trillion US Dollars [iii] – this more than the value which society derives globally from forests!

For direct benefits, some wetlands serve as important breeding grounds for fish, and many wetlands, due to the prolonged presence of water, can be used as dry season grazing areas, if undertaken on a sustainable (Wise Use) basis. Wetlands also contain a wide variety of species, some totally reliant on wetland habitats for their survival. Many of these species are used for food, craft manufacture, medicines, building material and fuel.

There are also many indirect hydrological functional benefits which wetlands provide. For instance, some wetlands act like giant sponges, holding back water during floods and releasing it during low flow periods. In a dry country like South Africa, this is crucial. By regulating water flows during floods, wetlands reduce downstream erosion and flood damage. Some wetlands are also able to trap pollutants such as sediment, heavy metals and disease causing organisms; improving water quality. It has been estimated that the demand for water in South Africa is likely to meet the economically exploitable supply for the country as a whole by about the year 2030. Without sufficient water we cannot grow enough crops, support the growth of industry or develop a growing tourism industry. Our economy is therefore dependent on a continual supply of water of sufficient quality and quantity. Wetlands help to regulate our water supply, and also aid in preventing erosion of rivers and thus siltation (and loss of storage capacity) of dams.

These water resources can thus make direct and indirect contributions to the well-being of humans, the environment and the economy, because different wetlands are able to variously improve water quality, trap sediment and/or regulate runoff.

Yet despite these benefits, wetlands are amongst the most impacted and degraded of all ecological systems, and global assessments indicate that the majority of remaining wetlands are degraded or under threat of degradation [iv]. The main culprits have been the drainage of wetlands for crops and pastures, poorly managed burning and grazing that has resulted in erosion, the planting of alien trees in wetlands, mining, pollution and urban development. Continued wetland destruction will result in less pure water, less reliable water supplies, increased erosion and flooding, lower agricultural productivity, and more endangered species.

3. TYPES OF WETLANDS

As described in the above sections, wetlands can potentially provide a wide variety of goods and services to society. However, the functional attributes and values of wetlands remain difficult to ascribe categorically. This is because there is a wide variety of different wetland types, and these different wetland types "work" differently (which is largely why reviews of wetland hydrological functions often display such widely varying results [v]).

One approach to accounting for the different types of wetlands is to group wetlands according to their landscape settings and hydrological functions. These types of wetland typing or classification systems have been shown to be useful in accounting for the different functions of various wetlands – even being prescribed by the US EPA for wetland studies [vi]. A modification [vii] of a Department of Water Affairs and Forestry wetland typing system [viii] which was recently developed discriminates different groups of wetlands according (Table 1) to their:

1) Hydrological characteristics: by the way water flows into, through and out of the wetland system, and
2) Position in the landscape: whether the wetland is located on the slope, crest or in the valley bottom – the geomorphological landscape position of the wetland.

Table 1: Landscape settings and flow characteristics of the HGM wetland types (after Rountree and Batchelor, *in prep.)*.

Landscape setting		**Flow pattern**	**Wetland Type**
Valley Bottoms	*Strongly confined valley floor*	channelled	**Rivers**
		standing water	**Lakes**
	Wide or unconfined valley floor	diffuse	**Unchannelled Valley Bottoms**
		channelled (parallel to valley)	**Channelled Valley Bottoms**
		channelled (meandering across valley)	**Meandering Floodplains**
Slopes		diffuse => diffuse	**Seepage wetlands**
		diffuse => surface/channel	
Crests		diffuse flow => standing water	
		standing water	**Depressional Pans**
Flat		No defined direction of drainage due to very flat landscape setting	**Flats**

This wetland typing system is useful for describing the characteristics of individual wetland units. Other larger scale information, such as the EcoRegion [1], geological and/or vegetation setting could also be used to provide a regional context for the wetland unit, as is described in the hierarchical wetland classification system developed by the South African National Biodiversity Institute [ix].

Describing and classifying common types of wetlands

The wetland typing system proposed above (Table 1) identifies seven basic wetland types across South Africa, with true rivers being a separate (eighth) category characteristic of confined valley floors. Thus in valley bottom positions of the landscape we could expect to find:

- Rivers;
- Lakes;
- Unchannelled Valley Bottoms;
- Channelled Valley Bottoms; and
- Meandering Floodplain systems

Seepage wetlands could be expected to be found in slope positions of the landscape, and depressional pans (sometimes surrounded by seepage wetlands) might be found in crest positions of the landscape. The characteristics of the seven basic wetland types (and contrasted to rivers) are described below.

Rivers

Linear fluvial, eroded landforms which carry channelized flow on a permanent, seasonal or ephemeral/episodic basis. The river channel flows within a confined valley (gorge) or within an incised macro-channel. The "river" includes both the active channel (the portion which carries the water) as well as the riparian zone.

Examples: the most common form of drainage lines in the country. Most of Eastern seaboard rivers are incised (constrained) due to uplift of the subcontinent and rejuvenation of the rivers.

Meandering Floodplains

Linear fluvial, net depositional valley bottom surfaces which have a meandering channel which develop upstream of a local (e.g. resistant dyke) base level, or close to the mouth of the river (upstream of the ultimate base level, the sea) . The meandering channel flows within an unconfined depositional valley, and ox-bows or cut-off meanders -

---

[1] EcoRegions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources, and are designed to serve as a spatial framework for the assessment, management and monitoring of water resources. In South Africa, EcoRegions form the basis of the DWAF: River Health monitoring assessments.

evidence of meandering – are usually visible at the 1:10 000 scale (i.e. observable from 1:10 000 orthomaps).

The floodplain surface usually slopes away from the channel margins due to preferential sediment deposition along the channel edges and areas closest to the channel. This can result in the formation of backwater swamps at the edges of the floodplain margins.

Examples: lower Pongolo, Mkuze and Usutu Rivers, KZN; also some of the upper tributaries of the Vaal River (e.g. Seekoeivlei, upper Wilge River).

Channelled Valley Bottoms

Linear fluvial, net depositional valley bottom surfaces which have a straight channel with flow on a permanent or seasonal basis. Episodic flow is thought to be unlikely in this wetland setting. The straight channel tends to flow parallel with the direction of the valley (i.e. there is no meandering), and no ox-bows or cut-off meanders are present in these wetland systems. The valley floor is, however, a depositional environment such that the channel flows through fluvially-deposited sediment. These systems tend to be found in the upper catchment areas.

Examples: fairly common in the headwaters and upper to middle reaches of the eastern seaboard rivers.

Unchannelled Valley Bottoms

Linear fluvial, net depositional valley bottom surfaces which do not have a channel. The valley floor is a depositional environment composed of fluvial or colluvial deposited sediment. These systems tend to be found in the upper catchment areas, or at tributary junctions where the sediment from the tributary smothers the main drainage line.

Examples: fairly common in the headwaters of the eastern seaboard rivers, specifically in the high Drakensberg, although increasingly rare due to channelization and erosion.

Lakes

These are depressions in the valley bottoms which may be temporarily, seasonally or permanently inundated. Unlike pans, they are not deflationary erosional features, but instead they have, or would have had, an outlet at the downstream end of the valley (a low point); which has been variously blocked or otherwise restricted by dune deposits; terminal moraines (e.g. Lake District; U.K.), landslides or other depositional features across the valley bottom. Their shape is therefore determined by the surrounding slopes/higher ground (in contrast to the deflational processes creating the typical circular or oval depressional pan shapes).

Examples: lakes of the Wilderness area, Western Cape; valley bottom lakes in Chrissiesmeer system, Mpumalanga.

Seepage wetlands

Seepage wetlands are the most common type of wetland (in number), but probably also the most overlooked. These wetlands can be located on the mid- and footslopes of hillsides; either as isolated systems or connected to downslope valley bottom weltands. They may also occur fringing depressional pans. Seepages occur where springs are decanting into the soil profile near the surface, causing hydric conditions to develop; or where throughflow in the soil profile is forced close to the surface due to impervious layers (such as plinthite laters; or where large outcrops of impervious rock force subsurface water to the surface).

Examples: small systems, but widespread in the landscape, particularly in granitic geologies.

Depressional Pans

Small (deflationary) depressions which are circular or oval in shape; usually found on the crest positions in the landscape. The topographic catchment area can usually be well-defined (i.e. a small catchment area following the surrounding watershed). Although often apparently endorheic (inward draining), many pans are “leaky” in the sense that they are hydrologically connected to adjacent valley bottoms through subsurface diffuse flow paths.

Examples: pans in the East Rand of Gauteng, Free State and NorthWest provinces; pans in Umfolozi, KZN; the high-lying pans in the Chrissiesmeer system, Mpumalanga.

Flats

In areas with weakly developed drainage patterns and flat topography, rainfall may not drain off the landscape very quickly, if at all, due to the low relief. In such areas (commonly characterized by aeolian deposits or recent sea floor exposures) the wet season water table may rise close to, or above, the soil surface, creating extensive areas of shallow inundation or saturated soils. In these circumstances the seasonal or permanently high groundwater table creates the conditions for wetland formation.

Examples: Cape Flats; northern KwaZulu-Natal coastal belt; Dolomitic areas (although many of these wetlands have desiccated due to the lowered regional water tables)

Alan: maybe you could develop one of your nice diagrams to visually show these various wetland types?

4. INDICATORS OF WETLANDS

As discussed above, in order to be classified as a wetland according to the National Water Act, an area must (1) have a water table which is usually at or near the soil surface (or which is periodically above the level of the soil) and (2) be characterised by wetland vegetation under normal circumstances.

For the reviewing and authorising agencies involved in water resource protection and regulation, it may not always be practical to undertake detailed site assessments prior to the commencement of EIA or WULA studies. In addition, highly variable intra- and inter-annual rainfall in South Africa mean that the water table in a wetland may not always be visible (i.e. at or close to the surface) at the time of a site survey; especially if the survey is undertaken in the dry season or in a very dry rainfall year. Similarly, wetland vegetation may be seasonal and thus not visible, or not dominant, if the site is sampled in a dry year or the dry season. Thus although wetlands are by their nature maintained by permanent to periodic presence of water; the water table may not be visible all year (or indeed even every year) due to seasonal and inter-annual rainfall variability. Identifying wetlands by the presence of water alone would thus not be a reliable approach to wetland identification.

Instead, a number of indicators or site criteria can be assessed to identify likely wetland areas. This approach allows for the identification of indirect indicators of prolonged saturation by water to be assessed, rather than only being able to assess the presence of a high water table at a site (which would then limit site assessments to the wet season of normal or wet rainfall years). Four indicators have been developed to assist with the identification of wetlands. These are:

1) The **position in the landscape**, which will help identify those parts of the landscape where wetlands are more likely to occur;
2) The type of **soil form** (i.e. the type of soil according to a standard soil classification system), since wetlands are associated with certain soil types;
3) The presence of **wetland vegetation species**, and
4) The presence of **redoxymorphic soil features**, which are morphological signatures that appear in soils with prolonged periods of saturation (due to the anaerobic conditions which result).

The presence of these distinctive indicators in an area would imply that the frequency and duration of saturation is sufficient to classify the area as a wetland, and the advantage of using these indicators over the examination of water table depth or vegetation alone is that these four indicators can be used at any time of the year (i.e. the indicators, with the possible exception of the vegetation species, are present in the dry season and in dry years).

These four indicators of wetland presence are discussed in more detail below.

Landscape Position as an indicator of wetland presence

A typical landscape can be divided into 5 main units (Figure 2), namely the:

- Crest (hilltop);
- Scarp (cliff);
- Midslope (often a convex slope);
- Footslope (often a concave slope); and
- Valley bottom.

These five primary landscape or terrain units can be used to describe position in the landscape (as we did in section 3 for describing wetland types). Since wetlands occur where there is a prolonged presence of water in the landscape, the most common place one could expect to find wetlands is on the valley bottom [x] (where the water flows down and accumulates).

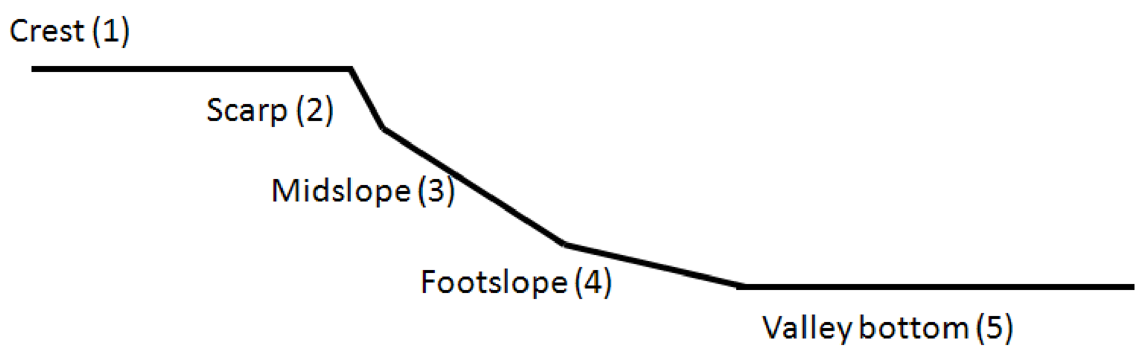


Figure 2: The five main landscape components or terrain units

The landscape position can thus be a useful preliminary indicator to screen for likely wetland locations across large areas, since wetlands are most likely to be found in the valley bottom terrain units. However, as we have seen with the depressional pans and seepages described in section 3, wetlands may also be found in depressions on the crest (indicated as a 1(5) terrain unit) or as seepage wetlands on the slopes due to the expression of either groundwater or interflow coming close to the soil surface.

Although this is not a diagnostic tool for identifying wetlands (because wetlands can occur across almost all terrain units), the landscape position indicator can be used to identify areas in which to focus site surveys, or (as in the case of valley bottoms in particular) where to request mandatory wetland or riparian delineations when authorising agencies are stipulating the requirements for more detailed specialist EIA or other similar studies for particular sites.

Soil Form as an indicator of wetland presence

Soil Forms are a particular level of a soil classification system which was developed to describe South African soils [xi]. The classification system uses the types and associations of soil and sub-soil layers (horizons) to classify different soil forms. Although primarily developed to assess agricultural potential, soil forms are useful indicators of possible wetland presence since there are a four soil forms only associated with wetlands, and several which can possible be present in seasonal or temporary wetland areas.

Champagne, Katspruit, Willowbrook and Rensburg soil forms <u>ALWAYS</u> denote wetlands. These soil forms are diagnostic of wetlands and are associated with permanently or seasonally saturated wetlands.

However, ***wetlands <u>may</u> also be present in areas characterised by the soil forms tabulated below:***

Avalon	Glencoe	Pinedene	Addo	Houwhoek
Bainsvlei	Kinkelbos	Sepane	Brandvlei	Inhoek
Bloemdal	Klapmuts	Tukulu	Dundee	Jonkersberg
Cartref	Kroonstad	Vilafontes	Etosha	Kimberley
Dresden	Longlands	Wasbank	Glenrosa	Molopo
Estcourt	Lamotte	Westleigh	Groenkop	Tsitsikamma
Fernwood	Montagu	Witfontein	*(signs of wetness for these soil forms are incorporated at the family level)*	
(signs of wetness for these soil forms are incorporated at the form level)				

Wetlands that are found in the above soil forms would usually be seasonal or temporary saturated wetlands. It is important to note that *the soil forms listed above are not diagnostic indicators of wetlands*. The presence of these soil forms only indicate a possible presence of wetlands, since in some instances the wet conditions may be deeper in the soil profile and thus neither result in wetland soils within 50cm of the surface nor in the occurrence of wetland vegetation on the surface.

Special cases of soil forms

1. If a soil profile qualifies as Champagne, Rensburg, Willowbrook or Katspruit form, it is not necessary that grey colours be present for the profile or horizon to qualify as hydromorphic as the topsoil horizon may be thicker than 50cm. Topsoils are usually dark in the permanent wetness zone due to the accumulation of organic matter.

2. If a soil profile qualifies as Fernwood form, grey E horizon colours may not necessarily indicate signs of wetness. Soil forming processes via podzolization from aeolian parent material could be responsible. Signs of profile wetness are in this case usually associated with dark, extremely high organic carbon topsoils defined as having moist Munsell values of 4 or less and chroma values of 1 or less (Refer to Appendix A).

With the exception of the Champagne, Katspruit, Willowbrook and Rensburg soil forms, the soil form indicator is again not diagnostic. However it can provide a very useful screening method for sites where geotechnical surveys have previously been undertaken, since the description of soil forms in the Geotechnical assessment would be able to indicate either areas of definite (in the case of Champagne, Katspruit, Willowbrook and Rensburg soil forms) or possible (in the case of any of the soil forms tabulated above being located on the site) wetlands on a site.

Vegetation as an indicator of wetland presence

Vegetation is a key component of the wetland definition in the National Water Act, since the definition of wetlands states that, *under normal circumstances*, wetland vegetation (species adapted to life in saturated soil) must be present for an area to be classified as a wetland.

In many wetlands, not all parts are saturated for the same length of time. Generally, there are three different zones in a wetland, which are distinguished according to the changing frequency of saturation (see figure 1). These three zones may not be present in all wetlands. The central part of the wetland, which is nearly always saturated, is referred to as the permanent zone of wetness. This is surrounded by the seasonal zone, which is saturated for a significant duration of the rainy season. The temporary zone in turn surrounds the seasonal zone, and is saturated for only a short period of the year that is sufficient, under normal circumstances, for the growth of wetland vegetation.

Using vegetation as a primary indicator requires undisturbed conditions ("normal circumstances") and expert plant species knowledge. Where such conditions and knowledge exist, vegetation is an extremely useful field indicator of wetlands. In addition, because plant communities undergo distinct changes in species composition as one moves along the wetness gradient from the centre of a wetland to its edge and into adjacent terrestrial areas, the changes in species composition provide valuable clues both for determining wetness zones as well as the outer edge of the wetland boundary (which would be at the outer edge of the temporary wetland zone).

The wetter parts of the wetland (those sections that are permanently to seasonally saturated) are typically dominated by obligate wetland plant species – those wetland plants which can *only* grow in wetland soils. A list of obligate wetland plants is provided in Appendix C. Obligate wetland plants are extremely useful for confirming the presence of wetlands at a site.

As one moves outwards towards the upslope terrestrial areas, the wetland begins to become drier and drier. These seasonally to temporarily saturated soils are more typically dominated by facultative wetland species (species preferentially, but not exclusively, found in wetlands). Although a high dominance of facultative wetland species may indicate that a wetland is possibly present; the occurrence of facultative species is *per se* not diagnostic of the presence of wetlands since these species can also occur in terrestrial environments.

Appendix C provides a comprehensive list of obligate wetland plants found in South Africa, The columns at the right of the Appendix indicting the province/s in which the facultative species are present.

Obligate and Facultative Wetland Plants

Wetlands are characterised by several environmental stresses that most plants are poorly equipped to handle. Fully aquatic plants are not equipped to deal with the periodic drying that occurs in many wetlands, whereas terrestrial plants cannot handle long periods of waterlogging. The most severe stress in wetlands is probably the anaerobic soil conditions associated with prolonged periods of saturation. Under these conditions, roots cannot respire through normal metabolic pathways, certain nutrients become unavailable to plants, and the concentrations of certain elements can reach toxic levels in the soil.

Despite these constraints, certain plant species have developed mechanisms to deal with the stresses of wetland environments. Through morphological, physiological or reproductive adaptation, these species have the ability to grow, compete, reproduce and persist in anaerobic soil conditions. Examples of these adaptations are the presence of air spaces in roots and stems that allow the diffusion of oxygen from exposed parts of the plant into the roots; adventitious roots (roots growing from unusual places); shallow root systems; large internal pores (hypertrophied lenticels) and seed dispersal mechanisms by water.

Hydrophilic (water-loving) species differ in the degree to which they are dependent on, or limited to, wetlands. Some species are *only* found in wetland environments, and are thus termed obligate wetland plants. This suite of plants is useful for reliably indicating the presence of wetlands.

Other plant species can occur in both wetland and non-wetland soils (although they are generally preferentially found in wetlands) and are known as facultative wetland species. There are a large number of seasonal and especially temporary wetlands that are characterised by the presence of facultative wetland plants or even terrestrial plant species. However, since facultative species can also be found outside of wetlands, they are not diagnostic indicators of wetlands.

CAUTION: wetland vegetation can respond relatively rapidly to alterations in hydrology, or to site disturbance. In wetlands where the inflows have been reduced, or sections of the wetland have been drained, the current vegetation cover may be comprised of terrestrial vegetation even though the site is a wetland (albeit dried out or drained). It is therefore critical to always check the soils of a site, since wetland soils have characteristic redoxymorphic features which are very reliable indicators of wetland condition. These latter features do not disappear even if the wetland has been drained or otherwise desiccated.

Redoxymorphic features as an indicator of wetland presence

The key criteria for classifying land as wetland is water – specifically that "*the water table is at or near the surface, or the land is periodically covered with shallow water"* [i]. Unfortunately the highly variable climate of southern Africa means that the water table may not necessarily be at or close to the surface in a regular, predictable manner year-on-year, or even be always seasonally predictable. These intra- and inter-annual variations in the extent of saturation/inundation of wetlands mean that the presence of the water table (or extent of flooding) will not always be a very reliable parameter for identifying wetlands. Thus the key criteria for classifying wetlands – a high water table and/or periodic inundation – cannot be reliably measured.

In soil that has been saturated for an extended time, roots and micro-organisms gradually consume the oxygen present in pore spaces in the soil. In an unsaturated soil, oxygen consumed in this way would be replenished by diffusion from the air at the soil surface. However, since oxygen diffuses 10 000 times more slowly through water than through air, the process of replenishing depleted soil oxygen in a saturated soil is significantly slower. Thus, once the oxygen in a saturated soil has been depleted, the soil effectively remains anaerobic. Prolonged anaerobic soil conditions result in a change in the chemical characteristics of the mineral elements of the soil, and these manifest visibly through changes in the soil colours. Thus although a high water table or the periodicity of inundation cannot be easily measured directly, it is possible to assess the soil properties for indications of saturation – by examining for the redoxymorphic features which result from prolonged anaerobic conditions.

The two important redoxymorphic features are mottling and gleying (Figure 3); both features caused by prolonged saturated conditions in the soil and the subsequent development of anaerobic conditions.

Gleying is characterised by the development of grey or blueish-grey colours in the mineral soil component. Certain soil components, such as iron and manganese, are insoluble under aerobic conditions. Iron is one of the most abundant elements in soils, and the iron oxide (rust) coatings over soil particles is responsible for the red and brown colours of many soils. However, under prolonged anaerobic conditions iron becomes soluble and can thus be dissolved out of the soil profile. Once most of the iron has been dissolved out of a soil, the soil matrix is left a greyish, greenish or bluish colour, and is said to be gleyed.

Mottling follows the same initial process as gleying, in that the iron becomes soluble and dissolved under anaerobic conditions. A fluctuating water table, common in wetlands that are seasonally or temporarily saturated, results in alternation between aerobic and anaerobic conditions in the soil. Lowering of the water table results in a switch from anaerobic to aerobic soil conditions, causing dissolved iron to return to an insoluble state and be deposited in the form of patches, or mottles, in the soil. Recurrence of this cycle of wetting and drying over many decades concentrates these bright (orange or red) insoluble iron compounds. Thus, soil that is gleyed but has many mottles may be interpreted as indicating a zone that is seasonally or temporarily saturated.

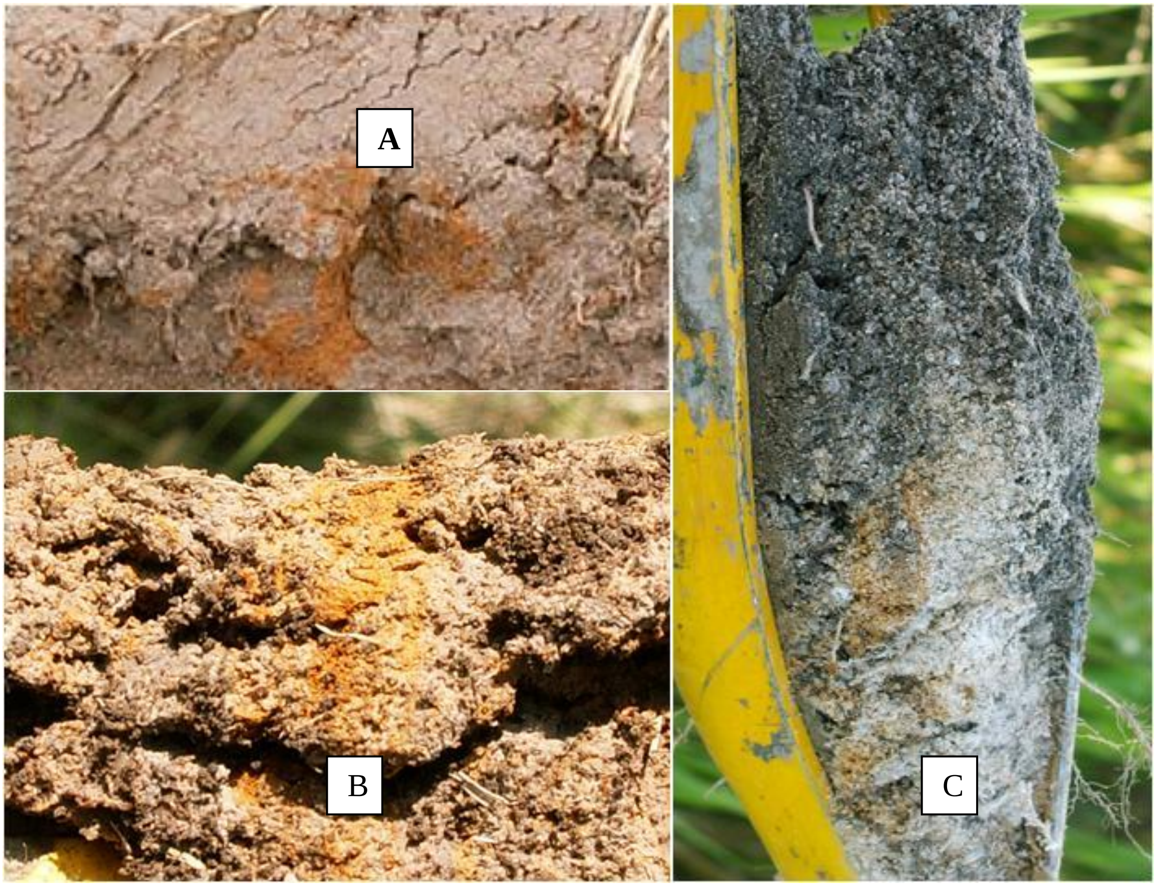


Figure 3: Mottles (A, B) and Gleyed soils (C).

Gleyed soil is characterised by the development of grey or blueish-grey colours in the mineral soil component. Mottling, occurring under conditions of a fluctuating water table, is the development of small patches of concentrated (usually red or orange) iron oxides.

The site is classified as wetland if these indicators are located within 50cm of the **original** soil surface. (i.e. in the case of developed sites, the predevelopment or pre-infilling level of the soil).

Another, albeit invisible, indicator of wetlands soils is odour. Sulphate, which is present in soil, can, like iron, similarly be reduced under the anaerobic conditions associated with saturated soils. The sulphate changes to hydrogen sulphide, a gas which has a rotten egg odour. This odour is often associated with saturated conditions; particularly in soils with high organic matter content as these provide high levels of sulphate.

FACTORS INFLUENCING REDOXYMORPHIC PROCESSES

Organic carbon

- A readily available source of organic carbon must be available for microbial respiration. Without organic carbon respiration will be extremely low and oxidation reduction reactions will be negligible.
- Low organic carbon soils may not exhibit redoximorphic features; whereas those soils with very high organic content can mask the gleyed colours and mottles due to the dark-coloured organics.

pH

- Soil pH affects the transformation of certain soil components (nitrate, manganese, iron, sulphur) via oxidation reduction reactions. Under alkaline (high pH) conditions these soil components will remain in an oxidized state and will not be reduced
- Alkaline soils may thus not show well expressed redoximorphic features.

Temperature

- If the soil/water temperature is low, typically <5°C, then the rate of microbial activity is very low. Consequently oxidation-reduction reactions will be slow or will not occur at all. Wetland soils in cold, high altitude areas may thus not show strong redoxymorphic features.

Although we have discussed four possible approaches, in practice the redoxymorphic features in the soil are used as the primary indicators, since the colours of various soil components are a reliable indicator of wetland soils. An additional benefit of gleying and mottling is that, unlike vegetation, these redoxymorphic indicators can be used on disturbed sites and can be sampled at any time of year (unlike vegetation).

Generally then, a grey soil matrix and/or mottles must be present within 50cm of the surface for the soil horizon to be classified as a wetland qualify. Wetland soils must display signs of wetness within 50cm of the soil surface. This depth has been chosen because experience internationally has shown that frequent saturation of the soil within 50cm of the surface is necessary to support hydrophytic vegetation, and the National Water Act defines wetland as a combination of saturated/inundates soils (indicated by redoxymorphic features) in combination with wetland vegetation.

The identification of signs of wetness within 50cm of the soil surface is usually a relatively simple procedure. However it is important to note that occasionally some wetland soils do not exhibit the typical characteristic mottles and gleying:

- In some situations, prolonged wetness may be manifested in an abundant accumulation of organic carbon in the topsoil. This organic carbon does not break down (due to persistent saturated conditions in the soil) and causes the upper layers of soil to develop very dark colours which may mask the gleying and mottles (*example: peat wetland soils*)
- In soils with very low iron content (such as former marine sediments which are typically iron depleted) or sites on recent alluvial deposits that are too recent to show morphological signs of wetness; very weak mottling develops (*example: the Cape flats, Tsitsikamma, northern KZN coastal plain*);

- In very well-drained soils (such as dolomitic and quartzitic derived soils), the seasonal and temporary zones of the wetland are often very constricted due to the fast drainage and limited opportunities for prolonged soil saturation (*example: Dolomites in Centurion, Gauteng).*

In order to standardise wetland assessments (specifically the assessment of gleying and mottling), a Munsell chart [2] should be consulted. If the following grey, dry Munsell colours are present within the top 50cm of the soil, the site qualifies as a wetland soil of either a temporary, seasonal or permanent nature:

• If hue is 2.5Y, then values of 5 or more and chroma values of 2 or less; or values of 6 or more and chroma values of 4 or less.

• If hue is I0YR, then a value of 4 and chroma values of 2 or less; or values of 5 or more and chroma values of 3 or less; or values of 6 or more with a chroma of 4.

• If hue is 7.5YR then values of 5 or more with a chroma of 2 or less; or values of 6 or more with a chroma of 4 or less.

• If hue is 5YR, then a value of 5 and chroma values of 2 or less; or values of 6 or more and chroma values of 4 or less.

• If hue is 5Y, then values of 5 or more and chroma values of 2 or less.

It has been recommended by Dr Donovan Kotze that soils be assessed in the moist state, since dry conditions are unlikely and impractical within wetland hydric soils.

In general however, in most across South Africa the standard indicators of gleying and mottling described above can be used to identify wetlands. The colours of these indicators are strongly influenced by the frequency and duration of soil saturation – in general, the higher the duration and frequency of saturation in a soil profile, the more prominent the grey colours become in the soil matrix. Conversely, mottles are usually absent in permanently saturated soils; are at their most prominent in seasonally saturated soils, becoming least abundant in temporarily saturated soils until they disappear altogether in the dry soils (Figure 4). Thus the permanent, seasonal and temporary wetness zones can be characterised to some extent by the redoxymorphic features that they display.

[2] A Munsell colour chart is a standardized colour chart that can be used to describe **hue** (i.e. its relation to red, yellow, green, blue and purple), **value** (i.e. its lightness) and **chroma** (i.e. its purity). Munsell colour charts are available which show that portion commonly associated with soils.

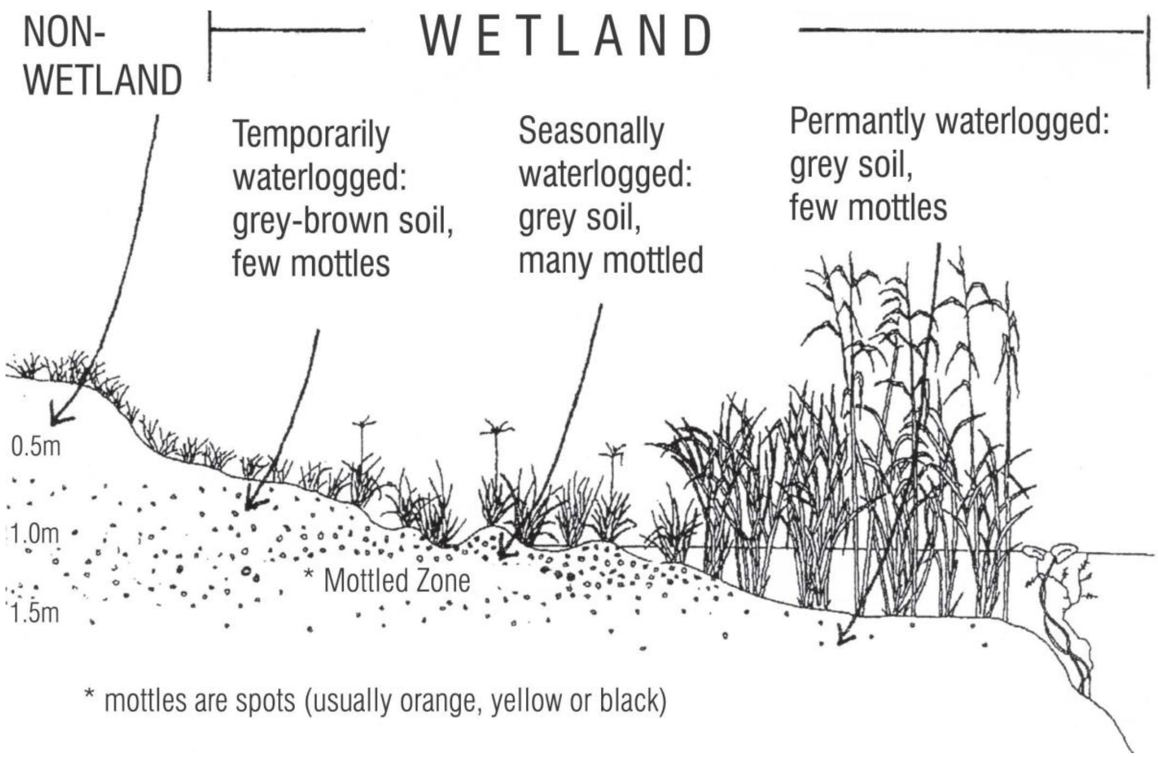


Figure 4: The characteristic redoxymorphic features which can be expected in the permanent, seasonal and temporary wetland zones.

Where modifications of the generic approach may be necessary:

In areas where there are:
- highly organic soils, such as peat;
- very recent alluvial deposits (such as recent alluvial fans in wetlands);
- very iron-poor soils, such as on sandy aquifers/old marine sediments; or
- very free-draining soils, such as Dolomitic or Quartzitic material;

there may be a requirement to slightly modify the way that the indicators are interpreted.

For example, in DOLOMITE and QUARTZITE areas, the soils are extremely free draining – usually the soil water drains very deep (often directly to the deep groundwater). Thus the water does not generally stay in the soil long enough for hydric indicators to develop. In these cases, the standard Landscape Position, Soil Form and Vegetation indicators can be applied, but mottles may be absent in top 50cm. Instead one should examine for high organic carbon (peat) in the soil as a redoxymorphic indicator of wetland soils. The seasonal and temporary wetland zones are often constricted or absent in these settings.

In SANDY AQUIFERS, grey soil colours can often occur which are not associated with the presence of water in the soil (i.e. grey colour is not a hydric indicator), and mottling can be extremely weakly developed due to low iron concentrations. In these situations, the standard Landscape Position, Soil Form and Vegetation indicators can be applied, but additionally examine for high soil carbon as an indicator of wetland soils.

These special cases are discussed in more detail in Appendix A, which outlines the slight modifications that need to be made to the standard indicators in order for the wetland soils to be correctly identified in these settings.

Permanent Zone

The permanently saturated zone of the wetland is characterised (Figure 5) by:

- A prominent grey (gleyed) matrix;
- Few or no high chroma mottles;
- Wetness all year round (if the hydrology is unaltered and the wetland is not drained), and
- A Sulphuric odour (rotten egg smell).

Figure 5: Wetland soils in a permanent zone, indicating the extensive grey (gleyed) matrix and absence of high chroma mottles
Photos: Nacelle Collins (inset: Mark Rountree)

Seasonal zone

The seasonally saturated zone of the wetland is characterised by:

- A Grey matrix of more than >10% of the soil volume;
- The occurrence of many low chroma mottles; and
- Significant periods of wetness (at least three months of saturation per annum).

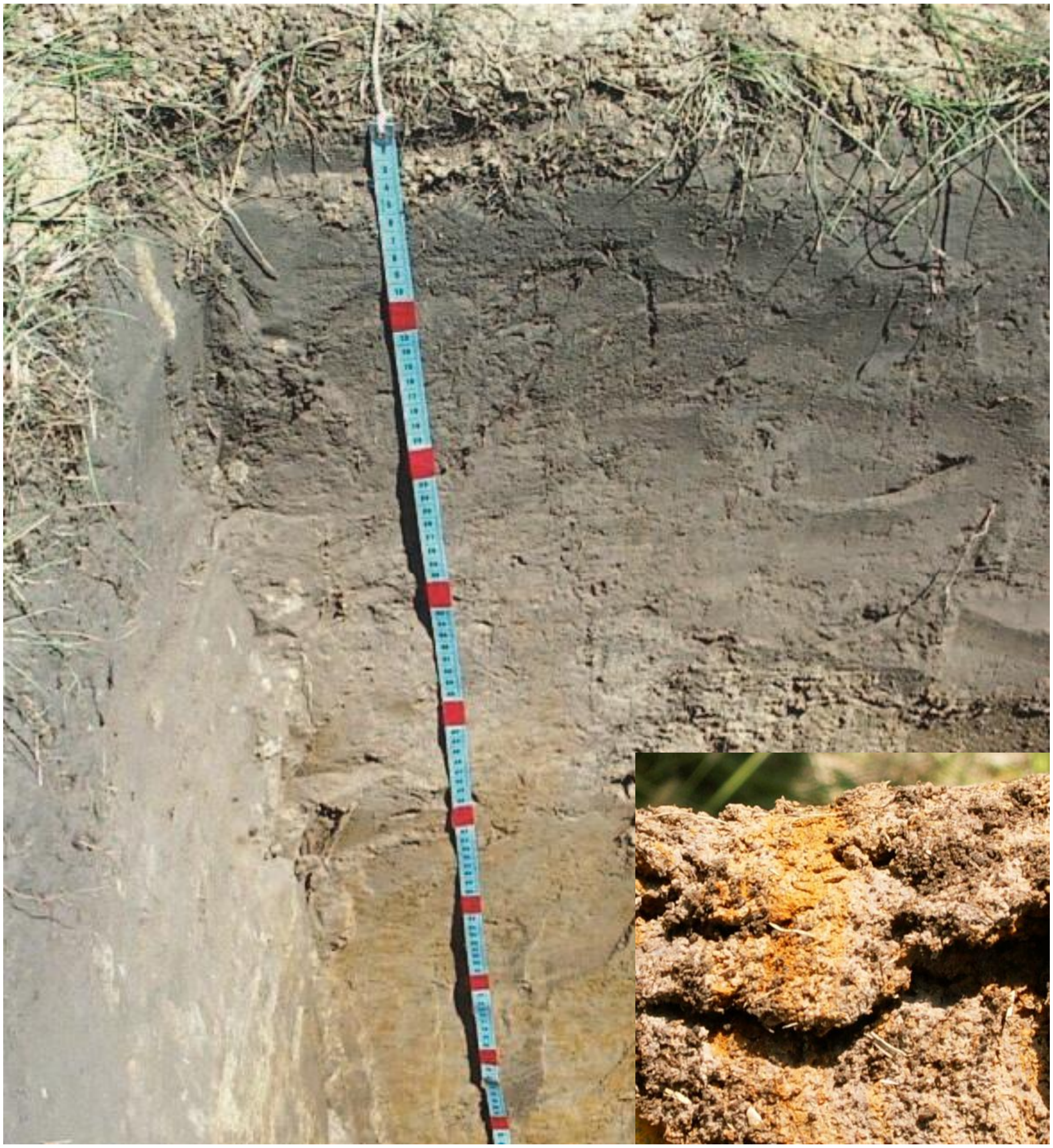


Figure 6: Wetland soils in a seasonal zone, indicating the grey (gleyed) matrix interspersed with numerous mottles
Photos: Nacelle Collins (inset: Mark Rountree)

Temporary Zone

The temporarily saturated zone of the wetland is characterised by:

- A minimal grey matrix of less than <10% of the soil volume;
- The presence of few high chroma mottles; and
- Short periods of saturation (typically less than three months of saturation per annum).

> The outer edge of the temporary zone is defined as the edge of the wetland (Figure 4)

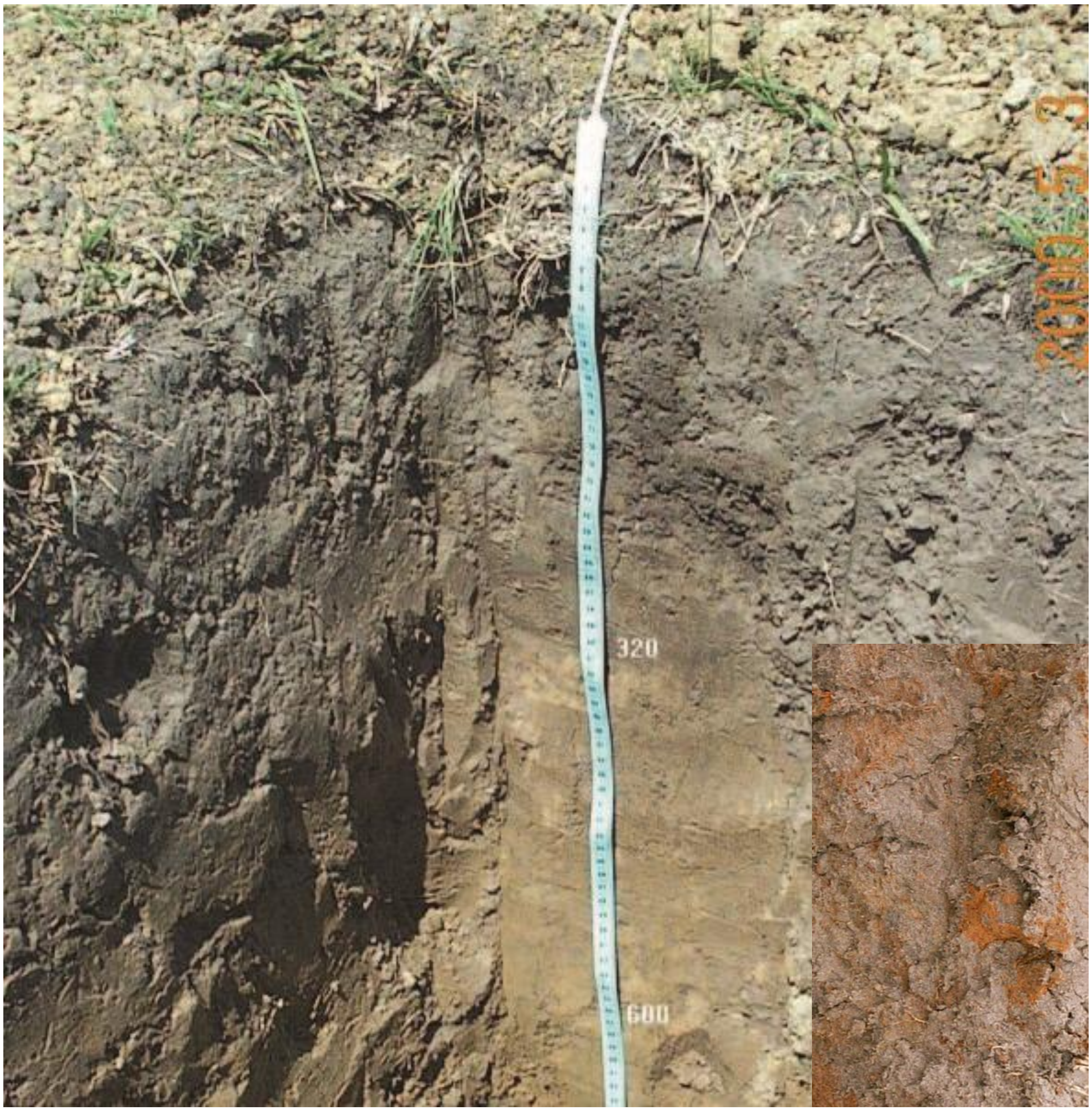


Figure 7: Wetland soils in a temporary zone, indicating the limited grey (gleyed) matrix interspersed with a few high chroma mottles.
Photos: Nacelle Collins (inset: Mark Rountree)

5. DELINEATING WETLANDS

As we have seen with the above indicators of wetlands, the most reliable, diagnostic indicators of wetlands are the redoxymorphic features in the soil. These features develop due to prolonged saturation (and associated anaerobic conditions) and can be used to indicate zones of a permanently, seasonally or temporarily high water table, as described in the characteristics of the permanent, seasonal and temporary wetland zones.

Whilst the identification of a wetland is useful, normally the requirement (specifically for EIA and WULA applications) is for the wetland to be delineated – for its boundaries to be precisely determined so that it can be mapped out and indicated as a sensitive area.

> The object of the delineation procedure is to identify the outer edge of the temporary zone of the wetland. This outer edge marks the boundary between the wetland (the water resource) and adjacent terrestrial areas.

The indicators of wetlands (landscape position; soil type; vegetation species and redoxymorphic features) will aid in the identification and approximate location of wetlands at a site, but the process of delineation then requires more intensive, field-based assessments to be undertaken. Remember, the purpose of delineation is to determine the boundary of the wetland – that 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 land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil*." [i]

Therefore wetlands must:

- Have a water table which is usually at or near the soil surface (or which is periodically above the level of the soil);
  and
- Under normal circumstances, be characterised by wetland vegetation.

A combination of redoxymorphic features (which are used as surrogates for indicating the depth of the water table) verified (when the conditions of the wetland are considered to be "normal") by the presence of wetland vegetation can thus be used to determine the boundaries of wetlands, since these indicators speak directly to the legal definition of wetlands as described in the National Water Act.

However, because vegetation responds relatively quickly to changes in soil moisture regime or management and may be easily transformed, the vegetation indicator can be less reliable than the redoxymorphic features (possibly indicating a reduced extent of wetland under drained or reduced flow conditions).

Gleying and mottling, on the other hand, are far more permanent indicators, but these indicators of soil saturation may persist for decades – possibly long after the hydrology of a wetland has changed. The advantage of the redoxymorphic features is that they can be used on sites where the surface and/or natural vegetation has been disturbed or removed.

The procedure of wetland delineation should thus use a combination of both redoxymorphic and vegetation indicators to confirm the boundaries of the wetland water resource.

Using Redoxymorphic features to identify the wetland edge

Following the guidelines of this indicator described in section 4 of this document, the outer edge of the temporary zone of the wetland should be determined. This should be done using a transect-based approach in the field.

Starting from the wettest (central or lowest-lying) part of the wetland, move perpendicularly upslope towards the surrounding terrestrial areas, sampling (with the aid of an auger or through other excavation means) the soil to a depth of at least 50cm. Note the presence of any gleying or mottling. Ensure that the indicators observed meet the requirements prescribed for the redoxymorphic indicators of wetland soils. Continue moving outwards from the wetland until the redoxymorphic indicators of wetland soils can no longer be found within the top 50cm of the soil. This will be the outer edge of the temporary wetland zone. At this stage the boundary indicated by redoxymorphic features should be verified using the vegetation indicators.

Using Vegetation to identify the wetland edge

Some plant species will only occur within wetlands and are termed obligate wetland plants (Table 2). These species can be treated as diagnostic indicators of wetlands. Other plant species may preferentially occur within wetlands, but may also occasionally be located outside of the legally defined wetland zones. These species are termed facultative species (Table 2), and whilst these are useful indicators in the field, such species are regionally or even locally specific (possibly being within wetlands of one region but outside wetlands in another region) and thus the interpretation of facultative species requires a significant degree of expert knowledge.

Table 2: The classification of plants according to occurrence in wetlands (based on the U.S. Fish and Wildlife Service Indicator Categories of Reed (1988).

Obligate wetland species	Almost always grow in wetlands (> 99% of occurrences).
Facultative wetland species	Usually grow in wetlands (67-99% of occurrences) but occasionally are found in non-wetland areas
Facultative species	Are equally likely to grow in wetlands and non-wetland areas (34-66% of occurrences).
Facultative dry-land species	Usually grow in non-wetland areas but sometimes grow in wetlands (1-34% of occurrences)

Thus with the exception of obligate wetland species (listed in Appendix C), when using vegetation indicators for delineation, emphasis is placed on the group of species that dominate the plant community, rather than on specific indicator species. Thus, the presence of scattered individuals of an upland plant species in a community dominated by wetland species is not sufficient to conclude that the area is not a wetland. Likewise, although the presence of obligate wetland species in an area confirms the wetland status of the site, the presence of a few wetland facultative species in a community dominated by upland species is not a sufficient basis for concluding that the area is a wetland. Facultative wetland species would usually be found in wetlands, but may also occasionally be found in terrestrial areas.

The emphasis in this document is on identifying the edge of the wetland water resource – i.e. the outer edge of the temporary zone. Additional information may be needed from a site and an understanding of the permanent, seasonal and temporary zones of a particular wetland may be required. To some degree, it is possible to characterise these zones by the types of hydrophilic vegetation they support (Table 3).

Table 3: A summary of the vegetation indicators which could be expected in the different wetness zones.

VEGETATION:	**Temporary Wetland Zone**	**Seasonal Wetland Zone**	**Permanent Wetland Zone**
If herbaceous:	Predominantly grass species; mixture of species which occur extensively in non-wetland areas, and hydrophilic plant species which are restricted largely to wetland areas.	Hydrophilic sedge and grass species which are restricted to wetland areas; *Phragmites australis*.	Dominated by: (1) emergent plants, including reeds (*Phragmites australis*), a mixture of sedges and bulrushes (*Typha capensis*), usually >1m tall; ***or*** (2) floating or submerged aquatic plants.
If woody:	Mixture of woody species which occur extensively in non-wetland areas, and hydrophilic plant species that are restricted largely to wetland areas.	Hydrophilic woody species, which are restricted to wetland areas.	Hydrophilic woody species, which are restricted to wetland areas. Morphological adaptations to prolonged wetness (e.g. prop roots).

The outer edge of the wetland – i.e. the outer edge of the temporary wetland zone – would be expected to be dominated by facultative wetland vegetation species (Table 3). An approach for employing vegetation as an indicator of wetland conditions had been developed, [xii] but is extremely time consuming to apply and requires a high degree of local specialist vegetation knowledge. In addition, the required information on regional wetland facultative plant species (on which the method is based) is not readily available, nor would this be easy to develop due to the variability of facultative species preferences within regions and between individual sites.

The basic approach to using vegetation to delineate wetland edges, or to verify the edges as indicated by the more reliable redoxymorphic features, is to assess the site according to the presence of obligate wetland species, and the presence and dominance of facultative wetland species.

- Check for the presence of any obligate wetland plants (as listed in Appendix C).

- In addition, rushes and all sedges (with the notable exception of *Cyperus esculentus* and *Cyperus rotundus*, which are commonly occurring weedy sedges that occur extensively on disturbed areas inside AND outside of wetlands) can be considered to be at least facultative wetland species (unless indicated as obligates in Appendix C)

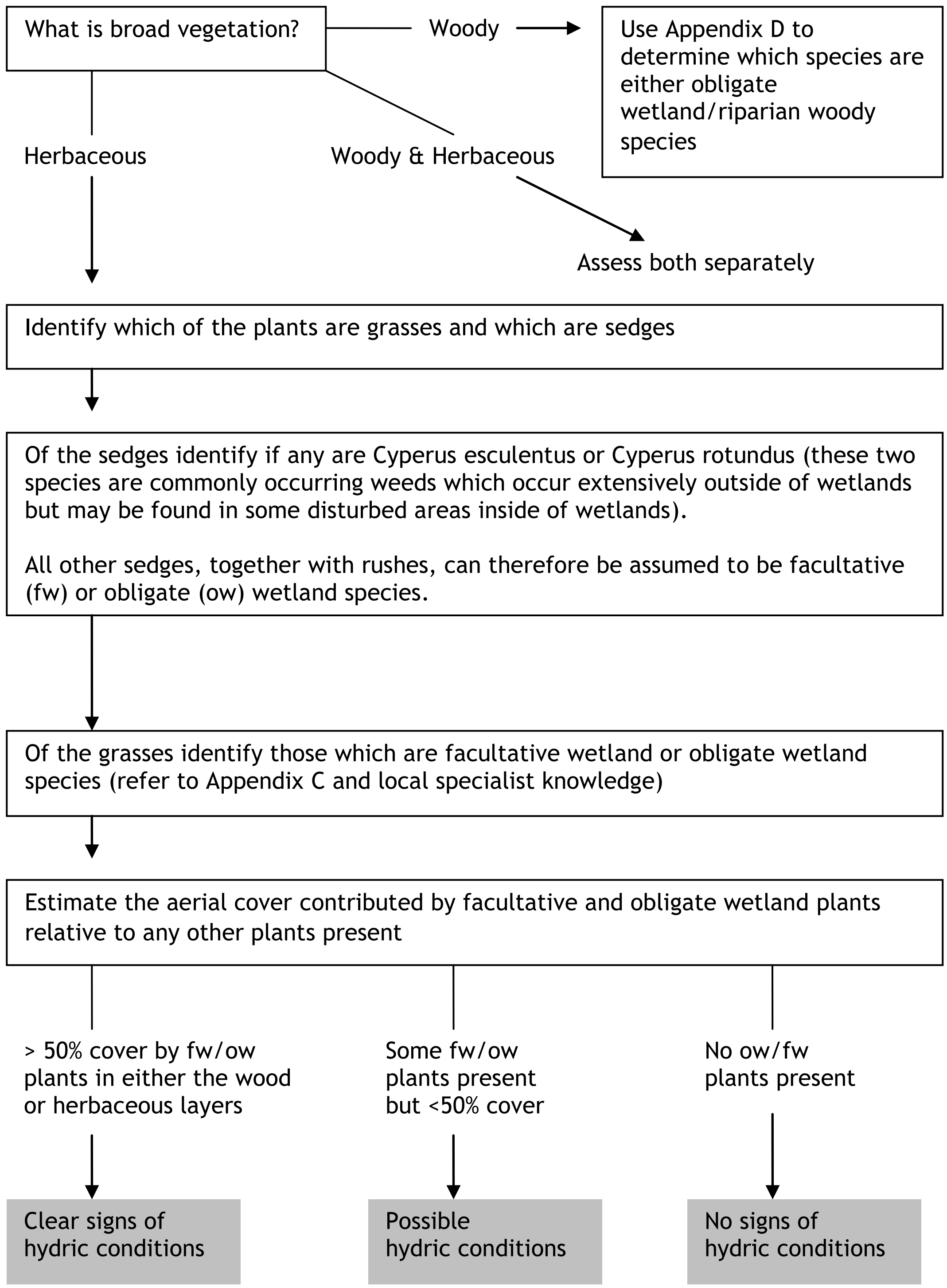
- The site should further be assessed based on the practitioner's local expertise to identify any other local or regional facultative wetland species.

To identify wetland areas using vegetation:

1) The presence of wetland obligate plant species can be considered to be diagnostic of wetland conditions (Appendix C provides a provisional list of obligate wetland plants for South Africa, denoted by the province in which they can be expected).

2) For other areas of the site which may not have readily identifiable obligate wetland plants, the zones should be assessed for the dominance of facultative wetland plants.
    a. Where more than 50% of the zone is covered by facultative wetland plants in either the wood or herbaceous layers, clear signs of wetland indications can be assumed.
    b. Where facultative plants are present, but their cover is less than 50% of the zone, this can be assumed to indicate possible wetland conditions. Confirm with the redoxymorphic features in the soil.
    c. Where no facultative plants are present, this can be assumed to indicate an absence of wetland conditions. However remember that if the degree of saturation/inundation of the wetlands has been reduced (e.g. through artificial drains or reduced flooding from upstream), then the vegetation is likely to indicate conditions less wet than what historically occurred. Confirm that there are no redoxymorphic features in the soil before confirming the terrestrial status of such sites.

Flow chart for using vegetation as an indicator of wetland conditions [1]



1 Remember that if the degree of wetness of the wetlands has been reduced (e.g. through artificial drains) the vegetation is likely to indicate conditions less wet than historically so.

Combining the indicators to delineate the edge of the wetland

The decision as to whether a particular area qualifies as a wetland is based on the number of wetland indicators it displays. The edges of a wetland are established at the point where these indicators are no longer present. While some wetlands display all of the indicators under undisturbed conditions, the critical question is: “what is the minimum set of indicators that need to be present in order to qualify an area as a wetland?”

Sole reliance on any one indicator as the determinant of wetlands can sometimes be misleading. Many plant species can grow successfully both in and out of wetlands, and soil wetness indicators may persist for decades following alteration of the hydrology of a wetland. The presence of multiple indicators provides a logical, defensible, and technical basis for identifying an area as wetland, but an area should display a minimum of either redoxymorphic features or wetland vegetation indicators in order to be classified as a wetland. Verification of the terrain unit and soil form indicators may increase the level of confidence in deciding the boundary, but these indicators are not diagnostic.

An area should display at least redoxymorphic features or wetland vegetation indicators in order to be classified as a wetland. The redoxymorphic features should be within 50cm of the soil surface.

The presence of both vegetation and redoxymorphic indicators increases the confidence and precision of the delineation, but these may not always occur simultaneously at all sites.

THE WETLAND DELINEATION PROCESS

Before going into the field

COLLECT ALL RELEVANT SUPPLEMENTARY INFORMATION
aerial photos, orthophotos, topographic maps, soil maps

↓

DESKTOP DELINEATION FROM AERIAL PHOTO / ORTHOPHOTO
using differences in colour, shading, texture and elevation

↓

In the field

ASSESS OVERALL LAYOUT OF WETLAND AND SURROUNDING AREA

↓

STARTING DOWNSTREAM, FIND WETTEST PART OF WETLAND AREA
using cues such as presence of water or obligate hydrophilic vegetation

↓

MOVING OUTWARD FROM WETTEST TO DRIEST ZONE, SAMPLE (top 50cm of soil profile) AT REGULAR INTERVALS ALONG A SERIES OF TRANSECTS

↓

DETERMINE THE WETNESS ZONE (PERMANENT / SEASONAL / TEMPORARY) FOR EACH POINT SAMPLED, USING WETNESS AND VEGETATION INDICATORS

↓

MARK OUTER BOUNDARY OF WETLAND BY PLACING FLAG AT POINT ON EACH TRANSECT WHERE WETLAND INDICATORS ARE NO LONGER VISIBLE

↓

USE THE FLAGS TO IDENTIFY A CONTOUR THAT DEFINES THE WETLAND BOUNDARY. VERIFY THE VEGETATION AND REDOXYMORPHIC INDICATORS AGAINST EACH OTHER

↓

FOLLOW THE CONTOUR, CHECKING PERIODICALLY THAT IT MATCHES THE WETLAND BOUNDARY

↓

RECORD THE BOUNDARY ON A TOPOGRAPHIC MAP USING GPS COORDINATES

↓

DELINEATE AN APPROPRIATE BUFFER ZONE TO PROTECT THE WETLAND

6. RIPARIAN AREAS

What is a riparian area?

Riparian zones are described as "*the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to and extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent areas*" [i],

Riparian zones can be thus be distinguished from adjacent terrestrial areas through their association with the physical structure (banks) of the river or stream, as well as the distinctive structural and compositional vegetation zones between the riparian and upland terrestrial areas (Figure 8). Unlike wetland areas, riparian zones are usually not saturated for a long enough duration for redoxymorphic features to develop. Riparian zones instead develop in response to (and are adapted to) the physical disturbances caused by frequent overbank flooding from the associated river or stream channel.

Figure 8: A well-developed, distinctive riparian zone along a river bank. Note the difference between the large, dense riparian forest and the small, sparsely wooded terrestrial upland vegetation in the background.
Photo: Mark Rountree

The riparian zone is usually small in headwater streams, becoming larger in mid-sized streams where it is likely to form a distinct band of vegetation whose width is determined by long-term (>50 years) channel dynamics and the size of the larger, very infrequent flood discharges. Riparian zones of large streams may form physically complex floodplains with long periods of seasonal flooding, lateral channel migration, oxbow lakes in cut-off channels and an associated diverse vegetative community. In the case of wide floodplains, some wetland elements may also be present (such as ox-bow lakes and backwater swamps).

Riparian areas may thus range from a few metres wide adjacent to small stream channels to more than a kilometre wide in floodplains. Both perennial and non-perennial streams support riparian vegetation. Because riparian areas represent the interface between aquatic and upland ecosystems, the vegetation in the riparian area may have characteristics of both aquatic and upland habitats. Many of the plants in the riparian area require plenty of water and are adapted to shallow water table conditions. Due to water availability and rich alluvial soils, riparian areas are usually very productive. Tree growth rate is high and the vegetation under the trees is usually lush in comparison to the upland terrestrial vegetation (Figure 8).

To account for these various types and widths of riparian zones, it is recommended that the type of river or stream channel with which the riparian zone is associated be examined. This is a useful predictive tool which can advise on the likely extent of riparian zone which could be expected (Table 4).

Why are riparian areas important?

Riparian areas perform a variety of functions that are of value to society, especially the protection and enhancement of water resources, and provision of habitat for plant and animal species.

Riparian areas can variously:

- store water and help reduce flood peaks;
- stabilize stream banks;
- improve water quality by trapping sediment and nutrients;
- maintain natural water temperature through shading for aquatic species;
- provide shelter, food and migration corridors for movement of both aquatic and terrestrial species;
- act as a buffer between aquatic ecosystems and adjacent upslope land uses;
- can be used as recreational sites; and
- provide material for building, muti, crafts and curios.

As described above, there are different characteristics of riparian zones depending largely on what zones of a river they are associated with. Thus not all riparian areas would be able to perform these functions to the same extent. Whilst some may be very good for flood attenuation, others may play more important bank stabilisation roles. The protection of the riparian zone enables a suitable buffer to be maintained between

Table 4: The zonal classification system for South African rivers [xiii], indicating the likely widths of riparian zones which could be expected to be associated with each river zone type.

River Type	Range of Slope	River Characteristics	Expected Riparian Zone width
Source zone	not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.	None/very small
Mountain headwater stream	0.1 - 0.7	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.	Very Small
Mountain stream	0.01 - 0.1	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool, plane bed, pool-rapid or pool riffle. Approximate equal distribution of >vertical= and >horizontal= flow components.	Small
Foothills (cobble bed)	0.005 - 0.01	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel, or cobble often present.	Moderate
Foothills (gravel bed)	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.	Large
Lowland sand bed or Lowland fllodplain	0.0001-0.001	Low gradient alluvial sand bed channel, typically regime reach type. Often confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.	Very wide
Additional zones associated with a rejuvenated river profile			
Rejuvenated bedrock fall / cascades	0.01 - 0.5	Moderate to steep gradient, often confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades, and pool-rapid.	Very small
Rejuvenated foothills	0.001 - 0.01	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro-channel activated only during infrequent flood events. A flood plain may be present between the active and macro-channel.	Moderate
Upland flood plain	0.0001-0.001	An upland low gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.	Very wide

landuse activities in the terrestrial areas and the possible impacts within the aquatic river channel itself. Maintaining riparian zones – including their naturally dense vegetation - also allows for bank stabilisation to be maintained and the risks of erosion of alluvial banks to be minimised.

7. INDICATORS OF RIPARIAN AREAS

Like wetlands, riparian areas can be identified using a set of indicators. The indicators for riparian areas are:

- Landscape position;
- Alluvial soils and recently deposited material;
- Topography associated with riparian areas; and
- Vegetation associated with riparian areas.

Landscape Position

As discussed above, a typical landscape can be divided into 5 main units (Figure 2), namely the:

- Crest (hilltop);
- Scarp (cliff);
- Midslope (often a convex slope);
- Footslope (often a concave slope); and
- Valley bottom.

Amongst these landscape units, riparian areas are only likely to develop on the valley bottom landscape units (i.e. adjacent to the river or stream channels; along the banks comprised of the sediment deposited by the channel).

Alluvial soils

Alluvial soils are soils derived from material deposited by flowing water, especially in the valleys of large rivers. Riparian areas often, but not always, have alluvial soils. Whilst the presence of alluvial soils cannot always be used as a primary indicator to accurately delineate riparian areas, it can be used to confirm the topographical and vegetative indicators. Quaternary alluvial soil deposits are often indicated on geological maps, and whilst the extent of these quaternary alluvial deposits usually far exceeds the extent of the contemporary riparian zone; such indicators are useful in identifying areas of the landscape where wider riparian zones may be expected to occur.

Topography and recently deposited material associated with riparian areas

The National Water Act definition of riparian zones refers to the structure of the banks and likely presence of alluvium. A good indicator of the presence of riparian zones is the presence of alluvial deposited material adjacent to the active channel (such as benches and terraces), as well as the wider incised "macro-channels" which are typical of many of southern Africa's eastern seaboard rivers.

Recently deposited alluvial material outside of the main active channel banks can indicate a currently active flooding area; and thus the likely presence of wetlands.

Vegetation associated with riparian areas

Unlike the delineation of wetland areas, where redoxymorphic features in the soil are the primary indicator, the identification of riparian areas relies heavily on vegetative indicators. Using vegetation, the outer boundary of a riparian area can be defined as the point where a distinctive change occurs:

- in species composition relative to the adjacent terrestrial area; and
- in the physical structure, such as vigour or robustness of growth forms of species similar to that of adjacent terrestrial areas. Growth form refers to the health, compactness, crowding, size, structure and/or numbers of individual plants.

It is thus a relative change in species composition and growth forms between the vegetation immediately adjacent to the channel versus that of the upland terrestrial areas which identifies the riparian zone. Where clear differences exist in the composition and structure of the vegetation located at the channel edge to that located slightly upslope, this is a good indication of the presence of a riparian zone.

These differences between riparian and terrestrial vegetation are primarily a result of:

- more water being available to species growing adjacent to watercourses than to those growing further away, and
- increased levels of flooding disturbances experienced by the species within the riparian zone than those in the upland terrestrial zone.

In addition to indicators of structural differences in vegetation, indicator species themselves can be used to denote riparian areas. A list of obligate riparian vegetation indicator species is provided in Appendix D. For the purposes of riparian zone delineation using plant species, we (re)define and utilize the following terms:

- **Obligate riparian:** these are species (see Appendix D for list) that occur almost exclusively in the riparian zone (> 90% probability). They are seldom found in non riparian areas, but where they are outside of riparian areas they still indicate wetness. They are not likely to occur in the upland. Obligate riparian species are conservative as such i.e. an obligate will remain an obligate throughout all geographic regions. (a plot of species occurrence from the aquatic zone will peak and taper off within the riparian zone)

- **Preferential riparian:** these are species that are preferentially, but not exclusively, found in the riparian zone (>75% probability). They may be found in non riparian areas as indicators of wetness. Where they do occur in the upland, they show progressive reductions in abundance, stature and vigour farther from the riparian zone. Preferential riparian species may harden to drought conditions, but will always indicate sites with increased moisture availability, and are therefore consistent indicators across geographic boundaries. (a plot of species occurrence from the aquatic zone will peak and taper off predominantly within the riparian zone, but may extend beyond)

- **Facultative riparian:** these species may occur in either riparian zones or the upland (>25% probability of occurrence in the riparian zone). They can habituate to more mesic conditions with a high probability of survival, or can tolerate higher levels of flooding disturbance or soil moisture. They are not good national indicators, but rather circumstantial indicators good for particular regions e.g. a species such as *Rhus pyroides* may not be an indicator of the riparian zone in perennial rivers in one region, but often is useful as an indicator of the riparian zone of ephemeral streams in another region. (when existing as an indicator, a plot of species occurrence from the aquatic zone will likely taper off beyond the riparian zone)

- **Upland:** these species are rarely found in riparian zone (<25% probability) and characterize terrestrial landscapes that border riparian zones. Upland species usually occur naturally in the upper parts of the riparian zone, but with low relative abundance. Increased occurrence of upland species in the riparian zone may indicate altered/decreased flows and a subsequent "drying" out of the riparian zone. (a plot of species occurrence from the aquatic zone will usually not taper off into the upland).

The presence of obligate riparian species, and/or the dominance of facultative riparian plant species can be taken as an indicator of the presence of a riparian zone.

8. DELINEATING RIPARIAN AREAS

As with the delineation approach for wetlands, the field delineation method for riparian areas focuses on two main indicators of riparian zones:

- Vegetation Indicators, and
- Topography of the banks of the river or stream.

Additional verification can be obtained by examining for any recently alluvial deposited material to indicate the extent of flooding and thus obtain at least a minimum riparian zone width. The following procedure should be used for delineation of riparian zones:

A good rough indicator of the outer edge of the riparian areas is the edge of the macro channel bank. This is defined as the outer bank of a compound channel, and should not be confused with the active river or stream channel bank. The macro-channel is an incised feature, created by uplift of the subcontinent which caused many rivers to cut down to the underlying geology and creating a sort of “restrictive floodplain” within which one or more active channels flow. Floods seldom have any known influence outide of this incised feature.

Within the macro-channel, flood benches may exist between the active channel and the top of the macro channel bank. These depositional features are often covered by alluvial deposits and may have riparian vegetation on them. Going (vertically) up the macro channel bank often represents a dramatic decrease in the frequency, duration and depth of flooding experienced, leading to a corresponding change in vegetation structure and composition.

Preparatory work prior to the field assessment

Before going into the field, collect all relevant supplementary information, including aerial photos, orthophotos, topographic maps and soil maps (if available) of the area to be visited. Aerial photography can assist in determining the extent of alluvial deposits, as well as if any vegetation lines which may be evident indicate a difference in species composition or more vigorous growth (Figure 8).

Complete a desktop delineation by estimating the wetland boundary from the aerial photo and drawing it onto the image, using clues such as topography, presence of water and differences in vegetation. This preliminary identification of the riparian area boundaries will enable more efficient field work, as well as ensuring that the practitioner has a “big picture”, overall view of the site prior to the site assessment.

Once in the field, find a convenient vantage point from which to assess the overall layout of the river, riparian zone and surrounding area. The basis of riparian delineation is through the use of vegetation indicators, and these are verified against geomorphological indicators.

The basic steps for riparian delineation are outlined in the text box below, with further detail and explanatory text provided in the sections which follow.

Step I: Assessment of site suitability

The riparian delineation method for the field only works at sites where the disturbances to the physical structure of the banks and associated vegetation has not been very severe. If the site to be assessed meets these criteria, proceed to step II.

For sites which have been heavily disturbed (i.e. where there is almost no indigenous vegetation remaining, and/or where the banks have been heavily engineered such that it is no longer possible to identify the original morphology of the banks), then a REFERENCE site will need to be located. The Reference site will need to be close by on the same or a similar sized river system, in an area of similar topography. The Reference Site can be used to provide an indication of the likely riparian extent prior to disturbance. Obviously this will however reduce the confidence in the assessment. If time allows and historical aerial photography is available for the site in question, it is highly recommended that these historical data sources be used to verify the appropriateness of the chosen Reference site/

Once the reference site is located, proceed with step II.

Step II: Assessment of vegetation composition and structure

The key guiding question which should be borne in mind when using vegetation to delineate the riparian zones is: does the vegetation under assessment differ in:

a) species composition (changes in abundance or occurrence of the particular species in question) OR
b) physical structure (stature, vigour)

from vegetation in the broader landscape? The broad aim of delineation is to determine the boundary/ies at which such differences occur. Should species composition and physical structure indicate different boundaries, precedence should be given to the greater (bearing in mind that boundaries set by use of plant species will also be refined by geomorphic considerations).

Steps for Riparian Delineation in the field

To delineate riparian areas, use the terrain unit indicator, vegetation indicator species, soil wetness indicator, combined with

- Geomorphology of the banks; and
- Extent of riparian vegetation.

Evidence of alluvial deposits can also be used.

STEPS to delineating the riparian zone:

I. Is the site relatively undisturbed (banks have not been extensively engineered, and the site is predominantly indigenous, naturally occurring vegetation)? If yes, proceed to step II. If no, proceed to step V.

II. Starting at the edge of the channel, use the regional riparian vegetation indicator list, identify the edge of the zone of (obligate) riparian plants.

III. At this point, check:

a. If there are any hydric indicators in the soil (refer to Wetland Delineation component).
b. If you are still in a zone of unconsolidated recent alluvial sediment.

If yes for either **a** or **b**, proceed outwards from the channel to identify the edge of these zones.

Once the answer to **a** and **b** are no, follow the same steps (II and III) using preferential and/or facultative riparian plant species *(Refer to the steps 1 to 12 from the vegetation assessment section below for further detail).*

Following completion of the above, proceed to step IV.

IV. Examine the geomorphology (shape) of the channel and banks. After moving away from the channel during steps II and III, you should be at or close to the edge of the top of the “macro-channel” bank (in the case of erosive rivers) or the edge of the active floodplain or flood zone (in the case of alluvial depositional rivers). At, or close to, this point you should see an inflection point (change in slope) between the riparian area and the upland (terrestrial) slopes. This can be taken as the edge of the riparian zone.

Using Reference Sites:

V. For sites which have been heavily disturbed (i.e. where there is almost no indigenous vegetation remaining, and/or where the banks have been heavily engineered such that it is no longer possible to identify the original morphology of the banks), then a REFERENCE site will need to be located. The Reference site will need to be close by on the same or a similar sized river system, in an area of similar topography. The Reference Site can be used to provide an indication of the likely riparian extent prior to disturbance. Once the reference site is located, proceed with step II.

Where problems may be encountered:

On floodplains, it is important to check whether the floodplain is active (i.e. regularly flooded under the current climatic regime) or a relict floodplain (meaning that the floodplain depositional area formed due to a wetter historical climate and now is no longer regularly flooded). The type of vegetation on the floodplain surface, presence of soil wetness indicators and the presence of ox-bows and other riparian and wetland features would provide the indications of the current levels of flooding/inundation/saturation.

> The key guiding question which needs to be addressed for the assessment of vegetation is: does the vegetation adjacent to the river channel differ in species composition or physical structure from vegetation in the broader landscape? If yes, then the zone can be classified as a riparian area.

Changes in species composition

Use some measure of species occurrence (quantitative, such as numbers of individuals, % aerial cover, or qualitative, such as high, moderate, low, absent classes) to describe the vegetation distributions along a transect moving perpendicularly away from the river channel. Follow the steps below to use vegetation as a guide to determining the edge of the riparian zone:

Start at the water edge (base flow for perennial rivers) or lowest point in elevation (seasonal or ephemeral streams)

1) Identify common obligates or obligates known to have broader range within the riparian zone (refer to Appendix D for list of riparian obligates).
2) Construct a quantitative or qualitative, detailed or general plot of plant occurrence (abundance, % cover or density) vs horizontal distance from the aquatic zone boundary or lowest point in channel profile
3) Note the distance at which the plant occurrence (obligates) becomes zero.
4) Repeat the process with additional obligates at the site
5) Use the greatest width indicated by all obligates to delineate the riparian zone. This is the *minimum* riparian zone (somewhere between this point and what is obviously upland lies the actual / current riparian zone boundary)

From this point on, preferential and facultative riparian species are used to legitimately extend the riparian zone

6) Choose species that are common at or close to the “minimum” riparian zone boundary, species that are known to the assessor as preferential, or species that are known to be or appear to be facultative in the given system.
7) Construct a plot of plant occurrence as before, paying attention to peaks, nick points and steepness of down-curves (steeper curves indicate narrower habitat requirements). Most preferential species will peak within the riparian zone (as will facultative species where they exist as indicators) with steep down curves that may or may not extend beyond the actual riparian zone. Extension beyond the actual boundary is usually partial (for down curve only).

Try to use preferential species that have narrow distribution curves since they will be more useful for boundary detection than gentle, broad distributions.

8) Demarcate a band between the farthest (from the aquatic zone) preferential species peak and the farthest preferential zero point. The actual riparian zone boundary lies somewhere in this band
9) Continue by constructing the same plots of common upland species (species that are widely distributed in the upland) to verify and fine-tune the boundary of the actual or current riparian zone.

Plots of upland species are expected to decline as they enter the riparian zone, but bear in mind that these species often occur naturally at low abundance in the riparian zone. Try to identify sharp declines or nick points in the plot/s, and relate these to preferential (facultative) species declines within the band where the actual boundary is likely.

10) Delineate the riparian zone compositional boundary according to best biological and riverine experience at this point, trying to accommodate as many indicator points (peaks, down curves, nickpoints) as possible.

Facultative species are not usually useful where they are amongst obligate and preferential riparian species. Where facultative species do indicate riparian zones, they are likely to behave as obligate or preferential species but, by definition, will only be useful for that particular site or system.

Changes in vegetation physical structure

Changes in the physical structure (stature & vigour) of plants within a population can be used to fine tune above if an assessment was possible, or make an assessment (especially useful in highly ephemeral species-poor systems).

Following from the initial riparian zone compositional boundary identified in point (10) above, verify or otherwise revise the boundary using an assessment of the physical structure of the vegetation as follows:

11) Examine the facultative and upland species at the site along the zone which was identified as the riparian compositional boundary (we use facultative and upland species since these will display changes to their physical structure across the boundary we are seeking, since the distributions of these species extends beyond into the upland zones).
12) Plot, as before, but using stature or vigour, common upland species or species common close to where the riparian zone structural boundary is likely to be. Look for declines as plants extend into the upland, and refine the initial boundary according to the information from this structural assessment of the riparian zone.

Step III: Check for redoxymorphic features and recent alluvium

Once the compositional riparian boundary has been determined and then verified against the structural riparian boundary, the practitioner should check

1) for any indications of recent alluvial deposits (wich would indicate that one is still within the recently flooded zones, and therefore still within the riparian zones); and
2) for any redoxymorphic features within the top 50cm of the soil. These latter features would denote a wetland areas attached laterally to the riparian zone (both being protected water resources).

The practitioner should continue to move outwards (away from the channel) until such time as the answer to both questions 1 and 2 below. Following this, proceed to step IV.

Step IV: verify the boundary using geomorphological indicators

Once step IV is reached, the practitioner should be at or very close to the edge of the real riparian boundary. He or she should examine the topography of the banks and macro-channel of the site; paying close attention to possible inflection points (changes in the shape) of the macro-channel bank. These nick-points on the cross-sectional profile – indicating a change in bank slope - would generally be representative of the change in upslope (terrestrial) versus longitudinal (riverine) processes; and thus indicate the extent of the riparian zone.

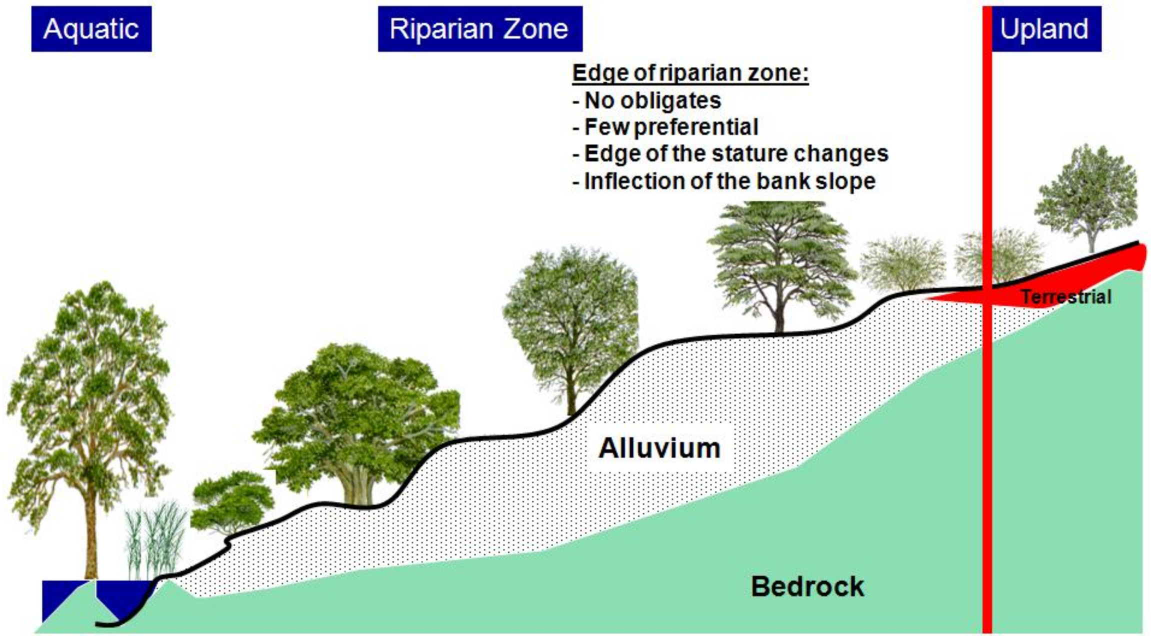


Figure 9: **A schematic diagram illustrating the edge of the riparian zone on one bank of a large river. Note the coincidence of the inflection (in slope) on the bank with the change in vegetation structure and composition. The edge of the riparian zone coincides with an inflectio point on the bank; where there are not obligates upslope; few preferential. The boundary also coincides with the outer edge of the stature differences.**
Figure: Mark Rountree

9. BUFFER ZONES

Buffer zones are areas of vegetation upslope of riparian/wetland boundaries, which are requested to protect the river/wetland from effects of adjacent development and/or landuse change. These buffer zones may variously protect the receiving wetland/stream from concentrated peak runoff volumes; provide feeding/breeding areas for wetland/river fauna and may enhance the corridor function of drainage lines [xiv].

General:

- No current national guidelines, or legislated requirement regarding buffer zones exist.
- Normally guided by local/provincial recommendations
- An agreed minimum buffer distance of 20m are required next to watercourses in afforested areas
- Specific (defensible) objectives should be identified

There need to be clear, specific objectives behind the requirement for buffer zones. There is currently a WRC study which is developing national guidelines for buffer zones … <<<<More detail on this section will be provided by Naomi's current WRC Buffer Zone guideline project before this document goes to press>>>>>>

10. FURTHER READING

Wetland Assessment Tools

DWAF, 2007. Manual for the assessment of a Wetland Index of Habitat Integrity for South African floodplain and channelled valley bottom wetland types by M. Rountree (ed); C.P. Todd, C. J. Kleynhans, A. L. Batchelor, M. D. Louw, D. Kotze, D. Walters, S. Schroeder, P. Illgner, M. Uys. and G.C. Marneweck. Report no. N/0000/00/WEI/0407. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa **(**www.dwaf.gov.za/rqs**)**

The WET-Management Series is a suite of documents and tools focussed on wetland management and rehabilitation which was recently been completed through the Water Research Commission **(**www.wrc.org.za**).**

Riparian Assessment Tools

MacKenzie, J. and C.J. Kleynhans, 2007. Module D: VegRAI – Vegetation Rapid Assessment Index *in* Kleynhans, C.J and M.D. Louw (eds). *Manual for EcoStatus Determination (version 2)*. Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC report.

Soils and soil classification

Forest Soils Data Base, 1993. FSD Working Methods. S.A. Forestry Industry

Kotze, D.C., Klug, J.R., Hughes, J.C. and Breen, C.M., 1996. Improved criteria for classifying hydromorphic soils in South Africa. S.Ar. J. Plant and Soil, 13(3)

McVicar et. al, 1977. Soil Classification: A Binomial System for South Africa. Department of Agriculture

Soil Classification Working Group, 1991. Soil Classification: A Taxonomic System for South Africa. Department of Agriculture

The Wise Use of Wetlands

Mondi/WESSA Wetlands Wise Use programme information sources ?.

APPENDIX A: SPECIAL CASES FOR WETLAND DELINEATION

Sandy Coastal Aquifers

Aeolian derived, sandy soils associated with sandy coastal aquifers often have grey profile colours, which are not necessarily associated with hydromorphic soil forming processes. The grey profile morphology could be attributed to stripping of sesquioxides off mineral grains via podzolization within the profile. Such grey soils, especially on upland sites and midslope sites, are thus not associated with zones of saturation and are thus not indicative of riparian or wetland habitats.

Specific soil properties (and thus indicators) on sandy coastal aquifers have been recognized which distinguish wetland habitats from drier sites. The delineation procedure is in essence similar to that described earlier but with refinement to the soil criteria.

The delineation procedure in sandy coastal areas involves.

• Classification of stream channels using hydrology (Appendix B)

• Recognition of the terrain morphological unit which must be in a bottom-land site (Section 3)

• Recognition of hydrophilic vegetation (Section 3) if undisturbed

• Recognition of specific soil criteria (detailed below) associated with sandy Aeolian soils in riparian habitats.

(i) Soil properties associated with the temporary zone of wetness in riparian and wetland habitats on sandy coastal aquifers

If the soil form is Fernwood then the profile:

• Has a dark topsoil (moist Munsell values of 4 or less and chroma values of 1 or less)

• Has an extremely high topsoil organic carbon content, amounts which vary but are usually more than 7% throughout the horizon

• Contains accumulation of plant residues which vary from finely divided to predominantly fibrous

• Has a low bulk density (soil material feels 'light' and foot stamping on the soil surface often results in vibrations)

• Has a peaty character

• Often exhibits vertical profile cracking in the dry state

• Is susceptible to ground fires

Excluded are layers of organic matter, which in certain cases accumulate on the soil surface e.g. layers of pine needles or leaves under commercial timber plantations.

If the soil form is Katspruit, Kroonstad, Longlands, Wasbank, Lamotte, Westleigh, Dresden, Avalon, Pinedene, Tukulu or Dundee then the profile:

• Has a dark topsoil (moist Munsell values of 4 or less and chroma values of 1 or less)

• Has a very high organic carbon topsoil content, usually more than 4% throughout the horizon

• Has signs of wetness (Section 3.2.3) within 50 cm of the soil surface

• Has a significant textural increase (within 50 cm of the soil surface) from the E or overlying horizon to the underlying soft plinthite, G horizon or unspecified material with signs of wetness, such that sandy profile textures in the E (or overlying horizons) become at least sandy clay loam in the underlying hydromorphic horizons

ii) Soil properties associated with the permanent and/or seasonal zone of wetness in riparian and wetland habitats on sandy coastal aquifers

Pedological criteria are similar as described for the temporary zone of wetness. However, excessively high organic carbon topsoils occur (organic carbon content >10%) and topsoils are typically peaty. Soil form is commonly Champagne. However, the other soil forms (described above) having >10% organic carbon in the topsoil may also occur.

Soils derived from Quartzides and Dolomites

Delineation of wetlands and riparian habitats on soils derived from quartzites and/or dolomites requires special mention, since often the permanent zone of wetness occurs immediately adjacent to ferralitic (and other soils lacking evidence of hydromorphy) and the seasonal and/or temporary zone is absent. This is attributed to soils derived from Quartzitic and Dolomitic parent materials being very well drained, and often deep, resulting in the required soil forming hydromorphic process being absent. The lateral extent of wetness is thus extremely limited and is confined to the permanent zone of wetness.

Despite this apparent anomaly (where the seasonal and temporary wetness zones are absent) delineation should be conducted as per methodology in the document where the following indicators are assessed:

• position in the landscape (must qualify as a terrain unit 5). However, unit 5 may also occur as a depression on a crest (1), midslope (3), or footslope (4), as depicted in Figure 2, and can then be described as 1(5), 3(5), or 4(5) respectively.

• presence of hydrophytic vegetation

• presence of hydromorphic soil forms (Champagne and Katspruit forms commonly occur in the permanent wetness zone)

• soil wetness indicator (accumulation of peat occurs and/or topsoils have an extremely high organic carbon content (significantly higher than adjacent soils in the surrounding landscape). Profile mottles due to hydromorphic soil processes may be absent in the top 50cm of soil.

Soil piping frequently occurs immediately adjacent to the permanent wetness zone. In this case, delineation should be beyond the piping zone.

Take note

Exceptions to this are Lamotte, Wasbank and Dresden soil forms which underlying podzolic subsoil (Lamotte form) or hard plinthite (Wasbank and Dresden forms).

Wetlands on Recent Alluvial Deposits

Note that the procedure for identifying redoxymorphic features in the soil profile to a depth of 50cm to determine the outer edge of the temporary zone works in most situations.

However, we must consider the situation where recent alluvial deposits (fluvial processes) are too sandy or too young for the redoxymorphic features to have developed sufficiently to be readily detectable (visible) in the profile. For example, recent sediment deposition (such as commonly occurs with the deposition of alluvial fans) within a large wetland system may bury the older wetland soils, and the new overlying material has not been *insitu* or anaerobic for a sufficiently time for redoxymorphic features to develop.

In such cases, it is the vegetation indicators that would be the dominant indicator in the delineation (since vegetation responds much faster – growth on the new sediment – than does the development of redoxymorphic features).

APPENDIX B: SPECIAL CASES FOR RIPARIAN ZONE DELINEATION

Riparian Vegetation on Recent Alluvial Deposits

The unique nature of a river is in most cases a result of both short-term and long-term fluvial processes. The importance of the river to the floodplain and the floodplain to the river cannot be overemphasized. In the long-term, floodplains result from the combination of the deposition of alluvial materials (aggradations) and down-cutting of surface geology (degradation) over many years. Sometimes this substrate can be described as young fluvial soils with no redoxymorphic characteristics. The pedogenetic processes are thus slower than the fluvial processes. This recent alluvial deposit is not a special case and is common throughout catchments.

In cases like this, the redoxymorphic characteristics may not always be visible within 50cm of the soil's surface, but the vegetation component still indicates riparian characteristics, and can be used as an indicator to delineate the riparian area. The edge of the macro channel can consist of bank parent material, but the vegetation still depends on the water in the active channel.

APPENDIX C: Preliminary list of Obligate Wetland Plants

The Table below lists what are considered to be obligate wetland plants, as well as indicating in what province/s of South Africa these species are likely to occur (*MP: Mpumalanga; LP: Limpopo; GA: Gauteng; NW: North-West; NC: Northern Cape; EC: Eastern Cape; WC: Western Cape; FS: Free State; KN: KwaZulu-Natal*).

FAMILY	TAXON	MP	LP	GA	NW	NC	EC	WC	FS	KN
AMARANTHACEAE	*Alternanthera sessilis (L.) DC.	X	X	X		X			X	X
HALORAGACEAE	*Myriophyllum aquaticum (Vell.) Verdc.	X	X	X			X	X	X	X
BRASSICACEAE	*Nasturtium officinale R.Br.	X	X	X	X		X	X	X	X
CYPERACEAE	Abildgaardia ovata (Burm.f.) Kral	X	X	X	X		X		X	X
POACEAE	Acroceras macrum Stapf	X	X	X			X	X		X
FABACEAE	Aeschynomene indica L.	X	X	X						X
LYTHRACEAE	Ammannia baccifera L. subsp. baccifera	X	X	X	X		X		X	
POACEAE	Arundinella nepalensis Trin.	X	X	X	X	X	X	X	X	X
CYPERACEAE	Bolboschoenus maritimus (L.) Palla			X		X	X	X		
POACEAE	Brachiaria arrecta (Hack. ex T.Durand & Schinz) Stent	X					X			X
CYPERACEAE	Bulbostylis schoenoides (Kunth) C.B.Clarke	X	X	X	X		X			X
CYPERACEAE	Carex *acutiformis Ehrh.	X		X	X		X	X	X	X
CYPERACEAE	Carex austro-africana (Kük.) Raymond	X	X	X			X			X
CYPERACEAE	Carex cognata Kunth	X	X	X	X		X	X	X	X
CYPERACEAE	Carex glomerabilis Krecz.	X		X			X	X	X	X
CYPERACEAE	Carpha glomerata (Thunb.) Nees						X	X		X
APIACEAE	Centella asiatica (L.) Urb.	X	X	X	X	X	X	X	X	X
CYPERACEAE	Cladium mariscus (L.) Pohl subsp. jamaicense (Crantz) Kük.	X	X	X	X	X	X	X		X
COMMELINACEAE	Commelina diffusa Burm.f. subsp. diffusa	X	X				X	X		X
COMMELINACEAE	Commelina diffusa Burm.f. subsp. scandens (Welw. ex C.B.Clarke) Oberm.	X	X	X						X
COMMELINACEAE	Commelina subulata Roth	X	X	X	X				X	X
ASTERACEAE	Cotula coronopifolia L.			X		X	X	X		
CYPERACEAE	Courtoisina cyperoides (Roxb.) Soják	X	X	X						X
CRASSULACEAE	Crassula aphylla Schönland & Baker f.							X		
CRASSULACEAE	Crassula inanis Thunb.	X					X	X	X	X

CRASSULACEAE	Crassula natans Thunb. var. natans	X	X	X	X	X	X	X	X	X
CRASSULACEAE	Crassula vaillantii (Willd.) Roth			X		X	X	X	X	X
CYPERACEAE	Cyperus *eragrostis Lam.		X	X	X	X			X	X
CYPERACEAE	Cyperus articulatus L.	X	X							X
CYPERACEAE	Cyperus congestus Vahl	X	X	X	X	X	X	X	X	X
CYPERACEAE	Cyperus denudatus L.f. var. denudatus	X	X	X	X		X	X	X	X
CYPERACEAE	Cyperus difformis L.	X	X	X	X	X	X		X	X
CYPERACEAE	Cyperus dives Delile	X	X				X			X
CYPERACEAE	Cyperus fastigiatus Rottb.	X	X	X	X	X	X	X	X	X
CYPERACEAE	Cyperus laevigatus L.	X	X	X	X	X	X	X	X	X
CYPERACEAE	Cyperus latifolius Poir.	X	X	X			X			X
CYPERACEAE	Cyperus longus L. var. tenuiflorus (Rottb.) Boeck.	X	X	X	X	X	X	X	X	X
CYPERACEAE	Cyperus marginatus Thunb.	X		X	X	X	X		X	X
CYPERACEAE	Cyperus papyrus L.	X	X							X
CYPERACEAE	Cyperus prolifer Lam.						X			X
CYPERACEAE	Cyperus textilis Thunb.						X	X		X
DROSERACEAE	Drosera madagascariensis DC.	X	X	X	X		X	X	X	X
POACEAE	Echinochloa colona (L.) Link	X	X	X	X	X	X		X	X
POACEAE	Echinochloa crus-galli (L.) P.Beauv.	X	X	X	X	X	X	X	X	X
POACEAE	Echinochloa haploclada (Stapf) Stapf	X	X	X						
POACEAE	Echinochloa jubata Stapf	X	X	X	X	X	X		X	X
POACEAE	Echinochloa pyramidalis (Lam.) Hitchc. & Chase	X	X	X			X	X		X
POACEAE	Echinochloa stagnina (Retz.) P.Beauv.	X	X	X					X	
CYPERACEAE	Eleocharis atropurpurea (Retz.) C.Presl	X	X	X						X
CYPERACEAE	Eleocharis dregeana Steud.	X		X	X		X		X	X
CYPERACEAE	Eleocharis limosa (Schrad.) Schult.	X	X		X	X	X	X	X	X
CYPERACEAE	Epischoenus quadrangularis (Boeck.) C.B.Clarke						X	X		
ERIOCAULACEAE	Eriocaulon abyssinicum Hochst.	X	X	X			X		X	X
ERIOCAULACEAE	Eriocaulon dregei Hochst.	X	X				X			X
ERIOCAULACEAE	Eriocaulon sonderianum Körn.	X	X	X	X		X		X	X
CYPERACEAE	Ficinia nodosa (Rottb.) Goetgh., Muasya & D.A.Simpson					X	X	X		X
CYPERACEAE	Fimbristylis complanata (Retz.) Link	X	X	X	X		X		X	X

CYPERACEAE	Fimbristylis dichotoma (L.) Vahl	X	X	X	X		X		X	X
CYPERACEAE	Fimbristylis ferruginea (L.) Vahl	X	X	X	X		X			X
COMMELINACEAE	Floscopa glomerata (Willd. ex Schult. & J.H.Schult.) Hassk.	X	X	X	X		X			X
CYPERACEAE	Fuirena coerulescens Steud.	X		X		X	X	X	X	X
CYPERACEAE	Fuirena hirsuta (P.J.Bergius) P.L.Forbes	X					X	X		X
CYPERACEAE	Fuirena pubescens (Poir.) Kunth var. pubescens	X	X	X	X	X	X		X	X
CYPERACEAE	Fuirena stricta Steud. var. stricta	X	X	X	X					X
CYPERACEAE	Fuirena umbellata Rottb.									X
GUNNERACEAE	Gunnera perpensa L.	X	X	X	X		X	X	X	X
ARALIACEAE	Hydrocotyle bonariensis Lam.						X			X
ARALIACEAE	Hydrocotyle verticillata Thunb.	X	X	X	X	X		X		X
CYPERACEAE	Isolepis cernua (Vahl) Roem. & Schult. var. cernua	X	X	X	X	X	X	X	X	X
CYPERACEAE	Isolepis fluitans (L.) R.Br. var. fluitans	X	X	X			X		X	X
CYPERACEAE	Isolepis incomtula Nees							X		
CYPERACEAE	Isolepis inyangensis Muasya & Goetgh.	X	X							X
CYPERACEAE	Isolepis ludwigii (Steud.) Kunth							X		
CYPERACEAE	Isolepis marginata (Thunb.) A.Dietr.					X		X		
CYPERACEAE	Isolepis natans (Thunb.) A.Dietr.	X					X	X		X
CYPERACEAE	Isolepis prolifera (Rottb.) R.Br.						X	X		X
CYPERACEAE	Isolepis sepulcralis Steud.	X	X			X	X	X	X	X
CYPERACEAE	Isolepis setacea (L.) R.Br.	X		X	X	X	X		X	X
JUNCACEAE	Juncus acutus L. subsp. leopoldii (Parl.) Snogerup					X	X	X	X	
JUNCACEAE	Juncus capensis Thunb.					X	X	X		
JUNCACEAE	Juncus dregeanus Kunth subsp. dregeanus	X	X	X	X	X	X	X	X	X
JUNCACEAE	Juncus effusus L.	X	X	X	X		X	X	X	X
JUNCACEAE	Juncus exsertus Buchenau subsp. exsertus	X	X	X	X	X	X	X	X	X
JUNCACEAE	Juncus kraussii Hochst. subsp. kraussii						X	X		X
JUNCACEAE	Juncus lomatophyllus Spreng.	X	X	X			X	X		X
JUNCACEAE	Juncus oxycarpus E.Mey. ex Kunth	X	X	X	X	X	X	X	X	X
JUNCACEAE	Juncus punctorius L.f.	X	X	X	X	X	X	X	X	X
JUNCACEAE	Juncus rigidus Desf.		X	X	X	X	X	X	X	X
CYPERACEAE	Kyllinga elatior Kunth						X			X

CYPERACEAE	Kyllinga erecta Schumach. var. erecta	X	X	X	X		X	X	X	X
CYPERACEAE	Kyllinga melanosperma Nees	X	X	X	X		X			X
CYPERACEAE	Kyllinga pulchella Kunth	X		X	X	X	X		X	X
HYDROCHARITACEAE	Lagarosiphon major (Ridl.) Moss ex Wager	X		X	X		X		X	X
HYDROCHARITACEAE	Lagarosiphon muscoides Harv.	X	X	X	X		X		X	X
HALORAGACEAE	Laurembergia repens (L.) P.J.Bergius subsp. brachypoda (Welw. ex Hiern) Oberm.	X	X	X	X	X	X	X	X	X
POACEAE	Leersia hexandra Sw.	X	X	X	X		X		X	X
POACEAE	Leptochloa fusca (L.) Kunth	X	X	X	X	X	X	X	X	X
SCROPHULARIACEAE	Limosella grandiflora Benth.	X				X	X	X	X	X
SCROPHULARIACEAE	Limosella longiflora Kuntze	X			X	X	X		X	X
SCROPHULARIACEAE	Limosella maior Diels	X	X	X	X	X	X		X	X
CYPERACEAE	Lipocarpha nana (A.Rich.) Cherm.	X	X						X	X
CYPERACEAE	Lipocarpha rehmannii (Ridl.) Goetgh.	X	X	X						X
ONAGRACEAE	Ludwigia adscendens (L.) Hara subsp. diffusa (Forssk.) P.H.Raven	X	X	X	X		X		X	X
ONAGRACEAE	Ludwigia octovalvis (Jacq.) P.H.Raven	X	X		X		X			X
ONAGRACEAE	Ludwigia palustris (L.) Elliott		X	X	X		X	X		X
LAMIACEAE	Mentha aquatica L.	X	X	X	X	X	X	X		X
SCROPHULARIACEAE	Mimulus gracilis R.Br.	X	X		X	X	X		X	X
IRIDACEAE	Moraea huttonii (Baker) Oberm.	X					X		X	X
HALORAGACEAE	Myriophyllum spicatum L.	X	X	X	X	X	X	X	X	X
LYTHRACEAE	Nesaea crassicaulis (Guill. & Perr.) Koehne		X							X
POACEAE	Oryza longistaminata A.Chev. & Roehr.		X							
HYDROCHARITACEAE	Ottelia ulvifolia (Planch.) Walp.	X	X	X						
POACEAE	Panicum hymeniochilum Nees	X	X				X			X
POACEAE	Panicum repens L.	X	X	X	X		X	X		X
POACEAE	Panicum subalbidum Kunth	X	X	X			X	X		X
POACEAE	Paspalidium geminatum (Forssk.) Stapf									X
POACEAE	Paspalum distichum L.	X	X	X	X	X	X	X	X	X
POACEAE	Paspalum scrobiculatum L.	X	X	X	X	X	X	X	X	X
POACEAE	Paspalum vaginatum Sw.						X	X		X
POLYGONACEAE	Persicaria *lapathifolia (L.) Gray	X	X	X	X	X	X	X	X	X
POLYGONACEAE	Persicaria *limbata (Meisn.) H.Hara	X	X	X	X	X			X	

POLYGONACEAE	Persicaria attenuata (R.Br.) Soják subsp. africana K.L.Wilson	X	X	X	X	X	X	X		X
POLYGONACEAE	Persicaria meisneriana (Cham. & Schltdl.) M.Gómez	X	X	X			X		X	X
POLYGONACEAE	Persicaria senegalensis (Meisn.) Soják forma albotomentosa (R.A.Graham) K.L.Wilson	X	X		X		X			X
POLYGONACEAE	Persicaria senegalensis (Meisn.) Soják forma senegalensis	X	X	X	X					X
POACEAE	Phragmites australis (Cav.) Steud.	X	X	X	X	X	X	X	X	X
POACEAE	Phragmites mauritianus Kunth	X	X	X	X				X	X
POLYGALACEAE	Polygala africana Chodat	X	X	X						
POLYGALACEAE	Polygala capillaris E.Mey. ex Harv. subsp. capillaris	X	X	X			X			X
POTAMOGETONACEAE	Potamogeton crispus L.		X	X	X		X		X	X
POTAMOGETONACEAE	Potamogeton octandrus Poir.	X	X	X						X
POTAMOGETONACEAE	Potamogeton pectinatus L.	X		X	X	X	X	X	X	X
POTAMOGETONACEAE	Potamogeton pusillus L.	X	X	X	X	X	X	X	X	X
POTAMOGETONACEAE	Potamogeton schweinfurthii A.Benn.	X	X	X	X	X	X	X		X
POTAMOGETONACEAE	Potamogeton thunbergii Cham. & Schltdl.	X	X	X	X		X	X	X	X
PRIONIACEAE	Prionium serratum (L.f.) Drège ex E.Mey.						X	X		X
CYPERACEAE	Pseudoschoenus inanis (Thunb.) Oteng-Yeb.					X	X	X	X	
CYPERACEAE	Pycreus chrysanthus (Boeck.) C.B.Clarke	X	X		X		X		X	X
CYPERACEAE	Pycreus cooperi C.B.Clarke	X	X				X			X
CYPERACEAE	Pycreus flavescens (L.) P.Beauv. ex Rchb.	X	X		X					
CYPERACEAE	Pycreus macranthus (Boeck.) C.B.Clarke	X	X	X	X		X		X	X
CYPERACEAE	Pycreus macrostachyos (Lam.) J.Raynal	X	X							X
CYPERACEAE	Pycreus mundii Nees	X	X	X	X		X	X	X	X
CYPERACEAE	Pycreus nitidus (Lam.) J.Raynal	X	X	X	X		X	X	X	X
CYPERACEAE	Pycreus pelophilus (Ridl.) C.B.Clarke	X	X							
CYPERACEAE	Pycreus pumilus (L.) Domin	X	X	X						X
CYPERACEAE	Pycreus rehmannianus C.B.Clarke	X	X				X			X
CYPERACEAE	Pycreus unioloides (R.Br.) Urb.	X	X	X	X		X			X
RANUNCULACEAE	Ranunculus *multifidus Forssk.	X	X	X	X	X	X	X	X	X
RANUNCULACEAE	Ranunculus meyeri Harv.	X		X	X		X	X	X	X
RANUNCULACEAE	Ranunculus multifidus Forssk.	X	X	X	X	X	X	X	X	X
RANUNCULACEAE	Ranunculus multifidus Forssk.	X	X	X	X	X	X	X	X	X
RANUNCULACEAE	Ranunculus rionii Lagger	X		X	X	X	X	X	X	

CYPERACEAE	Rhynchospora brownii Roem. & Schult.	X	X	X	X		X	X		X
CYPERACEAE	Rhynchospora holoschoenoides (Rich.) Herter						X			X
BRASSICACEAE	Rorippa fluviatilis (E.Mey. ex Sond.) Thell. var. fluviatilis	X	X	X	X	X	X		X	X
RUPPIACEAE	Ruppia maritima L.					X	X	X	X	X
POACEAE	Sacciolepis chevalieri Stapf	X	X	X	X					X
POACEAE	Sacciolepis typhura (Stapf) Stapf	X	X							
THEOPHRASTACEAE	Samolus porosus (L.f.) Thunb.						X	X		X
THEOPHRASTACEAE	Samolus valerandi L.	X	X	X	X	X	X	X		X
POACEAE	Schismus barbatus (Loefl. ex L.) Thell.					X	X	X	X	
POACEAE	Schismus inermis (Stapf) C.E.Hubb.						X	X		
CYPERACEAE	Schoenoplectus brachyceras (Hochst. ex A.Rich.) Lye	X	X	X	X		X		X	X
CYPERACEAE	Schoenoplectus corymbosus (Roth ex Roem. & Schult.) J.Raynal	X	X	X	X	X		X	X	X
CYPERACEAE	Schoenoplectus decipiens (Nees) J.Raynal	X	X	X			X	X	X	X
CYPERACEAE	Schoenoplectus erectus (Poir.) Palla ex J.Raynal		X			X				X
CYPERACEAE	Schoenoplectus leucanthus (Boeck.) J.Raynal	X	X			X			X	
CYPERACEAE	Schoenoplectus muricinux (C.B.Clarke) J.Raynal	X	X	X	X	X			X	X
CYPERACEAE	Schoenoplectus muriculatus (Kük.) Browning	X	X	X	X	X	X		X	X
CYPERACEAE	Schoenoplectus paludicola (Kunth) J.Raynal	X					X	X		X
CYPERACEAE	Schoenoplectus scirpoides (Schrad.) Browning		X			X	X	X		X
CYPERACEAE	Schoenoplectus senegalensis (Hochst. ex Steud.) Palla ex J.Raynal	X	X						X	X
CYPERACEAE	Schoenus nigricans L.	X			X		X	X	X	X
CYPERACEAE	Scleria dregeana Kunth	X	X	X			X			X
CYPERACEAE	Scleria woodii C.B.Clarke	X	X	X			X		X	X
APIACEAE	Sium repandum Welw. ex Hiern	X	X	X	X		X		X	X
HYPOXIDACEAE	Spiloxene aquatica (L.f.) Fourc.					X	X	X		
JUNCAGINACEAE	Triglochin bulbosa L.					X	X	X		X
JUNCAGINACEAE	Triglochin striata Ruíz & Pav.						X	X		X
TYPHACEAE	Typha capensis (Rohrb.) N.E.Br.	X	X	X	X	X	X	X	X	X
LENTIBULARIACEAE	Utricularia bisquamata Schrank	X	X	X		X	X	X		X
LENTIBULARIACEAE	Utricularia gibba L.	X	X	X	X	X	X		X	X
LENTIBULARIACEAE	Utricularia livida E.Mey.	X	X	X	X		X	X	X	X
LENTIBULARIACEAE	Utricularia prehensilis E.Mey.	X	X	X			X			X

LENTIBULARIACEAE	Utricularia stellaris L.f.	X	X	X	X		X		X	X
SCROPHULARIACEAE	Veronica anagallis-aquatica L.	X	X	X	X	X	X	X	X	X
HAEMODORACEAE	Wachendorfia thyrsiflora Burm.						X	X		
XYRIDACEAE	Xyris anceps Lam. var. anceps	X								X
XYRIDACEAE	Xyris capensis Thunb.	X	X	X	X		X	X	X	X
XYRIDACEAE	Xyris congensis Büttner	X	X	X	X					X
XYRIDACEAE	Xyris gerrardii N.E.Br.	X	X		X				X	X
ZANNICHELLIACEAE	Zannichellia palustris L.		X	X	X	X	X	X	X	
ARACEAE	Zantedeschia aethiopica (L.) Spreng.	X	X	X	X		X	X	X	X
ARACEAE	Zantedeschia albomaculata (Hook.) Baill. subsp. albomaculata	X	X	X			X		X	X
ZOSTERACEAE	Zostera capensis Setch.						X	X		X

APPENDIX D: Preliminary list of Obligate Riparian Plants

The Table below lists what are considered to be obligate riparian plants, as well as indicating in what province/s of South Africa these species are likely to occur in such a setting (*MP: Mpumalanga; LP: Limpopo; GA: Gauteng; NW: North-West; NC: Northern Cape; EC: Eastern Cape; WC: Western Cape; FS: Free State; KN: KwaZulu-Natal*). The list includes alien weeds and invader plants.

FAMILY	TAXON	HABITAT	WC	NC	EC	FS	KZN	NW	G	LP	MP
SALICACEAE	*Populus x canescens	Variable, but especially vleis and in river valleys	X	X	X	X	X	X	X	X	X
SALICACEAE	*Salix babylonica var. babylonica	Along streams.	X	X	X	X	X	X	X	X	X
FABACEAE	Acacia xanthophloea	Low-lying, swampy areas					X			X	X
ANNONACEAE	Annona senegalensis	Sandy soils along rivers, also in mixed scrub or woodland, on rocky outcrops and in swamp forest.					X			X	X
POACEAE	Arundinaria tessellata	Margins of high altitude forest, along streams and among rocks on mountain tops			X	X	X				
VERBENACEAE	Avicennia marina	Common in mangrove swamps; also encroaching back up feeder streams, and growing on banks of fresh water rivers.			X		X				
SALVADORACEAE	Azima tetracantha	Low altitudes in bush, scrub, woodland and thornveld, frequently along watercourses and in riverine thicket.	X		X		X			X	X
FABACEAE	Baphia racemosa	Usually in riverine forest.			X		X				
LECYTHIDACEAE	Barringtonia racemosa	Always near water, along banks of rivers, in fresh water swamps and occasionally in less saline areas of mangrove swamps.					X				
PROTEACEAE	Brabejum stellatifolium	Riverine species with water-dispersed fruits, occurring in sheltered valleys and along streams.	X								
ASTERACEAE	Brachylaena neriifolia	Stream banks and moist mountain forest.	X		X						
RUBIACEAE	Breonadia microcephala	Along banks of permanent streams and rivers, in riverine fringe forest.								X	X
EUPHORBIACEAE	Bridelia micrantha	Riverine forest; patches of relic forest, or in open woodland.			X		X			X	X
RHIZOPHORACEAE	Bruguiera gymnorrhiza	On seaward side of mangrove swamps.									
FABACEAE	Cassia petersiana	Most frequently found along rivers and streams in riverine fringe thicket.					X			X	X
ULMACEAE	Chaetacme aristata	Along streams in wooded grassland, in riverine fringe thicket, in wooded ravines and near the coast, often in scrub and forest.			X		X	X	X	X	X

COMBRETACEAE	Combretum caffrum	Along river and stream banks and in moist areas.			X						
COMBRETACEAE	Combretum erythrophyllum	Along river banks where it can form thick stands, with trunks reclining in and overhanging the water.		X	X	X	X	X	X	X	X
COMBRETACEAE	Combretum imberbe	Medium to low altitudes, in mixed woodland, often along rivers or dry watercourses, particularly on alluvial soils.					X	X	X	X	X
FABACEAE	Cordyla africana	Low altitudes in hot areas, most often forming part of riverine forest, and also in swamp forest.					X				X
EUPHORBIACEAE	Croton megalobotrys	On alluvial flats and almost always a constituent of riverine fringe forest or thicket.						X		X	X
LAURACEAE	Cryptocarya angustifolia	River valleys of the south-western Cape.	X								
CUNONIACEAE	Cunonia capensis	On stream banks and in moist forest, being abundant in the high, wet forests and in very wet crub forests around Knysna; under harsher conditions it becomes shrubby.	X		X		X				
CYATHEACEAE	Cyathea dregei	Forest margins, wooded kloofs and along streams on grassy mountainsides	X		X		X			X	X
STERCULIACEAE	Dombeya cymosa	In coastal bush or, further inland, along river and stream banks.			X		X			X	X
STERCULIACEAE	Dombeya pulchra	In wooded river valleys and along stream banks, also on mountainsides at high altitudes.								X	X
EUPHORBIACEAE	Drypetes arguta	Evergreen forest, often along streams			X		X				
ACANTHACEAE	Duvernoia adhatodoides	Evergreen forest, often along stream banks and in ravines.			X		X				
ERICACEAE	Erica caffra var. caffra	Mountain ravines, on cliffs, generally in damp situations	X		X		X				
MORACEAE	Ficus capreifolia	Swamps, and frequently forming tangled thickets along river banks and on sandy islands in the larger rivers.					X			X	X
MORACEAE	Ficus sycomorus	Frequently along river banks, forming a distinctive part of the riverine thicket; also in mixed woodland					X			X	X
SCROPHULARIACEAE	Freylinia lanceolata	Wide range of altitudes in moist areas, along stream and river banks and fringing vleis.	X		X						
GREYIACEAE	Greyia radlkoferi	In mountain forested gullies, along stream banks, fringing evergreen forest and among rocks.					X			X	X
CELASTRACEAE	Gymnosporia bachmannii	Rocky banks of rivers and streams in evergreen forest.			X		X				
ANACARDIACEAE	Harpephyllum caffrum	Riverine forest.			X		X				X
MALVACEAE	Hibiscus diversifolius subsp. rivularis	In damp places, along rivers or lining lakes, and in thickets.	X		X		X				
MALVACEAE	Hibiscus tiliaceus	Along the coast often fringing estuaries and tidal rivers.	X		X		X				

SAPINDACEAE	Hippobromus pauciflorus	Riverine thicket, scrub, along stream banks and at margins of evergreen forest.	X		X	X	X			X	X
LAMIACEAE	Iboza riparia	Rocky ourcrops and margins of evergreen forest, often near water.					X			X	X
AQUIFOLIACEAE	Ilex mitis	Most frequently along river banks and stream beds, in moist evergreen forest, sometimes straggling and leaning over the water. It is believed that the presence of this tree is an indication of underground water near the surface.	X		X	X	X	X	X	X	X
PROTEACEAE	Leucadendron conicum	In mountainous areas from 300 to 1000m asl, always in damp places, in valleys, ravines and along streams.	X		X						
PROTEACEAE	Leucadendron eucalyptifolium	Coastal mountains at altitudes 150 to 1600m asl, favouring moist conditions; frequent at edge of forests and along streams.	X		X						
PROTEACEAE	Leucadendron salicifolium	On acid soils from 0 to 1000m asl, characteristically forming almost hedge-like screens along the banks of streams.	X								
ROSACEAE	Leucosidea sericea	At high altitudes along streams and in kloofs, where it forms dense stands			X	X	X	X	X	X	X
OLEACEAE	Lincociera battiscombei	Occurring on banks of mountain streams, most frequently in riverine fringes andforested ravines.								X	
ACANTHACEAE	Macaya bella	Evergreen forest, often along stream and river banks.			X		X			X	X
CAPPARACEAE	Maerua gilgii	Arid areas of stony desert, often along river beds and dry watercourses.		X							
MYRSINACEAE	Maesa lanceolata	Margins of evergreen forest, almost always along rivers and streams, occasionally in open mountaingrassland.			X		X			X	X
MYRTACEAE	Metrosideros angustifolia	In mountainous areas, along watercourses and river banks where it can become locally common.	X	X							
RHAMNACEAE	Noltia africana	High altitudes, occassionally in open scrub and along stream banks.	X		X						
LOGANIACEAE	Nuxia oppositifolia	Along rivers and streams, in riverine thicket, among rocks and reeds.					X			X	X
OLEACEAE	Olea africana	Variety of habitats, usually near water, on stream banks, in riverine fringes, but also in open woodland, among rocks and in mountain ravines.	X	X	X	X	X	X	X	X	X
ARECACEAE	Phoenix reclinata	Along river banks in low-lying open grassland			X		X			X	X
EUPHORBIACEAE	Phyllanthus reticulatus	Low altitude riverine vegetation and thicket.					X			X	X
PIPERACEAE	Piper capensis	Moist, shady places, in forests and along streams	X		X		X			X	X
CUNONIACEAE	Platylophus trifoliatus	In forest or on stream banks	X		X						
URTICACEAE	Pouzolzia hypoleuca	Open woodland, wooded ravines, riverine thicket and sheltered among boulders on rocky koppies.					X	X	X	X	X
PRIONIACEAE	Prionium serratum	In water courses and river beds.	X		X		X				

CELASTRACEAE	Pseudosalacia streyi	Among rocks along river banks in evergreen forest, seldom far from the sea.			X		X				
APOCYNACEAE	Rauvolfia caffra	Nearly always associated with available ground water, along wooded stream banks and at the margins of evergreen forest.			X		X	X	X	X	X
RHAMNACEAE	Rhamnus prinoides	Along watercourses, in riverine forest and at margins of evergreen forest.	X		X	X	X		X	X	X
RHIZOPHORACEAE	Rhizophora mucronata	On inter-tidal mud flats, usually on the seaward side of mangrove swamp forests.			X		X				
ANACARDIACEAE	Rhus incisa	Scattered through open scrub and frequently occurring along the banks of rivers.	X	X	X						
ANACARDIACEAE	Rhus montana	Mountain areas, often along river banks.			X	X	X			X	X
ANACARDIACEAE	Rhus viminalis	Along river and stream banks.	X	X	X	X					
LYTHRACEAE	Rhyncocalyx lawsonioides	Margin of evergreen forest and along rivers.			X		X				
VERBENACEAE	Rotheca myricoides	Rocky places in thickets along streams, also in open woodland often associated with termite mounts.					X	X	X	X	X
SALICACEAE	Salix mucronata subsp. mucronata	Stream and river banks, in a wide range of habitats.	X	X	X	X	X	X			
SALICACEAE	Salix mucronata subsp. subserrata	Occurs along river and stream banks and on islands, in places likely to become inundated for at least part of the year.				X	X			X	X
CHENOPODIACEAE	Salsola aphylla	Frequently in dry, arid hot areas along dry watercourses.	X	X	X	X		X		X	
FABACEAE	Sesbania sesban subsp. sesban	In low lying areas usually near water, often on river or stream banks.			X		X			X	X
EUPHORBIACEAE	Spirostachys africana	Low altitude bush, often along rivers and streams.					X	X	X	X	X
MYRTACEAE	Syzygium cordatum subsp. cordatum	Along stream banks, in riverine thicket and forest, always near water or along watercourses, and in KZN, forming stands of almost pure swamp forest.			X		X			X	X
MYRTACEAE	Syzygium guineense subsp. guineense	Open deciduous woodland at medium to low altitudes, frequently fringing vleis, sometimes along river banks.					X			X	X
TAMARICACEAE	Tamarix usneoides	Occurring in and fringing desert areas, along brackish shore lines, river banks and frequently in dry river beds.	X	X	X						
ULMACEAE	Trema orientalis	Variety of habitats, usually moist soils, on forest margins, along watercourses, often a constituent of riverine fringe thicket, also in ravines and valleys and even along dry, sandy river-beds (smaller in drier habitats).			X		X	X	X	X	X
HAMAMELIDACEAE	Trichocladus ellipticus subsp. ellipticus	Occurring in rain forest, along streams and rivers where it is frequently dominant, and in swampy places.	X		X		X			X	X
RHAMNACEAE	Ziziphus mucronata	In a wide variety of habitats, in open woodland, often in alluvial soils along rivers, and frequently on termite mounts; it		X	X	X	X	X	X	X	X

		is said to indicate the presence of underground water.									
RHAMNACEAE	Ziziphus rivularis	Occuring among rocks and also along stream banks or in water courses.					X			X	X

REFERENCES

[i] South African National Water Act; Act 36 of 1998.

[ii] Department of Water Affairs and Forestry, 1997. *White Paper on a National Water Policy for South Africa.* DWAF: Directorate Communication Services, Pretoria.

[iii] Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M. 1997. The value of the world's ecosystem services and natural capital , *Nature*, vol. 387, p. 253.

[iv] Finlayson, C.M. and A.G. Spiers (eds) 1999. Global review of wetland resources and priorities for wetland inventory. Supervising Scientist Report 144, Supervising Scientist, Canberra.

[v] Bullock, A., K. Gilman, M. McCartney, D. Waughray, K. Blyth and A. Andrews. 1998. Hydrological strategy to develop and manage African wetland resources for sustainable agricultural use *IN Wetland Characterization and classification for sustainable agricultural development*, Food and Agriculture Organization of the United Nations, Sub-Regional Office for East and Southern Africa, Harare.

[vi] http://www.epa.gov/OWOW/wetlands/science/hgm.html; United States Environmental Protection Agency website; accessed July 2008.

[vii] Rountree, M. W. And A. L. Batchelor, (in prep). A classification system for wetland management in South Africa.

[viii] DWAF, 2007. *Manual for the assessment of a Wetland Index of Habitat Integrity for South African floodplain and channelled valley bottom wetland types* by M. Rountree (ed); C.P. Todd, C. J. Kleynhans, A. L. Batchelor, M. D. Louw, D. Kotze, D. Walters, S. Schroeder, P. Illgner, M. Uys. and G.C. Marneweck. Report no. N/0000/00/WEI/0407. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

[ix] Ewart-Smith, J.L., DJ Ollis, J.A. Day and H.L. Malan. 2006. *National Wetland Inventory: development of a wetland classification system for South Africa*. WRC Report No. KV 174/06.

[x] McVicar et. al, 1977. *Soil Classification: A Binomial System for South Africa*. Department of Agriculture

[xi] Soil Classification Working Group, 1991. *Soil Classification: A Taxonomic System for South Africa*. Department of Agriculture

[xii] Kotze, D.C. and Marneweck, G.C. 1999. Draft guidelines for delineating the boundaries of a wetland and the zones within a wetland in terms of the South African Water Act. As part of the development of a protocol for determining the Ecological Reserve for Wetlands in terms of the Water Act Resource Protection and Assessment Policy Implementation Process. Department of Water Affairs and Forestry, South Africa

[xiii] Rowntree, K.M., and Wadeson, R.A. (1998). A geomorphological framework for the assessment of instream flow requirements. *Aquatic Ecosystem Health and Management*, 1, 125-141.

[xiv] Fitcher, R.A. and J.C. Fischenich, 2000. *Design Recommendations for Riparian Corridor and Vegetated Buffer Strips*. US Army Engineer R&D Centre. http://www.wes.army.mil/el/emrrp/pdf/sr24.pdf