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Classification System for Wetlands and other Aquatic Ecosystems in South Africa

USER MANUAL: Inland Systems

Dean Ollis, Kate Snaddon, Nancy Job and Namhla Mbona

SANBI
Biodiversity for Life

Pretoria
2013

2013
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22

SANBI Biodiversity Series

The South African National Biodiversity Institute (SANBI) was established on 1 September 2004 through the signing into force of the National Environmental Management: Biodiversity Act (NEMBA) No. 10 of 2004 by President Thabo Mbeki. The Act expands the mandate of the former National Botanical Institute to include responsibilities relating to the full diversity of South Africa's fauna and flora, and builds on the internationally respected programmes in conservation, research, education and visitor services developed by the National Botanical Institute and its predecessors over the past century.

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SANBI's mission is to champion the exploration, conservation, sustainable use, appreciation and enjoyment of South Africa's exceptionally rich biodiversity for all people.

SANBI Biodiversity Series publishes occasional reports on projects, technologies, workshops, symposia and other activities initiated by or executed in partnership with SANBI.

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Artwork:	Chip Snaddon
Reviewers:	Prof. Jenny Day, Dr Justine Ewart-Smith, Retief Grobler, Dr Donovan Kotze, and Douglas Macfarlane
Technical editor:	Alicia Grobler
Cover design & layout:	Elizma Fouché
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Ross Holland


Jackie King


Erwin Sieben


Charlie Boucher


Bruce Paxton

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Dr Justine Ewart-Smith—Freshwater Consulting Group, Cape Town
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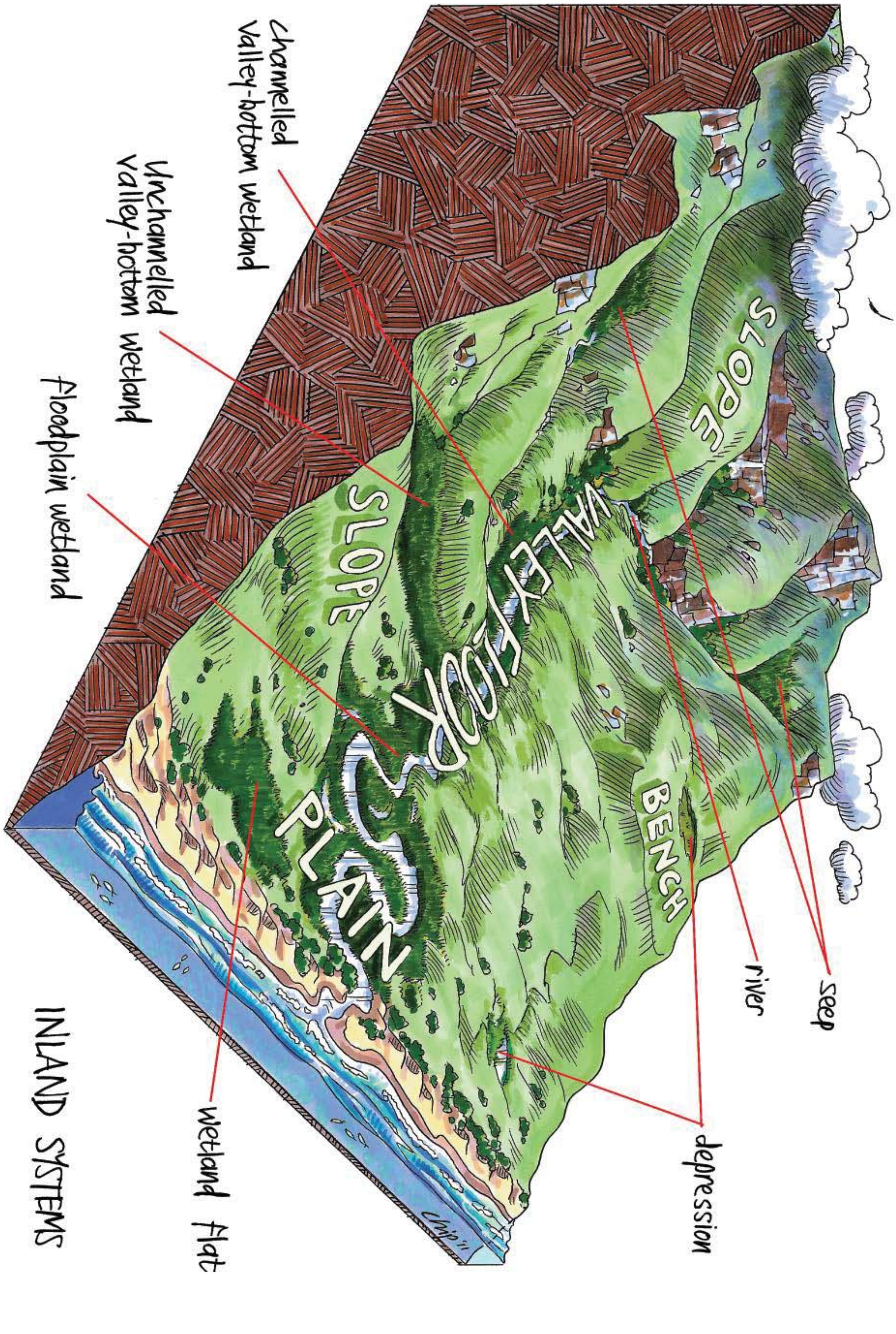
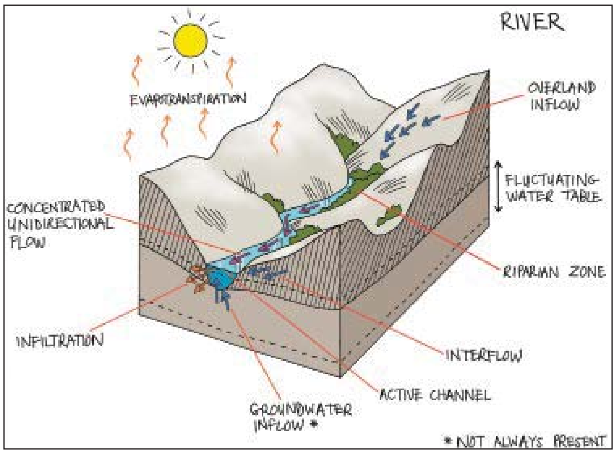
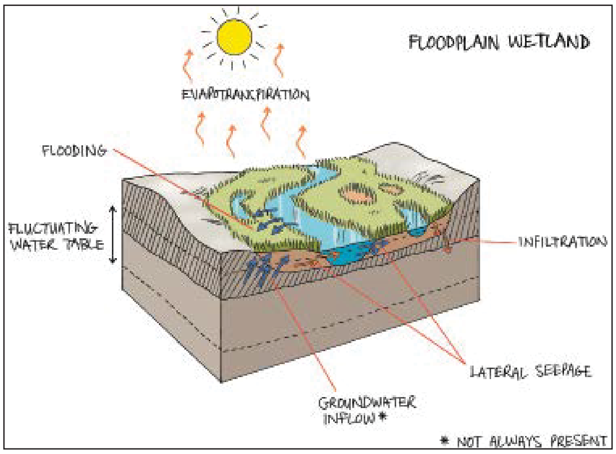
LIST OF ACRONYMS

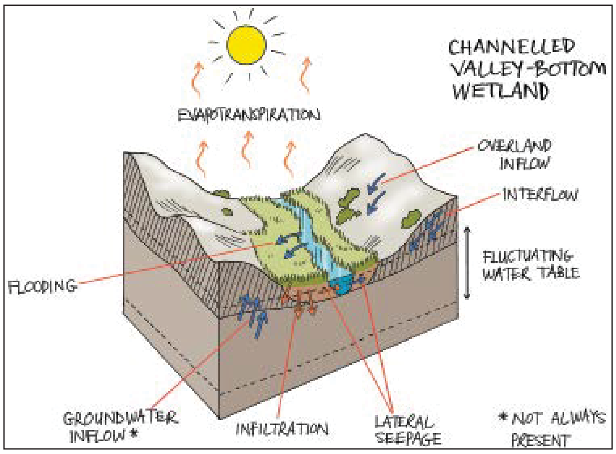
BGIS – SANBI's Biodiversity Geographic Information System
CSIR – Council for Scientific and Industrial Research
DWA(F) – Department of Water Affairs (and Forestry, i.e. prior to 2009)
FEPA – Freshwater Ecosystem Priority Area
GIS – Geographic Information System
HGM – hydrogeomorphic
NBA – National Biodiversity Assessment
NFEPA – National Freshwater Ecosystems Priority Areas
NSBA – National Spatial Biodiversity Assessment
NWA – National Water Act (Act No. 36 of 1998)
NWI – National Wetland Inventory
RHP – River Health Programme (of the Department of Water Affairs)
RQS – Resource Quality Services (of the Department of Water Affairs)
SANBI – South African National Biodiversity Institute
TDS – Total Dissolved Solids
UCT – University of Cape Town
WetVeg – wetland vegetation groups defined for the NFEPA project
WRC – South African Water Research Commission
WWTW – waste water treatment works

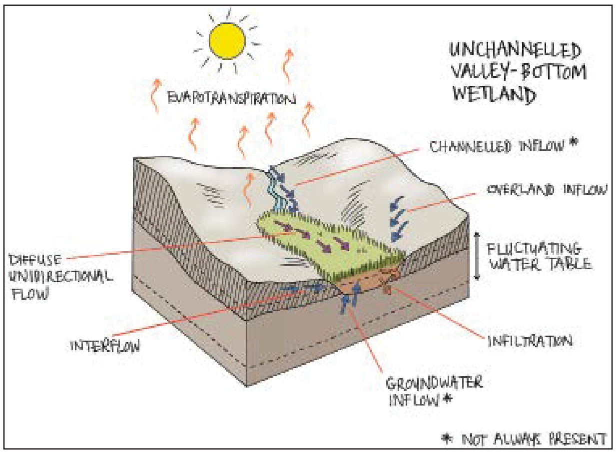


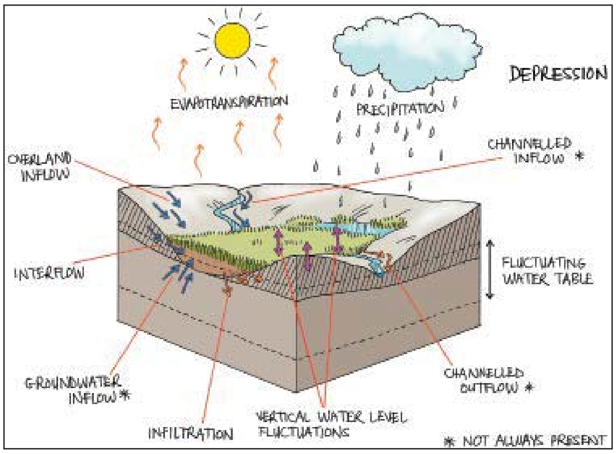
INLAND SYSTEMS
channelled Valley-bottom wetland
Unchannelled valley-bottom wetland
floodplain wetland
wetland flat
depression
river
seep
SLOPE
SLOPE
VALLEY FLOOR
PLAIN
BENCH

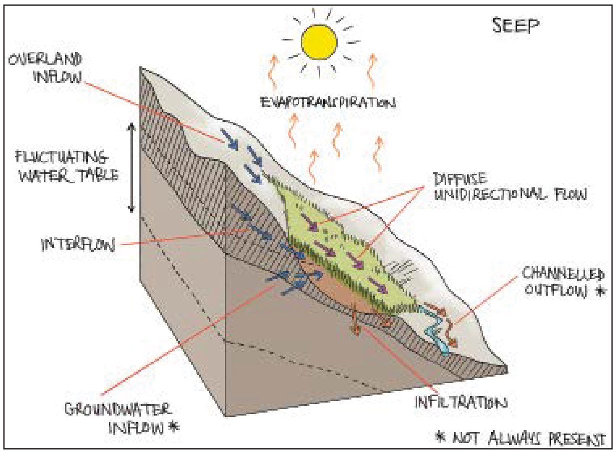


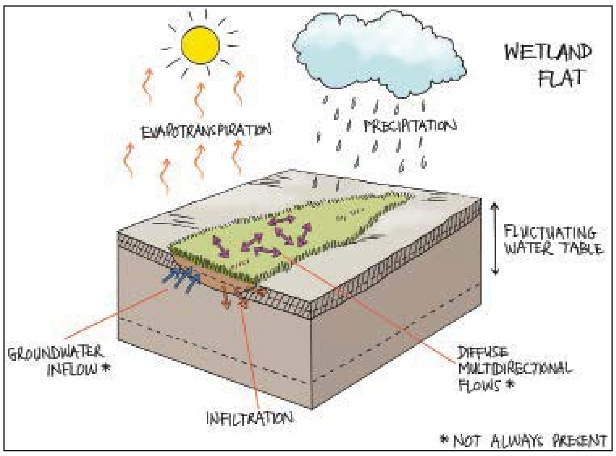












KEY

- INPUT
- OUTPUT
- THROUGHPUT


Japie Buckle


Jackie King


Erwin Sieben


Erwin Sieben


Erwin Sieben

1 INTRODUCTION

1.1 Background

In 2005, the Water Research Commission and the South African National Biodiversity Institute (SANBI) commissioned the development of a prototype National Wetland Classification System for the South African National Wetland Inventory, to encompass the broad suite of 'wetlands' as defined by the Ramsar Convention (see Box 1). A draft National Wetland Classification System was completed in 2006 (Ewart-Smith *et al*. 2006).

In late 2007, a follow-up project was initiated by SANBI to further develop and refine the draft National Wetland Classification System for widespread use throughout the country. The follow-up phase of the project was completed and an updated version of the classification system was presented to SANBI at the end of 2009 (Ollis *et al*. 2009; SANBI 2009). The compilation of the User Manual for the Classification System presented here and the accompanying dichotomous keys were subsequently commissioned by SANBI in late 2010.

This User Manual has been compiled by the Freshwater Consulting Group, who also coordinated the various phases of the project to develop a national classification system for wetlands and other aquatic ecosystems (excluding deep marine systems) on behalf of SANBI. Many people and organisations have, however, assisted with the development of the Classification System and provision of input into the compilation of this User Manual for Inland Systems (see Acknowledgements).

1.2 Name and scope of the Classification System

The classification system developed for SANBI was previously called a 'National Wetland Classification System'. The name of the classification system has been changed to a 'Classification System for Wetlands and other Aquatic Ecosystems in South Africa' (hereafter referred to as 'the Classification System'). This change was made to avoid confusion around the term 'wetland', which is defined differently by the Ramsar Convention and the South African National Water Act (Act No. 36 of 1998) (see Box 1). The scope of the Classification System has not been changed, however, in that it still includes all ecosystems that the Ramsar Convention is concerned with.

BOX 1: WHAT IS THE DIFFERENCE BETWEEN A WETLAND AND AN AQUATIC ECOSYSTEM?

The following definitions have been adopted for the Classification System:

Wetland—land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil (from the South African National Water Act; Act No. 36 of 1998).

Aquatic ecosystem—an ecosystem that is permanently or periodically inundated by flowing or standing water, or which has soils that are permanently or periodically saturated within 0.5 m of the soil surface.

Based on these definitions, for the purpose of the Classification System, wetlands are considered to be a type of aquatic ecosystem because it is the presence of water at some stage (either permanently or periodically, sometimes rather ephemerally) that distinguishes a wetland ecosystem from a terrestrial ecosystem. Besides wetlands, as defined above, aquatic ecosystems are taken to also include rivers; lakes, ponds, dams and other open waterbodies; estuaries; and (shallow) marine systems (see Section 2.1 for a more detailed description of the broad types of Inland Systems included in the Classification System). In terms of the legal definition (National Water Act, 1998), it is sometimes difficult to determine whether a particular aquatic ecosystem is a 'wetland'. This does not hamper the use of the Classification System, however, because you do not have to make such a distinction in the application of the Classification System.

In essence, the ecosystems included in the Classification System (i.e. all aquatic ecosystems, including wetlands, except for deep marine systems) encompass those that the Ramsar Convention defines, rather broadly, as 'wetlands', namely, "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (cited by Ramsar Convention Secretariat 2011).

From this point on, when reference is made to 'aquatic ecosystems' in this User Manual, the term is taken to include 'wetlands' as defined by the National Water Act, 1998 (see Box 1). It is, however, important to remember that the term 'wetland' is not synonymous with 'aquatic ecosystem' in that a wetland is taken to be a unique type of aquatic ecosystem when defined in this way. As such, when the word 'wetland' is used in this User Manual, reference is being made to a specific type of narrowly-defined aquatic ecosystem. This is different to the approach of the Ramsar Convention, whereby a wetland is very broadly defined to essentially encompass all aquatic ecosystems (except for deep marine systems).

BOX 2: Differences between Marine, Estuarine and Inland Systems

A **Marine System** is defined as that part of the open ocean overlying the continental shelf and/or its associated coastline, up to a depth of ten metres at low tide (after Lombard *et al*. 2005).

An **Estuarine System** is defined as a body of surface water—(a) that is part of a water course that is permanently or periodically open to the sea; (b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the water course is open to the sea; **or** (c) in respect of which the salinity is measurably higher as a result of the influence of the sea (after the Integrated Coastal Management Act; Act No. 24 of 2008).

An **Inland System** is defined as an aquatic ecosystem with no **existing** connection to the ocean. These ecosystems are characterised by the complete absence of marine exchange and/or tidal influence.

1.3 How to determine whether an aquatic ecosystem is an Inland System

Although the Classification System incorporates Marine, Estuarine and Inland Systems (Figure 1), as distinguished at Level 1, **this User Manual applies only to Inland Systems**. User Manuals for the classification of Marine and Estuarine Systems may be produced at a later stage.

The primary criterion for differentiating Inland Systems from Marine and Estuarine Systems is **the degree of connectivity with the ocean** (see definitions in Box 2). Inland Systems have **no direct, existing connection to the sea**. Marine Systems, in contrast, are part of the open ocean, while Estuarine Systems are not themselves part of the ocean but are permanently or periodically open to the sea. Most rivers (a type of Inland System) are indirectly connected to the ocean via an estuary at the downstream end—where marine exchange (i.e. the presence of seawater) or tidal fluctuations are detectable in a river channel that is permanently or periodically connected to the ocean, that portion of the river is defined as part of the Estuarine System.

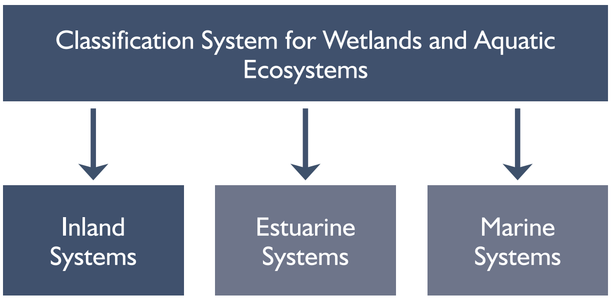


Figure 1. Primary components of the classification system for wetlands and aquatic ecosystems.

Figure 2. The southern African crown crab (*Hymenosoma orbiculare*) is of marine origin, yet it is found in Inland Systems such as Lake Sibaya.

Certain Inland Systems that are no longer connected to the sea may have had an historical connection to the ocean, which in some cases may have been relatively recent. Such systems (e.g. many of the coastal lakes in South Africa) often retain the saline character and much of the fauna associated with estuaries but are not considered to be Estuarine Systems because they do not have an **existing** permanent or periodic connection to the sea. For example, Lake Sibaya in Maputaland (eastern KwaZulu-Natal) is an Inland System with no present-day connection to the sea, but most of the crustacean fauna in the lake are of marine origin (Davies & Day 1998), such as the southern African crown crab (*Hymenosoma orbiculare*) shown in Figure 2.

While the degree of existing connectivity with the open ocean is the primary factor for distinguishing between Systems, the salinity (i.e. 'saltiness') of a wetland or an aquatic ecosystem does not influence whether or not it is classified as an Inland System. Some systems, such as the hypersaline Soutpan salt pan in the Agulhas Plain area (Figure 3), are characterised by very high salinities (> 150 g/kg), the accumulation of mineralised salts and, in some cases, the prevalence of salt-tolerant vegetation (e.g. the 'salt marsh' plant *Sarcocornia* spp.), but they have no existing connection to the open ocean. These

Figure 3. Soutpan, a salt pan on the Agulhas Plain that was historically used as a salt works, is an Inland System. Inset photograph shows salt marsh vegetation (*Sarcocornia* sp.).

systems probably derive their saltiness from ancient salt deposits, or high evaporation rates, as opposed to the present-day intrusion of seawater, and are classified as Inland Systems. The occurrence of highly saline Inland Systems such as these highlights why inland aquatic ecosystems have not been referred to as 'freshwater ecosystems' in the Classification System. However, it is important to remember that the two terms are often (rather confusingly!) used interchangeably.

1.4 Purpose and format of the User Manual

This User Manual aims to provide user-friendly guidance for application of the Classification System to inland aquatic ecosystems of South Africa. The Manual has been produced in a format that can be used in the field and is designed to appeal to a wide range of user-groups, including both non-specialists and experts.

The Manual includes a Glossary of important terms (Appendix 2) and a series of dichotomous keys for the classification of Inland Systems (Appendix 3), which have been included to facilitate consistent classification of inland aquatic ecosystems throughout the country. Worked examples of how to apply the Classification System are provided in Appendix 1. There is also a list of acronyms at the beginning of the Manual.

The pages of the User Manual have colour-coded tabs, to assist you in finding specific information. The main sections (Sections 3 to 7) have tabs that are colour-coded according to the diagram in Figure 5 (which also gives page references), while the additional sections have grey tabs.

2 OVERVIEW OF THE INLAND COMPONENT OF THE CLASSIFICATION SYSTEM

2.1 Types of Inland Systems included in the Classification System

Three broad types of Inland Systems are dealt with in the Classification System, as illustrated in Figure 4, namely:

1) **Rivers**, which are 'lotic' aquatic ecosystems with flowing water concentrated within a distinct channel, either permanently or periodically.

2) **Open waterbodies**, which are permanently inundated 'lentic' aquatic ecosystems where standing water is the principal medium within which the dominant biota live. In the Classification System, open waterbodies with a maximum depth greater than 2 m are called limnetic (lake-like) systems.

3) **Wetlands**, which are transitional between aquatic and terrestrial systems, and are generally characterised by (permanently to temporarily) saturated soils and hydrophytic vegetation. These areas are, in some cases, periodically covered by shallow water and/or may lack vegetation.

The Ramsar definition of 'wetland' encompasses all three types of Inland Systems listed above, whereas rivers and open waterbodies are not wetlands according to the narrower definition of the South African National Water Act (see Box 1).

2.2 Basis of the Classification System

It is widely accepted that hydrology (i.e. the presence or movement of water) and geomorphology (i.e. landform characteristics and processes) are the two fundamental features that determine the way in which an inland aquatic ecosystem functions, regardless of climate, soils, vegetation or origin (Semeniuk & Semeniuk 1995; Finlayson *et al*. 2002; Ellery *et al*. 2008; Kotze *et al*. 2008).

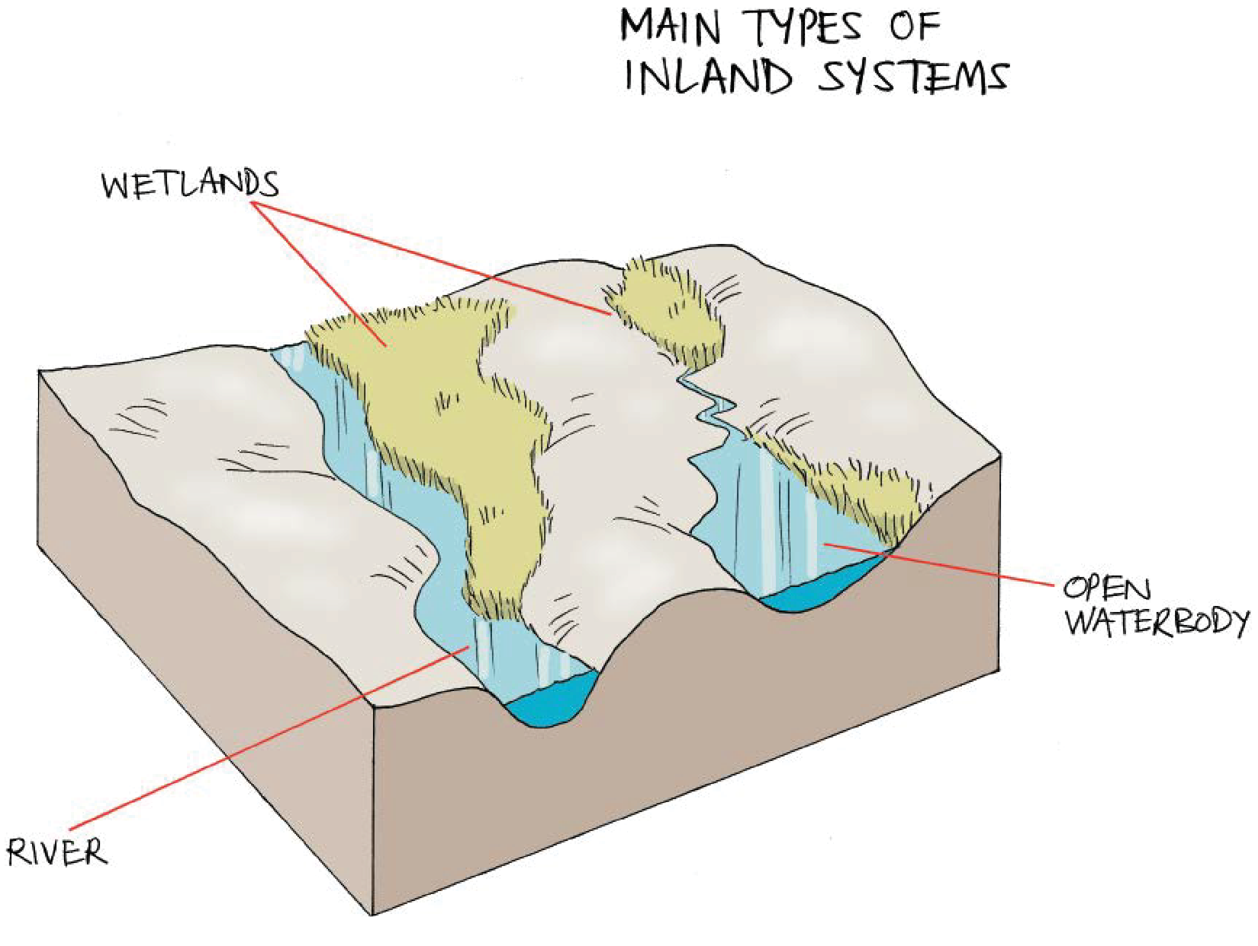


Figure 4. The three main types of Inland Systems—rivers, wetlands and open waterbodies.

This is the basic premise on which the hydrogeomorphic (HGM) approach to wetland classification is founded (Brinson 1993), whereby hydrological and geomorphological characteristics are used to distinguish primary wetland units. There is widespread agreement that wetland and aquatic ecosystem classification systems based on these characteristics are robust and consistent.

2.3 Overall structure of the Classification System

The inland component of the Classification System has a six-tiered structure (Figure 5). The tiered structure progresses from Systems (Marine vs. Estuarine vs. Inland) at the broadest spatial scale (Level 1), through Regional Setting (Level 2) and Landscape Units (Level 3), to Hydrogeomorphic (HGM) Units at the finest spatial scale (Level 4). At Level 5, Inland Systems are distinguished from each other based on the hydrological regime and, in the case of open waterbodies, the inundation depth-class.

At Level 6, six 'descriptors' have been incorporated into the Classification System. These descriptors allow you to distinguish between aquatic ecosystems with different structural, chemical, and/or biological characteristics.

As illustrated in Figure 5, **the HGM Unit (Level 4) is the focal point of the Classification System, together with the hydrological regime (Level 5) if this is known**. Levels 2 and 3 provide the broad biogeographical and landscape context for grouping HGM Units or Functional Units, while the descriptors at Level 6 provide a more detailed description of the characteristics of a particular HGM Unit or Functional Unit. At the very least, you are advised to classify an Inland System in terms of its HGM Units at Level 4.

An HGM Unit (Level 4) and its hydrological regime (Level 5) are taken together to be a Functional Unit, highlighting the fact that functioning of inland aquatic ecosystems is strongly influenced by the hydrogeomorphic characteristics and the hydrological regime of the ecosystem.

The diagram in Figure 5 gives the colour-coding of the tabs for Sections 3 to 7 of the User Manual and page references for the various components, to assist you in finding specific information quickly.

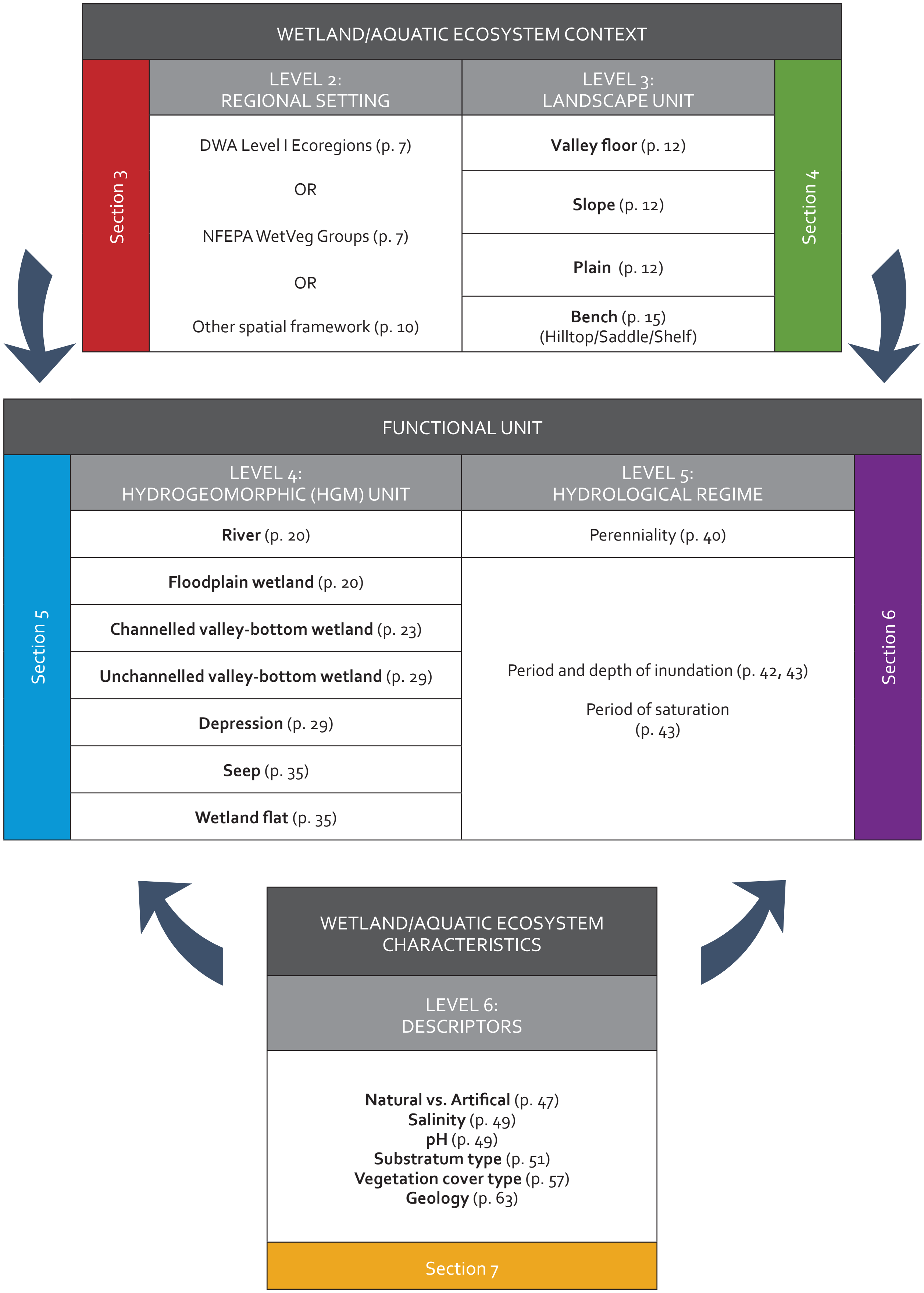


Figure 5. Overall structure of the inland component of the Classification System. This diagram highlights that the HGM Unit (Level 4) or the Functional Unit (Level 4 + Level 5) is central and that it is influenced by broad contextual information at Levels 1 to 3, with descriptors at Level 6 providing detailed information about the characteristics of a wetland or aquatic ecosystem. Note colour coding for each section and page references.

3 REGIONAL SETTING (LEVEL 2)

At Level 2 of the Classification System, it is recommended that you categorise the regional setting of the aquatic ecosystem that you are classifying, according to a preferred spatial framework.

3.1 Why is it useful to record the regional setting?

If you have looked at wetlands and other aquatic ecosystems in different parts of the country, you will probably agree that one can generally recognise biophysical differences between ecosystems in different regions. For example, a seepage wetland at high altitude in a high rainfall area would differ from a seepage wetland in a low rainfall, coastal setting, and in a different part of the country. It is important to take these differences into account when classifying aquatic ecosystems. The explicit categorisation of the regional setting is one way of achieving this.

By identifying the regional setting, you should gain some understanding of the broad ecological context within which an aquatic ecosystem occurs. In other words, the regional setting should provide you with some indication of the ecosystem characteristics that can be expected, simply on the basis of the broad-scale geographical location of the aquatic ecosystem.

3.2 Selection of an appropriate spatial framework

To categorise the regional setting of an Inland System at Level 2 of the Classification System, you must first select the spatial framework (see Box 3) that you think is most appropriate for your particular purpose.

Two optional spatial frameworks have been suggested at Level 2 of the Classification System, namely (1) Department of Water Affairs (DWA) Ecoregions and (2) National Freshwater Ecosystems Priority Areas (NFEPA) WetVeg Groups. Alternatively, you can choose another spatial framework other than these two.

BOX 3: WHAT IS A SPATIAL FRAMEWORK?

Spatial frameworks assist in distinguishing between areas that are different from one another, according to specific criteria. A spatial framework is generally presented as a map that divides a geographical area into a number of regions on the basis of pre-determined criteria. For example, the River Bioregions map (see Box 5) was developed specifically for rivers and is based on the known biogeographic distribution patterns of certain groups of riverine organisms.

Flexibility is allowed for at this Level because certain spatial frameworks are more suited to particular applications than they are to others. For example, the most appropriate spatial framework for the classification of aquatic ecosystems in the context of national water resource management might be the DWA Ecoregions, while a provincial vegetation map might be appropriate for fine-scale wetland conservation planning. If required, more than one spatial framework can be used to generate multiple regional categorisations.

If you are unsure of which spatial framework is most appropriate for your particular application, it is recommended that you categorise the regional setting of your wetland or aquatic ecosystem in terms of DWA Ecoregions.

3.2.1 *DWA Ecoregions*

The primary (so-called 'Level I') DWA Ecoregions (Kleynhans *et al*. 2005) are based on broad-scale patterns of physiography, climate, geology, soils and vegetation across the country. There are 31 Ecoregions across South Africa, including Lesotho and Swaziland (see map in Figure 6). DWA Ecoregions have most commonly been used to categorise the regional setting for national and regional water resource management applications, especially in relation to rivers.

3.2.2 *NFEPA WetVeg Groups*

The Vegetation Map of South Africa, Swaziland and Lesotho (Mucina & Rutherford 2006) groups vegetation types across the country according to Biomes (for example, Grassland or Savanna), which are then divided into Bioregions (for example, Mesic Highveld Grassland and Sub-Escarpment Grassland Bioregions). To categorise the regional setting for the wetland component of the NFEPA project (see Box 4), wetland vegetation groups (referred to as WetVeg Groups) were derived by further splitting Bioregions into smaller groups through expert input. There are currently 133 NFEPA WetVeg Groups (see map in Figure 7). It is envisaged that these groups could be used as a spatial framework for the classification of wetlands in national- and regional-scale conservation planning and wetland management initiatives.

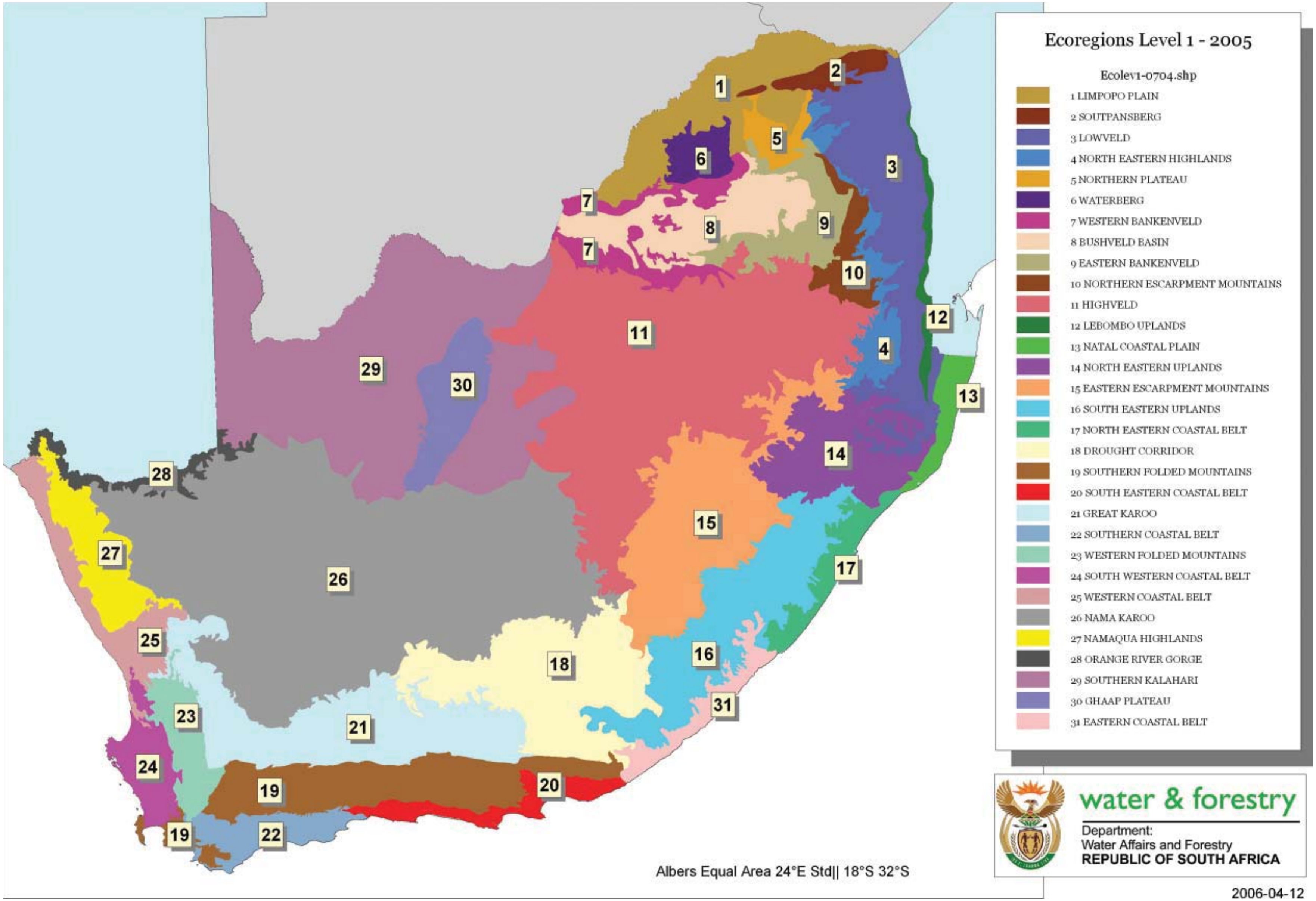


Figure 6. Map of DWA Level I Ecoregions [from http://www.dwaf.gov.za/IWQS/].

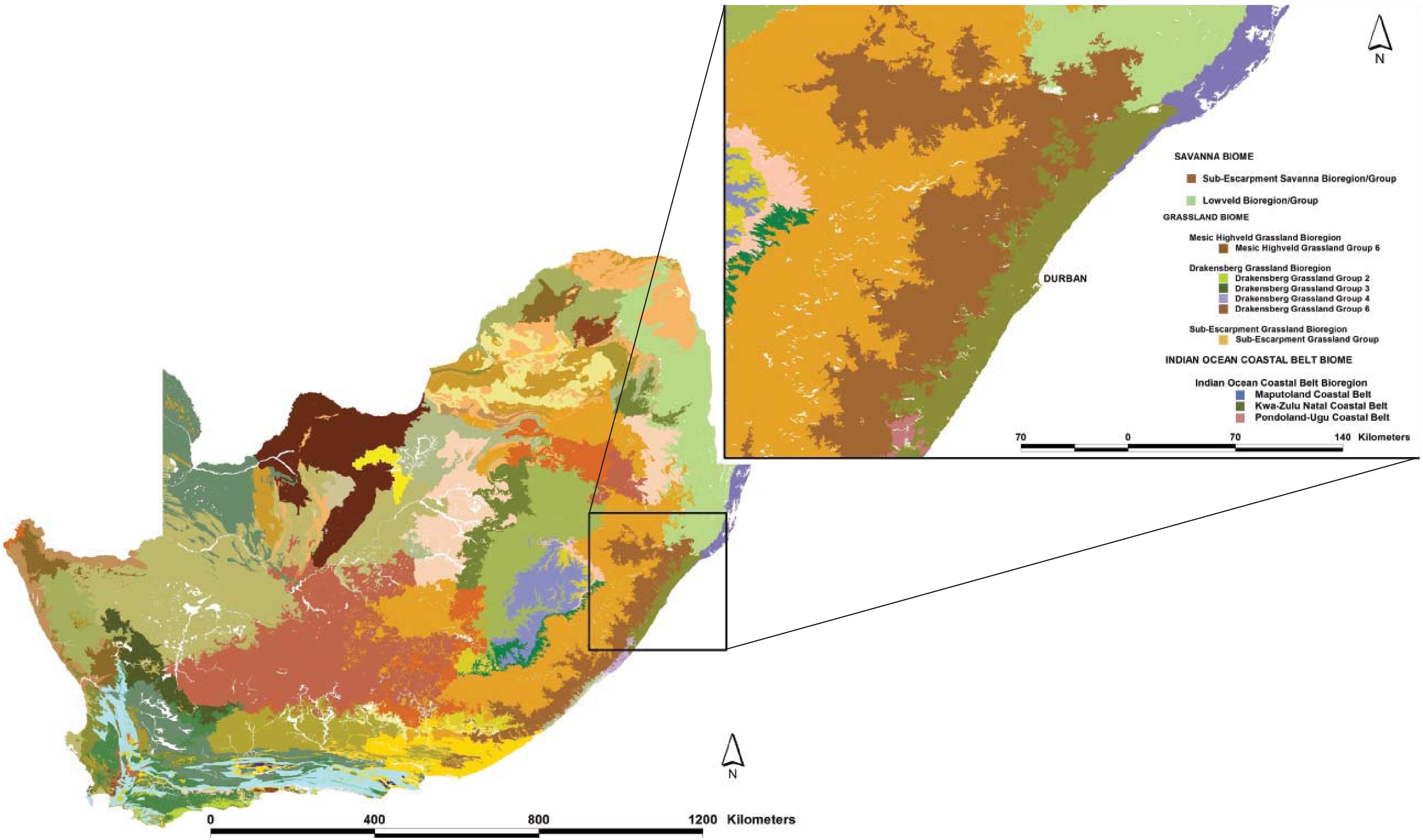


Figure 7. Map of NFEPA WetVeg Groups, with key to WetVeg Groups only shown for a zoomed-in portion of the map [compiled by Nancy Job].

BOX 4: SOME IMPORTANT NATIONAL-SCALE CONSERVATION PLANNING PROJECTS FOR INLAND AQUATIC ECOSYSTEMS

The **National Wetland Inventory (NWI)** aims to map the extent, location and characteristic of wetlands across the country. The NWI has released three wetland maps—the Beta Version, Wetland Map II, and Wetland Map III, the most recent of which includes wetland types.

The **National Freshwater Ecosystem Priority Areas (NFEPA)** project was a three-year partnership project (June 2008–May 2011), led by SANBI and the Council for Scientific and Industrial Research (CSIR). It aims to identify a national network of freshwater ecosystem priority areas (FEPAs), including rivers and wetlands, and to explore institutional mechanisms for their implementation.

The **National Biodiversity Assessment (NBA) 2011** follows on from the first National Spatial Biodiversity Assessment (NSBA), led in 2004 by SANBI in partnership with a range of organisations. NSBA 2004 was the first comprehensive national spatial assessment of the state of biodiversity, covering terrestrial, freshwater*, estuarine and marine environments. It included assessments of ecosystem threat status and ecosystem protection levels, which for the first time were comparable across these four ecosystems. SANBI's mandate includes reporting on the state of biodiversity in South Africa. For this reason, the decision was made to broaden the National Spatial Biodiversity Assessment to incorporate non-spatial or thematic elements, and to produce a National Biodiversity Assessment (NBA). The intention is to review the NBA approximately every five years.

* The freshwater component of NSBA 2004 only included rivers, whereas the freshwater component of NBA 2011 incorporates rivers and wetlands (using outputs from the NFEPA project).

3.2.3 *Other spatial frameworks*

You can, in fact, use any spatial framework that you think is most appropriate for the regional categorisation of the inland aquatic ecosystems you are dealing with, depending on the purpose of classification. Some of the available options are outlined in Box 5.

Information and maps for DWA Level I Ecoregions are available from the DWA-RQS website (http://www.dwaf.gov.za/iwqs/gis_data/ecoregions/get-ecoregions.asp), while information and maps for NFEPA WetVeg Groups, and for many of the other spatial frameworks that you may want to use at Level 2 of the Classification System, are available from SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

BOX 5: OPTIONAL SPATIAL FRAMEWORKS FOR USE AT LEVEL 2

- **Wetland Regions** (Cowan 1995), which were developed specifically for wetland planning and management, are based on geomorphological provinces and climate. Each region theoretically represents wetlands with a similar topography, hydrology and nutrient regime.
- **River Bioregions** (Brown *et al*. 1996), which were developed specifically for rivers, are based on the known biogeographic distribution patterns of certain groups of riverine organisms.
- **Geomorphic Provinces** (King 1967; Partridge *et al*. 2010) represent land areas containing a limited range of recurring landforms that reflect comparable erosion, climatic and tectonic influences.
- **Biomes** or **Bioregions** (Mucina & Rutherford 2006), which were developed for the regionalisation of vegetation types.
- **Secondary** or **Quaternary Catchments**, which are amalgamations of individual catchments at different scales.

3.3 A note on the issue of scale and an example

It is important to remember that the regions delineated by a spatial framework such as Ecoregions or WetVeg Groups are, generally, very large areas and that the boundaries between the regions are, in reality, ‘fuzzy’ rather than abrupt as suggested by the boundary lines on a map. As a result of this, an aquatic ecosystem that you are classifying may be located within a particular region according to the relevant map but, on the ground, it may be more characteristic of a neighbouring region. In these situations, you should record the more appropriate field-verified category as the regional setting (if known), rather than the desktop-based, map-derived category.

A good example of the issue of scale with regard to the regional setting is provided by the wetlands on the Bokkeveld Plateau, near Vanrhynsdorp in the Northern Cape (see Figure 8). According to the boundaries indicated on the Ecoregion map, the wetlands in this area are situated in the Great Karoo Ecoregion (DWA Level I Ecoregion # 21), near the boundaries of the Western Coastal Belt Ecoregion (DWA Level I Ecoregion # 25) to the west and the Western Folded Mountains Ecoregion (DWA Level I Ecoregion # 23) to the south. Nama Karoo is documented as the dominant vegetation type in the Great Karoo Ecoregion (Kleynhans *et al*. 2005). The dominant vegetation on the Bokkeveld Plateau, however, is actually Fynbos (specifically, Bokkeveld Sandstone Fynbos), which is more characteristic of the neighbouring Western Folded Mountains Ecoregion. Therefore, in this case it would be more appropriate to categorise the regional setting of the wetlands on the Bokkeveld Plateau as being characteristic of the Western Folded Mountains Ecoregion.

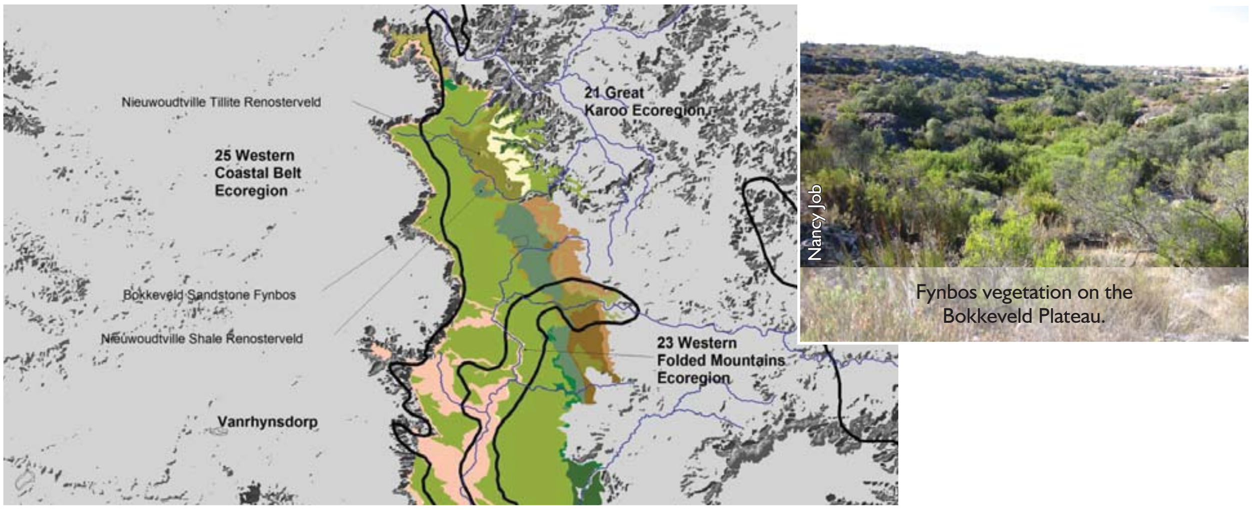


Figure 8. Map showing main vegetation types on the Bokkeveld Plateau (near Vanrhynsdorp, Northern Cape) in relation to DWA Level I Ecoregions. Inset photograph shows typical Bokkeveld Sandstone Fynbos vegetation in an area mapped as part of the Great Karoo Ecoregion.

4 LANDSCAPE SETTING (LEVEL 3)

At Level 3 of the Classification System for Inland Systems, a distinction is made between four Landscape Units on the basis of the landscape setting (i.e. topographical position) within which an aquatic ecosystem is situated.

4.1 Why is the landscape setting important?

The inclusion of landscape setting separately from the categorisation of the HGM Unit distinguishes the Classification System from some of the other wetland classification systems in use in South Africa. Its inclusion recognises that the hydrological and hydrodynamic processes acting within Inland Systems are likely to be strongly influenced by their topographical positions within the landscape, and by the geomorphological processes that have brought about and drive those topographical contexts. For example, the hydrological processes acting within a wetland on a slope are likely to be quite different from those acting within a wetland located on a hilltop or a plain. Certain HGM Units are typically associated with particular landscape settings, and thus identifying the landscape setting of an Inland System may assist in the identification of the HGM Unit. For example, seeps typically occur on slopes, valley-bottom wetlands typically occur along valley floors, and floodplain wetlands typically occur on plains (see Section 5).

The inclusion of Landscape Units also assists greatly in facilitating the desktop automation of the Classification System, which is especially important for national- and regional-scale initiatives such as the NWI, NFEPA and the NBA (see Box 4).

4.2 Landscape Units included in the Classification System

The Landscape Units included in the Classification System for Inland Systems are valley floor, slope, plain and bench, as described below.

4.2.1 Valley floor

Valley floor—the base of a valley, situated between two distinct valley side-slopes, where alluvial or fluvial processes typically dominate.

A river or longitudinal wetland often runs along a valley floor. The key factor to consider when deciding whether or not an Inland System is located on a valley floor is, however, the presence of valley side-slopes. If there are distinct valley side-slopes within approximately 500 m of an aquatic ecosystem, then you should categorise the landscape setting as a valley floor (see examples in Figure 9). If the side-slopes are located further than 500 m from an aquatic ecosystem, the landscape setting is more likely to be a plain.

4.2.2 Slope

Slope—an inclined stretch of ground typically located on the side of a mountain, hill or valley, not forming part of a valley floor. Includes scarp slopes, mid-slopes and foot-slopes.

Slopes can range from vertical cliffs to gently sloping areas (see photos in Figure 10). As a guideline, for purposes of the Classification System, the gradient of a slope is taken to be typically greater than or equal to 0.01 or 1:100.

To determine whether an aquatic ecosystem is located on a slope, you need to be able to determine whether the average gradient of the ground surface is more than approximately 1:100 or 0.01. If you are not sure how to calculate or estimate the gradient of a piece of ground, refer to the guidelines in Box 6.

4.2.3 Plain

Plain—an extensive area of low relief. These areas are generally characterised by relatively level, gently undulating or uniformly sloping land with a very gentle gradient that is not located within a valley. Gradient is typically less than 0.01 or 1:100.

This Landscape Unit includes coastal plains (bordering the coastline), interior plains and plateaus (areas of low relief but high altitude, occurring at the edge of the escarpment). Plains are differentiated from valley floors by the absence of surrounding side-slopes (typical of mountain ranges, hills, or other uplands). Valley side-slopes should generally **not** be observable within approximately 500 m of an aquatic ecosystem if it is on a plain. Some plains are essentially very wide valley floors.

Only very flat areas with a gradient of less than 0.01 or 1:100 are considered to be plains—if you are not sure how to calculate or estimate the gradient of a piece of ground, refer to the guidelines in Box 6. Another characteristic feature of plains is that they are significantly more extensive than benches in the landscape, generally being greater than 50 ha in extent (see examples in Figure 11).

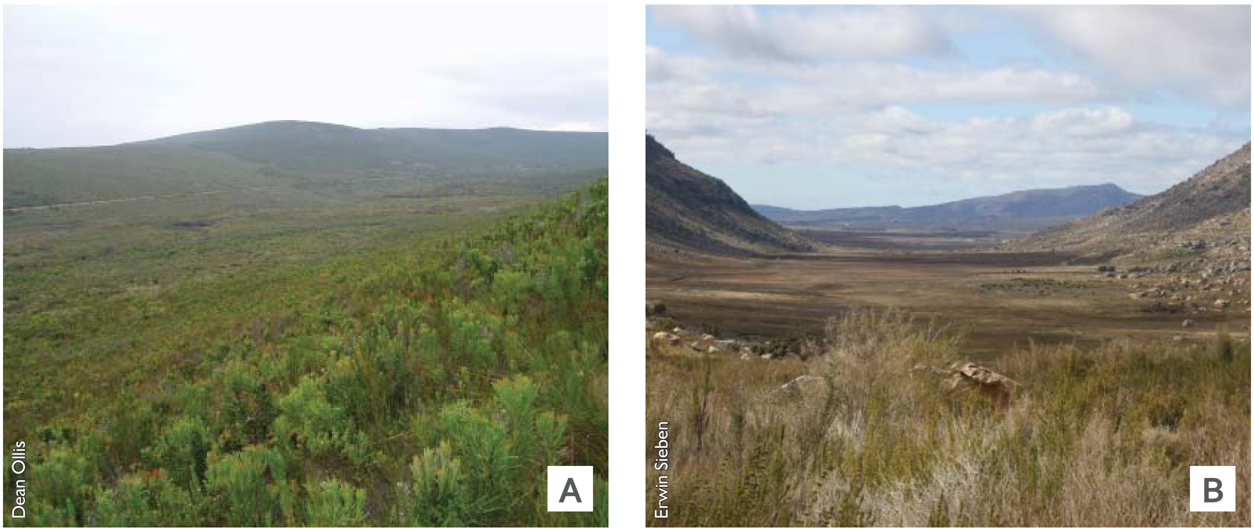


Figure 9. Photographs of valley floors. A, Greyton Nature Reserve, Western Cape; B, Driehoek, Cederberg, Western Cape.

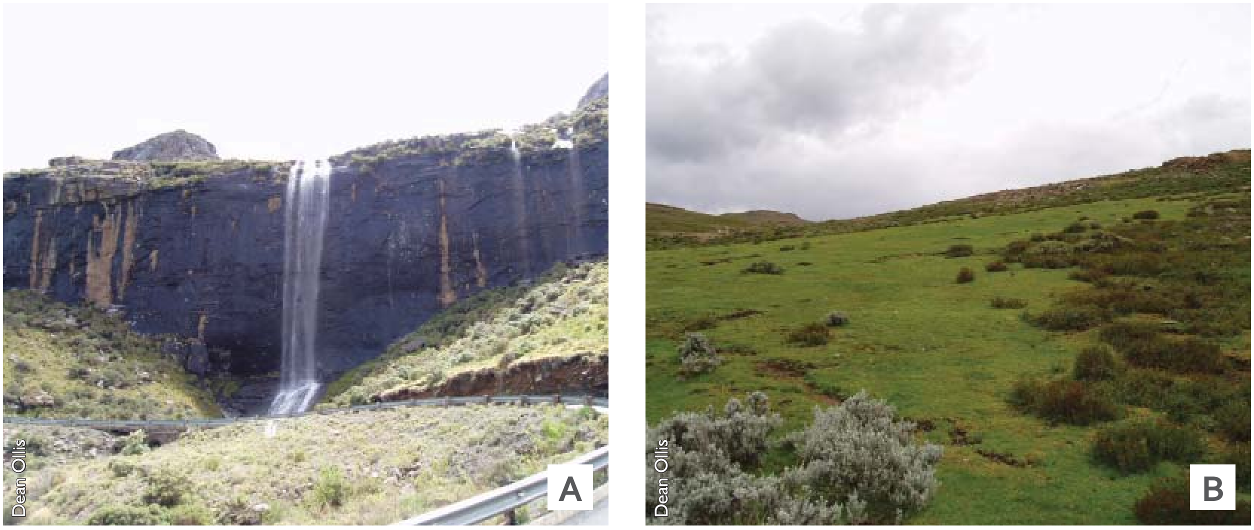


Figure 10. Slopes can range from vertical cliffs (A) to very gently-sloping areas (B). A, waterfall in Lesotho Highlands; B, seepage wetland in Lesotho Highlands.

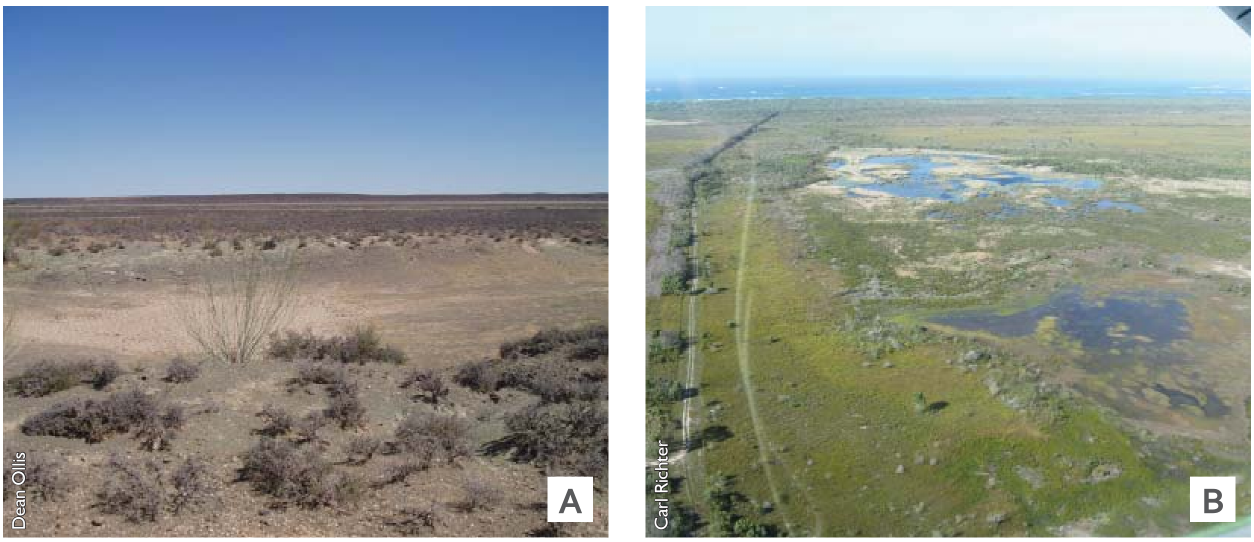


Figure 11. Examples of Inland Systems on plains. A, Karoo; B, Agulhas Plain.

BOX 6: THE MEASUREMENT OR ESTIMATION OF GRADIENT

If you are using a map, choose an upper and lower contour line that between them incorporate the section of ground for which gradient must be determined. Subtract the lower altitude from the higher one, to get the height difference between the two. Then measure the horizontal distance between the two chosen contour lines, using the same unit of measurement (e.g. metres) by converting the map units (e.g. centimetres) to ground units, taking into account the scale of the map.

The average slope or gradient between those contours is then calculated by dividing the vertical rise by the horizontal run, as follows:

$$\text{SLOPE} = \frac{\text{Height difference between contour lines (in metres)}}{\text{Horizontal distance between contour lines (in metres)}}$$

This can be expressed as an absolute number, or it can be converted into a percentage (by multiplying by 100) or a ratio. For instance, a slope of 0.01 is the same as a 1% or 1:100 slope. This is the equivalent of a piece of ground that rises vertically by 1 m over a straight-line horizontal distance of 100 m.

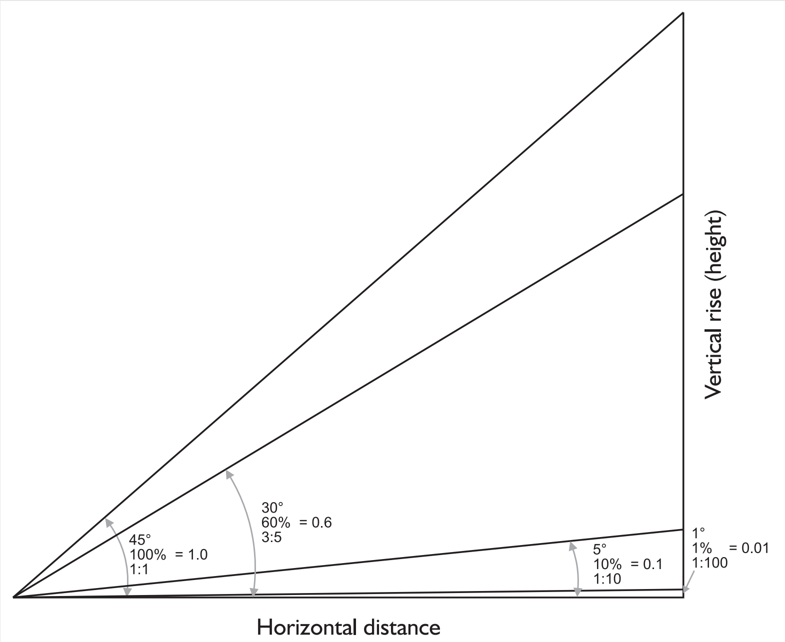


Figure 12. Illustration of the steepness of slopes ranging in gradient from 1:100 to 1:1.

Sometimes, slope is expressed as an angle, in degrees (Figure 12). To convert an absolute slope measurement to an angular unit, and *vice versa*, you can use the following trigonometric equations:

- Slope (in absolute units) = tangent of the slope in degrees [= tan(slope in degrees)]
- Slope (in degrees) = inverse of the tangent of the slope in absolute units [= $\tan^{-1}$(absolute slope)]

In the field, you can roughly determine the gradient by estimating the rise or fall of the ground over a known horizontal distance. It is important to remember that, if you use the actual ground distance between two points to estimate gradient, this distance (equivalent to the slope length) is longer than the horizontal straight-line distance (i.e. the 'run', as would be measured on a map). For gentle slopes, the difference in distance is negligible and you don't have to worry about it, but for steep slopes (e.g. those approaching 45 degrees) it becomes significant. Therefore, it is recommended that, when calculating the gradient of a steep slope in the field, you should first convert the measured ground distance to true horizontal straight-line distance, using the following equation:

$$\text{Straight-line horizontal distance (run)} = \sqrt{(\text{measured ground distance})^2 - (\text{vertical height difference})^2}$$

As a visual aid, the diagram in Figure 12 provides a representation of the steepness of different slopes, ranging in gradient from 1:100 to 1:1.

4.2.4 Bench

Bench—a relatively discrete area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops, saddles and shelves. Benches are significantly less extensive than plains, typically being less than 50 ha in area.

At Level 3B, you can distinguish between three different types of benches in the landscape, if required. The three options to choose from are hilltop, saddle and shelf (Figure 13).

(a) Hilltop

Hilltops (or crests) are relatively flat areas at the top of a mountain or hill flanked by down-slopes in all directions. The gradient of the surrounding slopes may vary from gentle to steep.

(b) Saddle

Saddles are relatively flat, high-lying areas flanked by down-slopes on two opposite sides in one direction and up-slopes on two opposite sides in an approximately perpendicular direction. The gradient of the surrounding slopes may vary from gentle to steep.

(c) Shelf

Shelves (sometimes called terraces or ledges) are relatively high-lying, localised flat areas along a slope, representing a break in slope with an up-slope on one side and a down-slope on the other side in the same direction. The gradient of the surrounding slopes may vary from gentle to steep.

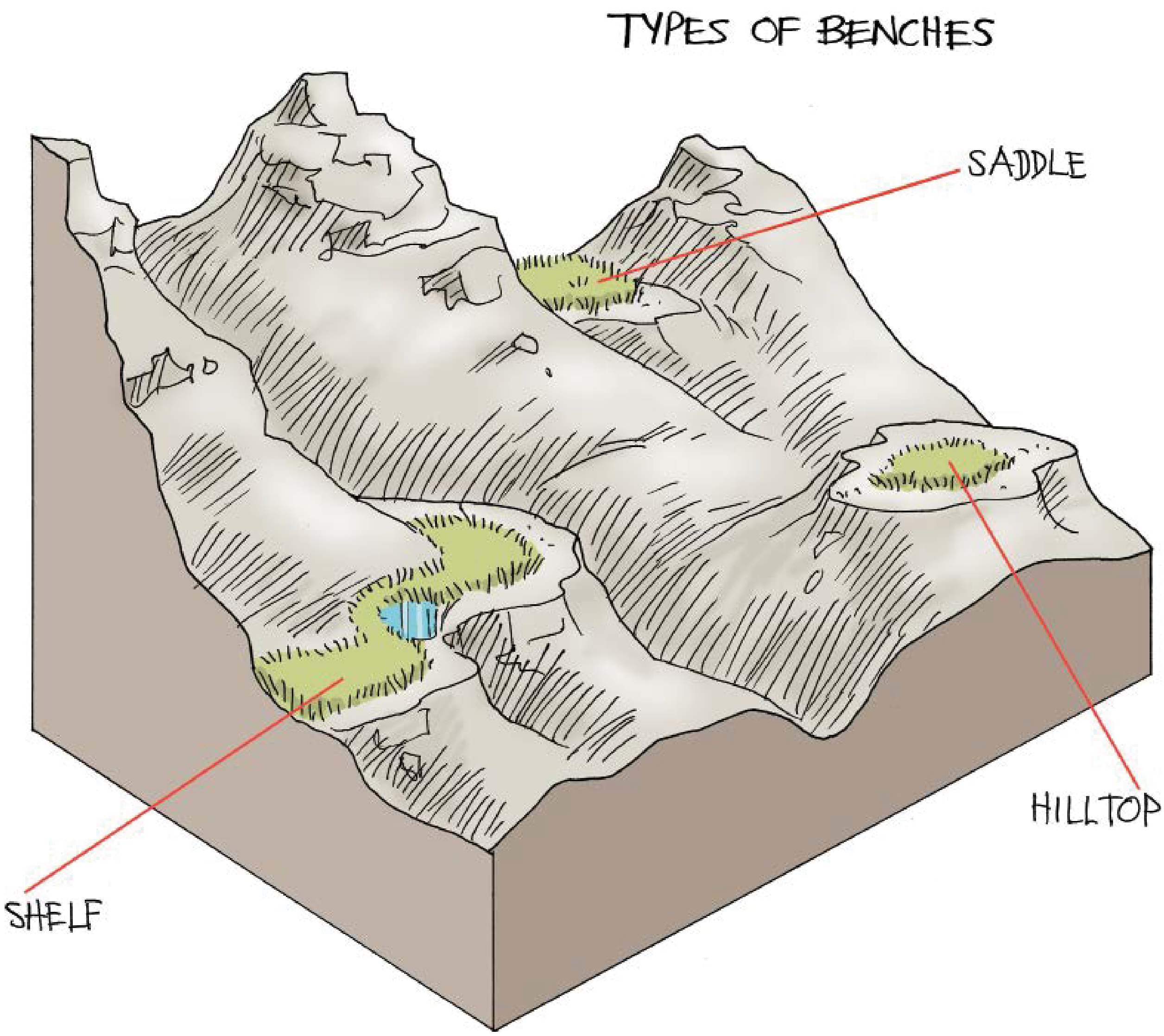


Figure 13. Illustrative drawing of wetlands on different bench types.

4.3 So, what is the landscape setting of my aquatic ecosystem? The importance of scale

The localised landscape setting is expected to directly influence the form and function of an Inland System. The **classification of the Landscape Unit should therefore be considered at the same scale as the aquatic ecosystem itself** (Figure 14). For example, the Maputaland Coastal Plain (northeastern KwaZulu-Natal) covers an area of more than 8 000 square kilometres and supports hundreds of wetlands. Within this geographical area, which can be considered a plain at a broad scale, wetlands actually occur in a variety of localised landscape settings (if taken at the scale of each wetland), including valley floors and slopes.

Sometimes the only way to resolve the issue of scale may be through groundtruthing of a landscape setting that was initially classified through desktop information alone. As such, you should not underestimate the importance of visiting an Inland System that you are trying to classify, either before or after a desktop classification.

Don't forget to use the dichotomous key for Landscape Units (Key 1, Appendix 3) and the accompanying glossary (Appendix 2) to assist you in classifying the landscape setting of an inland aquatic ecosystem!

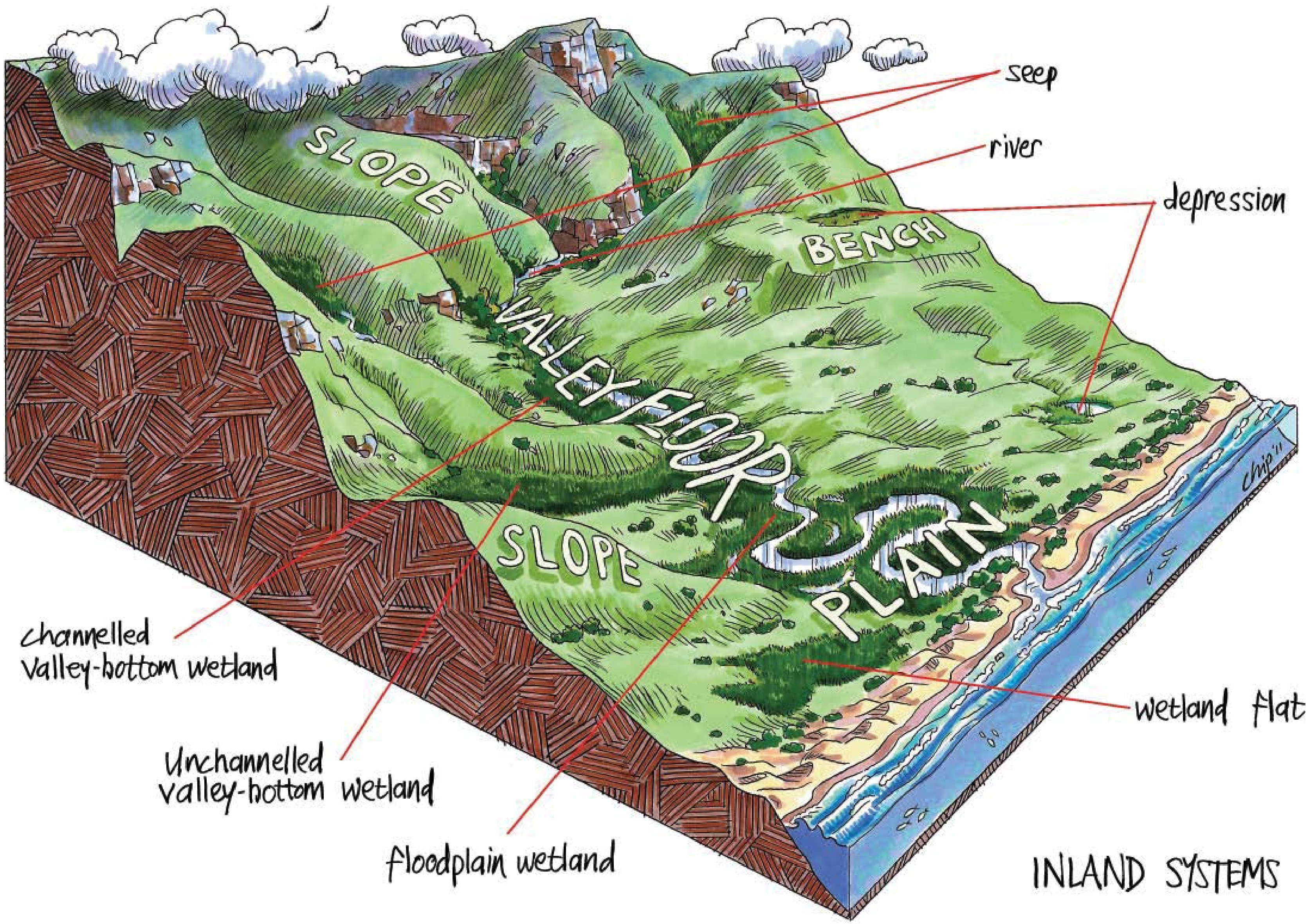


Figure 14. Illustration of the seven primary HGM Units and their typical landscape settings.

5 HYDROGEOMORPHIC UNIT (LEVEL 4)

Level 4 of the Classification System allows you to identify the HGM Units within an inland aquatic ecosystem. HGM Units are distinguished primarily on the basis of:

(i) Landform, which defines the shape and localised setting of the aquatic ecosystem.

(ii) Hydrological characteristics, which describe the nature of water movement into, through and out of the aquatic ecosystem.

(iii) Hydrodynamics, which describe the direction and strength of flow through the aquatic ecosystem.

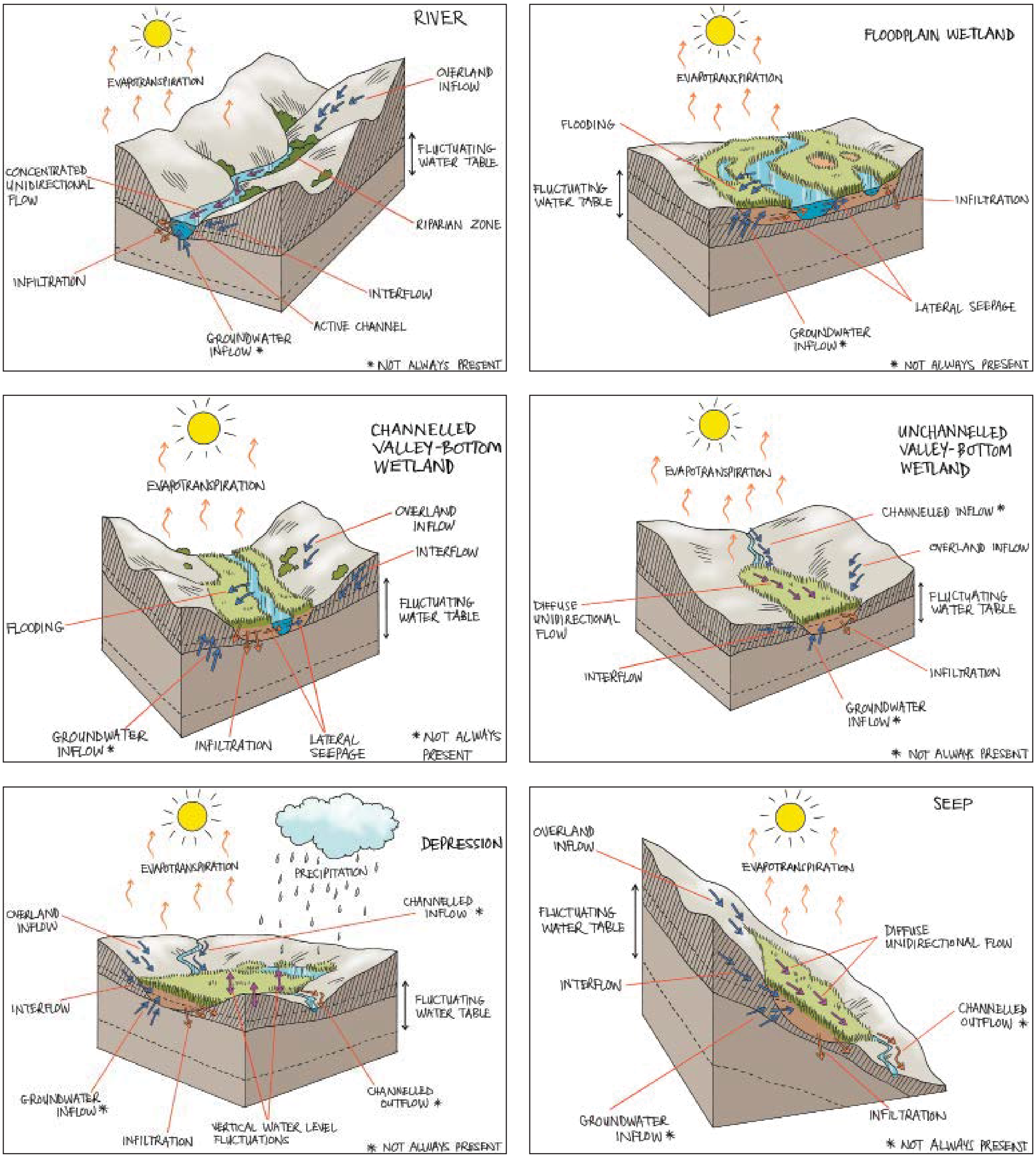
Seven primary HGM Types are recognised for Inland Systems at Level 4A, as described below and summarised in Table 1. The diagrams of primary HGM Types in Figure 15 show the dominant movement of water into, through and out of the various HGM Types.

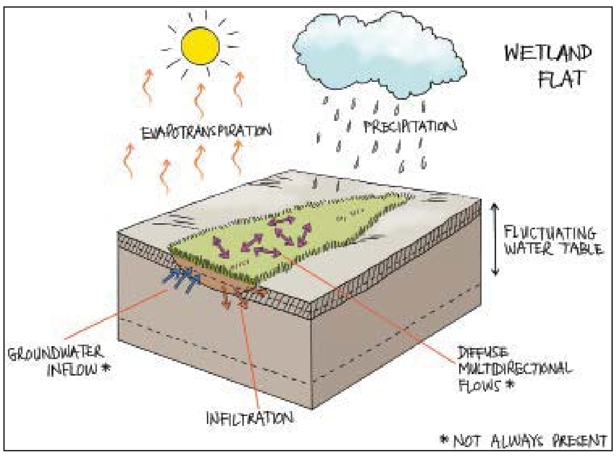
It is important to always bear in mind that a single Inland System could be made up of several HGM Units, as explained in Section 5.7.

For some levels of the Classification System, further classification of the primary categories is possible. For these levels, the primary catego-

Table 1. Hydrogeomorphic (HGM) Units for Inland Systems, showing the primary HGM Types at Level 4A and the sub-categories at Levels 4B to 4C

LEVEL 4: HYDROGEOMORPHIC (HGM) UNIT		
HGM type	*Longitudinal zonation/Landform/ Outflow drainage*	*Landform/Inflow drainage*
A	**B**	**C**
River	Mountain headwater stream	Active channel
		Riparian zone
	Mountain stream	Active channel
		Riparian zone
	Transitional	Active channel
		Riparian zone
	Upper foothills	Active channel
		Riparian zone
	Lower foothills	Active channel
		Riparian zone
	Lowland river	Active channel
		Riparian zone
	Rejuvenated bedrock fall	Active channel
		Riparian zone
	Rejuvenated foothills	Active channel
		Riparian zone
	Upland floodplain	Active channel
		Riparian zone
Channelled valley-bottom wetland	[not applicable]	[not applicable]
	[not applicable]	[not applicable]
Unchannelled valley-bottom wetland	[not applicable]	[not applicable]
	[not applicable]	[not applicable]
Floodplain wetland	Floodplain depression	[not applicable]
	Floodplain flat	[not applicable]
Depression	Exorheic	With channelled inflow
		Without channelled inflow
	Endorheic	With channelled inflow
		Without channelled inflow
	Dammed	With channelled inflow
		Without channelled inflow
Seep	With channelled outflow	[not applicable]
	Without channelled outflow	[not applicable]
Wetland flat	[not applicable]	[not applicable]





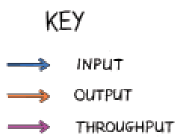


Figure 15. Amalgamated diagram of primary HGM types, highlighting their dominant water inputs, throughputs and outputs.

ries are referred to as Level A units and subsequent sub-divisions are then labelled with consecutive letters, up to Level D. For example, for HGM Units at Level 4, the primary HGM Types are referred to as Level 4A units, with further sub-divisions of these primary categories possible from Level 4B down to Level 4C.

5.1 Rivers

River—a linear landform with clearly discernable bed and banks, which permanently or periodically carries a concentrated flow of water. A river is taken to include both the active channel and the riparian zone as a unit (Box 7).

A conceptual illustration of a river is shown in Figure 16. Dominant water sources for rivers include concentrated surface flow from upstream channels and tributaries. Other inputs can include diffuse surface or subsurface flow (e.g. from an upstream seepage wetland), interflow (e.g. from valley side-slopes), and/or groundwater inflow (e.g. via springs). Water moves through the system, at least periodically, as concentrated flow and usually exits as such, except where there is a sudden decrease in gradient causing the outflow to become diffuse (in which case the river would grade into one of the wetland types). Other water outputs from a river include evapotranspiration and infiltration.

Concentrated, unidirectional flow within a distinct active channel, either permanently or periodically, is what characterises a river (see photos in Figure 17). As such, one of the key features to look for when trying to determine whether a particular Inland System is a river or not is the presence of relatively obvious channel banks (which may not be easy to determine visually in the case of well-vegetated systems) and/or a concentrated flow of water within a distinct channel (assuming the river is flowing at the time of your site visit).

It is important to note that not all features depicted as rivers on topographical or other maps (especially at a scale of 1:50 000 or less) would necessarily be considered rivers in terms of the Classification System. Some of these inland aquatic ecosystems may, instead be seeps or valley-bottom wetlands.

5.1.1 Longitudinal river zonation (Level 4B)

At Level 4B, rivers are divided into six primary longitudinal zones and three zones associated with a rejuvenated longitudinal profile, according to the geomorphological zonation scheme for rivers adopted by the River Health Programme (Rowntree & Wadeson 2000). The longitudinal river zones are described in Table 2. The DWA-RQS website provides maps of the longitudinal slope profiles derived for all rivers of South Africa mapped at a scale of 1:500 000 (http://www.dwa.gov.za/iwqs/gis_data/rivslopes/rivprofil.asp). The NFEPA rivers map (available via a link from http://bgis.sanbi.org/nfepa/NFEPAmap.asp) also provides longitudinal river zonation information for mainstem rivers and larger tributaries.

NOTE: where river zones have not yet been derived (e.g. on the DWA-RQS 1:500k river layer or the NFEPA river layer), they can be determined by using the gradient guidelines in Table 2 after calculating the gradient of the section of river being classified (using the guidelines for the calculation of gradient in Box 6).

It is important to remember that all longitudinal geomorphological zones are seldom represented along the length of a river. You may come across rivers that only have three or four zones, or rivers where the zones are not in the sequence shown in Table 2.

5.1.2 Active channel vs. riparian zone (Level 4C)

Rivers can be divided into the 'active channel' and 'riparian zone' components at Level 4C (Box 7; Figure 18). You would **only need to make this distinction in situations where a detailed description of a river is required and there is a need to apply the Level 6 'descriptors'** of the Classification System (see Section 7).

5.2 Floodplain wetlands

Floodplain wetland—a wetland area on the mostly flat or gently-sloping land adjacent to and formed by an alluvial river channel (Box 8), under its present climate and sediment load, which is subject to periodic inundation by overtopping of the channel bank.

Floodplain wetlands, as the name implies, generally occur on a plain and are typically characterised by a suite of geomorphological features associated with river-derived depositional processes, including point bars, scroll bars, oxbow lakes and levees (Figure 19).

Floodplain wetlands must be considered as wetland ecosystems that are distinct from but associated with the adjacent river channel itself, which must be classified as a 'river'. Remember that some river channels, especially in the more arid parts of South Africa, are vegetated (Box 7).

The definition of a floodplain wetland contains several key points that you should take note of. Firstly, a floodplain is a depositional surface formed by an **alluvial** river (Box 8), not an erosional surface or a surface formed by other non-riverine processes that can deposit sediments (such as wind-driven sands). Secondly, the floodplain is formed under the **current** climate and sediment load. Flat surfaces may be present along the margins of a river from previous eras of differing climate and/or sediment load, and these surfaces are called terraces. Terraces are generally not geomorphologically active, that is, they are not currently being built by river depositional processes. Finally, the floodplain is flooded (or inundated), on average, several times per year, during moderate peak flow events (such as a 1.5-year or 2-year flood). Terraces may be overtopped, but only by larger, less

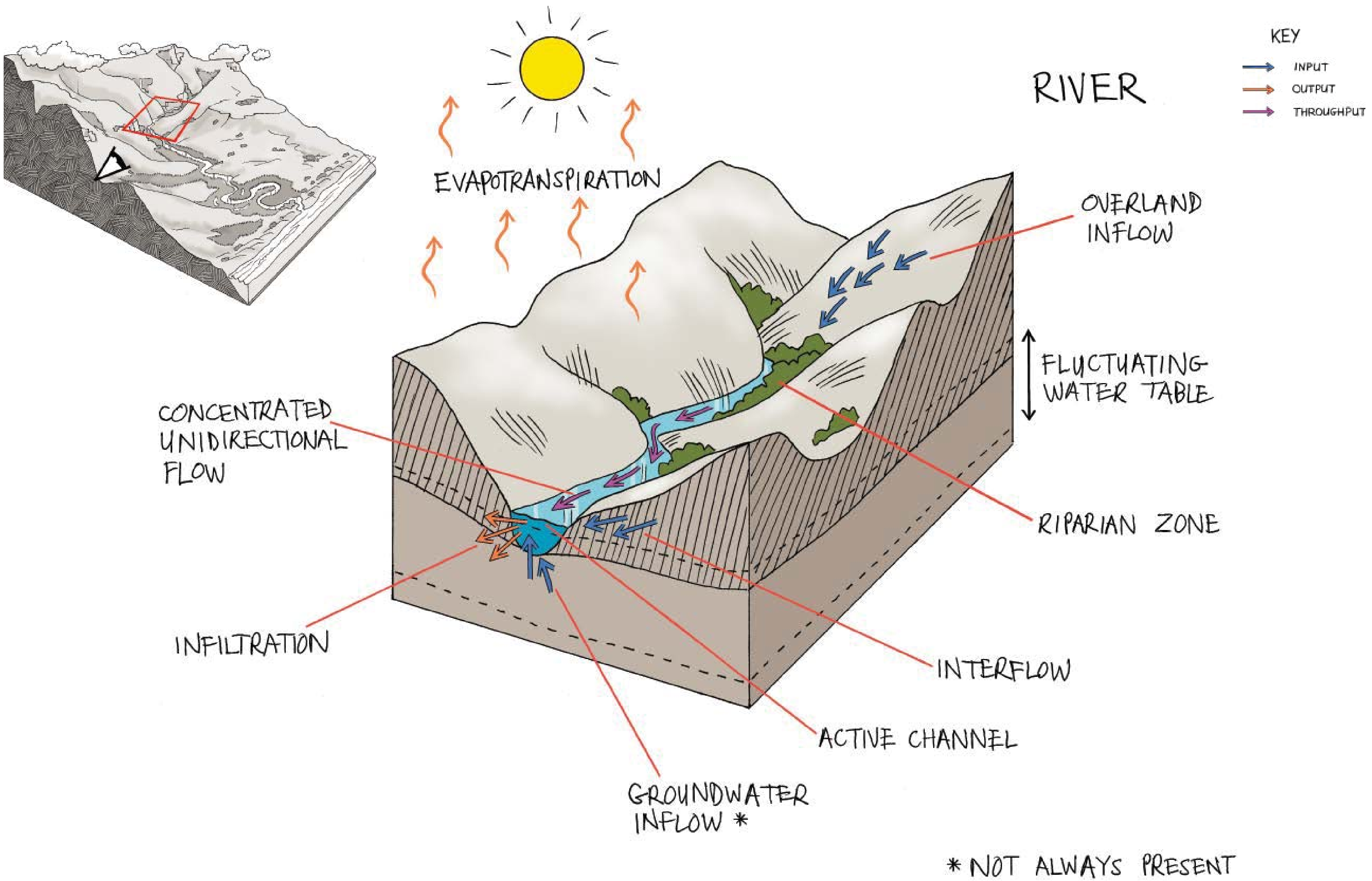


Figure 16. Conceptual illustration of a river, showing the typical landscape setting and the dominant inputs, throughputs and outputs of water.

Table 2. Geomorphological longitudinal river zones for South African rivers (after Rowtree & Wadeson 2000)

Longitudinal zone (and zone class)	Characteristic gradient	Diagnostic channel characteristics*
A. Zonation associated with a normal profile		
Source zone#	not specified	Low-gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
Mountain headwater stream	>0.1	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.
Mountain stream	0.040–0.099	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. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Transitional	0.020–0.039	Moderately steep stream dominated by bedrock or boulders. Reach types include plane bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited floodplain development.
Upper foothills	0.005–0.019	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 floodplain of sand, gravel or cobble often present.
Lower foothills	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. Floodplain often present.
Lowland river	0.0001–0.0010	Low-gradient, alluvial sand-bed channel, typically regime reach type. Often confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increase in silt content in bed or banks.
B. Additional zones associated with a rejuvenated profile		
Rejuvenated bedrock fall/cascades	>0.02	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.
Rejuvenated foothills	0.001–0.020	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 floodplain may be present between the active and macro-channel.
Upland floodplain	<0.005	An upland low-gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.

* Terms in green are defined in the glossary (Appendix 2)
\# In the Classification System, the source zone at the upper end of a river would typically be classified as one of the wetland types (e.g. a seep, an unchannelled valley bottom wetland, depression or wetland flat) and not as part of a river

frequent floods (e.g. 50-year or 100-year events). The inner edge of the floodplain is called bankfull. The bankfull channel, or active channel (Box 7), refers to the channel cross-section below the elevation of the floodplain.

Regular (or significant historical) water and sediment contributions from an associated river channel are what characterise the dynamic nature of a floodplain wetland. Another key characteristic of most floodplain wetlands is that they are generally located on a plain in terms of their landscape setting (see Section 4), although they can occur along the floor of a relatively wide valley with a low gradient (e.g. alongside the lower reaches of a Lower Foothill River).

Water and sediment enter floodplain wetlands mainly as overspill from a major river channel during flooding (Figure 20). Water movement through the wetland is predominantly horizontal and bidirectional (i.e. in and out of the wetland), in the form of diffuse surface or subsurface flow, although significant temporary containment of water may occur in floodplain depressions (Box 9). Water generally exits a floodplain wetland as diffuse surface and/or subsurface flow (often returning to the river channel), but infiltration and evapotranspiration of water from a floodplain wetland can also be significant, particularly if there are a number of depressional areas within the wetland.

NOTE: Not all parts of a floodplain are 'wetland' (see definition in Box 1). For exam-

Figure 17. Photographs of rivers: A, Doring River, Western Cape; B, Upper Nile River, Uganda; C, Wilge River, Free State; D, Makuleke River, Limpopo Province.

ple, levees are often characteristic features of a floodplain but tend to occur as dry areas of raised land flanking the river channel. It is worth noting, however, that such non-wetland features would typically only be mapped at a very fine scale of resolution.

Photographs of some typical floodplain wetlands are shown in Figure 21.

5.3 Valley-bottom wetlands

Valley-bottom wetland—a mostly flat wetland area located along a valley floor, often connected to an upstream or adjoining river channel.

Although valley-bottom wetlands are generally sites of sediment accumulation or temporary storage, as in the case of floodplain wetlands (see Section 5.2), the process of river-derived deposition is not nearly as important in these systems as it is in floodplain wetlands. As such, there tend to be few (if any) depositional features present within a valley-bottom wetland that can be ascribed to current riverine processes, although erosional features relating to riverine processes may be present. Valley-bottom wetlands are not formed by the process of flooding and large-scale sediment movement.

Valley-bottom wetlands are either channelled or unchannelled (Box 11).

5.3.1 Channelled valley-bottom wetlands

Channelled valley-bottom wetland—a valley-bottom wetland with a river channel running through it.

Channelled valley-bottom wetlands must be considered as wetland ecosystems that are distinct from, but sometimes associated with, the adjacent river channel itself, which must be classified as a 'river'. Remember that some river channels, especially in the more arid parts of South Africa, are vegetated (Box 7).

BOX 7: WHAT IS THE DIFFERENCE BETWEEN THE ACTIVE CHANNEL AND THE RIPARIAN ZONE OF A RIVER?

The active channel is the portion of a river that is inundated at sufficiently regular intervals to maintain channel form (i.e. the presence of distinct bed and banks) and keep the channel free of established terrestrial vegetation. Active channels are typically filled to capacity during bankfull discharge (i.e. during the annual flood, except for intermittent rivers that do not flood annually). Mid-channel bars (e.g. see photo of Doring River in Figure 17) and side bars are transient features that are considered to be part of the active channel.

The active channel of a river is generally situated within a confined valley (gorge) or within an incised macro-channel. Although active channels are typically free of established terrestrial vegetation, many rivers in South Africa are characterised by the presence of aquatic, wetland or pioneer vegetation within the active channel (Figure 18).

The riparian zone or riparian area of a river is the portion of land directly adjacent to the active channel (i.e. on the banks of the river), which is influenced by river-induced or river-related processes. These areas are commonly characterised by alluvial soils and by vegetation that is distinct from that of adjacent land areas in terms of its composition and physical structure. The riparian zone of a river is typically located between the outside edge of the active channel and the outside edge of the macro-channel.

Many riparian areas are well drained and would not be defined as wetlands (according to the South African National Water Act), especially in the upper reaches of rivers. However, some riparian areas are saturated or flooded for prolonged periods so that they would be considered wetlands and should be classified as such (instead of being classified as part of a river), using the wetland HGM Types (e.g. 'floodplain wetland' or 'channelled valley-bottom wetland').

Figure 18. The portion of the Riviersonderend near Greyton (Western Cape) is an example of a river with vegetation growing within the active channel (edge of the active channel shown by dotted white lines).

Channelled valley-bottom wetlands are characterised by their location on valley floors, the absence of characteristic floodplain features and the presence of a river channel flowing through the wetland (see photographs of typical channelled valley-bottom wetlands in Figure 22). A guideline to distinguish between floodplain and channelled valley-bottom wetlands is provided in Box 10, to assist you in cases where you are having difficulty determining which of these HGM Types is most relevant to a wetland you are trying to classify.

Figure 23 is a conceptual diagram of a channelled valley-bottom wetland, showing the dominant inputs and outputs of water. Dominant water inputs to these wetlands are from the river channel flowing through the wetland, either as surface flow resulting from flooding or as sub-

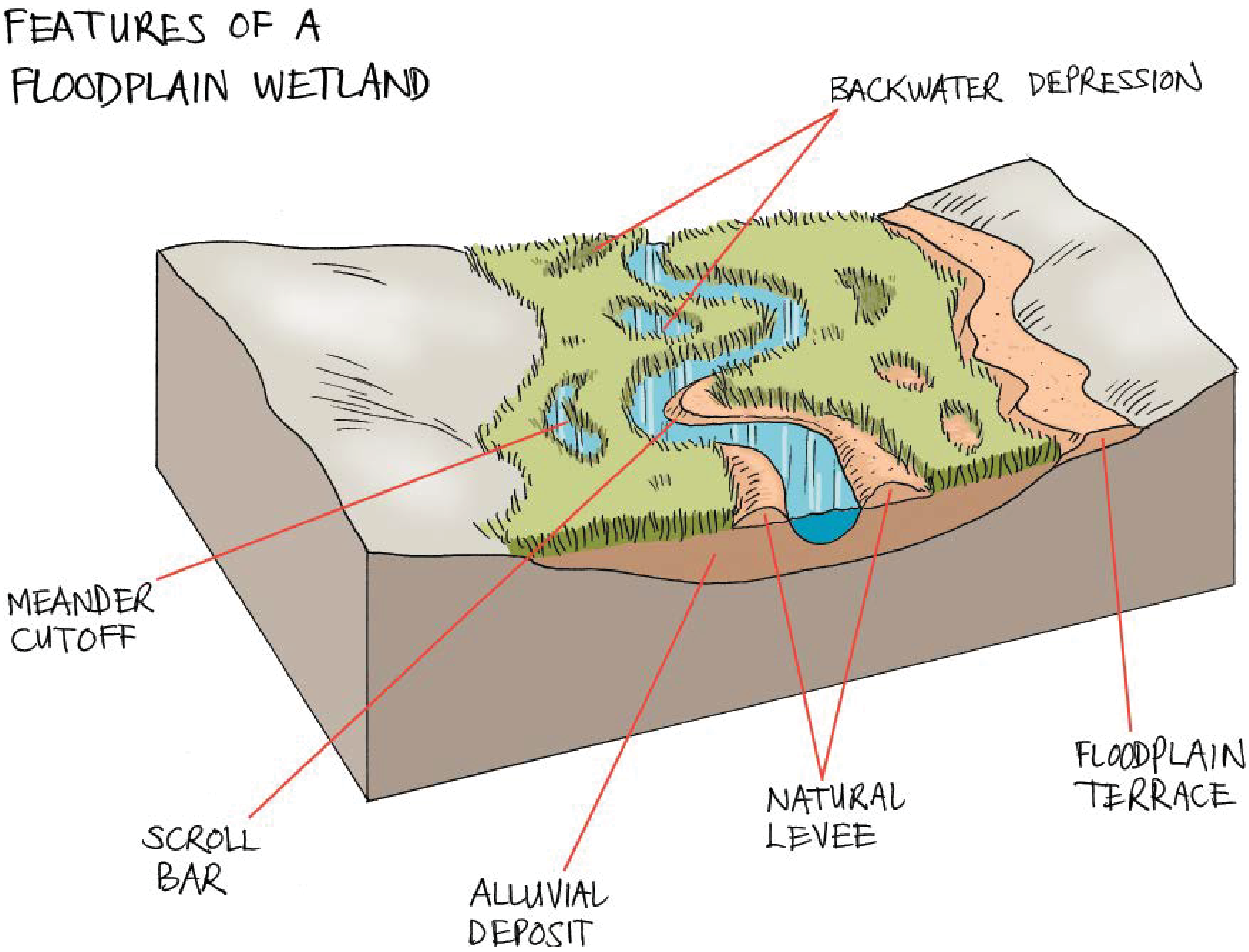


Figure 19. Typical features of a floodplain.

BOX 8: WHAT IS AN ALLUVIAL RIVER CHANNEL?

Alluvial river channels are self-formed features, meaning that they are shaped by the magnitude and frequency of the floods that they experience, and the ability of these floods to erode, deposit, and transport sediment. Alluvial channels are, therefore, formed in material that is able to move during moderate floods. This means that the bed and banks of an alluvial river channel are characteristically made up of unconsolidated mobile sediments such as silt, sand or gravel, or (in some cases) cobbles and small boulders. Alluvial river channels tend to erode their banks and deposit the eroded material on bars and on their floodplains.

surface flow, and/or from adjacent valley-side slopes (as overland flow or interflow). Water generally moves through the wetland as diffuse surface flow, although occasional, short-lived concentrated flows are possible during flooding events.

Water generally exits a channelled valley-bottom wetland in the form of diffuse surface or subsurface flow into the adjacent river, with infiltration into the ground and

BOX 9: WETLAND LANDFORMS WITHIN FLOODPLAIN WETLANDS (LEVEL 4B)

Floodplains are, in reality, complex landscapes (Figure 19) supporting a variety of features such as backwater depressions, meander cut-offs, alluvial ridges, levees, scroll bars, etc. It is often difficult to clearly distinguish between certain wetland features within a floodplain such as meander cut-offs and backwater depressions, particularly in active floodplain wetlands that are dynamic and within which there may be a continuum of younger and older features associated with channel migration.

To cater for these complexities in the simplest way possible, the Classification System allows you to further classify floodplain wetlands into 'floodplain flats' and 'floodplain depressions' at Level 4B. This does not stop you from taking note of the features within a floodplain wetland in a more detailed manner—for example, if you had sufficient information, you could record whether a 'floodplain depression' is a backwater depression or a meander cut-off (as in the worked example of the Wilge River wetlands presented in Appendix 1).

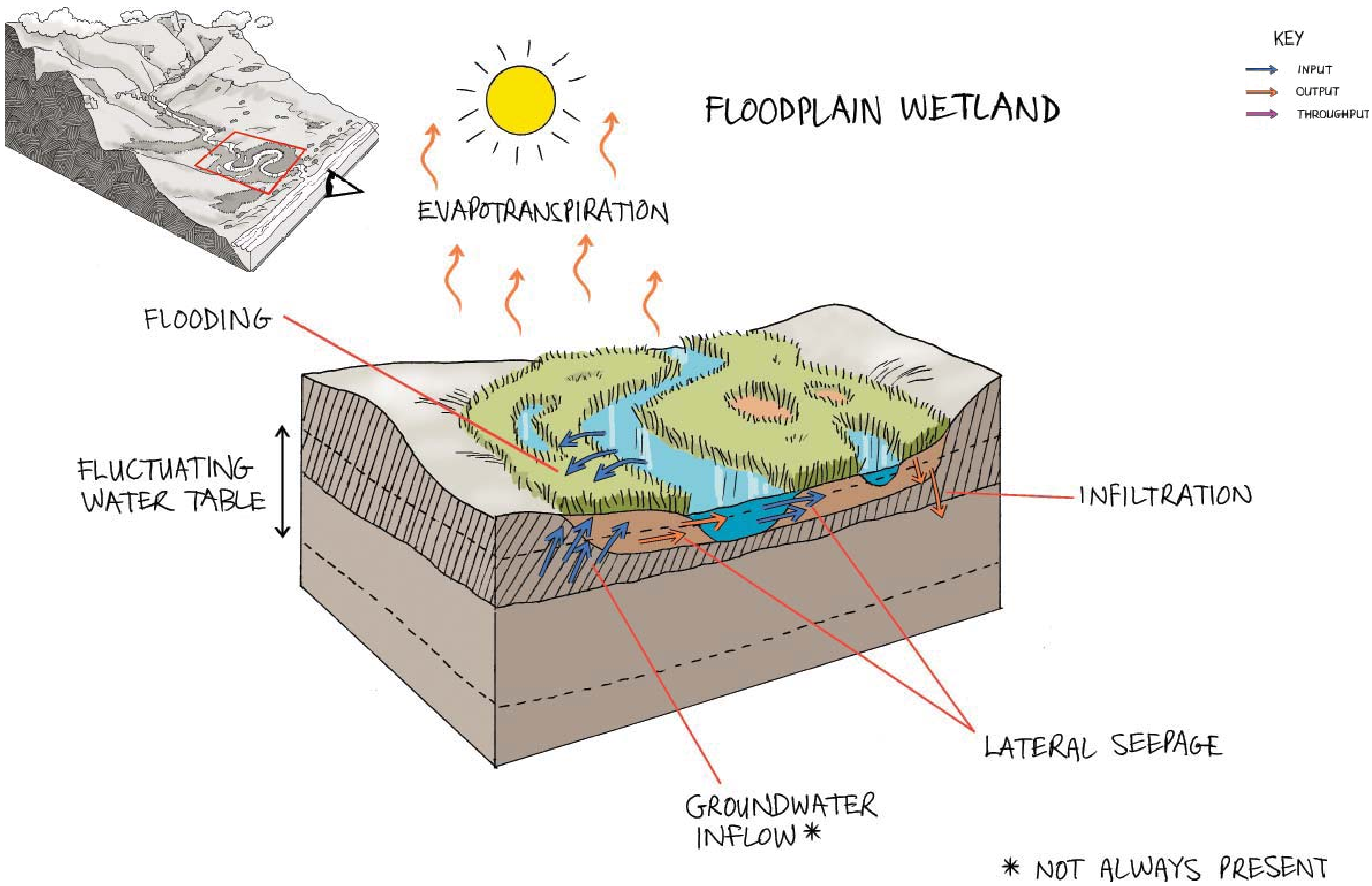


Figure 20. Conceptual illustration of a floodplain wetland, showing the typical landscape setting and the dominant inputs, throughputs and outputs of water.

Figure 21. Photographs of typical floodplain wetlands in the eastern Free State. A, Wilge River floodplain wetland; B, Seekoeivlei floodplain wetland along the Klip River.

BOX 10: A GUIDELINE TO DISTINGUISH BETWEEN FLOODPLAIN AND CHANNELLED VALLEY-BOTTOM WETLANDS

It may be difficult to consistently differentiate between channelled valley-bottom wetlands and floodplain wetlands, when the primary criteria for such a distinction are the importance of flooding and/or the presence of particular geomorphological features. This is especially so when one is trying to conduct a desktop classification of Inland Systems, without actually visiting them.

To overcome this difficulty, in the Classification System **the longitudinal zonation of the river flowing through the wetland can be used as a preliminary criterion for differentiating between a channelled valley-bottom wetland and a floodplain wetland** (Table 2). As a guideline, wetland areas adjacent to river channels in the Lowland River Zone or the Upland Floodplain River Zone (i.e. lowland rivers with gradients <0.001 and upland rivers with gradients <0.005) should, by default, be classified as 'floodplain wetlands', whereas wetlands that are also subject to periodic inundation by overtopping of the channel bank but are located in longitudinal river zones with steeper gradients, should tentatively be classified as 'channelled valley-bottom wetlands'.

This guideline may be problematic in certain situations, for example where distinct floodplain features and flooding processes are prevalent but the wetland occurs along a Lower Foothill River, thus leading to classification as a 'channelled valley-bottom wetland'. The presence of visible floodplain features should take precedence, however, and the wetland should be classified as a 'floodplain wetland' in situations like this.

A site visit to the wetland in question is strongly recommended, as this would allow the identification of the types of features characteristic of floodplain wetlands.

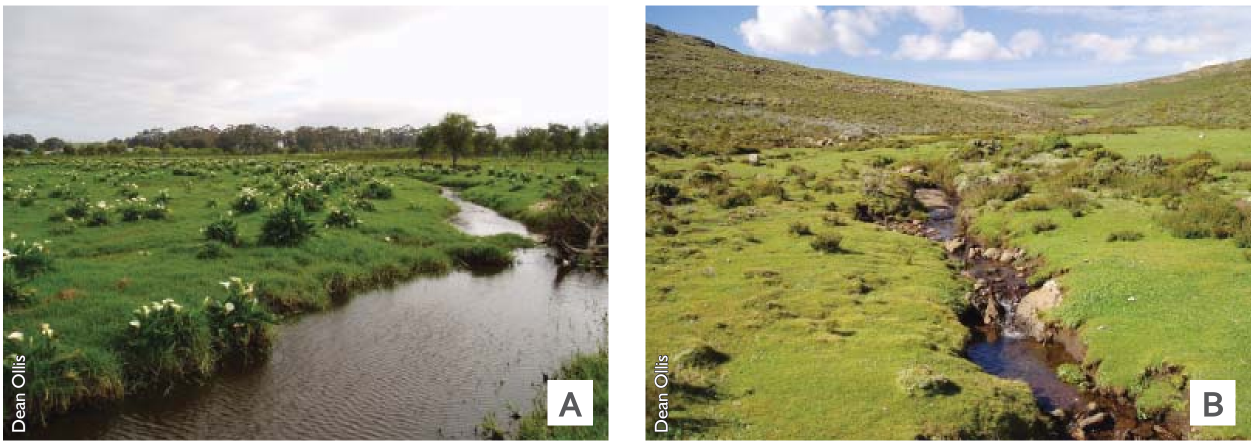


Figure 22. Photographs of typical channelled valley-bottom wetlands. A, along the Mosselbank River; B, an unnamed stream in the Lesotho Highlands.

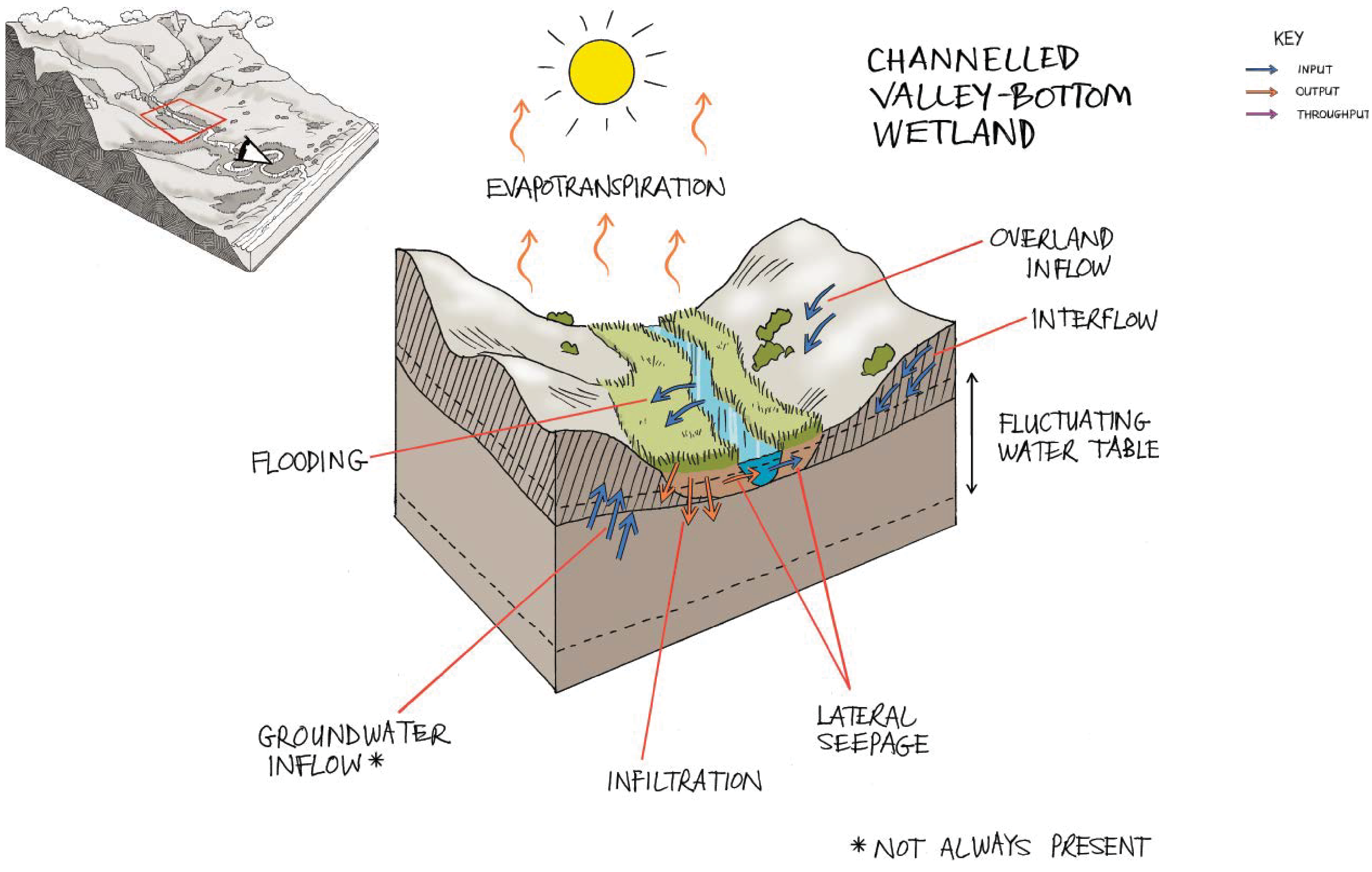


Figure 23. Conceptual illustration of a channelled valley-bottom wetland, showing the typical landscape setting and the dominant inputs, throughputs and outputs of water.

BOX 11: IS MY VALLEY-BOTTOM WETLAND CHANNELLED OR UNCHANNELLED?

Weakly developed channels are sometimes present in valley-bottom wetlands. Channels may be present in one part of a wetland and then disappear a short distance downstream. In these situations, you may find it difficult to decide whether a particular valley-bottom wetland is channelled or not.

The decision as to whether your valley-bottom wetland is channelled or unchannelled should, ultimately, be informed by an understanding of flow patterns within the wetland. If the channel is so weakly developed that diffuse flows remain dominant even during the dry season, rather than all being contained within the channel, then the HGM Unit should be classified as an 'unchannelled valley-bottom wetland'. If, on the other hand, most low flows are confined to a well-defined channel, the wetland should be classified as a 'channelled valley-bottom wetland'.

Valley-bottom wetlands that were historically unchannelled may have become channelled due to activities such as the construction of drainage channels or roads across the wetland. The establishment of such structures tends to concentrate surface flows, resulting in erosion and the subsequent formation of channels. While a wetland may be classified in its current state as a channelled valley-bottom wetland, in situations such as these, it would be important to also record its historical/natural classification as an unchannelled valley-bottom wetland if you think this is the case.

evapotranspiration of water from these wetlands also being potentially significant.

5.3.2 Unchannelled valley-bottom wetlands

Unchannelled valley-bottom wetland—a valley-bottom wetland without a river channel running through it.

Unchannelled valley-bottom wetlands are characterised by their location on valley floors, an absence of distinct channel banks, and the prevalence of diffuse flows. These wetlands are generally formed when a river channel loses confinement and spreads out over a wider area, causing the concentrated flow associated with the river channel to change to diffuse flow (i.e. the river becomes an unchannelled valley-bottom wetland). This is typically due to a change in gradient brought about by a change in base level at the downstream edge of the wetland (for example, where an erosion-resistant dolerite dyke is present) and the resulting accumulation of sediment. In some cases, an unchannelled valley-bottom wetland could occur at the downstream end of a seep, where a slope grades into a valley near the head of a drainage line. This is typical of highlands such as the Drakensberg Mountains.

Figure 24 shows a conceptual diagram of an unchannelled valley-bottom wetland. Water inputs are typically from an upstream channel that becomes dominated by diffuse (surface and subsurface) flow as it enters the wetland and seepage from adjacent slopes. There may also be groundwater input into the wetland. Water characteristically moves through the wetland in the form of diffuse surface or subsurface flow, but the outflow may be in the form of either diffuse or concentrated surface flow.

Infiltration and evapotranspiration from unchannelled valley-bottom wetlands can be significant, but horizontal, unidirectional, diffuse surface flow tends to dominate these wetland systems.

Photographs of some typical unchannelled valley-bottom wetlands are shown in Figure 25.

Remember that some river channels are vegetated (Box 7), especially in the more arid parts of South Africa where non-perennial or weakly perennial flow regimes are common. These river channels may, at first sight, appear to be unchannelled valley-bottom wetlands. The key features to look for when trying to distinguish between these two HGM Types are channel banks and evidence of periodic, concentrated water flow within a channel, both of which would be present in the case of a river.

5.4 Depressions

Depression—a wetland or aquatic ecosystem with closed (or near-closed[1]) elevation contours, which increases in depth from the perimeter to a central area of greatest depth and within which water typically accumulates.

Although they may at times have a river flowing into or out of them, depressions are especially characterised by their closed (or at least near-closed) contour shape, which makes them relatively easy to identify on topographic maps.

Depressions may be flat-bottomed (in which case they are often referred to as pans) or round-bottomed and may have any combination of inlets and outlets or lack them completely. In Figure 26 you can see photographs of a few

[1] A depression with one or more relatively major channels flowing into or out of it would not have totally closed elevation contours.

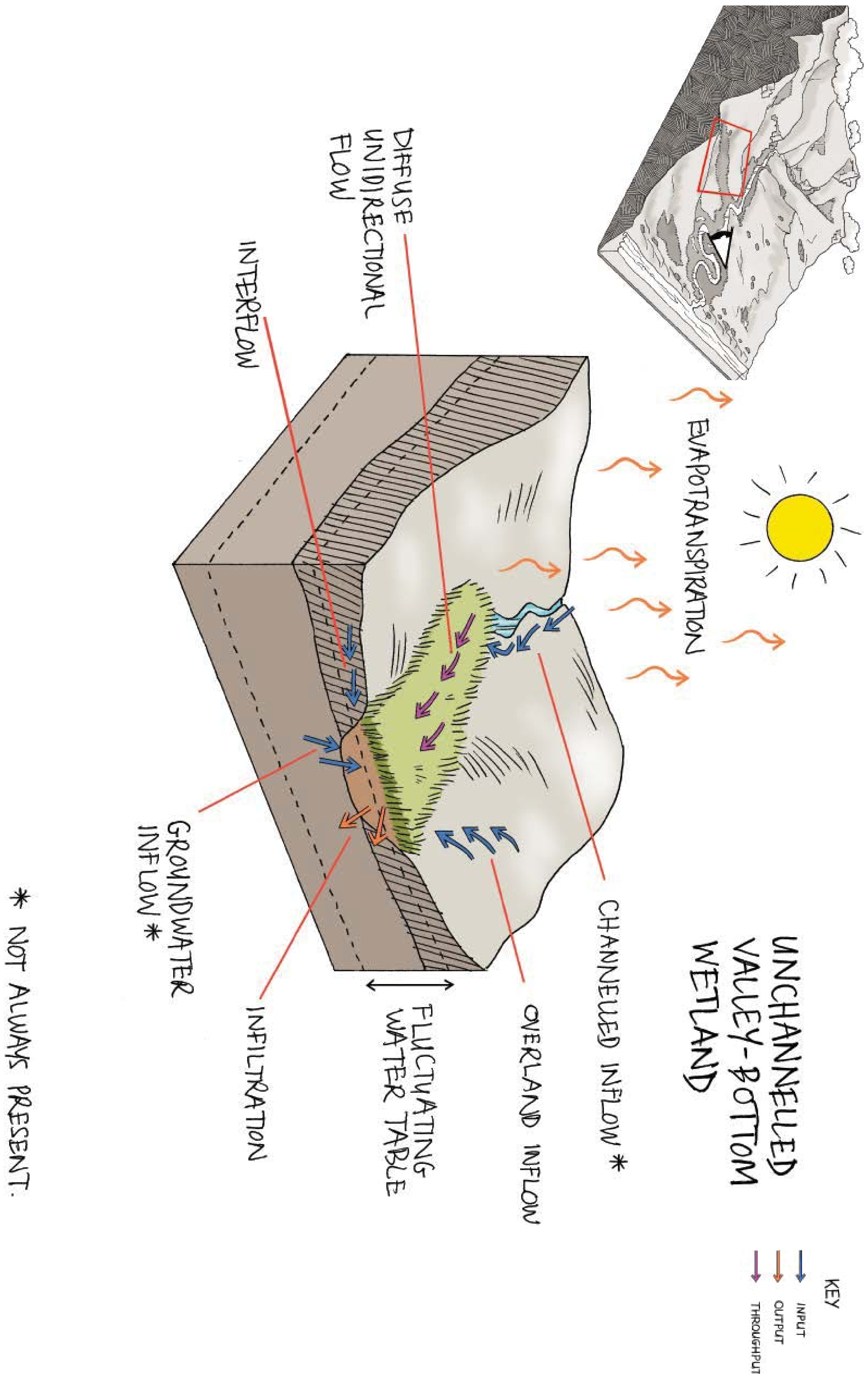


Figure 24. Conceptual illustration of an unchannelled valley-bottom wetland, showing the typical landscape setting and the dominant inputs, throughputs and outputs of water.

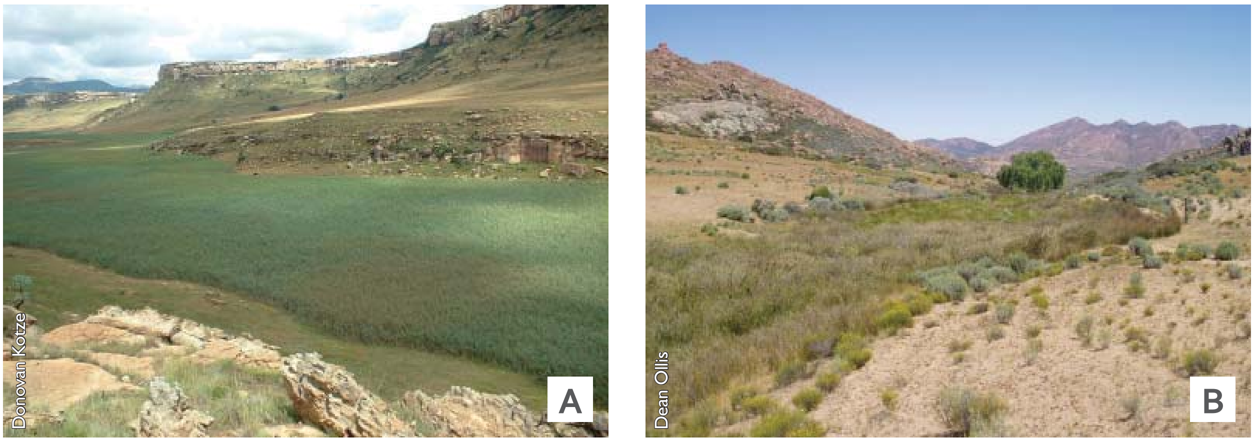


Figure 25. Photographs of typical unchannelled valley-bottom wetlands. A, Maloti-Drakensberg area; B, Kamiesberg Uplands of the Northern Cape.

examples of natural depressions, some of which have no inlets or outlets (i.e. Drakensberg tarn and Sirkelsvlei), one that has an outlet channel (i.e. Bass Lake), and one which has an inlet channel but no outlet channels (i.e. Burgerspan).

Some depressions are so extensive that, at first glance, they may appear to be large flat areas that could be classified as 'wetland flats' or 'floodplain flats', whereas over a long distance they are actually pan-shaped or basin-shaped features, meaning that they are actually 'depressions'. An extreme example of this is the famous Makgadikgadi Pans in Botswana. To confirm whether an apparently flat area has a depressional shape over a wide distance, you should consult a topographical map with contour lines (such as the 1:50 000 scale topographical maps produced by the South African department of National Geo-spatial Information).

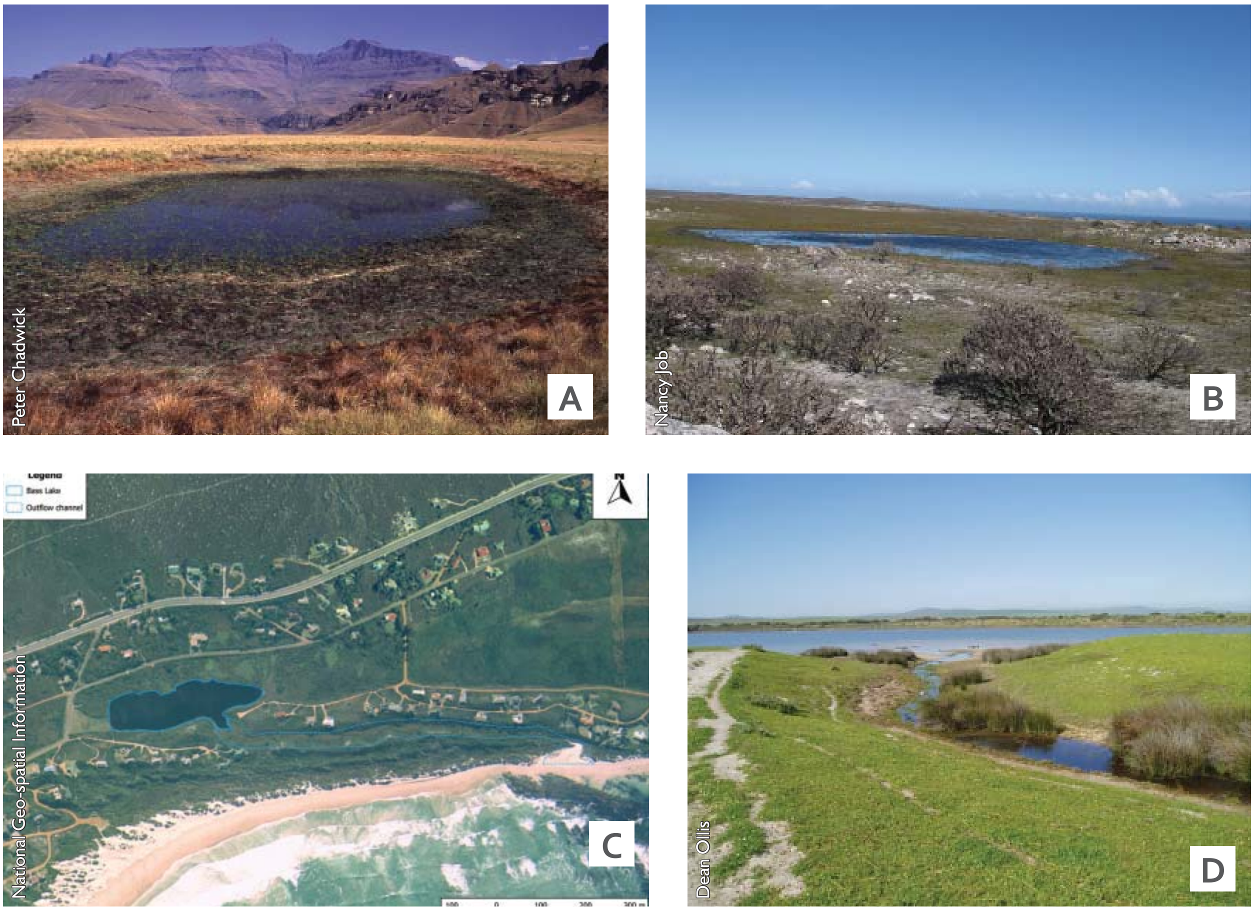


Figure 26. Photographs of natural depressions: A, high-altitude tarn in the Drakensberg; B, Sirkelsvlei in Cape Point Nature Reserve; C, aerial photo of Bass Lake (or Malkopsvlei) and its outflow channel, Betty's Bay; D, Burgerspan and its non-perennial inlet channel, near Darling in the Western Cape.

Most depressions occur either where the water table intercepts the land surface (such as on coastal plains along the South African coastline), or in semi-arid settings where a lack of sufficient water inputs prevents areas where water accumulates from forming a connection with the open drainage network. Lakes are a type of depression that typically forms in a valley floor, where some sort of obstruction leads to the 'drowning' of the valley through the accumulation of water behind a barrier (in the case of a dam, which can be considered an artificial lake, the barrier has been created by human intervention)—see Box 12 for a note on lakes and dams.

The dominant water inputs and outputs of a depression (see conceptual diagram in Figure 27) are dictated primarily by the outflow and inflow drainage characteristics, as classified at Levels 4B and 4C, respectively (see Sections 5.4.1 and 5.4.2). The hydrodynamics of a depression are, however, typically dominated by vertical water level fluctuations.

5.4.1 *Outflow drainage characteristics of depressions (Level 4B)*

At Level 4B of the Classification System, depressions are categorised according to their outflow drainage characteristics. Depressions can be classified as 'exorheic' (i.e. outward-draining) or 'endorheic' (i.e. inward-draining) in terms of their outflow drainage, with a third option to categorise a depression with an artificially regulated outflow drainage as 'dammed'. In addition, the outflow drainage can be categorised as 'unknown'.

By definition, water exits an endorheic depression by means of evaporation and infiltration only, whereas water can exit an exorheic depression as concentrated or diffuse surface flow, or as subsurface flow (see Box 13).

If you are unsure whether a depression that you are classifying has diffuse outward drainage or is inward-draining, you should simply record the outflow drainage as 'unknown' and move onto Level 4C. An example of such a situation is a depression without any outflow channels located near the coast, adjacent to a sand dune through which water could be draining without forming wetlands.

5.4.2 *Inflow drainage characteristics of depressions (Level 4C)*

At Level 4C, depressions can be further subdivided on the basis of their inflow drainage characteristics, into those 'with channelled inflow' (such as Burgerspan, as shown in Figure 26) and those 'without channelled inflow'.

Concentrated overland flow is typically a major source of water for depressions with channelled inflow, whereas this is not the case for depressions without channelled inflow, which tend to be fed primarily by interflow and/or groundwater inflow.

BOX 12: WHAT ABOUT LAKES AND DAMS?

As the definition of an Inland System includes all inland aquatic ecosystems (i.e. not just wetlands), lakes and other open waterbodies (e.g. Lake Fundudzi in Venda, the only true 'lake' in South Africa, and Bass Lake as shown in Figure 26) are considered to be types of Inland Systems in terms of the Classification System, even if they are artificial such as dams (see Section 7.1). You should classify all such open waterbodies as 'depressions' when applying the Classification System. This rule is based on the fact that the landform characteristics of such systems fit the definition of a depression in that they typically have closed (or near-closed) elevation contours and increase in depth from the perimeter to a central area of greatest depth. Lakes and other open waterbodies that have a maximum depth greater than two metres are called limnetic systems (see Section 6.2.3).

The characterisation of the inflow characteristics of a depression is important in understanding the functioning of these types of aquatic ecosystems, and in their management. For example, the functioning of a depression with channelled inflow will be directly influenced by the

BOX 13: HOW TO DETERMINE WHETHER OR NOT A DEPRESSION IS OUTWARD-DRAINING

If a depression has an outflow channel (such as Bass Lake, as shown in Figure 26), it is obvious that it drains outwardly by means of concentrated surface flow. The first step you should take in determining whether a depression is exorheic is, therefore, to observe whether any outflow channels are present (using remote sources of information and/or by conducting a site visit). The presence of diffuse surface flow and/or subsurface drainage out of a depression is, unfortunately, more difficult to ascertain and can often only be confirmed by undertaking detailed geohydrological studies. In particular, in most cases it is very difficult (often impossible) to determine the subsurface outflow drainage characteristics of a depression on the basis of remote sources of information such as maps and aerial photography.

Where water exits a depression as diffuse surface or subsurface flow into an adjacent wetland, such as a seep, the wetland may be visible on a satellite image or an aerial photograph, and it is likely to be observable during a site visit. In such cases, you can use the presence of an adjacent wetland to infer that the depression is exorheic.

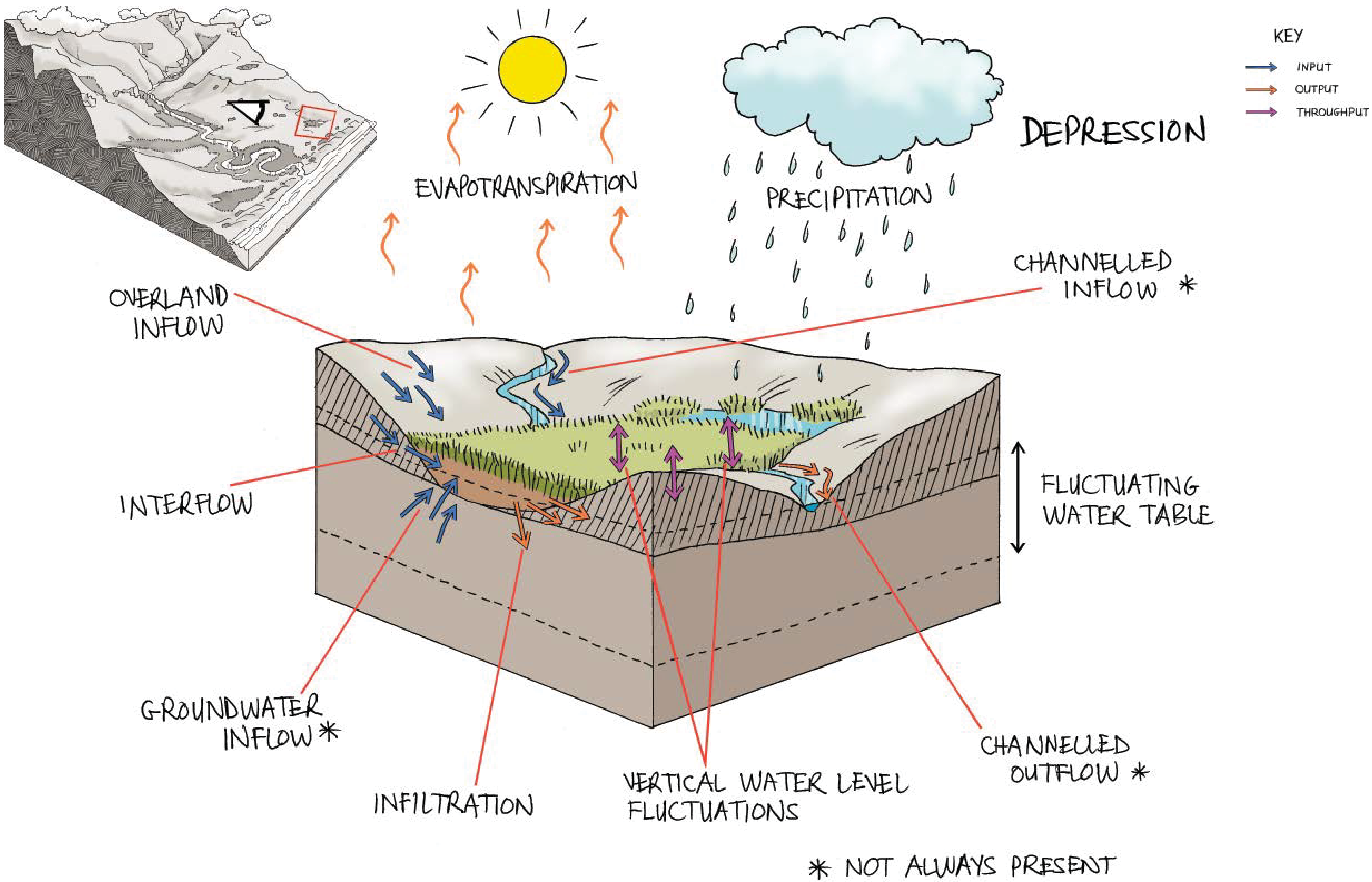


Figure 27. Conceptual illustration of a depression, showing the dominant inputs, throughputs and outputs of water.

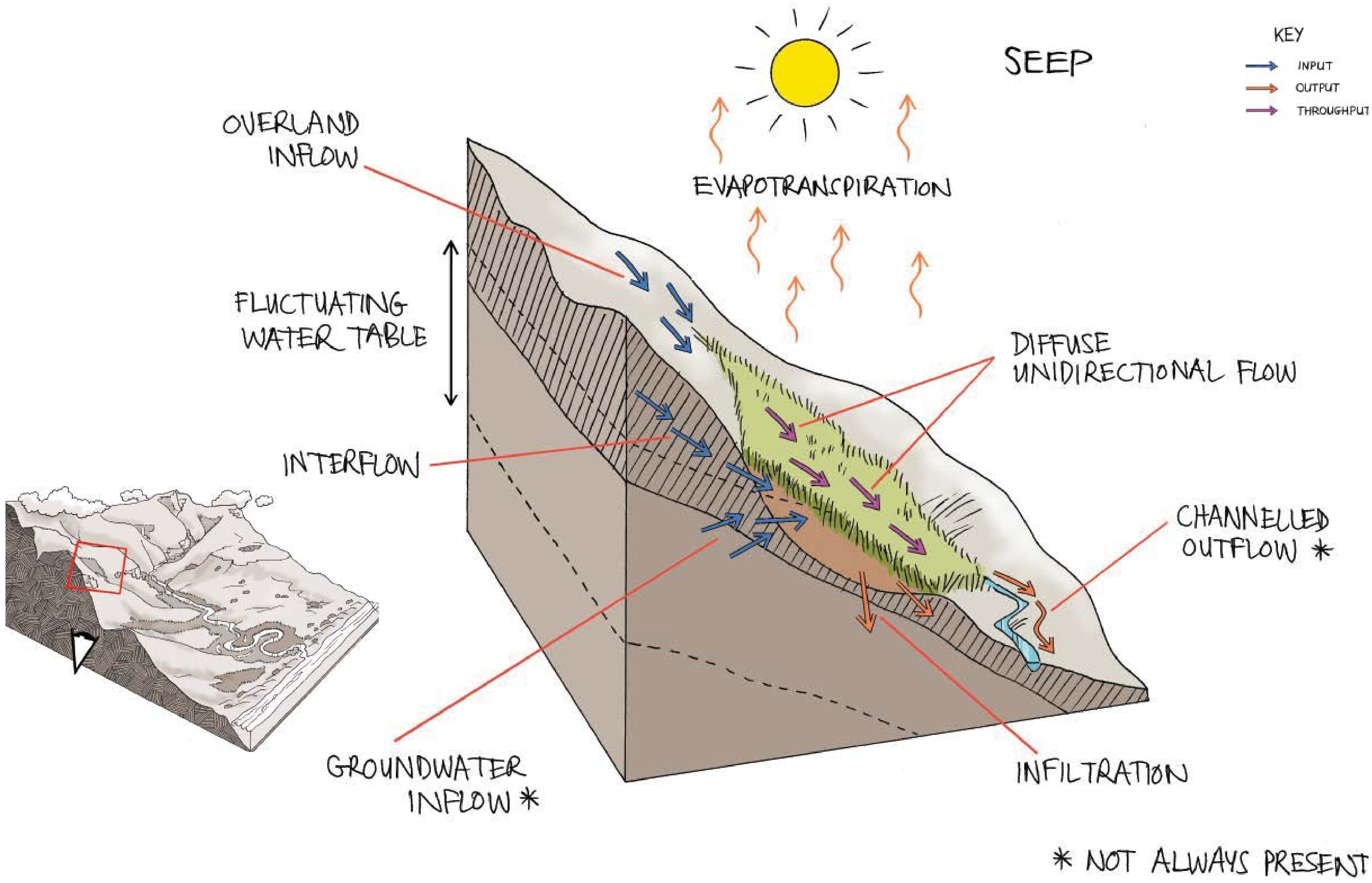


Figure 28. Conceptual illustration of a seep, showing the typical landscape setting and the dominant inputs, throughputs and outputs of water.

inflowing water and the management of such a system will have to take into account the water quality of the upstream drainage basin. In the case of a depression without channelled inflow, on the other hand, impacts associated with the immediate catchment are likely to play a more important role.

Many depressions do not have any outward (downstream) drainage or any inflow channels, as recorded at Levels 4B and 4C of the Classification System respectively, such as the Drakensberg tarn and Sirkelsvlei shown in Figure 26. These types of aquatic ecosystems are not connected to a river network and are sometimes referred to as 'isolated depressions'.

5.5 Seeps

Seep—a wetland area located on gently to steeply sloping land and dominated by colluvial (i.e. gravity-driven), unidirectional movement of water and material down-slope.

Seeps are often located on the side-slopes of a valley but they do not, typically, extend onto a valley floor.

Water inputs are primarily via subsurface flows from an up-slope direction. Water movement through the seep is mainly in the form of interflow, with diffuse overland flow (known as sheetwash) often being significant during and after rainfall events. A conceptual diagram of a seep, showing the dominant movement of water into, through and out of a typical seep is provided in Figure 28.

Seeps are characterised by their association with geological formations (lithologies) and topographic positions that either cause groundwater to discharge to the land surface or rain-derived water to 'seep' down-slope as subsurface interflow. Examples of places where these conditions occur are (1) on slopes where the water table intersects the land surface, resulting in groundwater discharge directly to the land surface; (2) land that is down-slope of a break in slope of the groundwater table; (3) where subsurface discontinuities in geological units (e.g. faults) cause upward movement of groundwater; or (4) on slopes where a relatively impervious subsoil layer impedes the infiltration of rain-derived water into the ground.

It is important to bear in mind that seeps can occur in relatively flat or very gently-sloping landscapes, as long as there is sufficient slope for there to be a unidirectional subsurface flow of water.

As for depressions, you can further classify seeps according to their outflow drainage characteristics at Level 4B.

5.5.1 *Outflow drainage characteristics of seeps (Level 4B)*

Seeps can be categorised into those 'with channelled outflow' and those 'without channelled outflow' (Figure 29).

Water exits from a seep with channelled outflow mostly by means of concentrated surface flow, whereas water exits from a seep without channelled outflow by means of a combination of diffuse surface flow, interflow, evaporation and infiltration.

NOTE: A seep abutting a distinct river channel and feeding into the channel via diffuse surface flow or subsurface flow, but not having a channelised outlet from the seepage area to the adjacent channel, should be classified as a 'seep without channelled outflow' even though it feeds into a channel.

5.6 Wetland flats

Wetland flat—a level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. Closed elevation contours are not evident around the edge of a wetland flat.

Figure 29. Photographs of: A, a seep with channelled outflow; and B, a seep without channelled outflow, both in the Lesotho Highlands.

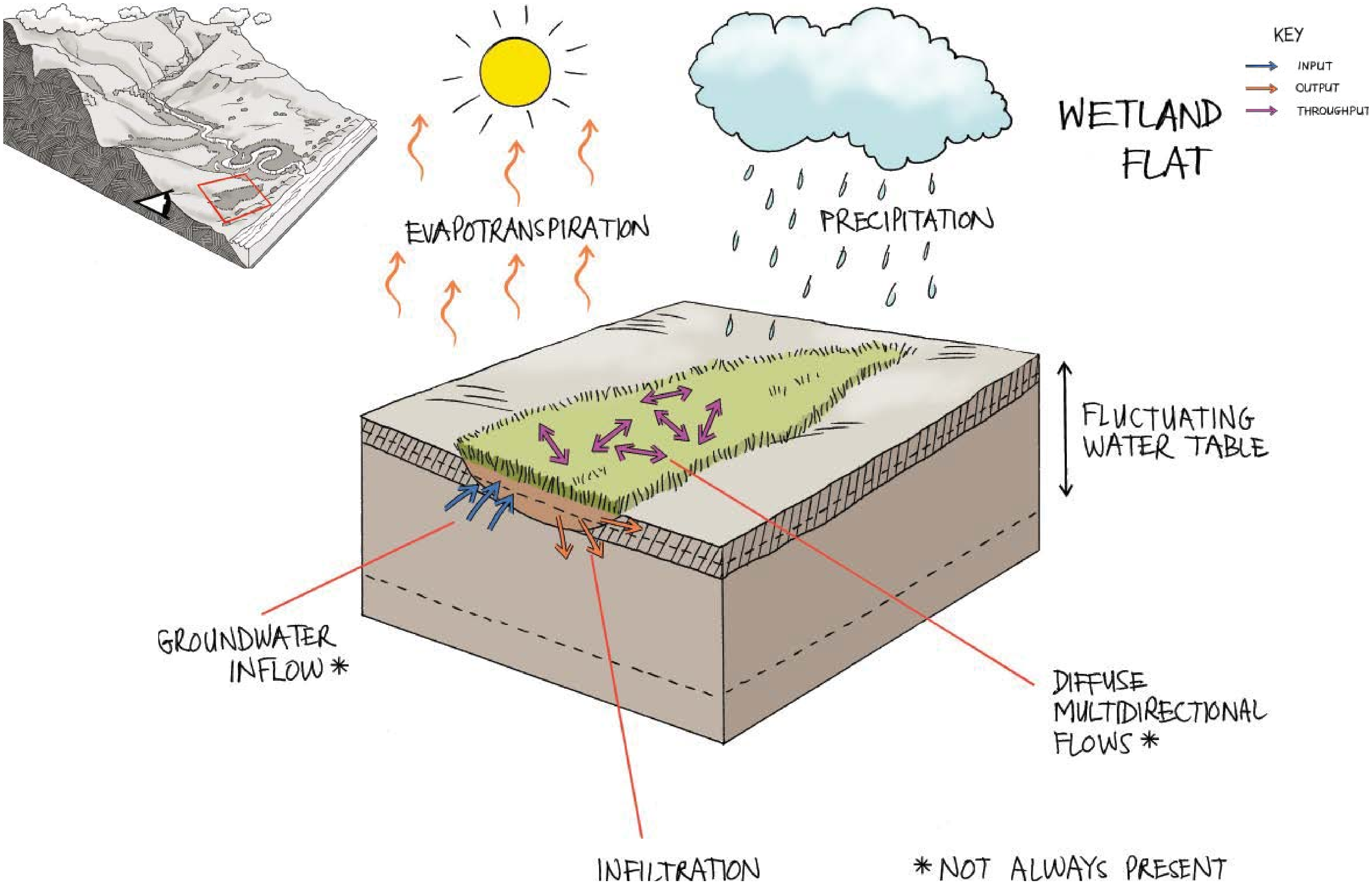


Figure 30. Conceptual illustration of a wetland flat, showing the dominant inputs, throughputs and outputs of water.

BOX 14: What is the difference between a wetland flat and a seep?

In certain situations, you may find it challenging to know whether a particular wetland is a seep or a wetland flat, as some seeps are found in foot- or toe-slope locations with extremely shallow gradients. One of the key differences between these two wetland types, at least in non-coastal areas, is that seeps are often fed primarily by the expression of groundwater at the ground surface whereas wetland flats away from the coast are typically fed by precipitation alone. Knowing the geology of the area and whether it is associated with strong groundwater to surface water linkages (as in the case of aquifer-dependent ecosystems), or digging exploratory soil plots of sufficient depth to establish whether the wetland is 'perched' above bedrock or dense clay (and, therefore, not linked to the groundwater) will help you to answer this question.

Another key difference between seeps and wetland flats, whether you are near the coast or in the interior of the country, is that seeps are typically associated with a relatively strong, unidirectional flow of water horizontally, whereas wetland flats are associated with very weak, multidirectional horizontal water movements, if any horizontal water flow is present at all.

This HGM Type was added to the Classification System in order to provide a way of classifying wetland areas on flat land (often on a coastal plain) that are not in any way connected to the drainage network (i.e. there are no river channels flowing into, out of, or through the system), and for which none of the other HGM Types seem to be appropriate.

A conceptual diagram of a wetland flat is shown in Figure 30. The primary source of water for a wetland flat is precipitation, with the exception of wetland flats situated on a coastal plain where groundwater may rise to or near the ground surface. Dominant hydrodynamics in wetland flats are bidirectional vertical fluctuations, with weakly-developed multidirectional horizontal water flows present in some cases. Water typically exits a wetland flat through evapotranspiration and infiltration.

Wetland flats are characterised by the dominance of vertical water movements associated with precipitation, groundwater inflow, infiltration and evapotranspiration. Horizontal water movements within these wetlands, if present, are multi-directional, due to the lack of any significant change in gradient within the wetland. The key differences between a wetland flat and a seep are explained in Box 14.

Figure 31 shows photographs of some typical wetland flats. It is important not to confuse these types of wetlands with floodplain flats (see Box 15).

5.7 Some final tips on deciding which HGM Units are relevant

Some aquatic ecosystems just do not fit neatly into any of the 'boxes' created by the differentiation of HGM Units at Level 4 of the Classification System. If you encounter such a situation when trying to classify an Inland System, you should select the HGM Unit that has hydrological and geomorphological characteristics that most closely resemble those of your system.

Looking at the landscape setting of an Inland System (as classified at Level 3) can help in identifying the most appropriate HGM Unit because certain HGM Units are more likely to occur in particular landscape settings than they are in others. For example, a seep typically occurs on a slope, a valley-bottom wetland typically occurs along a valley floor, and a floodplain wetland generally occurs on a plain.

It may also be that you need to split your Inland System into more than one HGM Unit. For instance, if you are

Figure 31. Photographs of wetland flats. A, Vergenoegd Farm, Stellenbosch; B, Agulhas Plain.

BOX 15: What is the difference between a wetland flat and a floodplain flat?

Wetland flats have been incorporated as a primary HGM Type at Level 4A of the Classification System, whereas floodplain flats have been included at Level 4B as micro-features within floodplain wetlands. It is important to recognise that a floodplain flat is connected to a drainage network, as part of a broader wetland complex associated with a river channel, while a wetland flat is not in any way connected to a drainage network. Wetland flats are fed only by precipitation and, in some cases, groundwater inflow.

trying to classify a wetland that consists of unchannelled valley-bottom wetland and seep sections as a single HGM Unit, you will get stuck until you split the wetland into these two HGM Types at Level 4A. Some worked examples of how inland aquatic ecosystems can be split into different HGM Units are given in Appendix 1 (see Examples 1 and 2).

On the other hand, you will also run into problems if you try to split an aquatic ecosystem into too many HGM Units. It is very important that the entire HGM Unit is classified and considered as a single entity at Level 4 of the Classification System. For example, if an endorheic depression consists of an unvegetated central portion that is permanently inundated with open water and a seasonally saturated outer margin that is vegetated, the entire system (i.e. the open-water central portion and the vegetated outer margin, together) is classified as a single HGM Unit at Level 4, namely a 'depression (endorheic)'. It is only at the lower levels of the Classification System (i.e. Levels 5 and 6) that the HGM Unit is described according to its hydroperiod and structural characteristics, and it may be useful to split an HGM Unit into sub-units for the application of these lower levels (e.g. see Example 4 for Tevreden Pan in Appendix 1).

A good example of an Inland System that is difficult to classify is an alluvial fan (e.g. Figure 32). These features are typically created when valleys open out or a stream flows from a narrow, relatively steep kloof onto a wider plain or valley floor with a lower gradient. These circumstances result in the deposition of much of the sediment load of a stream or seep, giving rise to an alluvial fan. Some alluvial fans (or portions of alluvial fans) have distinct channels, while others (such as the one shown in Figure 32) may lose their channelisation as water and sediment disperse and settle across the fan.

Alluvial fans do not clearly fall into any of the HGM Type categories included at Level 4A of the Classification System.

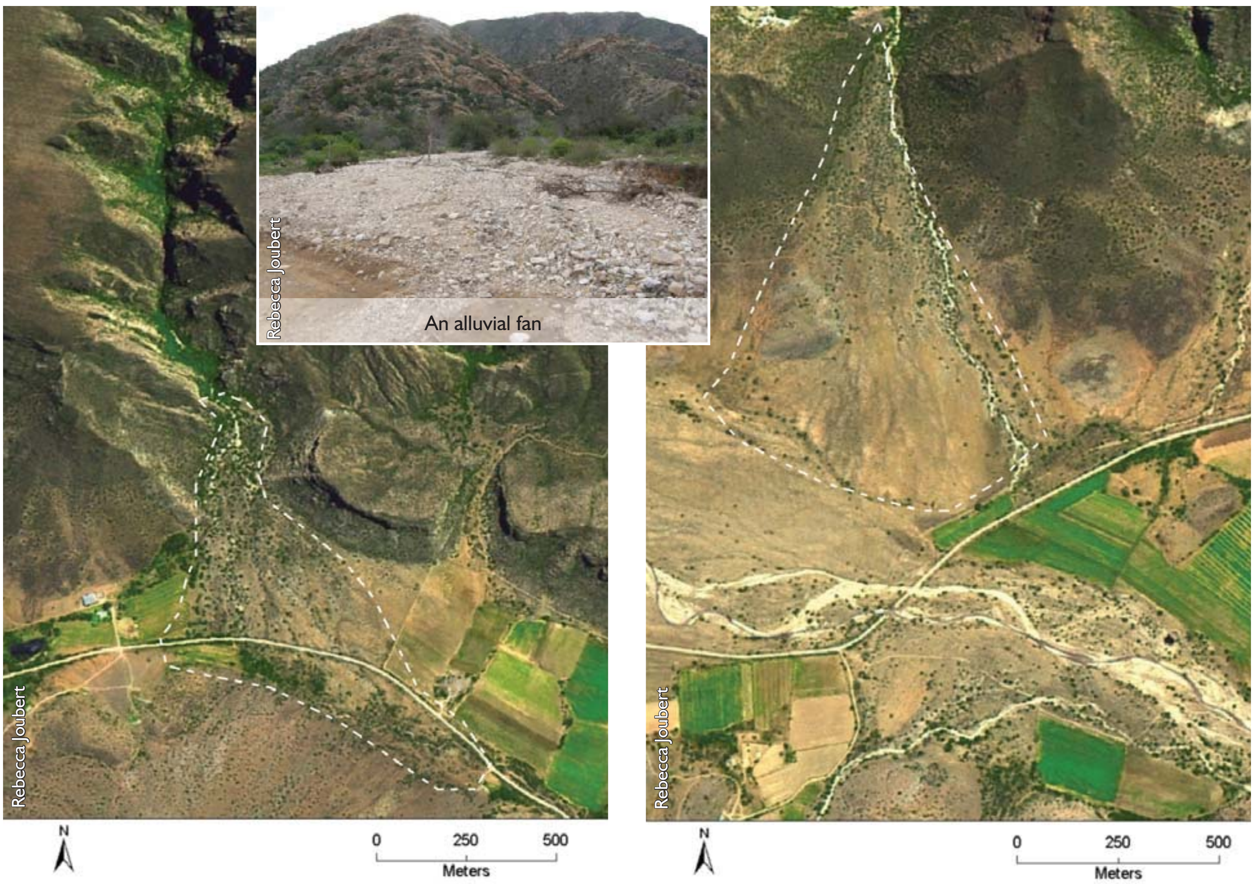


Figure 32. SPOT 2007 satellite images of alluvial fans (outlined in dashed white line) in the Baviaanskloof, Eastern Cape, with the inset photograph showing what the toe end of a typical alluvial fan in this area looks like [SPOT images provided by Rebecca Joubert].

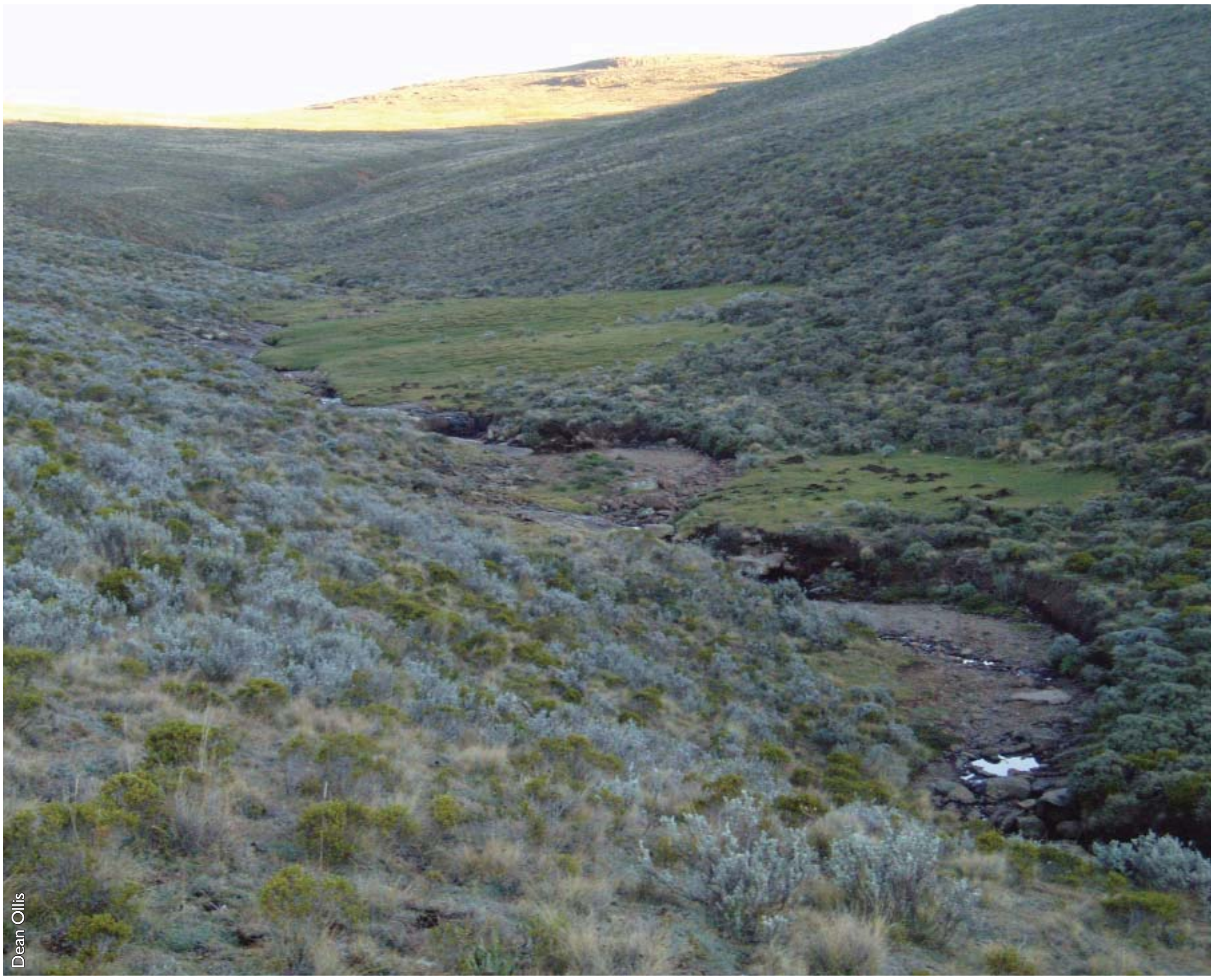


Figure 33. A potentially confusing wetland to classify, located along a river margin in the Lesotho Highlands.

According to the WET-Health document (MacFarlane *et al*. 2008), these wetland features are often classified as valley-bottom wetlands, with the distinction between channelled and unchannelled valley-bottom wetland depending on the degree of channel development present. The point is also made that, in many situations, it would be appropriate to classify the portion of an alluvial fan located on the slope as a seep, especially if this portion is dominated by diffuse flows. Some alluvial fans, or certain portions thereof, may even best be classified as rivers. The bottom line is that, in order to correctly classify a particular alluvial fan (or any Inland System, for that matter) in terms of the Classification System, you would need to know the landscape settings of the different portions of the fan and you would need to gain an understanding of how water and sediment is likely to be moving into, through and out of the system.

Another example of an Inland System that is difficult to classify are wetlands on the gentle toe-slope that feed into a river running along a valley floor (e.g. Figure 33). It is often very difficult to decide whether such wetlands should be classified as seeps or channelled valley-bottom wetlands. For the wetland in Figure 33, it can be seen that there is a distinct slope along which there is likely to be a unidirectional (diffuse) flow of water and the valley floor along which the adjacent river is flowing is very narrow. Therefore, in this case, it would probably be most appropriate to classify the wetland as a 'seep'. If the valley floor had been wider and/or the slope of the wetland was gentler, in which case the wetland would more than likely be fed by the river during high flows, perhaps it would then have been more appropriate to classify the wetland as a 'channelled valley-bottom wetland'.

These examples highlight how important it is to have some understanding of the way in which an Inland System functions and/or how it was formed in order to classify the HGM Unit/s accurately. If you are struggling to identify the most appropriate HGM Unit, you may need to obtain more information about the system before being able to proceed with the classification at Level 4. For instance, classification at desktop level can only be done with relatively low confidence, whereas a site visit to an aquatic ecosystem will allow you to collect more information about the characteristics of the system and how it functions, and will raise the confidence with which you can classify the system.

Don't forget to use the dichotomous key for HGM Units (Key 2, Appendix 3) and the accompanying glossary (Appendix 2) to assist you in classifying the HGM Units within an aquatic ecosystem!

6 HYDROLOGICAL REGIME (LEVEL 5)

While the HGM Unit is influenced by the source of water and how it moves into, through and out of an Inland System, the hydrological regime (as categorised at Level 5 of the Classification System) describes the behaviour of that water within the system and, for wetlands, in the underlying soil.

Why is the hydrological regime important? The behaviour of water within an Inland System (and its soils in the case of wetlands) directly affects its physical, chemical and biological characteristics and the overall functioning of the system. This is true for rivers, wetlands and open waterbodies. As an example, the frequency and duration of inundation and saturation of a wetland will determine its soil morphology and chemistry (e.g. level of oxygenation, build-up of carbon and nutrient cycling), and is thus one of the key determinants for the types of vegetation inhabiting the wetland.

The HGM Unit and hydrological regime of an Inland System together describe the Functional Unit (refer back to Figure 5). Some Inland Systems may be divided into several Functional Units. For example, a particular depression could be divided into a central, permanently inundated/saturated portion (constituting one Functional Unit), with a seasonally to intermittently saturated edge surrounding the centre (constituting another Functional Unit), while a different depression could be seasonally saturated throughout the wetland (i.e. it consists of one Functional Unit). To divide different parts of an HGM Unit according to differences in hydrological regime can be challenging due to uncertainty and a lack of confidence, especially when a system is only visited once or twice. Box 16 describes how you can use the presence of certain vegetation and soil characteristics to gain clues about the likely extent of wetness within a wetland, which will be useful if the Inland System for which you are trying to categorise the hydrological regime is a wetland.

If you want to classify the hydrological regime of an Inland System using the Classification System, you must categorise rivers according to the frequency and duration of flow (i.e. their perenniality), whereas all other HGM Units are categorised according to their hydroperiod (i.e. inundation and/or saturation period). For permanently inundated systems (i.e. open waterbodies), it is possible to further categorise the maximum depth of inundation, in order to differentiate between limnetic and littoral systems.

For the classification of the flow regime, the hydroperiod (inundation and saturation period) and the depth-class, a category of 'unknown' has been included. It is important to preferably use the primary categories (even with a low level of confidence) and reserve the 'unknown' category for situations in which there is simply insufficient information or knowledge available to categorise the hydrological regime with any degree of confidence.

NOTE: The categorisation of the hydrological regime for rivers is treated separately from that for the other HGM Types. This is because the **flow regime** is the major hydrological discriminator for rivers (which are generally flowing water or 'lotic' ecosystems), whereas the **period of inundation and saturation** (together with depth of inundation in the case of open waterbodies) are the major hydrological discriminators for other HGM Types (which are often standing water or 'lentic' ecosystems) (refer back to Figure 4).

6.1 River flow types (flow regime)

Rivers are either 'perennial' or 'non-perennial' (as categorised at Level 5A), and non-perennial rivers may be 'seasonal' or 'intermittent' (at Level 5B).

6.1.1 Perennial vs. non-perennial (Level 5A)

Perennial—flows continuously throughout the year, in most years.

Non-perennial—does not flow continuously throughout the year, although pools may persist.

Unknown—for rivers where the flow type is not known.

Examples of perennial rivers can be seen in Figure 17, while some examples of non-perennial rivers are shown in Figure 35.

6.1.2 Non-perennial sub-types (Level 5B)

Seasonal—with water flowing for extended periods during the wet season/s (generally between 3 to 9 months duration) but not during the rest of the year.

Intermittent—water flows for a relatively short time of less than one season's duration (i.e. less than approximately 3 months), at intervals varying from less than a year to several years.

Unknown—for rivers where it is not known whether a non-perennial system is seasonal or intermittent.

NOTE: Intermittent rivers have a far less predictable flow regime compared to perennial or seasonal rivers, and are frequently dry for long periods in arid regions.

BOX 16: Relationship between the inundation/saturation period, the soils and the vegetation in a wetland

In dry soils, the spaces between the soil particles are filled with air. In wet soils, however, the air is replaced by water and, due to biological activities in the soil (such as decomposition of organic matter by bacteria), the soil becomes depleted of oxygen, or anaerobic. The frequency and duration of soil saturation will have a direct effect on the extent of oxygen depletion. Under anaerobic conditions, minerals (primarily iron and manganese) in the soil move from an oxidised state, in which they impart distinct colours to the soil horizon, to a reduced state, in which they do not impart a distinct colour. As a result, soils that remain saturated for relatively long periods change colour, tending towards a greyer colour for most soil types. Soils that are wet for very long periods are often a blue- or green-grey colour called 'gleyed'. An exception is organic or peat soil, which is black in colour and camouflages the gley colours.

Where the saturation of a soil is non-permanent, conditions fluctuate between reduced (anaerobic) and oxidised states. This results in the formation of bright spots of colour where minerals are re-oxidised. These spots of colour in the soil are known as 'mottles' and they are one of the indicators of wetland areas that are seasonally or intermittently saturated.

The vegetation communities inhabiting a wetland occur in the zone where conditions are optimal for productivity. Thus, plant species that prefer saturated soil conditions year-round will be found in the permanently saturated or inundated zone of a wetland, whereas those that prefer seasonally saturated conditions will occur around the edges of the wettest zone, or only in seasonally saturated wetlands.

Figure 34 is a diagrammatic cross-section through a wetland, showing a typical gradient of wetness with different zones of saturation and inundation, and illustrating how the vegetation and soils in the upper 50 cm of the ground surface typically respond to the hydroperiod. Wetland vegetation and mottling of the soil are generally absent from the terrestrial zone, while the intermittently saturated zone generally has some wetland vegetation and sparse mottling of the soil. The seasonally saturated zone generally supports significant wetland vegetation (mostly grasses and sedges), and the soil is often greyish in colour with many mottles. Mostly wetland vegetation (sedges, rushes and reeds) occurs in the permanently saturated zone, where the soils are generally grey in colour with few or no mottles, and seasonal to permanent inundation is common.

Due to the above-mentioned relationships between the hydrology, soils and vegetation of a wetland, in the absence of long-term hydrological records (which is usually the case), soil morphology and/or vegetation can be used as indicators of the hydrological regime of a wetland by those with adequate experience.

Soil morphology characteristics are the result of long-term hydrological conditions, while the vegetation within a wetland is an indicator of recent conditions.

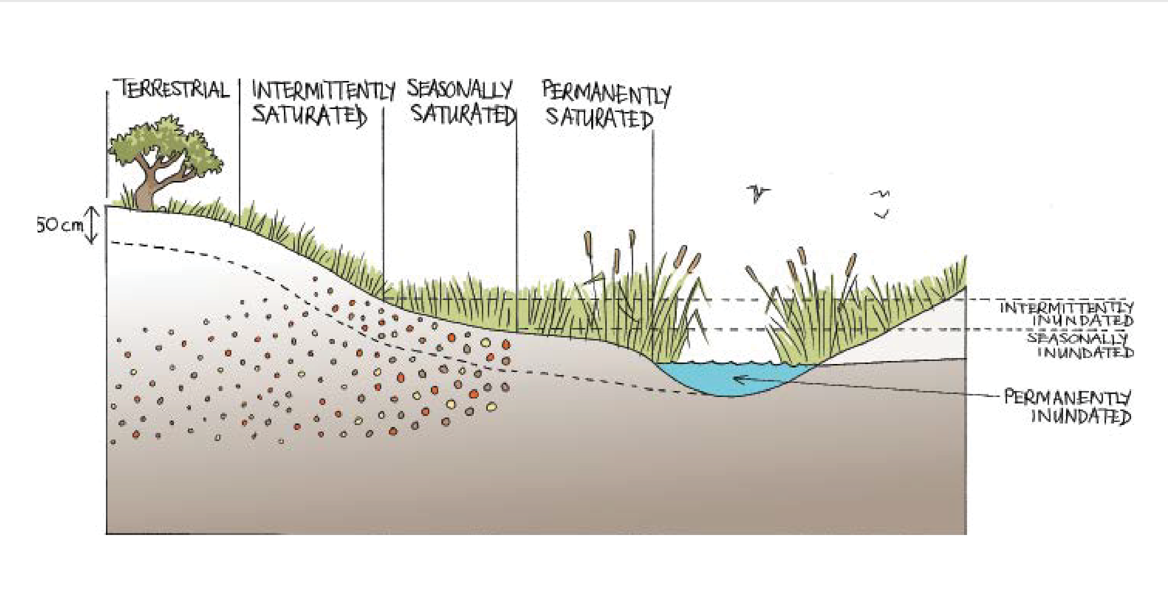


Figure 34. Diagrammatic cross-section through a hypothetical wetland, showing the different zones of saturation and inundation that could occur and illustrating how the vegetation and soils in the upper 50 cm of the ground surface typically respond to the hydroperiod [modified from Kotze 1996].

Figure 35. Non-perennial rivers (note absence of flow in photographs). A, Kamdeboo River in the Karoo; B, an unnamed tributary of the Seekoei River in the Free State.

6.2 Hydroperiod categories (for non-river Inland Systems)

For all Inland Systems that are not rivers (i.e. wetlands and open waterbodies), you should classify the hydrological regime according to the period of inundation (at Level 5A) and saturation (at Level 5B), together with the inundation depth-class (at Level 5C) in the case of permanently inundated open waterbodies (Table 3).

Box 17 explains the difference between inundation and saturation.

6.2.1 Period of inundation (Level 5A)

For Inland Systems other than rivers, five categories relating to the frequency and duration of inundation have been provided.

Level 5: Hydroperiod and depth of inundation		
A	B	C
Inundation periodicity	Saturation periodicity (within 0.5 m of soil surface)	Inundation depth-class
Permanently inundated	[not applicable]	Limnetic
		Littoral
		Unknown
Seasonally inundated	Permanently saturated	[not applicable]
	Seasonally saturated	[not applicable]
	Unknown	[not applicable]
Intermittently inundated	Permanently saturated	[not applicable]
	Seasonally saturated	[not applicable]
	Intermittently saturated	[not applicable]
	Unknown	[not applicable]
Never inundated	Permanently saturated	[not applicable]
	Seasonally saturated	[not applicable]
	Intermittently saturated	[not applicable]
	Unknown	[not applicable]
Unknown	Permanently saturated	[not applicable]
	Seasonally saturated	[not applicable]
	Intermittently saturated	[not applicable]

Table 3. Hydroperiod categories for non-river Inland Systems, showing the categories for the period of inundation (Level 5A) and saturation (Level 5B) and for the depth class of permanently inundated systems (Level 5C)

BOX 17: Inundation vs. saturation

The substratum (i.e. bottom) of an **inundated** aquatic ecosystem is covered by water. In other words, water can be seen on top of the ground surface (Figure 36).

Figure 36. Photograph of an inundated high-altitude wetland in the Drakensberg.

The underlying substratum, or soil, of a **saturated** wetland is waterlogged (i.e. the spaces between the substratum/soil particles are filled with water) but surface water is not necessarily present (Figure 37).

Figure 37. Photograph of saturated soil taken from a wetland in the Lesotho Highlands.

Permanently inundated—with surface water present throughout the year, in most years.

Seasonally inundated—with surface water present for extended periods during the wet season/s (generally between 3 to 9 months duration) but drying up annually, either to complete dryness or to saturation.

Intermittently inundated—holding surface water for irregular periods of less than one season (i.e. less than approximately 3 months), at intervals varying from less than a year to several years.

Never/rarely inundated—covered by water for less than a few days at a time (up to one week at most), if ever.

Unknown—for Inland Systems where the inundation period is unknown.

NOTE: Intermittently inundated aquatic ecosystems are often dry for long periods in arid regions.

6.2.2 Period of saturation (Level 5B)

In the Classification System, saturation is considered within the upper 0.5 m of the soil surface (which, for wetland delineation purposes, is the commonly accepted depth to which soil saturation is considered; Figure 34). The saturation period is classified according to the following categories.

Permanently saturated—where all the spaces between the soil particles are filled with water throughout the year, in most years. This equates to the 'permanent (inner) zone' of a wetland, according to the terminology used in the DWAF (2005) wetland delineation manual.

Seasonally saturated—with all the spaces between the soil particles filled with water for extended periods (generally between 3 to 9 months duration), usually during the wet season/s, but dry for the rest of the year. This corresponds to the 'seasonal zone' of a wetland, according to the terminology used in the DWAF (2005) wetland delineation manual.

Intermittently saturated—with all the spaces between the soil particles filled with water for irregular periods of less than one season (i.e. less than approximately 3 months). This corresponds to the 'temporary (outer) zone' of a wetland, according to the terminology used in the DWAF (2005) wetland delineation manual.

Unknown—for Inland Systems where the saturation period is not known.

NOTE: Categorisation of the saturation period is only really of relevance to wetlands, and not to rivers or open waterbodies.

6.2.3 Inundation depth-class (Level 5C)

Two depth classes have been included to categorise the maximum depth of inundation in permanently inundated Inland Systems (i.e. open waterbodies, which are typically depressions), as follows.

Limnetic—≥2 m maximum depth at the average annual low-water level.

Littoral—<2 m maximum depth at the average annual low-water level.

This allows for the distinction between deepwater habitats (*sensu* Cowardin *et al*. 1979), where water (rather than air) is the principal medium within which the dominant organisms live, and shallow areas where emergent vegetation tends to occur. A depth of 2 m is generally taken as a 'rule of thumb' for the maximum depth at which rooted emergent macrophytes can grow.

The presence of emergent vegetation can be used as a guide to whether a permanently inundated portion of a depression is limnetic or littoral, as most rooted vegetation cannot survive in water with a depth of 2 m or more[2]. Areas with emergent vegetation are almost always littoral. However, at the same time, it is important to note that **the absence of emergent vegetation does not necessarily imply that an area is limnetic**.

If you want to categorise the inundation depth-class of an open waterbody with a reasonable degree of confidence, you need to be able to estimate whether the **maximum** depth of inundation (i.e. the depth at the deepest part of the waterbody) is less than or greater than 2 m **at the average annual low-water level** (i.e. the typical water level near the end of a normal dry season).

6.2.4 Rating of the hydroperiod

Classification of the perenniality of a river is relatively straightforward because a particular river or section of a river is either perennial or non-perennial, and either seasonal or intermittent in the case of non-perennial rivers. The classification of the hydroperiod of a wetland or open waterbody is, however, somewhat more complicated. As previously mentioned, a non-riverine inland aquatic ecosystem is often not uniformly wet. Instead, the central area may be wetter than the outer edges or groundwater may seep in from one side and the other side may be less wet. A depression, for example, may have a central, permanently inundated core, with a seasonally inundated, permanently saturated zone surrounding the wet core, and an outer zone that is intermittently saturated.

An HGM Unit of a wetland or open waterbody can therefore comprise a variety of hydroperiods, as recorded at Levels 5A and 5B. To divide different parts of an HGM Unit into these hydroperiod categories can be challenging due to uncertainty (for example, when a particular aquatic ecosystem is visited only once, possibly at the dry time of year) and a lack of confidence in the interpretation of the hydroperiod from the plant species and/or soil characteristics in the case of a wetland. However, in situations where long term, detailed monitoring records are available, it may be possible and useful to map these different Functional Units.

For a wetland or open waterbody, the relative proportion of each hydroperiod category within each HGM Unit (i.e. the Functional Units) can be rated according to the rating system described in Box 18. This rating system can also be used for the categorisation of descriptors (see Section 7).

A worked example of how the rating system for the hydroperiod was applied to seeps in the Western Cape is provided in Appendix 1 (Example 3).

When you apply the rating system described in Box 18 to help you categorise the hydroperiod of a particular inland aquatic ecosystem, you should first estimate the proportion of each HGM Unit that is permanently inundated. You should then use the entire area of each HGM Unit that remains, after the permanently inundated portions have been taken into account, to separately rate the additional categories for the inundation period (at Level 5A) and the categories for the saturation period (at Level 5B). In other words, you don't split the HGM Unit up according to the different inundation period categories (as captured at Level 5A) and then rate the saturation period (at Level 5B) separately for the estimated proportion of the HGM Unit occupied by each inundation period category identified to be present. Rather, you rate the saturation period independently of the rating of the inundation period. This means that you can categorise the saturation period at Level 5B, using the rating system, even if you have not rated the inundation period at Level 5A. When the rating system is applied to the descriptors at Level 6, however, subordinate categories are rated for each primary category that is relevant (i.e. the HGM Unit is split when applying the rating system to descriptors) (see Section 7.7).

For certain applications or when you are out in the field, it may be necessary to generalise about the hydroperiod of an entire HGM Unit. To facilitate consistency between different users of the Classification System, guiding 'rules' for the assignment of dominance categories are presented in Box 19.

You don't need to use the rating scale (Box 18) and 'rules' for the assignment of dominant characteristics (Box 19) to classify the inundation depth-class of an open waterbody (at Level 5C of the Classification System) because the categorisation of inundation depth-class is based on the maximum depth of inundation of the entire waterbody. Instead, at Level 5C, you simply record whether the open waterbody that you are trying to classify is limnetic or littoral, based on the maximum depth of inundation at the average annual low water level (as explained in Section 6.2.3), together with an estimate of your degree of confidence in the categorisation.

[2] There are exceptions to this rule—for instance, floating mats of the common reed, *Phragmites australis*, can float on water deeper than 2 m as in the case of Tevreden Pan in Mpumalanga (see worked example in Appendix 1).

Don't forget to use the dichotomous keys for River Flow Type (Key 3a) and Hydroperiod (Key 3b) in Appendix 3 and the accompanying glossary (Appendix 2) to assist you in classifying the hydrological regime categories within your HGM Units!

BOX 18: Rating system for hydroperiod categories (at Level 5) and descriptors (at Level 6)

At Levels 5A and 5B of the Classification System, you can rate the relative proportion of each hydroperiod category present within a wetland or open waterbody using the following seven-point rating scale:

- 0 = not present (0%)
- 1 = rare (>0–5%)
- 2 = sparse (>5–25%, i.e. more than 5% but less than one-quarter)
- 3 = common (>25–50%, i.e. between one-quarter and a half)
- 4 = abundant (>50–75%, i.e. between a half and three-quarters)
- 5 = predominant (>75–95%, i.e. more than three-quarters but less than 95%)
- 6 = near-entire (>95–100%)

You can also use the rating scale above to rate the relative proportion of each descriptor applicable within an Inland System according to areal cover, at Level 6 of the Classification System. The grids in Figure 38 provide a visual guide as to what areal coverages of 5%, 25%, 50%, 75% and 95% look like. You can use these grids to help decide which rating is most appropriate when applying the rating scale for hydroperiod categories and descriptors.

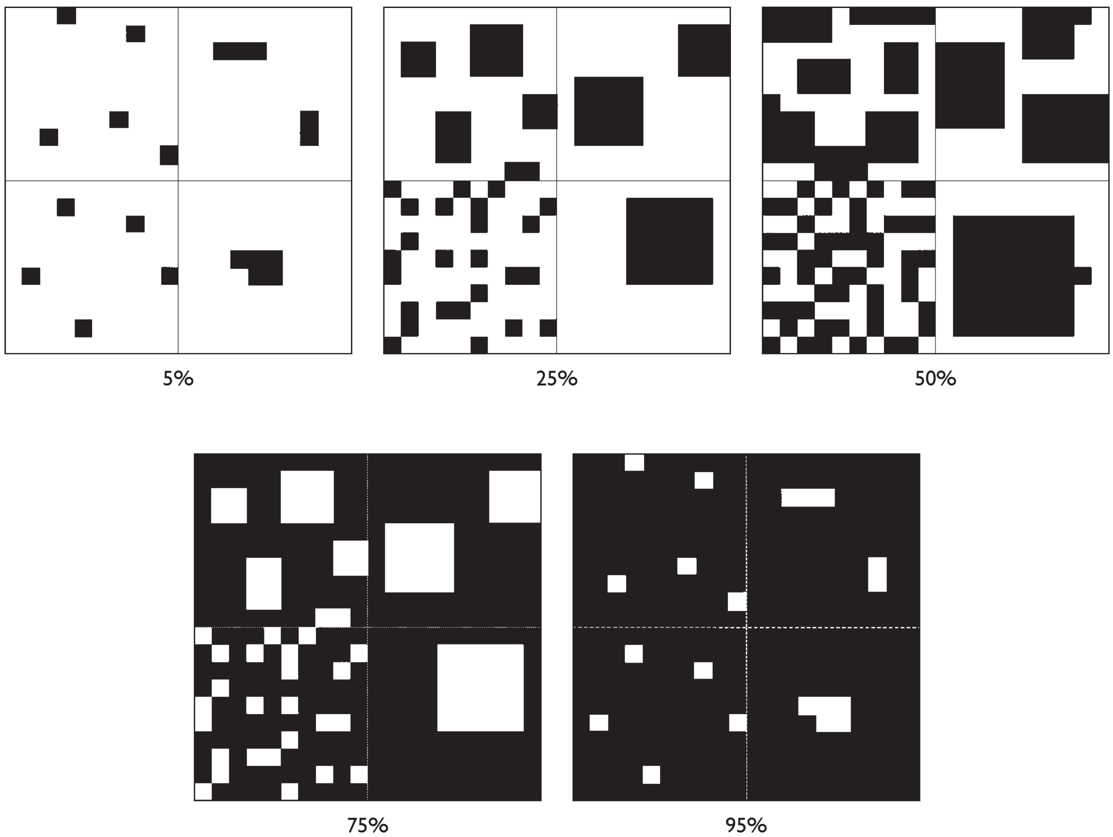


Figure 38. Rating grids showing proportional coverages of 5%, 25%, 50%, 75% and 95% (each quarter-grid of any one square has exactly the same proportion of black).

BOX 19: 'RULES' FOR THE ASSIGNMENT OF THE DOMINANT HYDROPERIOD CATEGORIES

1. For the inundation and saturation period at Levels 5A and 5B of the Classification System, respectively, any category with a proportional coverage of more than 50% (i.e. a rating of 4 to 6 in Box 18) should be considered to be dominant. Once you have established the dominant hydroperiod you could then state, for example, that a particular wetland is 'dominantly seasonally saturated'.

2. Where there is no hydroperiod category with a proportional coverage of more than 50% (i.e. a rating of 4 or more) but there is more than one hydroperiod category with a proportional coverage of greater than 25% (i.e. a rating of 3) for a particular wetland or open waterbody, the system should be described as having 'mixed dominance' in terms of its hydroperiod, with the co-dominant categories included in brackets thereafter. For example, the saturation hydroperiod of a wetland consisting of seasonally and intermittently saturated components, both with a proportional coverage of more than 25% but less than 50% (i.e. both rated as 3 in terms of the rating scale in Box 18), would be described as being of 'mixed dominance (seasonally/intermittently saturated)'.

7 DESCRIPTORS (LEVEL 6)

At Level 6 of the Classification System, several 'descriptors' are included for the structural/chemical/biological characterisation of Inland Systems. These descriptors are non-hierarchical in relation to one another and you can therefore apply them in any order, depending on their relevance to your purpose and/or the availability of information.

Figure 39 summarises the categories for all the Inland System descriptors included in the Classification System. Once you are familiar with the definitions of the various descriptors (outlined in more detail in the following sections), you can use this figure as a rapid reminder of the available descriptors, such as when you are in the field.

7.1 Natural vs. Artificial

The Natural vs. Artificial descriptor provides a means of recording whether a particular Inland System is naturally occurring or artificially created, as defined below.

Natural—existing in, or produced by nature; not made or caused by humankind.

Artificial—produced by human beings, not naturally occurring.

It is strongly recommended that, when applying the Classification System, you record whether an inland aquatic ecosystem is natural or artificial as a matter of course. If you do, the classification information that you collect can then be used for regional conservation planning and management initiatives for Inland Systems, where knowledge of the naturalness of a system is of vital importance. In addition, for certain applications where there could be legal implications (such as statutory Environmental Impact Assessments), it may be of paramount importance to indicate whether or not an Inland System on a particular site is likely to be a naturally-occurring feature.

It is important to note that the classification of an Inland System as natural or artificial is not the same as the as-

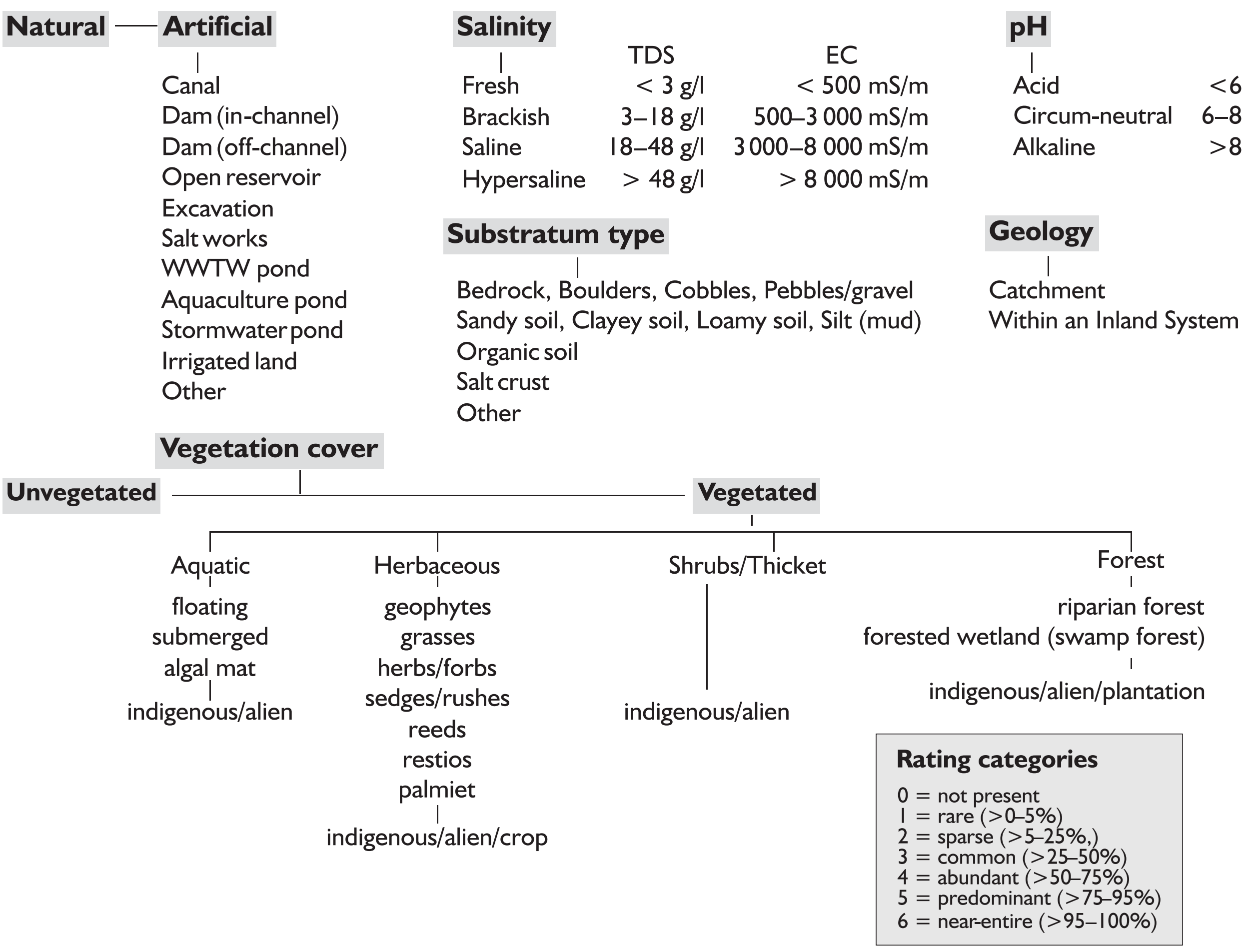


Figure 39. Summary of descriptors for Inland Systems.

sessment and categorisation of the present ecological condition, as explained in Box 20.

Artificial wetlands are aquatic ecosystems where hydric soil features have developed, or where wetland plants have colonised, in historically non-wetland areas due to human activities. For example, road construction may have resulted in impoundment of water in an area that previously was non-wetland. Wetlands may also develop in former non-wetland areas due to diversion of water for irrigation or other uses.

Artificial systems can be further categorised at Level 6B, as outlined below.

7.1.1 Artificial sub-categories

Canal—artificial waterway constructed for navigation or the conveyance of water, usually concrete-lined.

Dam (in-channel)—artificial body of water formed by the unnatural accumulation of water behind an artificial barrier that has been constructed across a river channel or an unchannelled valley-bottom wetland.

Dam (off-channel)—artificial body of water created specifically for the storage of water, and which is not located along the course of a river

BOX 20: CATEGORISATION OF PRESENT ECOLOGICAL CONDITION

Many natural Inland Systems have been modified or impacted to some degree by humans, and these modifications can greatly influence the character, or even classification, of the system. In the Classification System, however, natural systems are not categorised according to degree of modification or impact[3]. The assessment of ecological condition is a complex matter, beyond the ambit of classification of ecosystem type. A number of wetland assessment tools for Inland Systems are available for this purpose, including WET-Health (MacFarlane *et al*. 2008) and the DWAF (2007) Wetland Index of Habitat Integrity. There are also a number of assessment tools available for categorising the present ecological status of rivers, such as the various indices published by the WRC as series of documents constituting a Manual for EcoStatus Determination (see Kleynhans & Louw 2008 for a summary).

If you are classifying the ecosystem type of a modified but naturally-occurring aquatic ecosystem, you should categorise it as 'natural'. For example, the portion of the Berg River flowing through the town of Paarl in the Western Cape that has been extensively modified (especially along its banks; Figure 40A) but with minimal alteration of the river bed, and the entirely canalised portion of the Liesbeek River in Cape Town (Figure 40B) would both be classified as 'natural' because these systems occurred as natural rivers without intervention by humans having been necessary to bring them into existence. The canals flowing through the Green Point Urban Park near Cape Town's city centre (Figure 40C), on the other hand, are examples of an 'artificial' system because they did not exist prior to the creation of the Urban Park. The flow of water in these constructed canals was created by piping water from a spring on Table Mountain to the Park.

Figure 40. A, a natural but modified portion of the Berg River flowing through Paarl; B, a highly modified (canalised) portion of the naturally-occurring Liesbeek River flowing through a suburb of Cape Town; C, an artificial canal that was created within the Green Point Urban Park.

[3] It is important to remember that the **use of the word 'classification' in the National Water Resource Classification System** of the South African Department of Water Affairs **refers to the categorisation of the present ecological condition**, or Present Ecological Status (PES), of water resources, and **not the categorisation of ecosystem type** (as in the case of the Classification System for Inland Aquatic Ecosystems described in this User Manual).

channel or an unchannelled valley-bottom wetland (includes 'irrigation ponds' and 'farm dams').

Open reservoir—uncovered concrete structure for storing water.

Excavation—artificial depression created by digging out material from the ground.

Salt works—a place where salt is produced commercially, usually by evaporation of natural brines.

WWTW pond—artificial body of water associated with a wastewater (i.e. sewage) treatment works (WWTW), including effluent ponds, settling ponds, sludge ponds, oxidation ponds and maturation ponds.

Aquaculture pond—pond constructed for the cultivation of aquatic organisms for human consumption or use.

Stormwater pond—artificial body of water that forms part of a stormwater reticulation system, including retention ponds, detention ponds and attenuation ponds.

Irrigated land—areas purposefully supplied with water to aid the growth of plants (often crops), including land irrigated by controlled flooding, where the supply of water has resulted in the formation of an artificial wetland or aquatic ecosystem.

Other—any other feature forming a wetland or aquatic ecosystem that has been created by humans and is not named above.

Figure 40B is an example of a canal, while Figure 41 shows photographs of some of the other types of artificial inland aquatic ecosystems specifically included in the Classification System.

BOX 21: WHAT IS CONDUCTIVITY AND TDS?
(information taken from Dallas & Day 2004)

Material dissolved in water is commonly measured as the concentration of Total Dissolved Solids (TDS) or as conductivity. TDS concentration (expressed as a mass per unit volume, e.g. mg/l or g/l) represents the total quantity of dissolved material, organic and inorganic, ionised and unionised, in a water sample. Conductivity is a measure of the ability of a sample of water to conduct an electrical current. It is generally expressed in units of milli-Siemens per metre (mS/m), where a Siemen is the reciprocal of an ohm (the unit of electrical resistance). TDS and conductivity usually correlate closely for a particular type of water. For example, it has been found that, for South Africa as a whole, the TDS concentration in mg/l is approximately equal to the conductivity in mS/m multiplied by a factor of 6.6, although a multiplicand of 5.5 is somewhat more accurate for the naturally acidic waters of the southwestern Cape[4].

Natural TDS in inland aquatic ecosystems is determined by the geological formations the water has been in contact with, and physical processes such as evaporation and rainfall. Anthropogenic activities such as industrial effluents, irrigation and water re-use lead to increases in TDS and conductivity.

[4] It is important to bear in mind that TDS estimates based on conductivity measurements will be inaccurate if there is a large amount of un-ionised material (e.g. dissolved organic carbon) in the water because conductivity measurements only take ionised material into account.

7.2 Salinity

Salinity is a measure of the saltiness of water (technically, it actually refers to the concentration of dissolved inorganic matter in water). It is a very important parameter for Inland Systems because of the major influence that it has on the chemical and biological make-up and functioning of an inland aquatic ecosystem. Conductivity, which is a lot easier to measure, can be used as a surrogate measure of salinity and, except for waters with large quantities of dissolved organic matter, salinity is virtually the same as the TDS concentration (Box 21).

The salinity/conductivity of Inland Systems can be characterised using the categories outlined in Table 4.

Table 4. Total dissolved solids (TDS) or salinity (conductivity) categories

Salinity category	Salinity (or TDS) range	Conductivity range
Fresh	<3.0 g/l	<500 mS/m
Brackish	3.0–18.0 g/l	500–3 000 mS/m
Saline	18.0–48.0 g/l	3 000–8 000 mS/m
Hypersaline	>48 g/l	>8 000 mS/m

NOTE: Once-off measurements of salinity or conductivity within an Inland System are seldom representative, due to natural spatial, seasonal and diurnal fluctuations. Therefore, if possible, measurements should be obtained from a number of points within the system and on a number of occasions in different seasons so that the average conditions and the variability in salinity/conductivity can be determined.

7.3 pH

The pH of the water in an inland aquatic ecosystem (Box 22) is one of the key determinants of the biological community composition in the system, and is a very important measure in most types of Inland Systems.

The pH categories included in the Classification System are outlined in Table 5.

NOTE: Once-off measurements of pH within an Inland System are seldom representative, due to natural spatial, seasonal and diurnal fluctuations. Therefore, if possible, measurements

Figure 41. A, an in-channel dam (on an unnamed river in the Lesotho Highlands); B, an off-channel dam (with an open reservoir to the right); C, an excavation forming an open waterbody; D, a WWTW pond (at Piketberg WWTW, Western Cape); E, a stormwater pond (adjacent to a shopping centre in Worcester, Western Cape); and F, a feature pond at Green Point Park (Cape Town) that would be categorised as an 'other' type of artificial system.

BOX 22: WHAT IS PH?

pH is a measurement of the negative logarithm of the hydrogen ion concentration in a water sample or waterbody. Since pH is a log scale, a change of one unit represents a tenfold change in hydrogen ion concentration. The pH of pure water is 7.0 and is known as neutral (i.e. neither acidic nor alkaline). As the concentration of hydrogen ions in a solution increases, so pH decreases (below 7.0) and the solution becomes more acid. Conversely, as the concentration of hydrogen ions in a solution decreases, pH increases (above 7.0) and the solution becomes more alkaline (Dallas & Day 2004).

Table 5. pH categories

pH category	pH range
Acid	<6.0
Circum-neutral	6.0–8.0
Alkaline	>8.0

should be obtained from a number of points within the system and on a number of occasions in different seasons so that the average conditions and the variability in pH values can be determined.

7.4 Substratum type

It is usually important to record the substratum type of an Inland System (according to the categories in Table 6), even if it is predominantly covered by vegetation. This is because the substratum characteristics of an inland aquatic ecosystem affect the hydrological dynamics of the system. Substratum type also influences the vegetation composition within an aquatic ecosystem and the biological functions that the system can perform.

You will probably need to conduct a site visit to classify the substratum type of an Inland System with any degree of confidence. This is particularly true for wetlands, where an investigation of the soil profile is important (Box 23).

Table 6. Substratum type categories

	Level 6: Substratum type	
	A	**B**
	Substratum categories	
Rocky substrata	Bedrock	[not applicable]
Rocky substrata	Boulders	[not applicable]
Rocky substrata	Cobbles	[not applicable]
Rocky substrata	Pebbles/gravel	Pebbles
		Gravel
Mineral soil (<10% organic carbon)	Sandy soil	Sand
		Loamy sand
	Silt (mud)	[not applicable]
	Clayey soil	Clay
		Sandy clay
		Silty clay
	Loamy soil	Loam
		Sandy loam
		Silt loam
		Clay loam
		Sandy clay loam
		Silty clay loam
	Organic soil (>10% organic carbon)	Peat (>30% organic carbon)
		<30% organic carbon
	Salt crust	[not applicable]
	Other	[not applicable]

7.4.1 *Bedrock, boulders, cobbles and pebbles/gravel (rocky substrata)*

Unconsolidated rocky substrata such as boulders, cobbles, pebbles and gravel are most commonly found in rivers, whereas bedrock can be found in both lotic and lentic Inland Systems.

The photographs of the different kinds of rocky substrata in Figure 43 and the accompanying size-range guidelines should help you to distinguish between bedrock, boulders, cobbles and pebbles/gravel. At Level 6B, a distinction can be made between pebbles and gravel, if necessary for situations where the substratum is clearly one of these types.

Rock and/or mineral particles smaller than 2 mm in diameter, which are commonly referred to as the 'fine earth

BOX 23: THE IMPORTANCE OF LOOKING BEYOND THE SOIL SURFACE OF WETLANDS

When classifying the substratum types for Inland Systems, particularly in the case of wetlands, it is important to take the soil profile into account (Figure 42) and not just the substratum type at the surface. This is because the soil profile has a significant influence on the formation and functioning of a wetland ecosystem, including the way in which water enters and flows through a wetland. As such, the substratum types that are encountered at different depths should be recorded (e.g. loamy soil from surface to 100 mm depth, with sandy soil layer from 100 to 300 mm overlying deep clayey soil sub-layer >1.5 m; or peat from surface to >1 m; or salt crust on surface with clayey soil from surface to 500 mm; etc.).

NOTE: If you want to see what the soil profile of a wetland looks like, you will need to use a soil auger to extract soil samples from below the ground surface or, as in the case of detailed soil surveys, dig a series of soil profile pits such as the one shown in Figure 42.

Figure 42. Photograph of a wetland soil profile (a seasonally saturated Katspruit soil) showing the different layers below the ground surface.

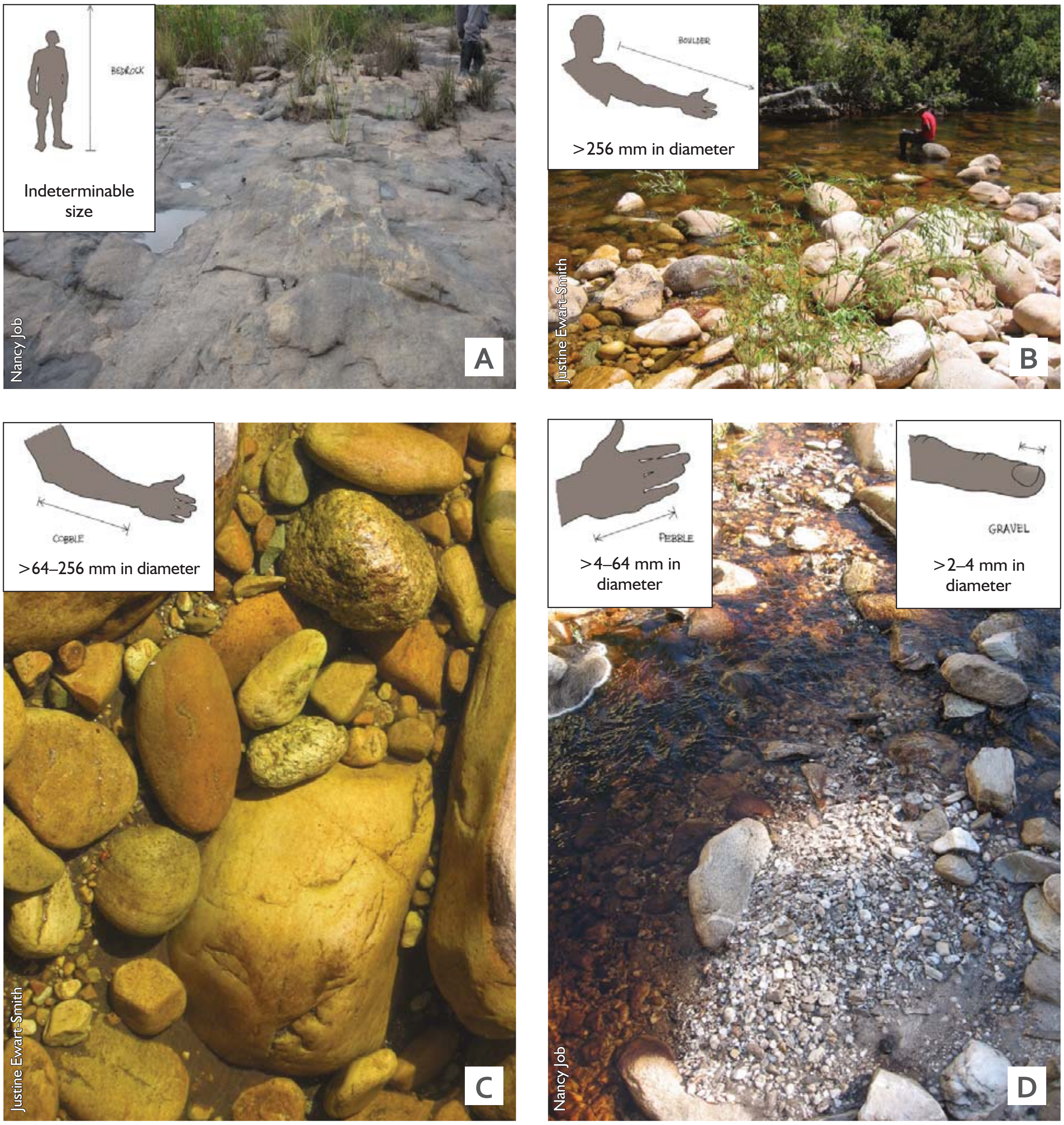


Figure 43. Photographs of rocky substratum types, with insets providing a pictorial guide to the size range of each type. A, bedrock (Goukou River, southern Cape); B, boulders (typical Western Cape mountain stream); C, cobbles (Western Cape river); D, pebbles interspersed with gravel in-between cobbles along a river bed.

fraction', are not rocky substrata but are rather the primary constituents of mineral soils.

7.4.2 Sandy soil, silt/mud, clayey soil and loamy soil (mineral soils)

Soils are typically described, through the soil profile (Box 23), in terms of their physical characteristics (texture, colour, structure, presence of hydromorphic indicators such as mottles, etc) and their physico-chemical properties (pH, nutrient levels, organic content, redox potential, etc.). While many of the physical characteristics can be visually estimated in the field, determination of the physico-chemical properties generally requires the analysis of soil samples in a laboratory. One of the most important characteristics of a soil, besides its organic content (see Box 25), is its texture because this helps to explain how the soil formed and how water is likely to move through the soil, amongst other things. For example, sandy soils tend to allow water to move relatively freely through them, whereas dense clayey soils tend to impede water movement and can lead to the occurrence of a 'perched water table' that is conducive to the formation of perched wetlands.

Soil texture refers to the relative proportion of sand-, silt- and clay-sized particles of minerals or rock fragments in a soil. Sand-sized particles have the largest diameter (size range: 0.05 to 2.00 mm), with silt/mud (size range: 0.002 to 0.050 mm) and clay (<0.002 mm) particles being substantially smaller. In reality, any soil consists of a mixture of grain sizes and the designated texture is determined by the relative proportions of the different grain sizes. The 'soil triangle' in Figure 44, which was developed by the United States Department of Agriculture (USDA) and is widely used around the world (in South Africa too), explains this concept. Loam is a soil type with relatively even proportions of sand-, clay- and silt-sized particles. Soils that are intermediate between the major categories can be described, for example, as 'sandy clay', 'silty loam', etc., as shown in Figure 44.

A proper description of the textural characteristics of a soil requires the sieving of soil samples through a series of sieves with different aperture sizes, to accurately determine the distribution of particle sizes. However, there are a number of techniques that can be used to roughly characterise soil texture in the field (see Box 24 for a few examples).

Photographs of the four main textures of mineral soil (sandy soil, clayey soil, silt, and loamy soil) are provided in Figure 45, together with an indication of the relative difference in particle grain size between the different categories. These photographs, together with the guidelines in Box 24, should help you to determine, through a site visit, the most likely primary substratum category of an aquatic ecosystem that has a substratum of mineral soil (as opposed to a rocky substratum).

Before describing the texture of a soil, you should try to determine whether the soil you are dealing with is a mineral soil or an organic soil, as the categorisation of the

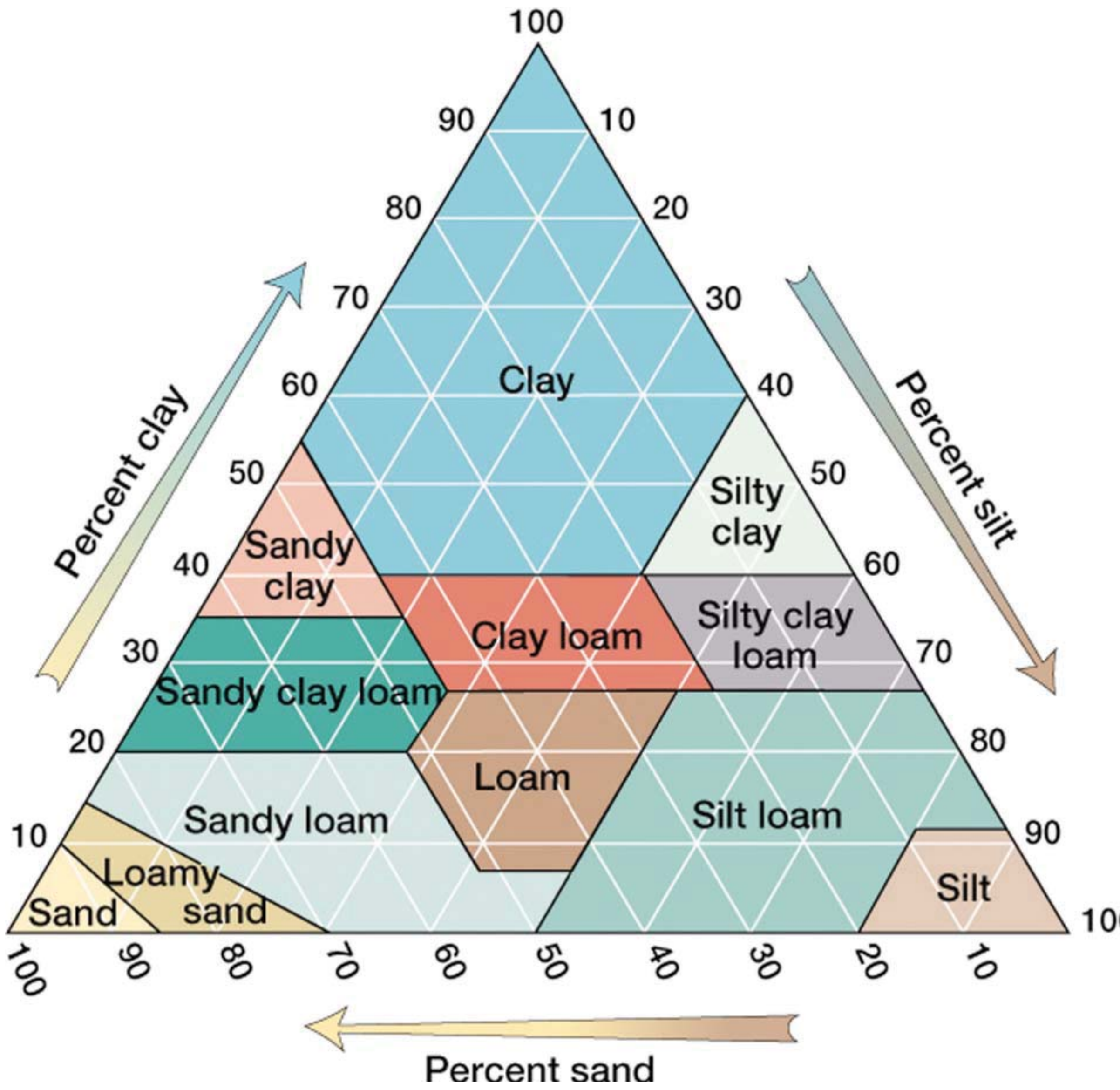


Figure 44. 'Soil triangle' developed by the USDA for categorising soil texture according to the relative proportions of sand-, silt- and clay-sized particles (NOTE: the axis for sand percentage runs horizontally, with the axes for silt and clay percentages running diagonally) [from http://philipmarshall.net/Teaching/rwuhp382/masonry/soil_texture.htm].

BOX 24: How to determine soil texture in the field

One way to rapidly determine whether a soil is dominated by sand-, silt- or clay-sized particles is to take a small sample of the soil, add water to it, and knead the wet soil between your fingers and your thumb until the aggregates are broken down. Then:

- If the soil is **sandy**, the particles will be large enough to grate against each other (i.e. the soil will be gritty) and the grains will be detectable by sight. Sand-dominated soils will also show no signs of stickiness or plasticity when wet.
- If the soil is dominated by **silt** (i.e. mud), the grains will not be detectable by feel but their presence will make the soil feel smooth and soapy or velvety (and possibly very slightly sticky).
- If the soil is **clayey**, it will be shiny, sticky and plastic when wet (or hard and cloddy when dry). Clayey soils (when wet) can be rolled easily into a 'sausage' (i.e. a cylinder shape) that can be bent into a circle without breaking apart.
- If the soil is **loamy** (i.e. it has relatively even proportions of sand-, silt- and clay-sized particles), it will have a slightly gritty feel and many of the individual sand grains will be visible to the naked eye, but there is sufficient silt and/or clay to give coherence to the soil so that it can be moulded into forms that will tolerate careful handling without breaking. Loamy soils (when wet) can easily be rolled into a 'sausage', but the 'sausage' cannot be bent into a circle without breaking.

A more detailed estimation of the textural class (as per Figure 44 and Level 6B in Table 6) can be made by going through the following questions to evaluate a moistened soil sample by feel:

1. Can the soil be shaped into a ball?
   - If the answer is NO, then the texture is **sand**.
2. Can the soil be shaped into a ball but not pressed into a ribbon?
   - If the answer is YES, then the texture is **loamy sand**.

If the soil can be pressed into a ribbon, note the length of the ribbon and take a small sub-sample of the soil. Then excessively wet the sub-sample in the palm of your hand and rub it with your forefinger of your other hand to determine the grittiness of the soil.

3. Can the soil be pressed into a ribbon no longer than 25 mm in length?
   - If the answer is YES, the possible textures are sandy loam, silt loam, silt or loam.
   - If the wet sub-sample feels gritty, the texture is **sandy loam**.
   - If the wet sub-sample feels very smooth with some grittiness, the texture is **silt loam**.
   - If the wet sub-sample feels smooth and silky, with no grittiness detectable to the fingers, the texture is **silt**.
   - If the wet sub-sample does not feel gritty or smooth, the texture is **loam**.
4. Can the soil be pressed into a ribbon that is 25 to 50 mm in length?
   - If the answer is YES, the possible textures are sandy clay loam, silty clay loam, clay, or loam.
   - If the wet sub-sample feels gritty, the texture is **sandy clay loam**.
   - If the wet sub-sample feels very smooth with some grittiness, the texture is **silty clay loam**.
   - If the wet sub-sample does not feel gritty or smooth, the texture is **clay loam**.
5. Can the soil be pressed into a ribbon that is >50 mm in length?
   - If the answer is YES, the possible textures are sandy clay, silty clay, or clay.
   - If the wet sub-sample feels gritty, the texture is **sandy clay**.
   - If the wet sub-sample feels very smooth with some grittiness, the texture is **silty clay**.
   - If the wet sub-sample does not feel gritty or smooth, the texture is **clay**.

texture is not relevant/necessary if the soil is organic. An explanation of the difference between a mineral soil and an organic soil is provided in Box 25.

7.4.3 Organic soil

Organic soils, with an organic carbon content of more than 10%, typically develop under conditions of nearly continuous saturation (Box 25) and therefore this is an important substratum type that is of relevance to certain wetlands and other aquatic ecosystems. Some organic soils could be classified as 'peat' (Table 6) but **not all organic soils are peat**, at least according to the definitions used in South Africa. Peat can be defined as "a sedentarily (in-situ) accumulated material comprising of at least 30% (dry mass) of dead organic matter" (Joosten & Clark 2002).

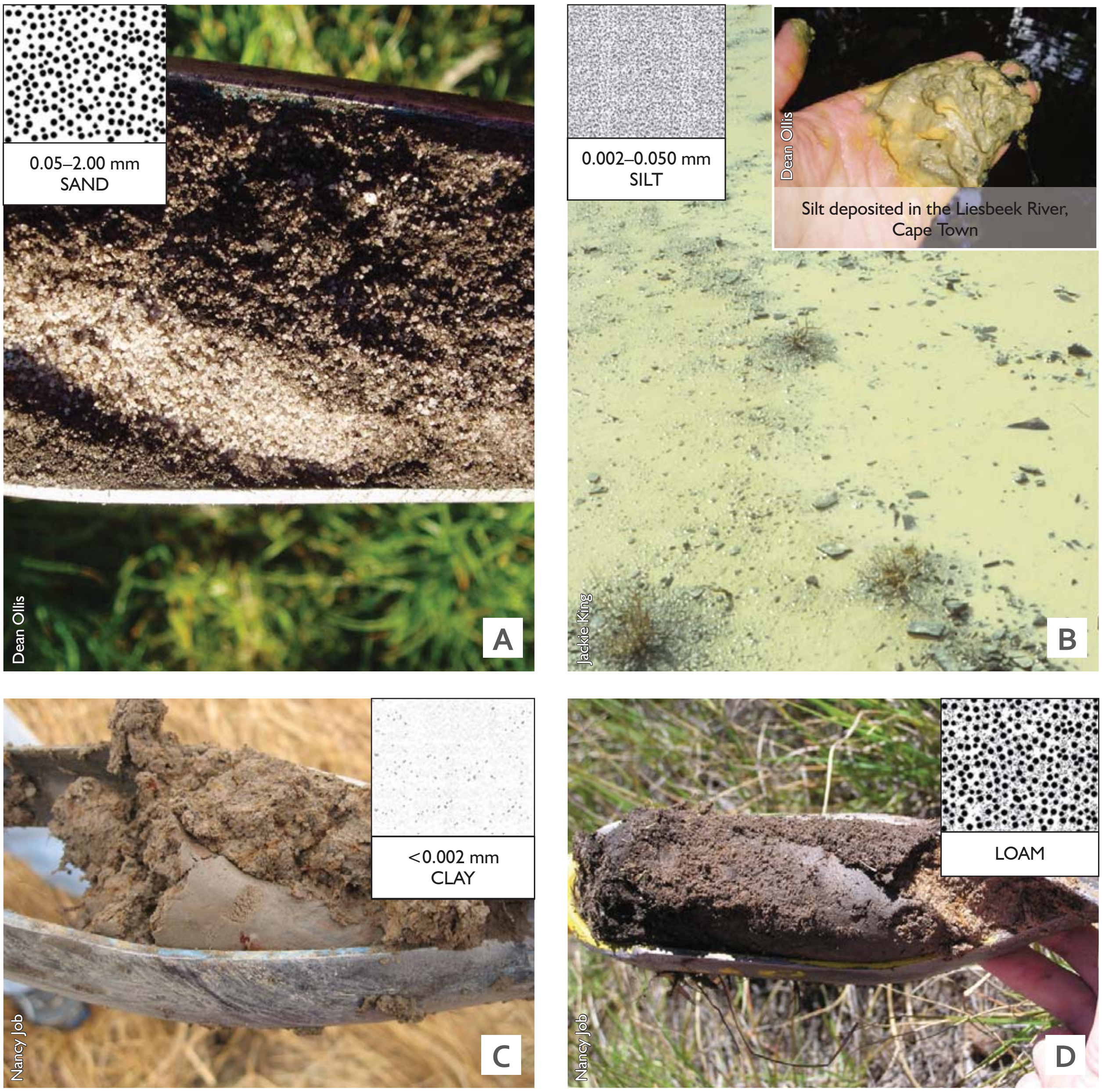


Figure 45. Photographs of mineral soils, with insets providing a pictorial guide to the relative particle sizes for each textural category. A, sandy soil; B, suspended silt in the Brak Rivier, Sutherland; C, clayey soil; D, loamy soil (with abrupt transition to sand) .

Peat can be recognised in the field, with a low level of confidence, through visual observations of soils that are black in colour, rich in dead/decomposing organic material, and permanently to near-permanently saturated (see photographs of typical peat in Figure 46). However, **the presence of peat can only be verified after laboratory analyses to determine whether the dry mass percentage of dead organic matter is greater than or equal to 30%**. Even more so than in the case of organic soils, you should be cautious about calling all soils that are black in colour and appear to contain a high proportion of decomposing organic matter, 'peat'.

A peatland is a type of wetland, defined as "an area with or without vegetation with a naturally accumulated peat layer that has a minimum thickness of 30 cm" (Joosten & Clark 2002; Ryden & Jeglum 2006). Although peatlands are quite rare in South Africa, largely due to the relatively warm (and relatively dry) climate that speeds up the breakdown of organic material and so prevents the formation of peat, they are an important, and threatened, type of ecosystem in the country (see Box 26).

NOTE: The substratum of an Inland System that consists of organic soil but does not meet the criteria to be peat, is simply categorised in the Classification System (at Level 6B) as an organic soil with <30% organic carbon.

7.4.4 Salt crust

The soil surface of some inland aquatic ecosystems are covered in a hard layer of alkali salts for relatively long periods

BOX 25: WHAT EXACTLY IS THE DIFFERENCE BETWEEN A MINERAL SOIL AND AN ORGANIC SOIL?

Organic carbon is one of the constituents of any soil, with the proportional amount varying from one soil to the next. According to the soil classification system used in South Africa (Soil Classification Working Group 1991), topsoil with an average organic carbon content of at least 10% throughout a vertical distance of 200 mm is defined to be an organic soil. This soil type, which is not widely distributed in South Africa, is broadly referred to as the Champagne Soil Form (internationally, organic soils are called Histosols). All other, non-organic, soils are defined as 'mineral soils' and should be described in terms of their texture.

Whereas mineral soils consist primarily of (sand-, silt, and/or clay-sized) rock and mineral fragments, organic soils are mostly made up of an accumulation of organic material in the form of plant and animal remains in varying stages of decomposition. Organic soils, therefore, tend to occur in environments where the rate of decay of organic matter is substantially slower than the rate of production. Such conditions occur in areas that are saturated with water for long periods in most years (i.e. in wetlands that are permanently or near-permanently saturated).

Although the colour of an organic soil is typically black or dark brown, not all soils with a dark (near-black) colour are necessarily organic soils. This is because an organic soil is distinguished on the basis of the organic carbon content, as per the accepted definition (≥ 10% throughout a vertical distance of at least 200 mm), and not on the basis of its appearance. Some mineral soils may have a relatively high organic carbon content (say 5%), compared to 'ordinary' mineral soils, and therefore have a very dark appearance but they do not have a sufficiently high proportion of organic carbon to qualify as a true organic soil (i.e. less than 10%). Such soils can be described as 'organic-rich mineral soils'.

Those with lots of experience in working with soils can, in some situations, judge the organic carbon content of a soil in the field on the basis of the darkness and a soft feel of the soil. However, **it is very difficult to establish with confidence whether dark-coloured soils are truly organic (as per the accepted definition) without taking soil samples to a laboratory for an analysis of the organic carbon content**. This is especially so if you do not have extensive field-experience in soil science.

Figure 46. Photographs of peat from Duivenhoks wetland, southern Cape.

of time, especially in arid or semi-arid regions where evaporation rates are very high. As Inland Systems with such a salt layer are physically, chemically and biologically distinct from systems without such a layer, a 'salt crust' category has been included as one of the substratum types in the Classification System. Some photographs of Inland Systems with salt crusts are shown in Figure 47, to aid you in the identification of this rather unique substratum type.

NOTE: A salt crust layer generally occurs on the soil surface, overlying one of the mineral soil substratum types (i.e. sandy/clayey/loamy soil or silt/mud).

7.4.5 Other substratum types

The additional category of 'other' substratum type has been included in the Classification System, largely to allow for the categorisation of artificial substrata (such as concrete) that may occur in certain Inland Systems. For example, the artificial stone and concrete bed of the portion of the Liesbeek River flowing through the suburbs of Newlands and Rondebosch in Cape Town (Figure 48) would be categorised as an 'other' substratum type.

BOX 26: PEATLANDS IN SOUTH AFRICA

South African peatlands can be found in a variety of landscapes. Eleven peatland ecoregions have been described in South Africa (Marneweck *et al*. 2001, presented in Grundling & Grobler 2005) and they support peatlands as varied as interdune tropical swamp forests on the east coast, percolation mires in the interior (on the southern African plateau) and palmiet peatlands in the Cape Fold Mountains. The largest peatland in the country, in KwaZulu-Natal, is the Mkhuze Delta which, together with Mbazwana swamp forest, forms the largest mire complex in South Africa (approximately 8 800 ha in extent). Not far from this is South Africa's oldest peatland, the Mfabeni Mire, which at 45 000 years old is one of the oldest active peat-accumulating wetlands in the world.

Peatlands are under great pressure in South Africa. In the Cape Fold Mountains, peat wetlands play a crucial role in flood attenuation, trapping sediment and slowing down water flow. When cultivation and infrastructure led to the draining and degradation of these peatlands, it severely altered their flood attenuating ability, leading to severe erosion and the washing away of precious agricultural land. Tens of thousands of tons of peat have been extracted from South Africa's karst fens outside Ventersdorp and Potchefstroom for the mushroom and horticulture industries. Peatlands in the Highveld have come under threat from mine prospecting, while elsewhere in the country peatlands have been drained and planted with crops (Grundling & Grobler 2005).

7.5 *Vegetation cover*

Characteristics of vegetation cover affect the composition of the biota inhabiting an Inland System and the ecosystem functions that the system can perform.

For the vegetation cover type, the Classification System allows for a distinction to be made between vegetated and unvegetated ecosystem units (at Level 6A), with no further sub-division of the 'unvegetated' category. Unvegetated Inland Systems will consist either of bare substratum or open water, or will fluctuate between these two states. The 'vegetated' category can be divided into vegetation form sub-categories (at Levels 6B, 6C and 6D), with further categorisation of the vegetation status possible (at Level 6E), as shown in Table 7.

7.5.1 Vegetation form

Vegetation is taken to include macro-algae and macrophytes (flowering plants). Four primary categories of vegetation form are included in the Classification System (at Level 6B), namely aquatic, herbaceous, shrubs/thicket, and forest.

(a) Aquatic vegetation

Aquatic vegetation refers to plants that are found principally on or below the water surface.

Aquatic plants are divided into the following categories (at Level 6C):

Floating aquatic vegetation—plants that have their foliage and flowers lying on the water surface. Floating aquatic vegetation can be 'free-floating' (with the roots dangling free in the water) or 'floating attached' (rooted in the underlying substratum, with only the leaves and flowers floating), as distinguished at Level 6D.

Submerged aquatic vegetation—plants occurring in water that are rooted in the underlying substratum and have their foliage below the water surface. These plants are characterised by only producing reproductive organs (i.e. flowers) above the water surface.

Algal mat—attached or floating macro-algae (i.e. larger algal forms visible to the naked eye).

Figure 47. Photographs of salt crusts on the surface of Soutpan and Springfield 'pans' in the Western Cape.

Figure 48. Photograph of the stone and concrete bed of a canalised portion of the Liesbeek River, an example of a substratum type that would fall under the 'other' category.

Photographs of the different kinds of aquatic vegetation are shown in Figure 49.

NOTE: Emergent macrophytes are plants that are rooted in the substratum of an aquatic ecosystem but that emerge above the water surface (if present), with most of the plant structures visible above the surface. These plants are not considered to be aquatic vegetation because they do not occur primarily on or below the water surface. Instead, they should be classified as 'herbaceous vegetation' or, if they are woody, as 'shrubs/thicket' or 'forest' vegetation.

(b) Herbaceous vegetation

Herbaceous (i.e. non-woody) vegetation, as classified at Level 6B, can be divided into a number of sub-categories at Level 6C (Box 27).

Table 7. Vegetation cover, form and status categories (Levels 6A to 6E)

LEVEL 6: VEGETATION COVER, FORM & STATUS				
A	B	C	D	E
Vegation cover	Vegetation form			Vegetation status
Vegetated	Aquatic	Floating	Free-floating	Indigenous
				Alien
			Floating attached (rooted)	Indigenous
				Alien
		Submerged	[not applicable]	Indigenous
				Alien
		Algal mat	[not applicable]	Indigenous
				Alien
	Herbaceous	Geophytes	[not applicable]	Indigenous
				Alien
		Grasses	[not applicable]	Indigenous
				Alien
				Crop
		Herbs/Forbs	[not applicable]	Indigenous
				Alien
				Crop
		Sedges/Rushes	Sedges	Indigenous
				Alien
			Rushes	Indigenous
				Alien
		Reeds	[not applicable]	Indigenous
				Alien
		Restios	[not applicable]	Indigenous
		Palmiet	[not applicable]	Indigenous
	Shrubs/Thicket	[not applicable]	[not applicable]	Indigenous
				Alien
	Forest	Riparian Forest	Upper River Riparian Forest	Indigenous
				Alien
				Plantation
			Lower River Riparian Forest	Indigenous
				Alien
				Plantation
		Forested Wetland (swamp forest)	[not applicable]	Indigenous
				Alien
				Plantation
Unvegetated	[not applicable]	[not applicable]	[not applicable]	[not applicable]

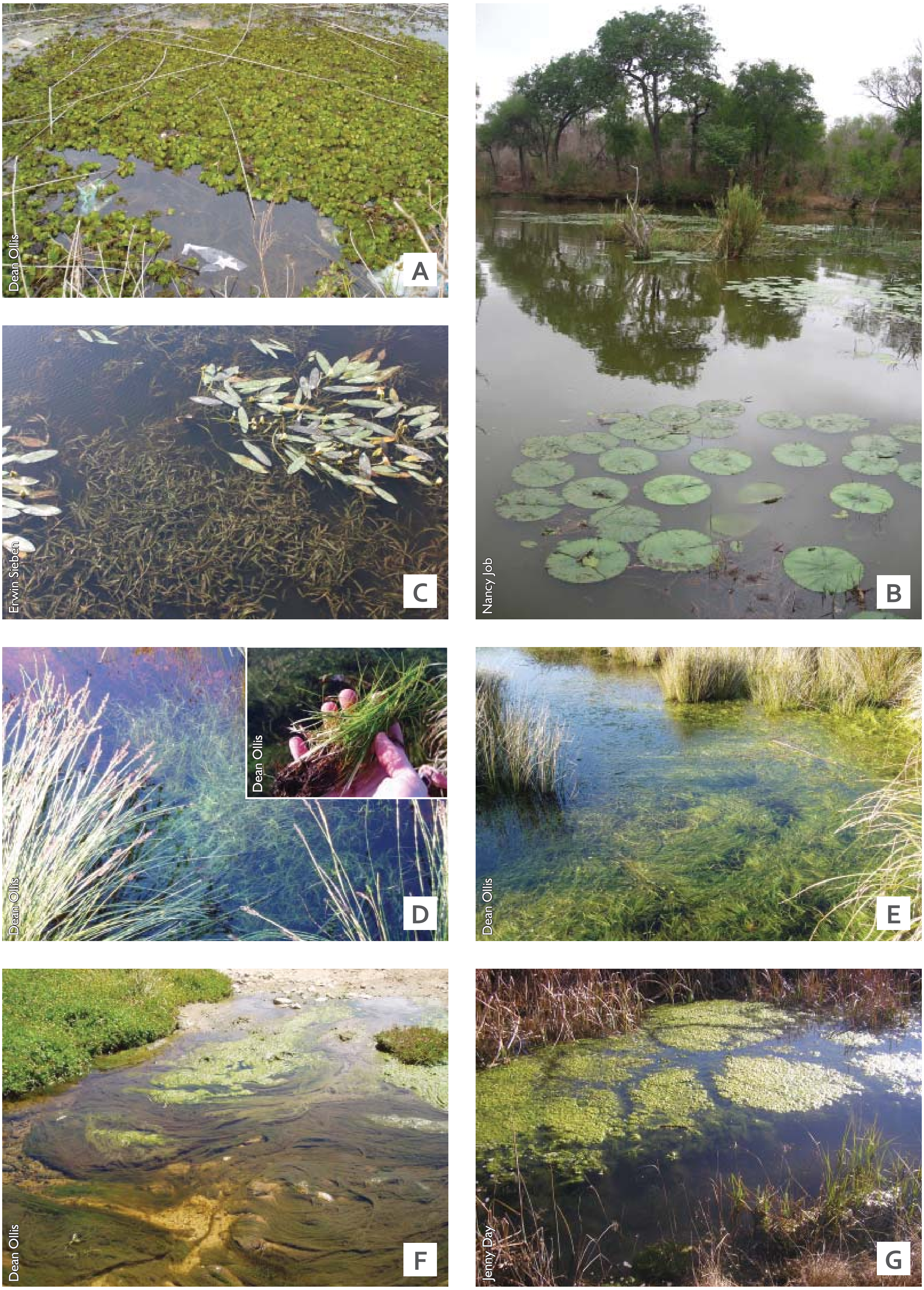


Figure 49. A, free-floating aquatic vegetation (alien invasive Kariba weed, *Salvinia molesta*); B and C, two examples of floating attached aquatic vegetation (water lily, *Nymphaea* sp. and Cape pond lily, *Aponogeton distachyos*); D and E, two examples of submerged aquatic vegetation (pondweed, *Potamogeton* sp., in a Betty's Bay wetland and an unidentified aquatic plant in a wetland on the Cape Peninsula); F and G, two examples of algal mats (in a river channel in the Western Cape and in a small weir in the Free State).

BOX 27: Types of herbaceous vegetation (Level 6C)

Geophytes—non-woody plants, generally less than 2 m tall, that propagate by underground storage organs (i.e. bulbs, tubers, corms, rhizomes, or stolons).

Grasses—tuft-forming or creeping non-woody plants without brightly coloured flowering parts and with leaves that consist of three parts: leaf blade, leaf sheath and ligule (membrane or ring of hairs found between leaf blade and leaf sheath).

Herbs/forbs—non-woody flowering plants, generally less than 2 m tall, which are not sedges, rushes, reeds, restios, palmiet or geophytes.

Sedges—stiff, grass-like plants of the family Cyperaceae, sometimes referred to as 'nutgrasses'. Sedges are distinguished from grasses in that they generally do not have a leaf sheath (their leaves are attached directly to the culm or stem), or when they do, it is closed around the culm, whereas grasses have an open leaf sheath. The culms of many (but not all) sedges are triangular in cross section, while the culms of grasses are always cylindrical.

Rushes—stiff, non-woody plants of the genus *Juncus*, which grow in tufts of cylindrical unbranched stems with flowering parts branching off to the side of the stem near the apex. The so-called bulrush, *Typha capensis*, is usually considered to be a reed, not a rush.

Reeds—tall (up to 3 m), unbranched plants with stiff (semi-woody) stems or long, relatively stiff leaves, which generally grow at the water's edge with their roots submerged in water or saturated soil. *Phragmites australis* (common reed) is an example of a typical reed, with the stiff-leaved bulrush or cattail (*Typha capensis*) also considered to be a reed.

Restios—plants of the family Restionaceae, which have very small leaves consisting only of scale-like sheathes that envelope the culms or stems; the sheaths are often brown, and the culms or stems green. Restios grow predominantly in the southwestern Cape, where they constitute one of the three main elements of Fynbos vegetation (the other two elements being proteas and ericas).

Palmiet—leafy *Prionium serratum* plants, commonly associated with rivers and valley-bottom wetlands. Palmiet tends to dominate systems, forming dense stands. It is a robust shrub with semi-woody stems. It produces a large root mass and deep rooting system able to grow through recently deposited sandy sediments and stabilise them.

NOTE: Sedges and rushes are combined into a single category (i.e. sedges/rushes) at Level 6C of the Classification System (Table 7), as it is often very difficult to distinguish between these different types of herbaceous vegetation in the field, especially if you are not a botanical specialist. A distinction between the two vegetation forms can be made at Level 6D, if you know which plant is present and it is necessary to differentiate between the two for your particular application.

Photographs of some of the different kinds of herbaceous vegetation are shown in Figure 50. It is also recommended that you refer to the guide to South African wetland plants, recently published by the Water Research Commission (Van Ginkel *et al.* 2011), for assistance in identifying some of the more common wetland plants.

NOTE: It is difficult to tell whether a particular plant species is a geophyte without uprooting the plant to see if it has an underground storage organ. For example, the Arum lily (*Zantedeschia aethiopica*) (which can be seen in the photograph of the valley-bottom wetland along the Mosselbank River in Figure 22) and *Spiloxene aquatica* (known as the Cape star or golden star, as shown in Figure 51) are both geophytes that occur in numerous seasonal wetlands in the Western Cape.

(c) Shrubs/thicket

Shrubs are self-supporting, generally multi-stemmed, woody plants less than five metres in height, including true shrubs, young trees and trees that are small or stunted as a result of environmental conditions. A very dense growth of shrubs is called thicket.

Photographic examples of Inland Systems dominated by shrubs/thicket are shown in Figure 52.

(d) Forest

A forested Inland System is characterised by woody vegetation dominated by trees[5] with a canopy cover of 75% or more (i.e. with overlapping crowns). A forest may or

[5] Trees are defined as self-supporting, single-stemmed woody plants that are **five metres or more in height.**

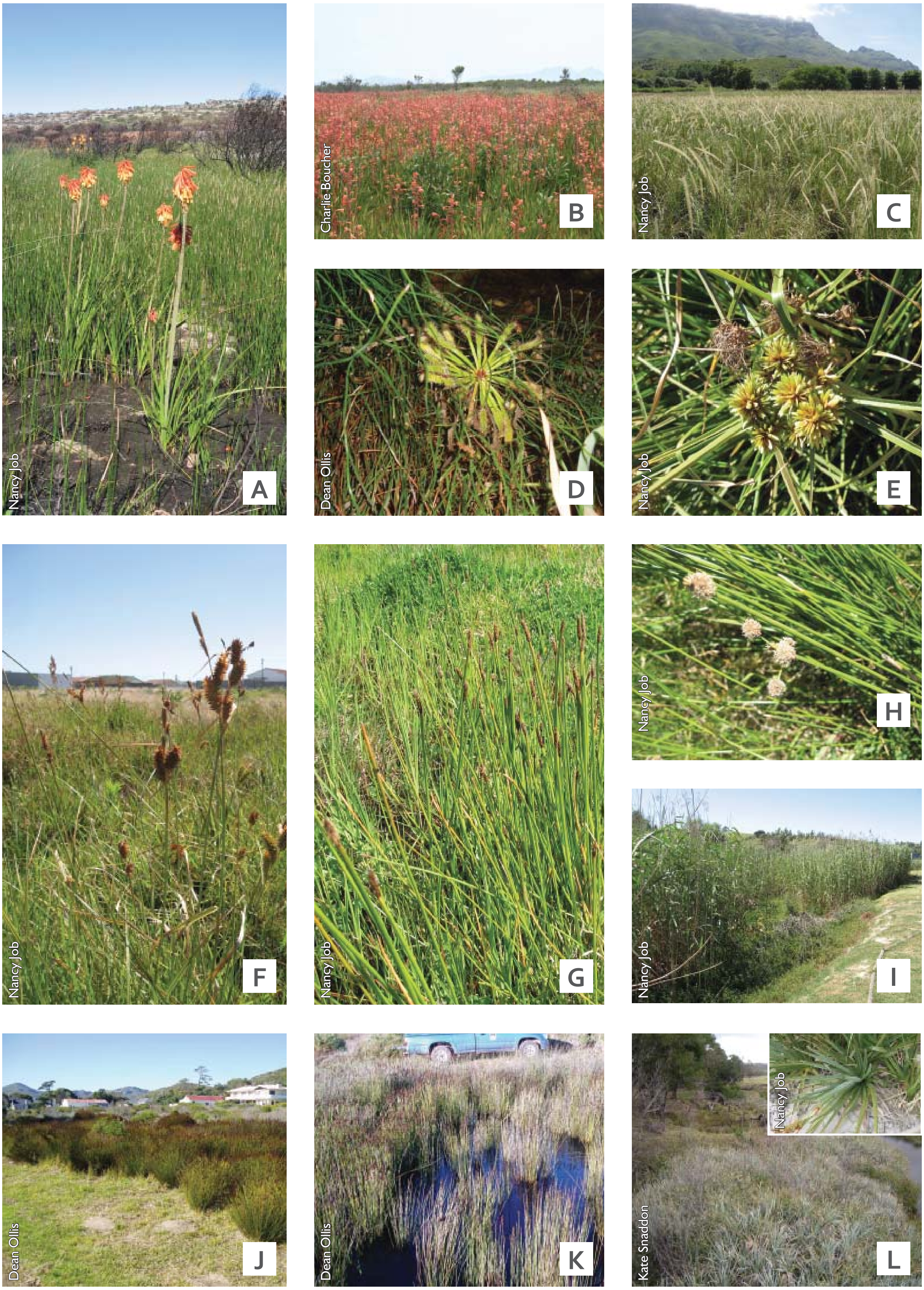


Figure 50. Photographs of the different herbaceous vegetation types. A and B, two examples of geophytes (red hot poker, *Kniphofia uvaria*, and *Watsonia meriana*); C, a grass (*Pennisetum macruorum*); D, a herb/forb (sundew, *Drosera* sp.); E, F and G, three examples of sedges (*Cyperus* sp., *Carex* sp. and *Eleocharis* sp.); H, a rush (*Juncus* cf. *punctorius*); I, a reed (common reed, *Phragmites australis*); J and K, restios (*Elegia tectorum*); L, palmiet (*Prionium serratum*).

Figure 51. Photograph of the geophyte *Spiloxene aquatica* in a seasonally inundated wetland on Vergenoegd Wine Estate, Western Cape.

may not have an understorey of young trees or shrubs and an herbaceous layer below an overstorey of mature trees.

In the Classification System, forested Inland Systems are divided into 'riparian forest' and 'forested wetland' at Level 6C, with the option to further divide riparian forests into upper and lower river types at Level 6D.

> **Riparian forest**—a community of trees (i.e. a forest) occurring in the riparian zone of a river (see Box 7 for an explanation of what the riparian zone is). Riparian forests can be further categorised as an 'Upper River riparian forest' (occurring along the upper reaches of a river) or a 'Lower River riparian forest' (occurring along the lower reaches of a river)[6].

> **Forested wetland (swamp forest)**—a community of trees (i.e. a forest) occurring in soils that are permanently saturated or seasonally inundated with non-saline water. Forested wetlands are often fed primarily by groundwater that is close to or at the surface of the ground, and sometimes occur in peat soils.

Photographs of indigenous riparian forests are shown in Figure 53.

Swamp forests are the only indigenous forested wetland type associated with Inland Systems in South Africa. They are restricted to the KwaZulu-Natal and Eastern Cape provinces, where they are distributed in pockets and narrow ribbons extending in a narrow belt along the Indian Ocean coast. Photographs of this highly restricted type of ecosystem are shown in Figure 54.

NOTE: A forested wetland is only referred to as a 'swamp forest' if it is vegetated with indigenous trees. A wetland area that has been invaded by alien trees or encroached upon by a plantation should be referred to as a 'non-indigenous forested wetland'.

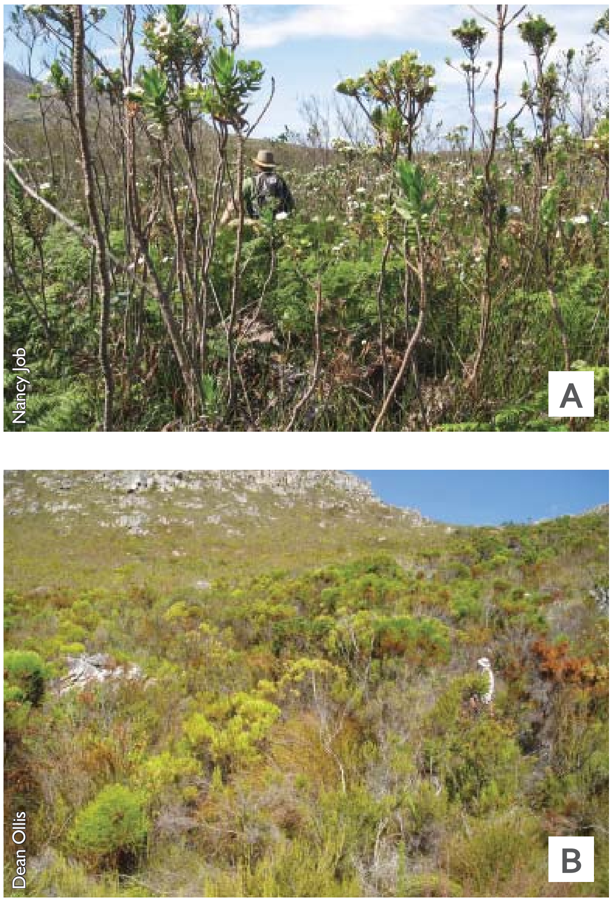


Figure 52. Photographs of wetlands and aquatic ecosystems with shrubs/thicket vegetation. A, *Osmitopsis asteriscoides* stand in a wetland near Betty's Bay; B, mountain seep in the Western Cape dominated by *Berzelia lanuginosa* and *Leucadendron* shrubs.

7.5.2 Vegetation status

The categorisation of the status of the vegetation within an Inland System (as outlined below) is important because ecosystems that have been invaded by invasive alien plants, or that have been planted with crops or plantations, are very different from ecosystems dominated by indigenous vegetation.

> **Indigenous vegetation**—plants that occur naturally in a particular area.

> **Alien vegetation**—plants that are not indigenous to a particular area. Many (but not all) alien plants are alien invasive species.

> **Crop**—consisting of cultivated plants.

> **Plantation**—an area in which trees have been planted, especially for commercial purposes, in contrast to a forest consisting of indigenous or alien invasive trees.

[6] The lower reaches of a river include the Lower Foothill, Lowland River and Upland Floodplain Zones, whereas the upper reaches include all the other longitudinal zones (after Rowntree & Wadeson 2000)—see Table 2.

Figure 53. Photographs of an indigenous Upper River riparian forest. A, along the upper reaches of the Gobos River in the Western Cape; B, an indigenous Lower River riparian forest of fever trees (*Acacia xanthophloea*) in the Makuleke portion of the Kruger National Park.

Most of the photographs of vegetated Inland Systems included in this User Manual show indigenous vegetation (e.g. Figures 26, 31, 36, 50, 52, 53 and 54). The photograph of free-floating Kariba weed (*Salvinia molesta*) in Figure 50 is an example of an alien (and, in this case, highly invasive) aquatic plant[7], while the Kikuyu grass (*Pennisetum clandestinum*) growing in between the Arum lilies along the Mosselbank River valley-bottom wetland (Figure 22A) is an example of an alien (and also invasive) grass (a type of herbaceous vegetation). A few more photographs of alien vegetation, crops and plantations occurring in aquatic ecosystems are shown in Figure 55, to assist you in categorising the vegetation status when you are dealing with an Inland System that does not consist of indigenous vegetation.

Take note of the guiding 'rules' for the assignment of dominance categories that relate specifically to the categorisation of Vegetation Form and Vegetation Status in Box 28.

Figure 54. A, indigenous forested wetlands (swamp forests), showing the trees inside a typical swamp forest; B, edge of the swamp forest in the southern part of Mfabeni Swamp.

7.6 Geology (lithology)

The dominant geology of the catchment of an Inland System, and within the system itself, is important because of the deterministic role that geology is known to play in the formation and functions of different Inland Systems (DWAF 2007). This is why provision has been made for recording the geological (or lithostratigraphic) units within an Inland System and its catchment, as one of the descriptors at Level 6 of the Classification System.

Information on geological units (e.g. Groups and Formations) can be obtained from the series of 1:250 000 scale

[7] Most, if not all, of the free-floating aquatic plants that occur in South African Inland Systems are alien invasive species.

Figure 55. Photographs of non-indigenous vegetation in wetlands and aquatic ecosystems: alien shrubs. A, oleander (*Nerium oleander*); B and C, lantana (*Lantana camara*); D, long-leaf wattle (*Acacia longifolia*); E and F, alien riparian forests consisting of black wattle (*Acacia mearnsii*) and gum trees (*Eucalyptus* sp.) that do not form part of a plantation; G, a crop of sugarcane (an example of a non-indigenous grass species); H, a plantation of pine trees (*Pinus* sp.) in a wetland area forming a non-indigenous forested wetland.

BOX 28: 'RULES' FOR THE ASSIGNMENT OF DOMINANT DESCRIPTORS

1. For each descriptor at Level 6 of the Classification System, categories with a proportional coverage of more than 50% (i.e. a rating of 4 to 6 in Box 18) should be considered to be dominant. For example, an open waterbody that consists of 75–95% fresh water (salinity <3 g/l) that is acidic (pH <6) (i.e. a rating of 5 in both cases), with a small proportion (less than, say 20%) of brackish water that is circum-neutral (i.e. a rating of 1 or 2 in both cases), would be described as 'dominantly fresh' in terms of it salinity and 'dominantly acid' in terms of its pH.

2. Where there is no category with a proportional coverage of more than 50% (i.e. a rating of 4 or more) but there is more than one category with a proportional coverage of greater than 25% (i.e. a rating of 3) for a particular descriptor, the descriptor should be described as having mixed dominance, with the co-dominant categories included in brackets thereafter. For example, the substratum of a the active channel of a river consisting of boulders and cobbles, both with a proportional coverage of more than 25% but less than 50% (i.e. both rated as 3 in terms of the rating scale in Box 18), would be described as being of 'mixed dominance (boulders/cobbles)'.

3. The characterisation of the dominant **Vegetation Form** (at sub-levels 6B to 6D) should be based on the uppermost layer of vegetation and an areal cover of greater than 50% (i.e. a rating of 4 to 6). For example, an Inland System with 55% areal cover of trees with overlapping crowns (i.e. forest) over a shrub layer (i.e. shrubs/thicket) with a 65% areal cover would be classified as a 'forest-dominated' system; an Inland System with 40% areal cover of trees with overlapping crowns over the same (65%) shrub layer would, however, be classified as a 'shrub/thicket-dominated' system. When trees or shrubs alone cover less than 50% of the area within an Inland System but in combination cover 50% or more, the system should be classified as 'shrub/thicket-dominated'. When trees and shrubs together cover less than 50%, the system would be classified as being dominated by aquatic or herbaceous vegetation, as the case may be. If the total vegetation cover of an Inland System is less than 25% (i.e. a rating of 1 or 2), it should be classified as dominantly unvegetated (at Level 6A).

4. The characterisation of the dominant **Vegetation Status** of an Inland System (at sub-level 6E) generally refers to the status of the dominant Vegetation Form that has been classified at Levels 6B to D, for example grasses (one of the herbaceous vegetation forms), reeds (another one of the herbaceous vegetation forms) or shrubs/thicket. If the dominant Vegetation Form within an Inland System consists of alien vegetation, a crop or a plantation, but the system still has some indigenous vegetation, the dominant Vegetation Form of the indigenous vegetation must also be recorded.

geological maps available from the Council for Geoscience (see www.geoscience.org.za for a list of available products, prices, and purchasing details). Where fine-scale geological maps exist (e.g. 1:50 000 scale geological maps produced for certain areas by the Council for Geoscience, or maps produced for specific projects from geological surveys), you should preferentially use this information. The source of geological information that you use to categorise the geology/lithology of an Inland System and its catchment should always be referenced.

7.7 Rating of Inland System descriptors

Each Inland System is likely to comprise a mix of the structural/chemical/biological characteristics described in the previous sections. The same approach is followed as in the case of the hydrological regime, whereby each descriptor can be rated in terms of its relative abundance (using the rating system described in Box 18), together with an indication of the level of confidence of the rating. Remember, though, that when the rating system is used to categorise selected descriptors, subordinate categories are rated separately for each primary category that is relevant (i.e. the HGM Unit is split when applying the rating system to descriptors), unlike in the case of using the rating system to categorise the hydroperiod (where the HGM Unit is categorised as a whole for both Level 5A and Level 5B, as explained in Section 6.2.4). This is because the sub-categories for descriptors (e.g. at Level 6B or 6C) are unique to a particular over-arching category (e.g. an artificial sub-type at Level 6B is not applicable to a natural wetland, as categorised at Level 6A for the natural vs. artificial descriptor; and the herbaceous vegetation sub-types at Level 6C are not applicable to aquatic vegetation, as categorised at Level 6B for the vegetation cover descriptor), whereas the categories for the classification of the saturation period at Level 5B are the same for all inundation periods as categorised at Level 5A.

The classification of Inland Systems at Levels 1 to 4 of the Classification System is considered to be consistent, typically changing only over relatively long periods (of the order of decades or longer) or as a result of dramatic disturbances. The same is generally true for the hydrological regime at Level 5. In contrast, a number of the features that are classified at Level 6 may change naturally in space and over time (i.e. type and cover of vegetation, substratum, and various chemical features such as salinity and pH). In order to minimise inconsistencies that might result from these natural variations, you are encouraged to record the time of year in which these more dynamic features are assessed. Some features may vary seasonally, and so should preferably be assessed in both the wet and dry seasons.

For certain applications, it may be necessary to generalise about the Inland System descriptors for an entire HGM Unit. To facilitate consistency between different users of the Classification System, guiding 'rules' for the assignment of dominance categories are presented in Box 28.

To implement the guiding 'rules' for the assignment of dominant categories for Vegetation Form and Vegetation Status (numbers 3 and 4 in Box 28), you must remember to categorise the vegetation form of both the non-indigenous (alien/crop/plantation) vegetation and the indigenous vegetation in a wetland or other aquatic ecosystem that is dominated by non-indigenous vegetation but within which some indigenous vegetation is still present. The reason for applying the Classification System in this manner is that the classification of the dominant indigenous vegetation form occurring within an Inland System is important for many potential applications (including conservation planning, wetland rehabilitation prioritisation and wetland health assessments), even if the system consists partly or mostly of invasive alien vegetation, cropland or plantation.

A worked example of how the rating system for descriptors was applied to seep wetlands in the Western Cape is provided in Appendix 1.

8 APPLICATION OF THE CLASSIFICATION SYSTEM

The Inland component of the Classification System for aquatic ecosystems has already been applied to the National Wetland Map, to generate a National Wetland Inventory (NWI) that includes wetland types. It has also been used in the National Freshwater Ecosystem Priority Areas (NFEPA) project and the wetland component of the 2011 update of the National Biodiversity Assessment (see Box 4).

It is envisaged that the Classification System could be used for a range of different purposes. Potential uses include wetland inventories (at national, regional and local scales), conservation planning initiatives for Inland Systems (broad-scale and fine-scale), wetland and river rehabilitation planning, assessments of wetland and river health, assessments of wetland services/functions, water resource planning and management (e.g. application to Ecological Reserve Determinations), catchment management planning, municipal application to Integrated Development Planning and the compilation of Spatial Development Frameworks, State of Environment reporting, design of wetland and river monitoring programmes, etc. The tiered structure of the Classification System provides increasing amounts of detail at the different levels of the Classification System, with more extensive information generally required to classify an aquatic ecosystem unit at each successive level. Where more detailed information is available (e.g. through extensive fieldwork), ecosystem units can be classified to a finer level and with greater confidence. Ultimately, the use of the Classification System is constrained by the type and extent of information available.

NOTE: It is very important that, when applying the Classification System, you should give an indication of the confidence with which you have selected categories at each level, from Level 3 (i.e. for Landscape Units at Level 3, HGM Units at Level 4, Hydrological Regime categories at Level 5 and Descriptor categories at Level 6). You should use the confidence categories of high, medium or low, as follows:

- **High confidence**—data, photographs or other types of evidence exist (typically requires fieldwork or site visits to be undertaken).
- **Medium confidence**—there may not be hard evidence, but you are fairly sure of your classification (typically requires a good knowledge of Inland Systems in the area, but does not necessarily require fieldwork to be undertaken).
- **Low confidence**—no evidence exists, and you are uncertain about the accuracy of your classification (typically implies that no fieldwork or site visits were undertaken, and/or that your working knowledge of Inland Systems in the area is relatively poor).

A few worked examples of the application of the Classification System to inland wetlands are provided in Appendix 1. You should refer to these worked examples to make the Classification System more tangible to you, by seeing how it has been applied to some real-life systems.

Don't forget to use the dichotomous keys (Appendix 3) and accompanying glossary (Appendix 2), in addition to the guidance provided in this User Manual, to assist you in applying the Classification System to inland aquatic ecosystems!

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Useful website addresses:

BIODIVERSITY GIS: http://bgis.sanbi.org/

DEPARTMENT OF WATER AFFAIRS: http://www.dwa.gov.za/

RAMSAR CONVENTION: http://www.ramsar.org/

RIVER HEALTH PROGRAMME: http://www.dwaf.gov.za/iwqs/rhp/index.html

WATER RESEARCH COMMISSION: http://www.wrc.org.za/

WETLANDS PORTAL OF SOUTH AFRICA: http://www.wetlands.za.net/

WORKING FOR WETLANDS PROGRAMME: http://wetlands.sanbi.org/

APPENDIX 1: WORKED EXAMPLES OF THE APPLICATION OF THE CLASSIFICATION SYSTEM

Introduction to worked examples

This appendix presents four worked examples of how the Classification System has actually been applied to selected inland aquatic ecosystems in South Africa. These examples should assist you in applying the Classification System to wetlands and other inland aquatic ecosystems that you are trying to classify.

The worked examples that were selected are as follows (see locality map in Figure 56):

- Worked example 1: Wilge River and floodplain wetlands (Free State).
- Worked example 2: Langvlei (Kamiesberg, Northern Cape).
- Worked example 3: Oudebos and Drakenstein seepage wetlands (Western Cape).
- Worked example 4: Tevreden Pan (Mpumalanga).

The first two worked examples show how the Classification System was applied from Level 1 to Level 4 (i.e. up to HGM Units).

The third example, which actually describes the classification of two separate wetlands, is a detailed one that shows how the Classification System was applied all the way from Level 1 down to Level 6.

The final worked example shows how the Classification System was applied to a rather unique aquatic ecosystem that was quite 'tricky' to classify, with a particular focus on the complicated aspects and the use of the rating system developed for the application of Levels 5 and 6.

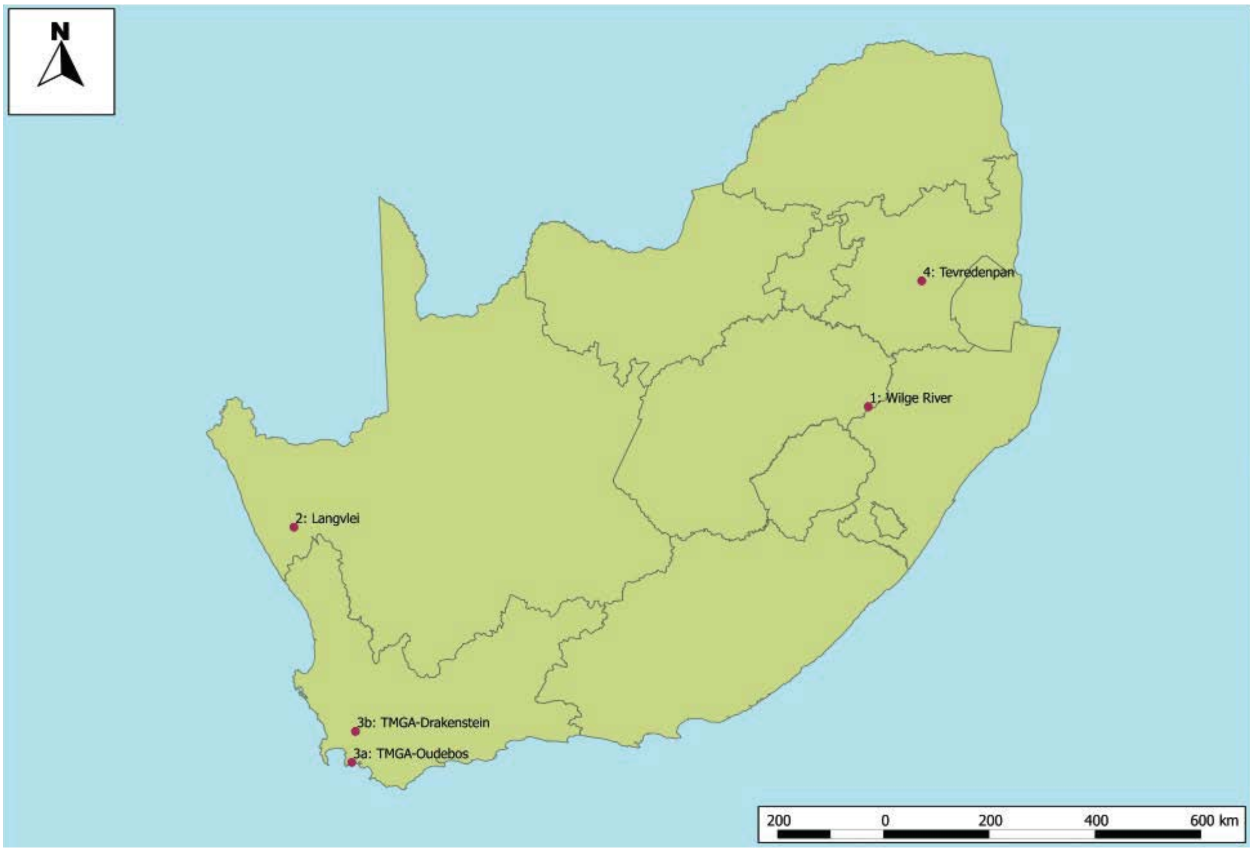

Figure 56. Map of South Africa (with provincial boundaries) showing the locations of the inland aquatic ecosystems included as worked examples.

EXAMPLE 1: Wilge River and Floodplain Wetlands (Free State)

Douglas MacFarlane (Eco-Pulse Environmental Consulting Services) provided information and GIS map layers for this worked example.

The Wilge River and associated wetland system is located in the Free State Province, just east of the N3 highway between the towns of Ladysmith and Harrismith. A portion of this river and associated wetland system, as shown on the map in Figure 57, has been included as a worked example of the application of the Classification System up to Level 4.

A summary of the classification of this aquatic ecosystem is given in Table 8, below, followed by a detailed explanation of how the Classification System was applied.

Being located in the interior of the country at an altitude of over 1 000 m above sea level, it is obvious that the portion of the Wilge River and its associated wetland that was mapped (see Figure 57) has no connection with the open ocean whatsoever. Therefore, it is an Inland System, as classified with a high level of confidence at Level 1. As the purpose of the classification of this aquatic ecosystem was simply to test the application of the Classification System, both the DWA Ecoregions and the NFEPA WetVeg Groups were used as the default spatial frameworks at Level 2. The relevant DWA Level I Ecoregion is the Highveld Ecoregion (Ecoregion 11, after Kleynhans *et al*. 2005), while the relevant NFEPA WetVeg Group is the Mesic Highveld Grassland Group 1 (after Nel *et al*. 2011). This was ascertained, in this example, by using GIS to overlay the mapped wetland area on the relevant spatial layers[8] and seeing which Ecoregion/s and WetVeg Group/s intersected with the wetland area (e.g. see Ecoregion map in Figure 58). The confidence rating was medium for the categorisation of the DWA Ecoregion (see Table 8) because the mapped wetland area is near the eastern edge of the Highveld Ecoregion, within 500 m of the adjacent Eastern Escarpment Mountains Ecoregion (as shown on the map in Figure 58). There-

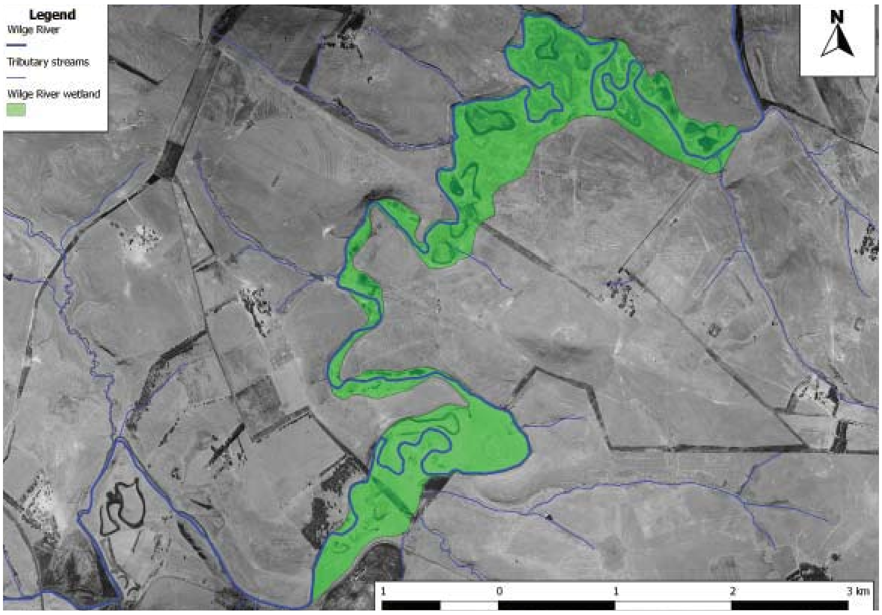

Figure 57. Portion of Wilge River and associated wetland that was mapped and classified.

Table 8: Summary of results of the application of Levels 1 to 4 of the Classification System to the Wilge River and associated wetland (confidence rating of classification at each level given in brackets)

Level 1	**Level 2**		**Level 3**	**Level 4: HGM Unit**		
System	***DWA Ecoregion/s***	***NFEPA WetVeg Group/s***	***Landscape Unit***	***4A***	***4B***	***4C***
INLAND (high)	Highveld (medium)	Mesic Highveld Grassland Group 1 (high)	Valley floor (high)	River (high)	Upland floodplain (high)	not applied
				Floodplain wetland (high)	Floodplain flat (medium)	n/a
					Floodplain depressions (high)	n/a

[8] GIS shapefiles for DWA Ecoregions were obtained from DWA's RQS website (www.dwaf.gov.za/iwqs/gis_data/ecoregions/get-ecoregions.asp) and those for NFEPA WetVeg Groups from SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

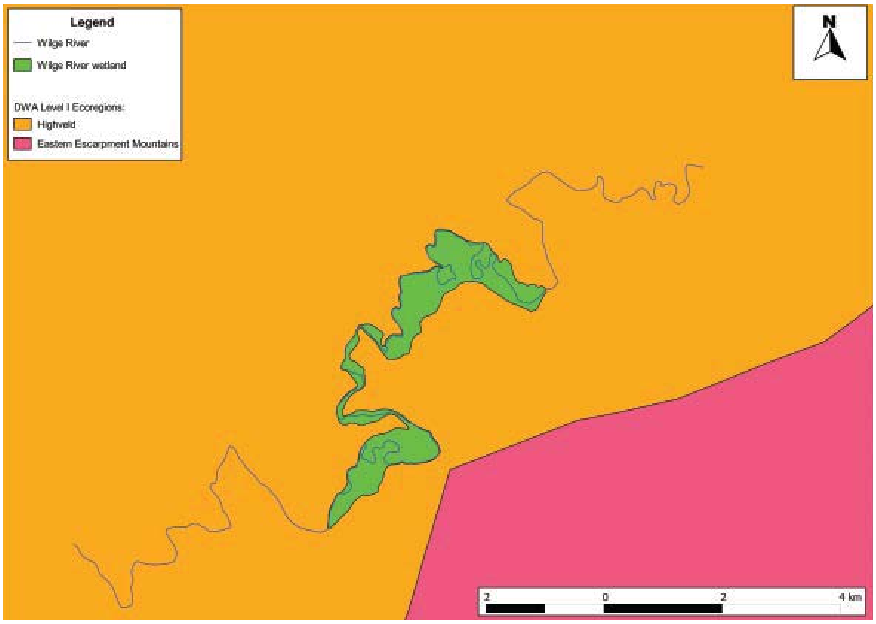

Figure 58. DWA Ecoregion map for the portion of Wilge River and associated wetland that was classified.

fore, ground-truthing of the physical characteristics and vegetation of the area would be necessary to confirm which is actually the most appropriate Ecoregion. The confidence rating for the categorisation of the NFEPA WetVeg Group was, however, high (see Table 8) because the aquatic ecosystems being classified did not fall near the boundary of two WetVeg Groups, with the closest neighbouring WetVeg Group (Sub-Escarpment Group 3) situated approximately 10 km to the southeast.

The GIS 'shapefiles' for the orthophoto contour lines (at 5 m contour intervals) and spot heights (in metres above mean sea level) that are freely available from the Chief Directorate: National Geo-spatial Information were overlaid on the GIS map of the Wilge River wetland (Figure 59), to assist in the determination of the landscape setting of the wetland area. In addition, Google Earth imagery of the area was viewed, and the 'tilt' tool in Google Earth was used to visualise the landscape setting in 3D.

By looking at the map in Figure 59 and the tilted 3D Google Earth imagery (not shown here), it was apparent that the wetland area that was mapped along a section of the Wilge River is located along the floor of a valley[9]. The landscape setting of the wetland and the adjacent river was, therefore, classified as a 'valley floor' at Level 3. The valley side-slopes are clearly well within 500 m of the river centreline and the outer edges of the wetland (as interpreted from contour lines on the map in Figure 59), which is the guideline for distinguishing between a val-

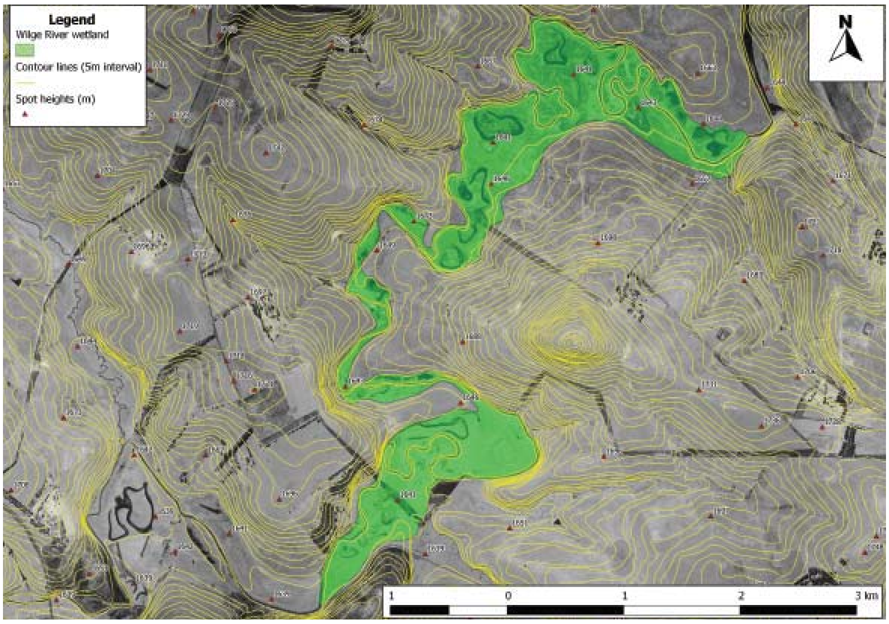

Figure 59. Contour lines (5 m interval) and spot heights (m AMSL) showing the topography in the vicinity of the portion of the Wilge River wetland that was mapped and classified.

[9] A valley is defined as an elongated, relatively narrow region of low land between ranges of mountains, hills, or other high areas, often having a river running along the bottom (see Glossary in Appendix 2).

ley floor and a plain as the assigned Landscape Unit (see Section 4.2.1 of the User Manual). Based on the use of all the above information and confirmation of the landscape setting through a site visit to the area (by Douglas MacFarlane), the confidence rating for the classification of the Landscape Unit as a 'valley floor' is high (see Table 8).

Two primary HGM types were identified as distinct but interconnected aquatic ecosystems in this worked example—a 'river' and a 'floodplain wetland', as classified with a high level of confidence at Level 4A (see Table 8).

The portion of the Wilge River flowing through the mapped wetland area (see Figure 17C in the User Manual) is clearly "a linear landform with clearly discernible bed and banks, which permanently or periodically carries a concentrated flow of water" because relatively obvious channel banks and a concentrated flow of water (at least periodically) within a distinct channel are both present. It was thus classified as 'river' at Level 4A with a high level of confidence, following the definition and guidelines provided in Section 5.1 of the User Manual.

According to the longitudinal zonation information obtained from DWA's Resource Quality Services website[10], the mapped portion of the Wilge River is in 'geo-class F', representative of rivers with a gradient of less than 0.001 (i.e. in the Lowland River or Upland Floodplain Zones, as per Table 2 in Section 5.1.1 of the User Manual). Because the portion of the Wilge River under consideration is on the interior plateau at an altitude of >1 500 m AMSL and has a gradient of less than 0.001, it was classified with high confidence as an Upland Floodplain river at Level 4B (see Table 8). No distinction was made between the 'active channel' and the 'riparian zone' of the Wilge River for this worked example, which could be done at Level 4C if required for the application of descriptors, for example.

The wetland area that was mapped along the Wilge River clearly has a number of typical floodplain features, including meander cut-offs and backwater depressions (e.g. see Figure 57 and photo 1 of Figure 21 in the User Manual that shows a typical meander cut-off or oxbow lake within this wetland complex). This wetland is also located adjacent to a portion of the river in the Upland Floodplain Zone with a gradient of <0.001. Following the definitions and guidelines in Sections 5.2 and 5.3 of the User Manual, including the preliminary guideline for distinguishing between floodplain wetlands and channelled valley-bottom wetlands on the basis of river zonation given in Box 10, the Wilge River wetland was thus classified with a high degree of confidence as a 'floodplain wetland' at Level 4A (see Table 8).

At Level 4B, for the floodplain wetland area that was mapped along the Wilge River, it was relatively easy to distinguish between 'floodplain flat' and 'floodplain depression' areas, with the meander cut-offs and backwater depressions that were mapped making up the 'floodplain depression' areas (as shown on the map in Figure 60). As such, there was a high degree of confidence in the classification of HGM Units at this level (see Table 8).

For this worked example, the Wilge River and associated wetlands were not classified beyond HGM Units at Level 4.

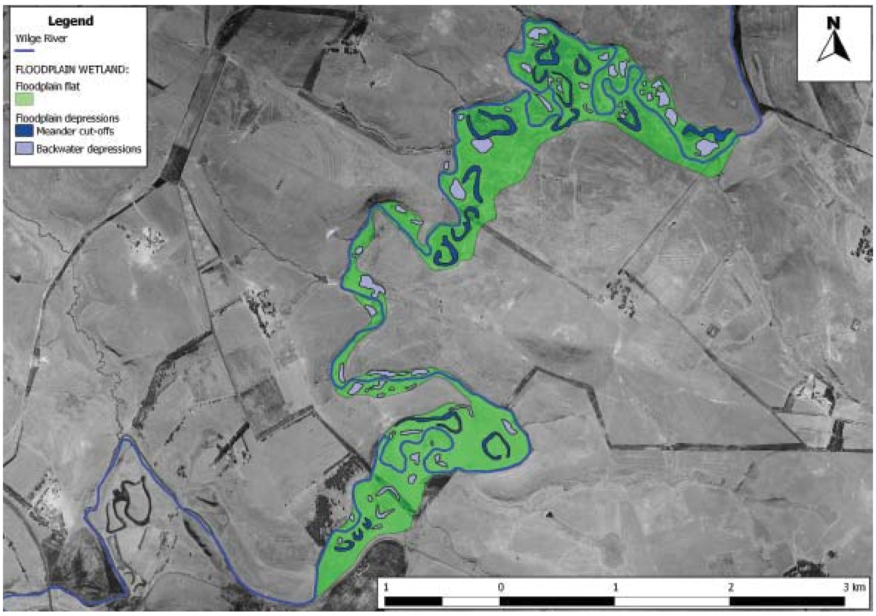

Figure 60. Map of the 'floodplain flat' and 'floodplain depression' areas within the Wilge River floodplain wetland, as categorised at Level 4B of the Classification System, with the distinction between areas mapped as 'meander cut-offs' and 'backwater depressions' shown for the floodplain depressions.

[10] GIS shapefiles of the gradient-derived longitudinal river zones for 1:500 000 scale rivers in DWA "Primary Drainage Region C", which includes the Wilge River, were downloaded from www.dwa.gov.za/iwqs/gis_data/rivslopes/rivprofil.asp

EXAMPLE 2: Langvlei (Kamiesberg, Northern Cape)

The Langvlei wetland system is a natural (i.e. non-artificial) inland aquatic ecosystem near the town of Leliefontein in the Kamiesberg Uplands, Northern Cape Province (see map in Figure 61) that has been extensively altered from its unimpacted natural state through communal agricultural activities, including cultivation and livestock grazing. Details about the current ecological condition of the wetland system are provided by Kotze *et al*. (2010).

A description of the classification of this wetland and associated non-perennial river system, which is located in a region with an arid to semi-arid climate (Mean Annual Precipitation <400 mm), has been included as another worked example of the application of the Classification System up to Level 4.

A summary of the classification of the Langvlei system is given in Table 9, below, followed by a detailed explanation of how the Classification System was applied.

Forming part of the interior uplands of the Kamiesberg region of the Northern Cape, at an altitude of over 1 000 m above sea level, it is obvious that the portion of the Langvlei wetland and associated river system (as mapped in Figure 61) has no connection with the open ocean whatsoever. It was, therefore classified as an Inland System with a high level of confidence at Level 1. Both the DWA Ecoregions and the NFEPA WetVeg Groups were applied as the default spatial frameworks at Level 2. The relevant DWA Level I Ecoregion is the Namaqua Highlands Ecoregion (Ecoregion 27, after Kleynhans *et al*. 2005), while the relevant NFEPA WetVeg Group is Namaqualand Cape Shrublands Granite Renosterveld (after Nel *et al*. 2011). This was ascertained by using GIS to overlay the mapped wetland area on the relevant

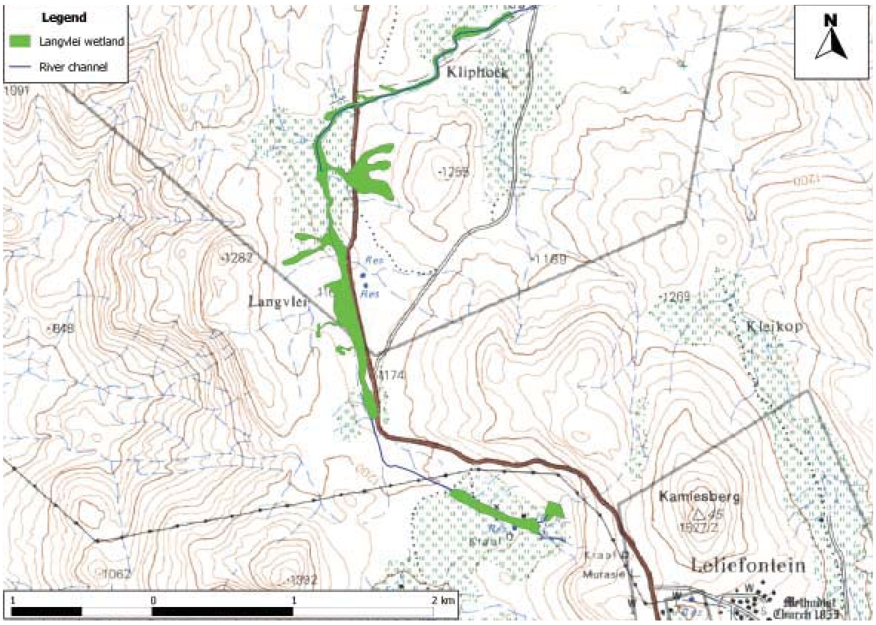

Figure 61. Portion of topographical map 3018AC showing the Langvlei wetland and associated river channel in relation to the town of Leliefontein (Kamiesberg Uplands, Northern Cape).

Table 9: Summary of results of the application of Levels 1 to 4 of the Classification System to the Langvlei wetland and associated river system (confidence rating of classification at each level given in brackets)

Level 1	**Level 2**		**Level 3**	**Level 4: HGM Unit**		
System	***DWA Ecoregion/s***	***NFEPA WetVeg Group/s***	***Landscape Unit***	***4A***	***4B***	***4C***
INLAND (high)	Namaqua Highlands (high)	Namaqualand Cape Shrublands Granite Renosterveld (medium)	Valley floor (high)	Unchannelled VB wetland (high)	n/a	n/a
				Channelled VB wetland (high)	n/a	n/a
				River (high)	Transitional (low)	not applied
					Upper foothills (low)	not applied
			Slope (low)	River (high)	Mountain stream (medium)	not applied
			Slope (high)	Seep (high)	With channelled outflow (high)	n/a
					Without channelled outflow (low)	n/a

spatial layers[11] and seeing which Ecoregion/s and WetVeg Group/s intersected with the wetland area. The confidence rating was recorded as high for the categorisation of the DWA Ecoregion (see Table 9) because the mapped wetland area is not near the boundary of the Namaqua Highlands Ecoregion (with the nearest adjacent Ecoregion more than 25 km away at its closest point). The confidence rating recorded for the categorisation of the NFEPA WetVeg Group was, however, only medium (see Table 9) because the neighbouring Namaqualand Hardeveld WetVegGroup that almost surrounds the Namaqualand Cape Shrublands Granite Renosterveld Group is relatively close, located less than 1 km to the west and less than 5 km to the northeast of the Langvlei system, introducing some uncertainty to the validity of the desktop-based classification at this level.

The only contour lines available for the Kamiesberg area were those on the 1:50 000 scale topographical map (3018AC, as shown in Figure 61), which are at a coarse interval of 20 m. Based on this information and observations made during a site visit to the Langvlei system in November 2007 (e.g. see photograph in Figure 62), it was concluded that the system occurs within a highland valley in the mountainous Kamiesberg Uplands. Kotze *et al*. (2010) also describe the Langvlei wetland as lying in a valley oriented roughly from north to south, surrounded by steeply-sloping metamorphosed granitic rock rises several hundred metres above the valley floor. The landscape setting was, therefore, categorised as a 'valley floor' for some of the mapped aquatic ecosystems associated with the Langvlei system, while for others it was categorised as a 'slope' on the side of the valley (see Table 9, which also gives the confidence rating for each categorisation).

At Level 4A, the Langvlei aquatic ecosystem was divided into four primary HGM types—'unchannelled valley-bottom (VB) wetland', 'channelled valley-bottom (VB) wetland', 'river', and 'seep', with varying degrees of confidence (see Table 9 and map in Figure 63).

The main Langvlei wetland situated along the valley floor was classified as a valley-bottom wetland, portions of which do not have a distinct river channel running through the wetland (categorised as 'unchannelled valley-bottom wetland') and portions of which do (categorised as 'channelled valley-bottom wetland', e.g. Figure 65). The definitions and guidelines for the classification of valley-bottom wetlands in the User Manual (Section 5.3) informed these categorisations. For the portions of Langvlei categorised as unchannelled VB wetland, the landscape setting was clearly a valley floor and there was an obvious lack of distinct channel banks with evidence of diffuse flows within the wetland (e.g. Figure 64). As such, the classification was considered to be at a high level of confidence (see Table 9). The classification of a portion of the wetland as channelled VB wetland was also with a high degree of confidence because of the unambiguous landscape setting along a valley floor, the presence of a river channel with distinct banks flowing through the

Figure 62. Photograph of the highland valley that the Langvlei system runs through in the Kamiesberg Uplands.

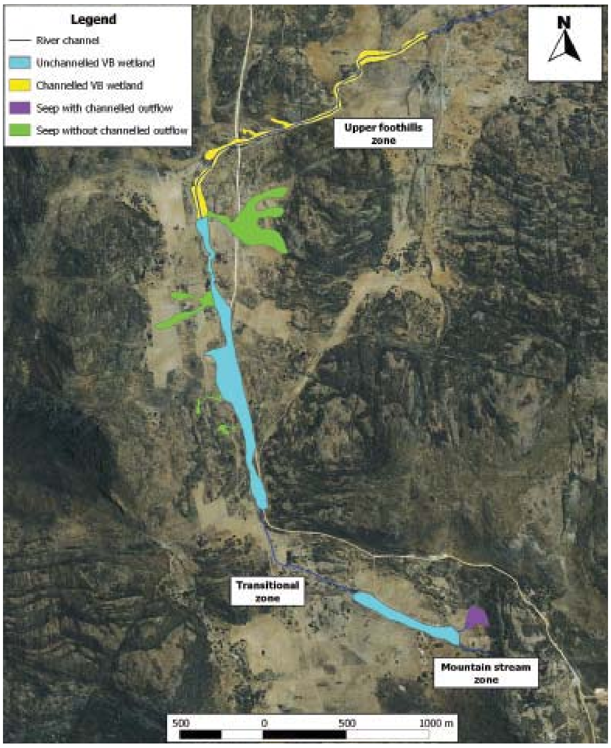

Figure 63. Map of the HGM Units making up the Langvlei aquatic ecosystem, as categorised at Level 4 of the Classification System, with labels provided for the longitudinal zones determined for the mapped sections of river.

wetland (e.g. Figure 65) and the absence of characteristic floodplain features.

Along the valley floor of the Langvlei system, there are sections with a distinct river channel that were classified as 'rivers' at Level 4A with a high degree of con-

[11] GIS shapefiles for DWA Ecoregions were obtained from DWA's RQS website (www.dwaf.gov.za/iwqs/gis_data/ecoregions/get-ecoregions.asp) and those for NFEPA WetVeg Groups from SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

Figure 64. A portion of unchannelled valley-bottom wetland along the valley floor of the Langvlei system (note the absence of a distinct river channel and the presence of diffuse flows).

Figure 65. A portion of channelled valley-bottom wetland along the valley floor of the Langvlei system (note the presence of a distinct river channel with a concentrated flow of water and the absence of floodplain features in the wetland areas adjacent to the channel).

fidence (see Table 9)—these are linear landforms with clearly discernible bed and banks, which periodically carry a concentrated flow of water. Some of these sections of river flow through wetland areas, such as those reaches flowing through the area classified as channelled VB wetland (as described above), while other sections do not flow through wetlands but do flow into or out of wetland areas (as shown on the map in Figure 63). The gradients of the river sections were roughly estimated from the 20 m interval contour lines from the relevant 1:50 000 scale topographical map (as shown in Figure 61), following the guidelines for the estimation of gradient provided in Box 6 of the User Manual. These coarse gradient estimates were used to categorise the longitudinal zonation of the river sections, with a low level of confidence[12], according to the geomorphological zonation scheme (after Rowntree & Wadeson 2000) presented in Table 2 of the User Manual. The section of river flowing between the two portions of unchannelled VB wetland was calculated to have a gradient of approximately 0.03, placing it in the 'Transitional' zone, while the gradient of the section of river flowing through and out of the portion of channelled VB wetland was calculated to be approximately 0.01 and it was categorised as falling in the 'Upper foothills' zone (see Table 9 and the map in Figure 63).

The categorisation of the river associated with the channelled VB wetland portion of the Langvlei wetland as an Upper Foothills river (at Level 4B), with a gradient much steeper than 0.005 (therefore not in the Lowland River or Upland Floodplain zones) supports the classification of this portion of wetland as a channelled VB wetland, as opposed to a floodplain wetland, according to the guideline provided in Box 10 of the User Manual.

The river channels flowing into the upper (southeastern) portion of the Langvlei wetland (see map in Figure 63) are located on a very steep slope with an estimated gradient of 0.08, which is well within the range of gradients characteristic of the Mountain Stream zone (see Table 2 in the User Manual). In addition, it was visually confirmed that the substratum of these river channels is bedrock-dominated. Therefore, the classification of the river zonation (at Level 4B) as 'Mountain stream' was considered to be at a medium level of confidence for these particular river sections (see Table 9). The degree of confidence in classification of the landscape setting of these steep rivers as a 'slope' (at Level 3) was, however, low because it could be argued that the rivers run along the floor of a small, localised valley.

For the Langvlei worked example, no distinction was made between the 'active channel' and the 'riparian zone' of the rivers (at Level 4C) because the classification was not taken beyond Level 4, where such a distinction may become important.

All the wetlands on the side-slopes of the valley associated with the Langvlei system were classified, with a high degree of confidence, as 'seeps' at Level 4A (see Table 9 and the map in Figure 63). These wetland areas are all clearly located on slopes (not in valley floors), based on an interpretation of the topographic map (Figure 61) and visual observations made during a site visit to the area, and they would thus be dominated by the gravity-driven, unidirectional movement of water and sediment in a

[12] More detailed gradient data (e.g. fine-scale contours with an interval of 5 m) and more information of the geomorphological characteristics of the relevant river sections (e.g. relating to the substratum of the river bed, the channel form and the valley form) would be required to increase the degree of confidence.

Figure 66. A hillslope seep with channelled outflow on a valley side-slope in the upper reaches of the Langvlei system (note the presence of a distinct channel exiting the seep on the down-slope side).

down-slope direction, which is what distinguishes a seep from other HGM types (as explained in Section 5.5 of the User Manual). One of the mapped seeps, which feeds into the upper (southeastern) portion of the Langvlei system (see map in Figure 63 and photograph in Figure 66), was classified as a 'seep with channelled outflow' at Level 4B, with a high degree of confidence because of the obvious presence of an outflow channel on the down-slope side of the seep. For all the other mapped seeps associated with the Langvlei system, the presence or absence of an outflow channel was not confirmed during the site visit to the area and the classification of the outflow drainage (at Level 4B) as 'without channelled outflow' was based on an interpretation of relatively coarse-scale satellite (SPOT) imagery. The degree of confidence in these classifications was, therefore, low (as indicated in Table 9).

EXAMPLE 3: Oudebos and Drakenstein seepage wetlands (Western Cape)

The Table Mountain Group Aquifer (TMGA) extends from the Bokkeveld Mountains in the north to Cape Agulhas in the south, and to Port Elizabeth in the east. This aquifer is one of a number of potential water resource schemes under investigation for future water supply to the City of Cape Town. The prime geological target for the possible abstraction of groundwater from the TMGA is the Table Mountain Group and, more specifically, the Peninsula Formation, particularly where potential target sites occur within close proximity to existing surface water storage dams. A baseline monitoring programme of potentially groundwater dependent, minimally impacted rivers and wetlands in the areas surrounding Cape Town is currently in progress, as part of the City's investigation into the possible ecological effects that may arise from large-scale abstraction from the TMGA (City of Cape Town 2008). Two of the wetland monitoring sites for the TMGA project were selected for inclusion as worked examples of the complete application of the Classification System, up to Level 6. The two wetlands are:

- 'Oudebos seep', a control site in the Kogelberg Nature Reserve near the seaside town of Kleinmond (see map in Figure 67).
- 'Drakenstein seep', a site located near Wemmershoek Dam (see map in Figure 68).

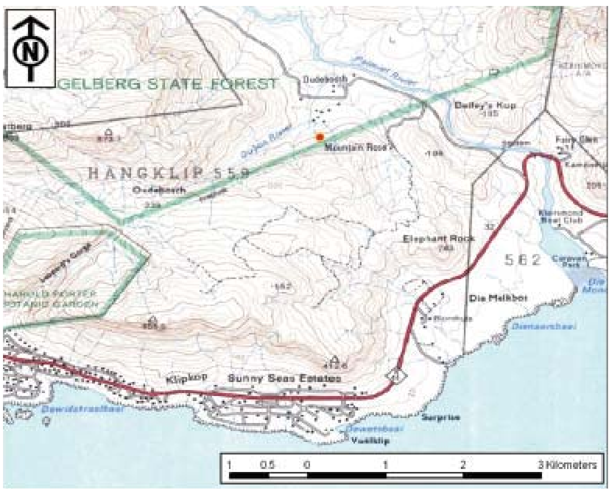

Figure 67. 1:50 000 scale topocadastral map (3418BD) showing location of 'Oudebos seep' (red dot) in the Kogelberg Nature Reserve.

A number of visits to both sites were undertaken in the past few years, as part of the implementation of the TMGA monitoring programme. Such site visits are generally essential for the full application of the Classification System to Level 6.

Level 1 to 4: HGM Units and their contextual setting

A summary of the classification of the Oudebos and Drakenstein seepage wetlands, from Level 1 to 4, is given in Table 10.

Neither the Oudebos nor the Drakenstein seep are located along the coast, and neither of these wetlands ever has a direct connection to the open ocean. Therefore, they were both classified as Inland Systems at Level 1 with a high degree of confidence (see Table 10).

The selected spatial framework at Level 2 was DWA Level 1 Ecoregions because the NFEPA WetVeg Groups were still under development when the initial studies on the TMGA wetlands were undertaken. The Oudebos seep is located in the Southern Folded Mountains Ecoregion, while the Drakenstein seep is located in the South Western Coastal Belt Ecoregion (after Kleynhans *et al*. 2005). This was ascertained by using GIS to overlay the locations of the wetlands (as points) on the GIS shapefiles for DWA Level 1 Ecoregions obtained from DWA's Resource Quality Services website (www.dwaf.gov.za/iwqs/gis_data/ecoregions/get-ecoregions.asp). According to the findings of this exercise, however, the

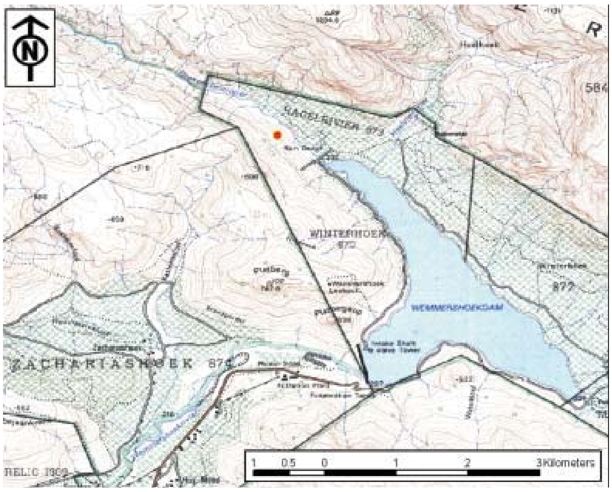

Figure 68. 1:50 000 scale topocadastral map (3319CC) showing location of 'Drakenstein seep' (red dot) near Wemmershoek Dam.

Figure 69. Photograph of the Oudebos seep, showing its unmistakable landscape setting to be a 'slope'.

Figure 70. Photograph of the Drakenstein seep, showing that its landscape setting is also unmistakably a 'slope'.

Drakenstein seep was found to be located close to the junction between the South Western Coastal Belt, the Southern Folded Mountains and the Western Folded Mountains Ecoregions, so the DWA Ecoregion was recorded with a low level of confidence in the case of this wetland (see Table 10). This issue was not encountered for the Oudebos seep, therefore the confidence rating of the categorisation of the Ecoregion at Level 3 was high for this wetland.

At Level 3 (Landscape Unit), the landscape setting of both wetlands is clearly a 'slope' with a gradient much steeper than 0.01, as determined with a high degree of confidence from the contour lines on the relevant 1:50 000 scale topographical maps (see Figures 67 and 78) and visual observations made during site visits (see photographs in Figures 69 and 70).

Both the Oudebos and Drakenstein seeps are groundwater-fed wetlands located on relatively steep slopes that are characterised by diffuse, unidirectional, down-slope water movement, at least periodically (as confirmed by a number of site visits to these wetlands in different seasons). They are, as such, archetypical Mountain Fynbos hillslope seepages and were thus classified as 'seeps' at Level 4A with a very high degree of confidence (see Table 10). At Level 4B, both seeps were classified with a high degree of confidence as being 'without channelled outflow' in terms of their outflow drainage characteristics (see Table 10), due to the confirmed absence of an outlet channel from either of these seeps (as evident in the photos in Figures 69 and 70). Although the Drakenstein seep feeds into the Drakenstein River channel, the slope that this seep is located on forms one of the side-slopes of the valley through which the Drakenstein River runs (see map in Figure 68) and the connection between the hillslope seep and the Drakenstein River channel is characterised by diffuse flows, as opposed to concentrated flow in a distinct channel. Therefore, following the guidelines for such situations given in Section 5.5.1 of the User Manual, this seep was classified as being *without* channelled outflow despite its location adjacent to a distinct river channel.

Table 10. Summary of results of the application of Levels 1 to 4 of the Classification System to the Oudebos and Drakenstein seepage wetlands (confidence rating of classification at each level given in brackets)

WETLAND NAME	**Level 1**	**Level 2**	**Level 3**	**Level 4: HGM Unit**		
	System	*DWA Ecoregion/s*	*Landscape Unit*	*4A*	*4B*	*4C*
Oudebos seep	INLAND (high)	Southern Folded Mountains (high)	Slope (high)	Seep (high)	Without channelled outflow (high)	n/a
Drakenstein seep	[as above]	South Western Coastal Belt (low)				

Rating system for hydroperiod and descriptor categories

The hydroperiod (and depth of inundation) of a wetland can be characterised at Level 5 of the Classification System, while at Level 6 a number of optional 'descriptors' are provided for describing the characteristics of a wetland or other inland aquatic ecosystem (as explained in detail in Sections 6 and 7 of the User Manual). At both Levels 5 and 6 of the Classification System, the relative proportions of each of the categories that have been included for the various parameters are rated, using a rating system explained in Box 18 of the User Manual. The rating system is an ordinal, seven-point scale ranging from 0 to 6 (as shown again for ease of reference in Table 11).

A series of grids are presented in Figure 38 of the User Manual, as a visual aid in distinguishing between areal coverage of 5%, 25%, 50%, 75% and 95% when applying the rating scale for hydroperiod categories and descriptors. These grids were used to assist in the application of the rating scale to the Oudebos and Drakenstein seeps, at Levels 5 and 6.

Level 5: Hydroperiod of HGM Units

Detailed groundwater level and soil moisture data collected from wetland sampling sites during the initial phase of the baseline monitoring programme for the TMGA project, as summarised in the report on the first year of monitoring data (City of Cape Town 2009), were used to inform the classification of the hydroperiod of the Oudebos and Drakenstein seeps. Following the terminology of the Classification System and the definitions given in the User Manual (Section 6.2.1 and the Glossary) to distinguish between the different categories for the period of inundation (at Level 5A), the hydroperiod of Oudebos seep was classified as mostly 'seasonally inundated' (rating = 5, i.e. predominant), with small portions of the wetland considered to be 'intermittently inundated' (rating = 2, i.e. sparse) or 'never/rarely inundated' (rating = 1, i.e. rare) (see Table 12). Drakenstein seep was also classified as mostly 'seasonally inundated' (rating = 5), but with small portions that are 'permanently inundated' (rating = 2), 'intermittently inundated' (rating = 2) and 'never/rarely inundated' (rating = 1) in this case. The confidence level of the classification of the period of inundation was high for both the Oudebos and Drakenstein seeps, due to the availability of groundwater level and soil moisture data, and observations of the wetness characteristics of the wetlands having been made during a number of site visits at different times of year.

The inundation depth-class of the permanently inundated portion of the Drakenstein seep was not classified (as 'limnetic' or 'littoral') at Level 5C because such categorisation is not really applicable to very shallowly inundated seep wetlands, being more appropriate for open waterbodies that are generally depressions.

In terms of the saturation period within 500 mm of the ground surface level (as recorded at Level 5B of the Classification System), the hydroperiod of Oudebos seep was further classified as mostly 'seasonally saturated' (rating = 5), with small portions that are 'permanently saturated' or 'intermittently saturated' (rating = 2), while the Drakenstein seep was classified as nearly entirely 'permanently saturated' (rating = 6), with small portions that are 'seasonally saturated' (rating = 1) (Table 13). The definitions of the different categories for the period of saturation, as presented in the User Manual (Section 6.2.2 and the Glossary), were consulted to assist in the determination of which categories were relevant. Permanently inundated portions of wetland, which were only present in the case of the Drakenstein seep, were excluded when estimating the proportional coverage of the different categories for the saturation period because (as per Table 3 of the User Manual) the categorisation of the saturation period is not applicable to such areas. The entire remaining portions of the HGM Units (i.e. the whole area that was not categorised as permanently inundated) was considered when estimating the proportional ratings for the saturation period of the Oudebos and Drakenstein seeps, as explained in the User Manual (Section 6.2.4).

Classification of the saturation period was, as in the case of the inundation period, considered to have been with a reasonably high level of confidence for both the Oudebos and Drakenstein seeps, due to the availability of soil moisture data and a number of site visits having been undertaken at different times of year (which included soil auger observations).

Table 11. Description of rating categories for the characterisation of HGM Units at Levels 5 and 6 of the Classification System, giving the percentage ranges represented by each category (from Box 18 of the User Manual)

Rating category	Description	Proportional coverage
0	Not present	none
1	Rare	>0%–5%
2	Sparse	>5%–25%
3	Common	>25%–50%
4	Abundant	>50%–75%
5	Predominant	>75%–95%
6	Near-entire	>95%–100%

Table 12. Classification of the inundation period of the Oudebos and Drakenstein seeps (at Level 5A), according to the rating categories in Table 11

LEVEL 5A:	Proportional rating (0–6)	
Inundation period	Oudebos seep	Drakenstein seep
Permanently inundated	0	2
Seasonally inundated	5	5
Intermittently inundated	2	2
Never/rarely inundated	1	1
Unknown	n/a	n/a

If the HGM Units and the hydroperiod categories that were identified for the Oudebos and Drakenstein seeps are brought together, several 'Functional Units' (as explained in Section 6 and Figure 5 of the User Manual) can be derived. In terms of the inundation period (referring back to Table 12), three Functional Units could be distinguished for the Oudebos seep (namely a portion of 'seasonally inundated seep', a portion of 'intermittently inundated seep', and a portion of 'rarely inundated seep'), whereas four Functional Units could be distinguished for the Drakenstein seep (with an additional portion of 'permanently inundated seep'). In terms of saturation period (Table 13), on the other hand, there were potentially three Functional Units in the Oudebos seep (i.e. portions of 'permanently saturated seep', 'seasonally saturated seep', and 'intermittently saturated seep'), versus two in the Drakenstein seep (where there was no 'intermittently saturated seep'). The problem with the derivation of Functional Units in this way is that the units are not mutually exclusive (e.g. a portion of 'seasonally inundated seep' could overlap with portions of 'permanently saturated seep' and 'seasonally saturated seep'). One could derive mutually exclusive Functional Units by considering the inundation period and the saturation period in combination, and rating the relative proportion of saturation periods (at Level 5B) that are present within each inundation period category that is relevant (at Level 5A). For example, the relative proportions of 'permanently saturated' and 'seasonally saturated' components would be rated separately within the 'seasonally inundated' and 'intermittently inundated' categories, and so on. This becomes very complicated, however, and requires detailed field data. The derivation of such detailed Functional Units was not necessary for this worked example (as is usually the case) and a more pragmatic and useful approach was taken by deriving the dominant Functional Units in each wetland (as explained in the summary at the end of this worked example).

Level 6: Descriptors for HGM Units

The optional descriptors included at Level 6 of the Classification System are 'natural vs. artificial', salinity, pH, substratum type, vegetation cover type, and geology/lithology. For this worked example, all six descriptors were applied to both the Oudebos and Drakenstein seeps, according to the rating system explained in Section 7.7 of the User Manual (also see Table 11).

Table 13. Classification of the saturation period of the Oudebos and Drakenstein seeps (at Level 5B of the Classification System), according to the rating categories in Table 11, excluding the permanently inundated portions of the wetlands

LEVEL 5B:	**Proportional rating (0–6)**	
Saturation period	**Oudebos seep**	**Drakenstein seep**
Permanently saturated	2	6
Seasonally saturated	5	1
Intermittently saturated	2	0
Unknown	n/a	n/a

Figure 71. A bare patch of soil within the Oudebos seep.

Natural vs. artificial

Both the Oudebos and Drakenstein seeps were classified as entirely 'natural' (rating = 6) in terms of the 'natural vs. artificial' descriptor at Level 6, with a high degree of confidence. This is because they are both clearly naturally-occurring wetlands that exist independently of any human influence.

Geology (lithology)

The geology/lithology of the Oudebos and Drakenstein seeps was classified as consisting entirely of 'Peninsula Formation (Table Mountain Group)' and 'Skurweberg Formation (Table Mountain Group)', respectively (rating = 6 in both cases). This categorisation was made according to the relevant 1:250 000 scale geological maps (3318 Cape Town for the Oudebos seep and 3319 Worcester for the Drakenstein seep) obtained from the Council for Geoscience and confirmed by finer scale geological maps presented in the Year 1 Monitoring Report for the TMGA project (City of Cape Town 2009). As such, there was a high level of confidence associated with the classification of the geology of both wetlands.

Vegetation cover, form and status

In terms of vegetation cover, both the Oudebos and Drakenstein seeps were classified as almost entirely 'vegetated' (rating = 6 and 5, respectively) at Level 6A (see Table 14). Portions of both wetlands were, however, categorised as 'unvegetated', consisting of very sparse patches of bare soil within the Oudebos seep (rating = 1, see Figure 71) and scattered boulders in the Drakenstein seep (rating = 2, see Figure 72). The classification of the vegetation cover at Level 6A (according to the proportion of vegetated vs. unvegetated areas) was considered to be at a high level of confidence for the Oudebos and Drakenstein seeps because it was based on field-based observations made during a number of site visits to both wetlands.

Figure 72. Drakenstein seep, looking upslope, showing boulders scattered amongst the vegetation within the wetland.

Figure 73. A portion of 'shrub/thicket' vegetation in the Oudebos seep, which is dominated by the shrub species *Berzelia lanuginosa*.

The vegetation forms within the vegetated portions of the Oudebos and Drakenstein seeps were classified according to the categories and descriptions outlined in Section 7.5.1 of the User Manual, using the relevant definitions in the Glossary (Appendix 2 of the User Manual). The primary vegetation forms within the Oudebos seep, as recorded at Level 6B, comprised of a mix of 'herbaceous' plants (proportional rating = 3) and 'shrubs/thicket' (proportional rating = 4) (Table 14), with the shrub component being dominated by *Berzelia lanuginosa* ('vleiknoppiesbos') (Figure 73).

The primary vegetation forms within the Drakenstein seep, as recorded at Level 6B (see Table 14), were also mostly a mix of 'herbaceous' plants (proportional rating = 3) and 'shrubs/thicket' (proportional rating = 4), with the shrub component in this case dominated by *Osmitopsis asteriscoides* ('mountain/swamp daisy') (Figure 74). Small patches of 'aquatic' vegetation (proportional rating = 1) in the form of algal mats were, however, also recorded within the inundated portions of the Drakenstein seep (e.g. Figure 75), which were not present in the drier Oudebos seep.

At Level 6C, the more detailed forms of herbaceous vegetation that were classified to be present within the Oudebos seep (see Table 14) were mainly 'restios' and 'herbs/forbs' (proportional rating = 3), with 'grasses' and 'sedges/rushes' also occurring (proportional rating = 2). In the case of the Drakenstein seep, 'restios' were the most prominent herbaceous vegetation form (rating = 4), with 'grasses', 'herbs/forbs' and 'sedges/rushes' also present (rating = 2). Although the relative proportion of 'aquatic' vegetation within the Drakenstein seep, as recorded at Level 6B, was rated to be rare (rating = 1), all of this vegetation comprised algal mat and therefore the 'algal mat' category at Level 6C was given a proportional rating of 6 (see Table 14).

The classification and rating of the proportional coverage of the different vegetation forms within the Oudebos and Drakenstein seeps, at Levels 6B and 6C, was primarily

Figure 74. A portion of 'shrub/thicket' vegetation in the Drakenstein seep, which is dominated by the shrub species *Osmitopsis asteriscoides*.

Figure 75. One of the patches of 'aquatic' vegetation in the form of an 'algal mat' present within the Drakenstein seep.

Table 14. Classification of the vegetation cover and vegetation forms associated the Oudebos and Drakenstein seeps (at Levels 6A to 6C), according to the rating categories in Table 11

LEVEL 6A:	**Proportional rating (0–6)**	
Vegetation cover	**Oudebos seep**	**Drakenstein seep**
Vegetated	6	5
Unvegetated	1	2

LEVEL 6B:	**Proportional rating (0–6)**	
Vegetation form (primary)	**Oudebos seep**	**Drakenstein seep**
Aquatic	0	1
Herbaceous	3	3
Shrubs/Thicket	4	4
Forest	0	0

LEVEL 6C (for 'Aquatic'):	**Proportional rating (0–6)**	
Vegetation form (detailed)	**Oudebos seep**	**Drakenstein seep**
Floating	0	n/a
Submerged	0	n/a
Algal mat	6	n/a

LEVEL 6C (for 'Herbaceous'):	**Proportional rating (0–6)**	
Vegetation form (detailed)	**Oudebos seep**	**Drakenstein seep**
Geophytes	0	0
Grasses	2	2
Herbs/Forbs	3	2
Sedges/Rushes	2	2
Reeds	0	0
Restios	3	4
Palmiet	0	0

based on visual observations made during data collection trips for the TMGA project, but no actual measurements of the proportional coverage of the different vegetation forms were made (e.g. through the use of vegetation sampling grids). Therefore, there is only a medium level of confidence in the proportional ratings estimated for the vegetation form categories (as presented in Table A3-7). The further sub-categorisation of the vegetation form that is possible at Level 6D for certain Level 6C forms (see Table 7 in Section 7.5 of the User Manual) was not applied to the Oudebos or Drakenstein seeps, as it was only potentially applicable to the 'sedges/rushes' category (which can be split into 'sedges' and 'rushes') and no detailed distinction of the proportional coverage of sedges versus rushes was undertaken.

The vegetation associated with the Oudebos and Drakenstein seeps is near-pristine, naturally-occurring Fynbos vegetation (Figures 69 and 70). Therefore, at Level 6E, the vegetation status was categorised as 'indigenous' with a high degree of confidence for all the (Level 6B and 6C) vegetation forms present.

Substratum type

For the Oudebos and Drakenstein seep wetlands, the substratum type was only categorised at the surface, due to a lack of detailed observations of the soil profile at different depths. It was, however, noted during site visits that the upper soils of both wetlands are underlain by a rocky layer at relatively shallow depths (less than 500 mm below the surface, where recorded using a soil auger), particularly for the Drakenstein seep (where the rocky layer was generally encountered less than 200 mm below the surface, where recorded).

The upper substratum of the Oudebos seep was classified, at Level 6A, as consisting mostly of 'sandy soil' (rat-

Table 15. Classification of the surface substratum of the Oudebos and Drakenstein seeps (at Level 6A), using the rating categories in Table 11

LEVEL 6A: Substratum categories	Proportional rating (0–6)	
	Oudebos seep	Drakenstein seep
Bedrock	0	1
Boulders	1	2
Cobbles	0	0
Pebbles/gravel	2	4
Sandy soil	5	2
Silt (mud)	0	0
Clayey soil	0	0
Loamy soil	0	0
Organic soil	0	0
Salt crust	0	0
Other	0	0

Figure 76. Upper substratum of part of the Drakenstein seep (obtained by means of a soil auger), showing that this portion of the wetland is inundated and the soil consists mostly of saturated gravel.

ing = 5), with small proportions of 'pebbles/gravel' (rating = 2) and 'boulders' (rating = 1) also present at the surface (Table 15). The Drakenstein seep, on the other hand, consisted mostly of 'pebbles/gravel' at the surface (rating = 4), with small proportions of 'sandy soil' (rating = 2), 'bedrock' (rating = 1) and 'boulders' (rating = 2) also present (Figure 76). The degree of confidence in the classification of the substratum type, at the surface, was high for both seeps because it was based on field observations and the use of a soil auger.

At Level 6B, it was noted that all the 'sandy soil' (as recorded at Level 6A) was 'sand' (rating = 6) and that the 'pebbles/gravel' substratum (as recorded at Level 6A) consisted entirely of 'gravel' (rating = 6), for both wetlands. No further distinction of any of the other primary (Level 6A) substratum categories was applicable at Level 6B (see Table 6 in the User Manual).

Salinity

The salinity of both the Oudebos and Drakenstein seeps was classified as entirely 'fresh', (proportional rating = 6). The degree of confidence was high because this categorisation was based on the conductivity measurements recorded in these wetlands during the first year of monitoring undertaken for the TMGA project (City of Cape Town 2009), with all conductivity measurements during that period being less than 30 mS/m (i.e. an order of magnitude lower than the Classification System's guideline threshold of <500 mS/m for 'fresh' water given in Table 4 of the User Manual).

pH

The pH of both the Oudebos and Drakenstein seep wetlands was classified as entirely 'acid' (proportional rating = 6), with a high level of confidence. This categorisation was based on soil and water pH measurements collected from these wetlands during the first year of monitoring for the TMGA project consistently being less than 6.0 (City of Cape Town 2009), which is the guideline threshold for 'acid' conditions according to the Classification System (as presented in Table 5 of the User Manual).

Summary (Levels 5 and 6): Dominant hydroperiod and descriptor categories

For the classification of the Oudebos and Drakenstein seeps, the dominant (Level 5) hydroperiod categories and (Level 6) descriptor categories were determined from the proportional ratings presented above, using the 'rules' for the assignment of dominant categories provided in the User Manual. This was an important step in this worked example, to gain a better sense of the overall characteristics of the seeps, as described by the hydroperiod and descriptor categories.

The hydroperiod of the Oudebos seep was summarised as being 'dominantly seasonally inundated' (in terms of the period of inundation at Level 5A) and 'dominantly seasonally saturated' (in terms of the period of saturation at Level 5B), as shown in Table 16. This was based on the selection of the categories for the inundation and saturation period that were recorded to have a proportional coverage of more than 50% (i.e. a rating of 4 to 6) at Levels 5A and 5B of the Classification System, respectively, as per 'rule 1' for the assignment of the dominant hydroperiod given in Box 19 of the User Manual (under Section 6.2.4). The hydroperiod of the Drakenstein seep was determined in the same way and was shown to also be 'dominantly seasonally inundated' in terms of the period of inundation at Level 5A, but 'dominantly permanently saturated' in terms of the period of saturation at Level 5B (see Table 16). Determination of the dominant inundation depth-class was not applicable because, firstly, neither of the wetlands were dominantly permanently inundated and, secondly (even if one of the wetlands had been dominantly permanently inundated), classification of the inundation depth-class is more appropriate for open waterbodies than for seep wetlands.

Table 16. Summary Table showing the dominant hydroperiod of the Oudebos and Drakenstein seeps, at Level 5 of the Classification System, based on the 'rules' provided in the User Manual (Box 19, Section 6.2.4)

WETLAND NAME	Dominant hydroperiod (and inundation depth-class) [Level 5]		
	Level 5A: Inundation period	**Level 5B: Saturation period**	**Level 5C: Inundation depth-class**
Oudebos seep	Seasonally inundated	Seasonally saturated	n/a
Drakenstein seep	Seasonally inundated	Permanently saturated	n/a

The 'dominant Functional Units' within the Oudebos and Drakenstein seeps were determined on the basis of the dominant hydroperiod categories (as summarised in Table 16). Following this approach, for the Oudebos seep the dominant Functional Unit was identified to a '*seasonally inundated, seasonally saturated seep*', whereas in the case of the Drakenstein seep it was identified to be a '*seasonally inundated, permanently saturated seep*'. These dominant Functional Units provide a good overall description of the broad functional characteristics of the two wetlands that were classified.

For each descriptor at Level 6, the dominant categories for the Oudebos and Drakenstein seeps were determined in a similar way to the derivation of the dominant hydroperiod categories (as described above), that is, by selecting the descriptor category in each case that was recorded to have a proportional coverage of more than 50% (i.e. a rating of 4 to 6), as per 'rule 1' for the assignment of the dominant descriptor categories given in Box 28 of the User Manual (under Section 7.7). The results of this exercise for the Oudebos and Drakenstein seeps are presented in Table 17.

The dominant descriptor categories in Table 17 could be used, for example, to describe the characteristics of the Oudebos seep as follows:

The Oudebos seep is a natural wetland with an underlying geology/lithology dominated by Table Mountain Group sandstones of the Peninsula Formation, which is mostly covered in vegetation dominantly comprising of indigenous shrubs. The surface substratum of the wetland is dominated by sandy soil, and the water within the wetland is generally fresh and acidic.

Table 17. Summary Table showing the dominant characteristics of the Oudebos and Drakenstein seeps according to the descriptors at Level 6 of the Classification System, based on the 'rules' provided for the assignment of dominant descriptors in the User Manual (Box 28, Section 7.7)

WETLAND NAME	Dominant descriptor categories [Level 6]										
	Natural vs. artificial			Vegetation cover, form and status				Substratum type			
	6A	6B: Artificial sub-categories	Geology (lithology)	6A: Veg cover	6B: Primary veg form	6C & 6D: Detailed vegetation form	6E: Veg status	6A: Primary categories	6B: Secondary categories	Salinity	pH
Oudebos seep	Natural	n/a	Peninsula Formation	Vegetated	Shrubs / Thicket	n/a	Indigenous	Sandy soil	Sand	Fresh	Acid
Drakenstein seep	Natural	n/a	Skurweberg Formation	Vegetated	Shrubs / Thicket	n/a	Indigenous	Pebbles / gravel	Gravel	Fresh	Acid

EXAMPLE 4: Tevreden Pan (Mpumalanga)

Description of Tevreden Pan

The following background information was taken mostly from previous studies on Tevreden Pan and the surrounding area by McCarthy *et al*. (2007) and Grundling *et al*. (2007).

Tevreden Pan is a wetland 'pan' system located in the northern part of Mpumalanga's so-called 'Lake District', which forms the eastern extremity of South Africa's interior 'pan belt'. The 'pan field' of the Mpumalanga Lake District differs substantially from other pan fields in the country in several respects. Pans in the pan fields of the more arid western interior of the country (mostly in the Northern Cape and Free State), for example, tend to be large, dry, floodplain-like features, elongated along river courses, versus the typically isolated, oval-shaped, permanently inundated pans that characterise the Mpumalanga Lake District. The density of pans in the Mpumalanga Lake District is also much higher than the densities found in the pan fields to the west. A total of approximately 320 pans occur in the Mpumalanga Lake District, ranging in size from less than a hectare to over 1 000 ha (Lake Chrissie). Tevreden Pan is approximately 300 ha in extent.

Tevreden Pan is a rather unique inland aquatic ecosystem in that it is a relatively deep open waterbody with floating beds (or mats or rafts) of peat in the middle of the waterbody/pan that support dense growths of *Phragmites australis* reeds, surrounded by a narrow outer ring of open water (see aerial photograph in Figure 77). It is apparently, by far, the biggest reed-dominated pan in the Mpumalanga Lake District, with *Phragmites australis* reed-pans not being common in the District. Preliminary investigations of Tevreden Pan by Grundling *et al*. (2007) indicated that the depth of the open water fringe around the outside of the reed beds is greater than 5 m in places and that the floating (reed-covered) peat beds are up to at least 1.5 m in thickness. Accumulating deposits of peat, approximately 0.5 m in thickness, were also observed on the clayey floor of the pan. It is thought that Tevreden Pan is an example of a lake or open waterbody that is in the process of being filled in by a floating mat of accumulating peat, making this peatland an unusual inland aquatic ecosystem in the South African context.

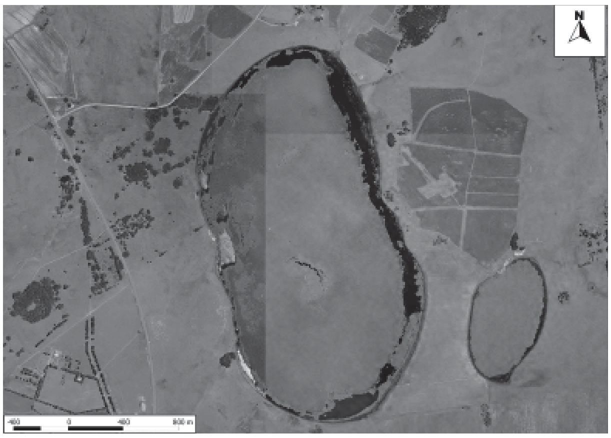

Figure 77. Aerial photograph of Tevreden Pan (the big 'pan' in the middle of the picture), showing the floating reed-beds surrounded by a fringe of open water [image obtained from Chief Directorate: GeoSpatial Information].

The classification of Tevreden Pan, which was initially undertaken as part of the field-based testing of an earlier version of the Classification System (see Ollis *et al*. 2009), has been included as a worked example of how the current version of the Classification System was applied to an atypical aquatic ecosystem. The focus of this worked example is specifically on some of the 'tricky' aspects that had to be dealt with when applying the Classification System.

Classification of Tevreden Pan

Tevreden Pan is located on a plateau in the interior of the country, at an altitude of more than 1 700 m AMSL, and is therefore unmistakably an 'Inland System' (as categorised at Level 1 of the Classification System) with absolutely no connection to the open ocean. The regional and landscape settings of this inland aquatic ecosystem were not classified, at Levels 2 and 3 of the Classification System, respectively, for this worked example.

HGM Unit (Level 4)

The 'pan' is clearly a depressional feature with closed elevation contours (e.g. see aerial photo in Figure 77) and it does not have an observable surface outflow, with water presumably exiting the aquatic ecosystem primarily via evapotranspiration (infiltration into the clay-rich bottom sediments would be very limited). As such, Tevreden Pan was classified as an 'endorheic depression' (at Level 4A+B) with a high degree of confidence, based on the relevant definitions and guidelines provided in the User Manual (especially Section 5.4). Although there are a number of seeps feeding into Tevreden Pan from the gentle slopes partially surrounding the pan, there are no distinctly channelised inflows of water, as confirmed through analysis of Google Earth imagery and visual observations made during a site visit to the pan. Therefore, the pan could be further classified (with a high degree of confidence) as being 'without channelled inflow' at Level 4C.

Overall, it was relatively uncomplicated, at the HGM Unit level, to classify Tevreden Pan as an endorheic depression without channelled inflow. If the classification was stopped here, however, none of the unique features of this inland aquatic ecosystem (as described above) would be captured. As such, further classification of the hydroperiod (at Level 5) and certain descriptors (at Level 6) was pursued in this worked example.

HGM sub-units

To aid with the application of the hydroperiod categories and selected descriptors to Tevreden Pan, the HGM Unit was divided into a number of sub-units with distinct characteristics. It is important to note that the division of the HGM Unit (an endorheic depression in this case) was not used to identify separate types of aquatic ecosystems, but rather to assist in the more detailed description of the characteristics of the HGM Unit at the lower levels of the Classification System.

Three distinct HGM sub-units were identified and delineated within the Tevreden Pan depression (as shown in Figure 78), namely:

- The floating reed-beds in the middle of the pan.
- The fringe of permanent open water surrounding the floating reed-beds.
- The outer edge of the pan that is not permanently inundated.

Below are photographs of the floating reed-beds in Tevreden Pan (Figure 79) and the outer edge of the pan (Figure 80). The open water in the pan can also be seen in both photographs.

The approximate area occupied by each HGM sub-unit in Tevreden Pan was calculated, using GIS, and the relative proportion of the total area represented by each sub-unit was determined (see Table 18).

Explanations are given below of how the above-mentioned HGM sub-units, and their relative proportions,

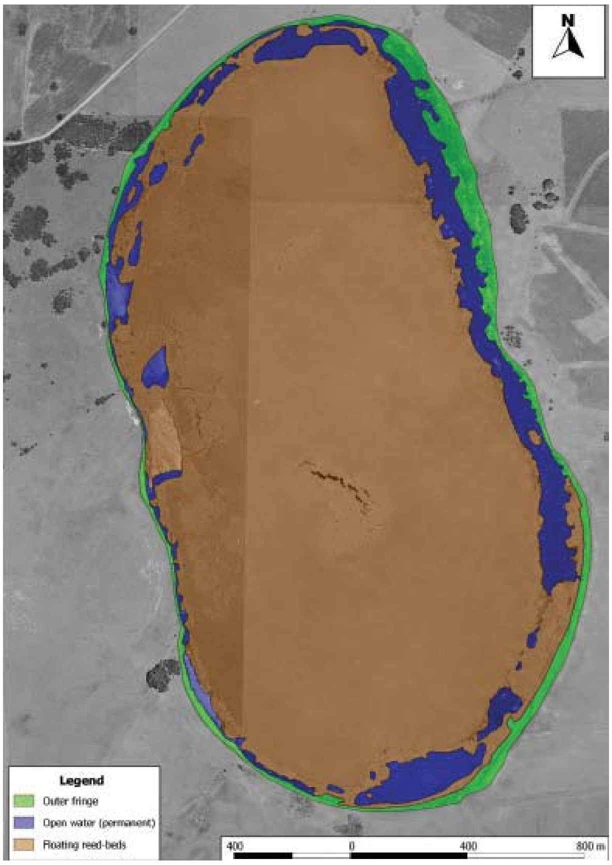

Figure 78. Map of the sub-HGM units delineated within the Tevreden Pan depression, for application of Levels 5 and 6 of the Classification System.

were used in the classification of the hydroperiod and selected descriptors for Tevreden Pan.

Hydroperiod (Level 5) and Functional Units

The inundation period of Tevreden Pan was classified (at Level 5A) with a high degree of confidence on the basis of written information about the depression, discussion with people with a good knowledge of the ecosystem (in particular, Anton Linström who was working for Mpumalanga Parks and Tourism Agency), and visual observations made during a site visit to the pan in June 2008. The proportional coverage by the various inundation periods (permanently inundated, seasonally inundated, etc.) were first estimated for each HGM sub-unit within Tevreden Pan, using the rating scale developed for the application of Level 5 and 6 of the Classification System (as presented in Table 11). The relative surface area occupied by each HGM sub-unit (as summarised in Table 18) was then used to derive ratings for the different inundation periods in Tevreden Pan as a whole (see results in Table 19). For example, the 'permanently inundated'

Figure 79. Photograph of the floating reed-beds in Tevreden Pan and the band of open water between the reed-beds and the edge of the pan.

Figure 80. Photograph of the wetland area that is not permanently inundated along the edge of the Tevreden Pan depression, with the open water that is situated between the edge of the depression and the floating reed-beds visible on the right.

category was given ratings of zero for the floating reed-beds, 6 for the open water, and zero for the outer edge of the depression. These ratings were then, respectively, multiplied by the proportional area of each HGM sub-unit (85% for the floating reed-beds, 10% for the open water, and 5% for the edge of the pan), and added together to derive the overall rating for the Tevreden Pan depression as a single HGM Unit, as follows:

$$\text{Rating (permanently inundated)} = (0 \times 0.85) + (6 \times 0.10) + (0 \times 0.05) = 0.6 \text{ (rounded off to 1)}$$

The inundation depth-class of the permanently inundated portion of Tevreden Pan (i.e. the open water area) was classified with high confidence as 'limnetic' at Level 5C, based on knowledge of the *maximum* depth of inundation within the open water area being more than 2 m at the annual average low water level (as reported by Grundling *et al*. 2007). No ratings were applied to categorise the inundation depth-class because, as explained in the User Manual (Sections 6.2.3 and 6.2.4), the classification of inundation depth-class is based solely on the maximum depth of inundation of the entire permanently inundated portion of the HGM Unit that is being classified.

The saturation period (at Level 5B) was classified following the same approach used to classify the inundation period. Classification of the saturation period was not applicable for the open water component, however, because this area is permanently inundated. The saturation period of the floating reed-beds, which consist of 'rafts' of actively forming peat, were categorised as entirely 'permanently saturated' (rating = 6, see Table 13) with a high level of confidence because actively forming peat tends to be restricted to permanently saturated areas. The outer edge of the depression was categorised as being mostly 'permanently saturated' (rating = 4), with relatively small portions that are 'seasonally saturated' or 'intermittently saturated' (rating = 2 in both cases). This was with a medium degree of confidence because it was based mostly on visual observations and anecdotal information, without any investigations of hydromorphic characteristics of the soils having been undertaken. Overall, as a single HGM Unit, the saturation period of Tevreden Pan was categorised as mostly 'permanently saturated' (rating = 5), due to the large surface area occupied by the permanently saturated floating reed-beds, with small portions of the pan (around the edges) that are 'seasonally saturated' and 'intermittently saturated' (see Table 20).

Table 18. Total surface areas of the three HGM sub-units that were delineated for Tevreden Pan and relative proportions of the whole depression represented by each sub-unit

HGM sub-unit	Area (ha)	Proportional area
Floating reed-beds	276	85%
Open water	32	10%
Outer edge	19	5%
Tevreden Pan depression (all sub-units)	327	100%

The dominant hydroperiod (and inundation depth class) categories were determined from the proportional ratings presented above, using the 'rules' for the assignment of dominant categories provided in the User Manual (Box 19, Section 6.2.4) as in the case of the worked example for the Oudebos and Drakenstein seeps. For Tevreden Pan, however, the dominant hydroperiod was determined for the whole HGM Unit (an endorheic depression) and for each of the three HGM sub-types that were delineated (i.e. the floating reed-beds, the open water, and the outer edge of the pan). A summary of this exercise is presented in Table 21. Overall, the dominant hydroperiod of Tevreden Pan as a whole HGM Unit came out as 'dominantly never/rarely inundated' and 'permanently saturated', with the categorisation of the inundation depth not being applicable because the HGM Unit as a whole was not categorised as dominantly permanently inundated.

In terms of the identification of dominant Functional Units, Tevreden Pan as a whole can be described as a '*permanently saturated endorheic depression (without channelled inflow) that is never/rarely inundated*', based on the dominant hydroperiod (as summarised in Table 21) and the classification of the HGM Unit/s. This essentially describes the floating reed-bed portion of the depression because this sub-HGM unit occupies most (85%) of the surface area of the pan, by far. Within the depression, each of the sub-HGM units could also be identi-

Table 19. Classification of the inundation period of Tevreden Pan (at Level 5A of the Classification System), according to the rating categories in Table 11

LEVEL 5A:	Proportional rating (0–6)			
Inundation period	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Permanently inundated	0	6	0	**1**
Seasonally inundated	0	0	2	**1**
Intermittently inundated	0	0	4	**1**
Never/rarely inundated	6	0	1	**5**
Unknown	n/a	n/a	n/a	**n/a**

Table 20. Classification of the saturation period of Tevreden Pan (at Level 5B of the Classification System), according to the rating categories in Table 11, excluding the permanently inundated portions of the depression

LEVEL 5B:	**Proportional rating (0–6)**			
Saturation period	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Permanently saturated	6	n/a	4	**5**
Seasonally saturated	0	n/a	2	**1**
Intermittently saturated	0	n/a	2	**1**
Unknown	n/a	n/a	n/a	**n/a**

Table 21. Summary Table showing the dominant hydroperiod of Tevreden Pan and its HGM sub-units, at Level 5 of the Classification System

Component	**Dominant hydroperiod (and inundation depth-class) [Level 5]**		
	Level 5A: Inundation period	**Level 5B: Saturation period**	**Level 5C: Inundation depth-class**
Floating reed-beds	Never/rarely inundated	Permanently saturated	n/a
Open water	Permanently inundated	n/a	Limnetic
Outer edge	Intermittently inundated	Permanently saturated	n/a
Whole HGM Unit	Never/rarely inundated	Permanently saturated	n/a

fied as Functional Units, such as a '*permanently inundated, limnetic portion of an endorheic depression*' (i.e. the open water) and an '*intermittently inundated, permanently saturated portion of an endorheic depression*' (i.e. the outer edge of the pan).

Selected descriptors (Level 6)

Three descriptors (at Level 6) were selected for application to Tevreden Pan:

- Natural vs. artificial.
- Substratum type.
- Vegetation cover, form and status.

The 'natural versus artificial' descriptor was applied because the User Manual recommends that this descriptor should be applied as a matter of course when classifying an aquatic ecosystem. Tevreden Pan was categorised as entirely 'natural' (rating = 6) with a high level of confidence because it is clearly not an artificially created system, rather it represents one of the many natural pans in the eastern Highveld pan field.

For Tevreden Pan, the substratum type was categorised at the surface (i.e. for an upper layer) and for the underlying layer (i.e. a lower layer, where there is a change in the substratum type with depth). The depth of each of these layers was not determined or estimated for this worked example. The rating of the primary substratum categories (at Level 6A) was done in the same way as the rating of the inundation and saturation periods, using the proportional areas of the sub-HGM units to determine the overall rating for the depression as a whole (see results in Table 22). Overall, the upper layer of the substratum in Tevreden Pan was categorised as mostly 'organic soil' (rating = 5), with the lower layer consisting mostly of 'other' substratum (rating = 5), which (rather unusually!) represents the layer of water below the floating reed-beds in the pan. The results for the individual HGM sub-units also show, for example, that the open water areas and the outer edge of the depression are situated above a lower layer of 'clayey soil' (rating = 6 in both cases), with an upper substratum layer of 'organic soil' (rating = 4) and 'silt (mud)' (rating = 3) on top of this in the case of the open water areas.

At Level 6B, all the 'organic soil' in the upper layer of substratum associated with Tevreden Pan (as classified at Level 6A) was categorised as 'peat' (rating = 6) because the material has been confirmed to be peat through investigations by Grundling *et al*. (2007) and others. Although the 'loamy soil' and 'clayey soil' in the upper layer of substratum associated with the outer edge of the pan could also be categorised in more detail at Level 6B (see Table 6 in Section 7.4 of the User Manual), this further classification was not applied in the case of the Tevreden Pan worked example because there was insufficient information. No further categorisation of any of primary substratum categories was made (at Level 6B) for the lower layer of substratum associated with Tevreden Pan, for the same reason.

The degree of confidence in the classification of the substratum types associated with Tevreden Pan was high for the upper layer of substratum but low for the lower layer. This was due to a lack of detailed information in the case of the latter, with the classification of substratum types in the lower layer based primarily on very limited anecdotal information.

Table 22. Classification of the upper and lower layers of the substratum associated with Tevreden Pan (at Level 6A), using the rating categories in Table 11

LEVEL 6A: Substratum categories	Proportional rating (0–6)							
	UPPER LAYER				LOWER LAYER			
	Floating reed-beds	Open water	Outer edge	Whole HGM Unit	Floating reed-beds	Open water	Outer edge	Whole HGM Unit
Bedrock	0	0	0	**0**	0	0	0	**0**
Boulders	0	0	0	**0**	0	0	0	**0**
Cobbles	0	0	0	**0**	0	0	0	**0**
Pebbles/gravel	0	0	0	**0**	0	0	0	**0**
Sandy soil	0	0	0	**0**	0	0	0	**0**
Silt (mud)	0	3	3	**1**	0	0	0	**0**
Clayey soil	0	0	2	**1**	0	6	6	**1**
Loamy soil	0	0	3	**1**	0	0	0	**0**
Organic soil	6	4	0	**5**	0	0	0	**0**
Salt crust	0	0	0	**0**	0	0	0	**0**
Other	n/a	n/a	n/a	**n/a**	6	n/a	n/a	**5**

Classification of the vegetation cover and vegetation forms associated with Tevreden Pan was fairly complicated, due to the rather unique nature of this aquatic ecosystem. As described earlier, most of the pan is covered in floating 'rafts' of peat that support dense growths of the common reed, *Phragmites australis*. Although the peat bodies on which these reed-beds grow are floating, the vegetation itself is not floating on water (it is rooted in the peat) and does not constitute 'aquatic vegetation' (defined as 'plants that grow principally on or below the water surface', according to the Glossary of the User Manual). Instead, the reeds are a form of 'herbaceous vegetation' (defined as 'non-woody plants with soft stems, generally less than five metres tall' in the Glossary). Surrounding the floating reed-beds in the pan are permanently inundated open water areas that, at first glance or from aerial photographs, appear to be unvegetated. On closer inspection (e.g. through a site visit to the aquatic ecosystem), however, it can be seen that relatively large portions of the open water areas are actually dominated by submerged aquatic vegetation (as shown in Figure 81), including species such as *Lagarosiphon muscoides*, *Potamogeton thunbergii* and *P. pectinatus* (Grundling *et al*. 2007).

The outer edge of the Tevreden Pan depression is mostly vegetated, although there are unvegetated patches of bare ground. Most of the vegetation in the wetland area around the edge of the pan consists of sedges (including *Cyperus difformis*) and/or rushes (including *Juncus effusus*) (e.g. see Figure 80), although there are also grasses, some patches of reeds, and herbs/forbs (e.g. *Chenopodium glaucum*) growing in this area (Grundling *et al*. 2007).

Table 23 shows how the classification of the vegetation cover and form was dealt with (at Levels 6A to 6C), using the rating scale of the Classification System and the sub-HGM units that were delineated within Tevreden Pan. Overall, the results show that the vegetated portions of the HGM Unit are mostly covered in 'herbaceous vegetation' (rating = 5 at Level 6B), with a small amount of 'aquatic vegetation' (rating = 1 at Level 6B) in relation to the whole pan, although the vegetated portions of the open water area, considered on their own, consist entirely of 'aquatic vegetation' (rating = 6 for open water at Level 6B). It is important to note that the classification of the detailed vegetation forms (at Level 6C) was based on the relative proportions within the respective primary vegetation forms (as classified at Level 6B). For example, the proportional ratings for 'aquatic vegetation' at Level 6C were estimated in relation to the total coverage of aquatic vegetation alone, and not in relation to the total area covered in vegetation (irrespective of form) or the total area of unvegetated and vegetated areas considered together. In other words, the aquatic ecosystem was split into sub-units at the preceding level before applying Level 6C (the same applied to the application of the rating

Figure 81. Photograph of submerged aquatic vegetation in a portion of the open water component of Tevreden Pan.

Table 23. Classification of the vegetation cover and vegetation forms associated Tevreden Pan (at Levels 6A to 6C), according to the rating categories in Table 11.

LEVEL 6A:	**Proportional rating (0–6)**			
Vegetation cover	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Vegetated	6	3	5	**6**
Unvegetated	1	4	2	**1**

LEVEL 6B:	**Proportional rating (0–6)**			
Vegetation form (primary)	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Aquatic	0	6	0	**1**
Herbaceous	6	0	6	**5**
Shrubs/Thicket	0	0	0	**0**
Forest	0	0	0	**0**

LEVEL 6C (for 'Herbaceous'):	**Proportional rating (0–6)**			
Vegetation form (detailed)	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Geophytes	0	n/a	0	**0**
Grasses	0	n/a	2	**1**
Herbs/Forbs	0	n/a	1	**1**
Sedges/Rushes	0	n/a	4	**1**
Reeds	6	n/a	2	**5**
Restios	0	n/a	0	**0**
Palmiet	0	n/a	0	**0**

LEVEL 6C (for 'Aquatic'):	**Proportional rating (0–6)**			
Vegetation form (detailed)	**Floating reed-beds**	**Open water**	**Outer edge**	**Whole HGM Unit**
Floating	n/a	0	n/a	**0**
Submerged	n/a	6	n/a	**6**
Algal mat	n/a	0	n/a	**0**

categories at Levels 6B and 6D). This is why 'submerged' aquatic vegetation was given a rating of 6 for the whole HGM Unit at Level 6C, because all the aquatic vegetation that occurs in the HGM Unit is submerged aquatic vegetation, even though the total area of aquatic vegetation (as classified at Level 6C) is very small in relation to the entire area of the pan.

The classification of vegetation cover and form (at Levels 6A to 6C), as presented in Table 23, was undertaken with a high degree of confidence because it was based on existing information about the vegetation, a site visit, and relatively precise mapping of sub-HGM units. Further categorisation of the vegetation form at Level 6D, which was only applicable to the 'sedges/rushes' category that was present in the 'outer edge' component of the HGM Unit, was not undertaken in the case of this worked example due to insufficiently detailed information about the coverage by different sedge/rush species in the wetland area around the outer edge of the pan.

All the vegetation associated with Tevreden Pan is understood to be naturally-occurring to the area or has become naturalised in the area, based on available information and communication with aquatic scientists with better knowledge of the region. Therefore, at Level 6E, the vegetation status was categorised as 'indigenous' with a medium to high degree of confidence for all the (Level 6B and 6C) vegetation forms present.

For each of the selected descriptors at Level 6, the dominant categories were determined for Tevreden Pan as a whole and, separately, for the three sub-HGM units that were identified within the depression (following the 'rules' provided for the assignment of dominant descriptors in Box 28 of the User Manual, Section 7.7). The results of this exercise (as presented in Table 24) indicate that Tevreden Pan as a whole (already classified at Levels 4 and 5 as an endorheic depression that is dominantly permanently saturated and never/rarely inundated) is an entirely natural (i.e. non-artificial) aquatic ecosystem with an upper substratum dominantly consisting of organic soil (peat, to be more precise), above a lower layer dominantly consisting of water (in other words, most of the upper substratum of peat is floating on a layer of water). In terms of vegetation cover, the pan is dominantly vegetated, with the dominant vegetation form being indigenous herbaceous vegetation consisting mostly of reeds.

The results in Table 24 can also be used to describe the dominant characteristics of each of the sub-HGM units that were classified at Level 6. For example, the dominant characteristics of the open water areas within the pan are that these are dominantly unvegetated, natural areas with an underlying substratum consisting of a layer of organic soil (peat, in particular) above a layer of clayey soil. Referring back to dominant hydroperiod characteristics of these open water areas (Table 21), once can see that these open water areas are mostly permanently inundated with relatively deep water (>2 m maximum depth, i.e. limnetic).

Key points highlighted by this worked example

This worked example of the relatively unique Tevreden Pan aquatic ecosystem shows that, although it is a bit more difficult to understand and apply than typical classification scenarios, the Classification System can be applied to relatively complex situations such as this.

A number of key points were highlighted through the application of the Classification System in this worked example, including the following:

- Application of the Classification System up to Level 4 (HGM Units) is, generally, quite straightforward; it is at Levels 5 and 6 that complicated situations tend to arise.
- While it is more difficult to classify an aquatic ecosystem beyond Level 4, it is also at these lower levels that the unique or special features of ecosystems tend to be identified and captured. This highlights the importance of going beyond Level 4 when using the Classification System for certain purposes, such as environmental impact assessments, where the characteristics of the identified HGM Units need to be understood.
- A relatively in-depth knowledge of an aquatic ecosystem, or availability of relatively detailed existing information, is necessary to properly apply the lower levels of the Classification System. The importance of site visits and collection of field data, or of local knowledge, cannot be over-emphasised here.
- It is important not to forget that the HGM Unit is the focal point of the classification system and all the results of more detailed classification must refer back to the HGM Unit (e.g. by deriving the dominant characteristics using the 'rules' provided for this purpose).

Table 24. Summary Table showing some of the dominant characteristics of Tevreden Pan, according to the selected descriptors at Level 6 of the Classification System

Component	Dominant categories for selected descriptors [Level 6]									
	Natural vs. artificial		Substratum type			Vegetation cover, form and status				
			Upper layer		Lower layer			Detailed vegetation form		
	6A	6B: Artificial sub-categories	6A: Primary categories	6B: Secondary categories	6A: Primary categories	6A: Veg cover	6B: Primary veg form	6C	6D	6E: Veg status
Floating reed-beds	Natural	n/a	Organic soil	Peat	Other (water)	Vegetated	Herbaceous	Reeds	n/a	Indigenous
Open water	Natural	n/a	Organic soil	Peat	Clayey soil	Unveg-etated	n/a	n/a	n/a	n/a
Outer edge	Natural	n/a	Loamy soil / Silt (mud)	[not applied]	Clayey soil	Vegetated	Herbaceous	Sedges/ Rushes	[not applied]	Indigenous
Whole HGM Unit	Natural	n/a	Organic soil	Peat	Other (water)	Vegetated	Herbaceous	Reeds	n/a	Indigenous

- The identification and delineation of sub-HGM units, and estimation of the relative proportions of the HGM Unit occupied by each, is a very useful way of more objectively and accurately applying the rating system developed for Levels 5 and 6 of the Classification System. This is especially the case for relatively complex aquatic ecosystems such as Tevreden Pan, but would not be necessary for simple situations where the rating categories can just be visually estimated ('eye-balled') using aerial imagery or during a site visit.
- It is very useful to identify the dominant hydroperiod and dominant descriptor categories (for selected descriptors that are applied), at Levels 5 and 6, for the HGM Unit/s as a whole and for the individual sub-HGM units within an aquatic ecosystem (if such sub-units are delineated). The results of such an exercise (as presented in Tables 21 and 24 for the Tevreden Pan worked example) provide a good summary of some of the key information required to gain a better understanding of the characteristics of the HGM Units within an aquatic ecosystem that is being classified.

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APPENDIX 2: GLOSSARY

NOTE: underlined words are defined elsewhere in the Glossary.

acid: where the pH of water is less than 6; see Table 5 in User Manual.

active channel: the portion of a river that conveys flowing water at sufficiently regular intervals to maintain channel form (i.e. the presence of distinct bed and banks) and keep the channel free of established terrestrial vegetation.

algae: simple, plant-like organisms with no roots, stems or leaves, ranging in size from microscopic (often unicellular) forms to large (multicellular) forms.

algal mat: an extensive growth of attached or floating, filamentous macro-algae, usually bright green when living and, when dry, forming a grey felt-like covering.

alien vegetation: plants that are not indigenous to a particular area.

- NOTE: Many (but not all) alien plants are alien invasive species.

alkaline: where the pH of water is greater than 8; see Table 5 in User Manual.

alluvial: relating to or derived from unconsolidated material that has been deposited and/or shaped by flowing water, especially along the course of a river.

alluvial channel (*cf*. bedrock channel): a channel formed in unconsolidated material that is able to move during floods (i.e. sand, gravel, cobbles or small boulders).

- NOTE: A 'mixed channel' (consisting of alternating bedrock and alluvial sections) and a 'fixed boulder bed channel' (dominated by large boulders that are unlikely to move, except during extreme flood events) are intermediate channel types between an alluvial channel and a bedrock channel.

aquaculture pond: a pond constructed for the cultivation of aquatic organisms for human consumption or use.

aquatic vegetation: plants that grow principally on or below the water surface.

aquatic ecosystem: an ecosystem that is permanently or periodically inundated by flowing or standing water, or which has soils that are permanently or periodically saturated within 0.5 m of the soil surface.

- NOTE: According to this definition, a wetland is taken to be a type of aquatic ecosystem.

areal cover: measurement of the cover, as a percentage (%), of a feature or descriptor within a wetland or aquatic ecosystem, as seen from an aerial view.

artificial: produced by human beings, not naturally occurring.

bedrock: solid (consolidated), relatively unweathered rock that typically lies beneath surface deposits of soil or alluvium [greater in size than the height of a tall person].

bedrock channel (*cf*. alluvial channel): a channel formed in solid (consolidated) rock, though there may be loose (unconsolidated) material present locally.

bedrock fall (river reach type in a bedrock channel): a steep channel where water flows directly on bedrock with falls and plunge pools.

bench (as relating to landscape setting): a relatively discrete area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops, saddles and shelves. Benches are significantly less extensive than plains, typically being less than 50 ha in area.

boulder: large rock with a diameter greater than 256 mm [greater in size than the length from inside of armpit to wrist].

brackish (as relating to salinity/conductivity): slightly salty. For purposes of the Classification System, brackish water is categorised as having a salinity (or TDS concentration) of 3 to 18 g/l, and/or a conductivity of 500 to 3 000 mS/m.

canal: an artificial waterway constructed for navigation or the conveyance of water, and usually concrete-lined.

cascade (river reach type in a bedrock channel): high-gradient channel dominated by waterfalls, cataracts, plunge pools and bedrock pools.

catchment: the land area from which water runs off into a specified wetland or aquatic ecosystem; a drainage basin.

channel: a landform consisting of two distinct banks and a bed that continuously or periodically conveys flowing water.

channelled valley-bottom wetland: a valley-bottom wetland with a river channel running through it. Channelled valley bottom wetlands are characterised by their position on valley floors and the absence of characteristic flood-plain features. Dominant water inputs to these wetlands are from the river channel flowing through the wetland, either as surface flow resulting from flooding or as subsurface flow, and/or from adjacent valley-side slopes (as overland flow or interflow).

circum-neutral: where the pH of water is between 6 and 8.

classification: the arrangement and division of things into classes or categories according to shared characteristics; categorisation.

clayey soil: a very fine-textured sedimentary deposit dominated by naturally-occurring inorganic (i.e. mineral) soil particles less than 0.002 mm in diameter.

cobble: a rock with a diameter of 64 to 256 mm [between the length of an average-sized hand, measured from bottom of wrist to half-way along middle finger, and the length from inside of elbow to wrist].

concentrated flow (*cf*. diffuse flow): a flow of water contained within a distinct channel. Rivers are characterised by concentrated flow, either permanently or periodically.

conductivity: a measure of the ability of a sample of water to conduct an electrical current, providing an indication of the concentration of Total Dissolved Salts (TDS) in water. Conductivity can be used as a surrogate measure of salinity.

crop (as relating to vegetation status): consisting of cultivated plants, as opposed to indigenous or alien vegetation.

dam (in-channel): an artificial body of water formed by the unnatural accumulation of water behind an artificial barrier that has been constructed across a river channel or an unchannelled valley-bottom wetland.

- NOTE: An in-channel dam is, by definition, a type of depression.

dam (off-channel): an artificial body of water created specifically for the storage of water, and which is *not* located along the course of a river channel or an unchannelled valley-bottom wetland (includes 'irrigation ponds' and 'farm dams').

- NOTE (1): An off-channel dam is, by definition, a type of depression.
- NOTE (2): Water accumulates within these dams through surface runoff, precipitation, and the diversion or pumping of water from other locations (such as from rivers via canals/pipelines, or from groundwater via wind pumps).

dammed: as relates to a depression, where an artificial barrier across a channel, valley-bottom wetland or seep has led to the unnatural accumulation of water, thus forming a depression with its outflow drainage determined by the nature or operation of the artificial barrier.

- NOTE: Dammed depressions (i.e. 'dams') are, by definition, artificial features.

depression: an inland aquatic ecosystem with closed (or near-closed) elevation contours, which increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates. Dominant water sources are precipitation, groundwater discharge, interflow and (diffuse or concentrated) overland flow. Dominant hydrodynamics are (primarily seasonal) vertical fluctuations.

- NOTE (1): Depressions may be flat-bottomed (in which case they are often referred to as 'pans') or round-bottomed, and may have any combination of inlets and outlets or lack them completely.
- NOTE (2): For purposes of the Classification System, natural lakes (including coastal lakes) and dams (i.e. artificial lakes), which are typically drowned valley floors, are considered to be depressions.

delineation (of a wetland): the determination of the boundary of a wetland based on soil, vegetation and/or hydrological indicators.

dichotomous key: a written tool for identifying or classifying unknown objects through a process of elimination, generally consisting of pairs of contrasting statements or questions about the characteristics of the objects being identified or classified.

diffuse (surface or subsurface) flow (*cf*. concentrated flow): when water flow is not concentrated within a distinct channel, but is rather spread as sheet-flow on the ground surface, or as seepage below the ground surface.

ecoregions: geographic regions delineated on the basis of physical/abiotic factors.
- NOTE: The 'Level I Ecoregions' for South Africa, Lesotho and Swaziland (Kleynhans *et al*. 2005), developed by the Department of Water Affairs (DWA), are applied at Level 2 of the Classification System. These Ecoregions are based on physiography, climate, geology, soils and potential natural vegetation.

ecosystem: a biological community of interacting organisms and their physical environment.

emergent vegetation (*cf*. submerged vegetation): plants that are rooted in the substratum of an inland aquatic ecosystem but that emerge above the water surface (if present), with most of the plant structures visible above the surface. These plants are not considered to be aquatic vegetation because their leaves and flowers do not occur primarily on or below the water surface.

endorheic (*cf*. exorheic): as relates to a depression, inward-draining with no transport of water into downstream systems via subsurface or surface flow. Water leaves via evapotranspiration and infiltration only.

estuarine system: a body of surface water, (a) that is part of a watercourse that is permanently or periodically open to the sea; (b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the watercourse is open to the sea; *or* (c) in respect of which the salinity is measurably higher as a result of the influence of the sea.
- NOTE: The upstream boundary of an estuary is taken to be the extent of tidal influence (i.e. the point up to where tidal variation in water levels can still be detected), *or* the extent of saline intrusion, *or* the extent of back-flooding during the closed mouth state, *whichever is furthest upstream*.

evaporation: the loss of water from a free water surface or from the soil surface by vaporisation (i.e. the conversion of liquid water into a gaseous state).

evapotranspiration: the movement of water from the Earth's surface into the atmosphere through the combined processes of evaporation and transpiration.

excavation: an artificial depression created by digging out material from the ground.

exorheic (*cf*. endorheic): as relates to a depression, outward-draining with water transported to downstream systems via concentrated or diffuse surface flow, or as subsurface flow.

floating aquatic vegetation: plants that have their foliage and flowers lying on the water surface, which can either be free-floating or floating attached (i.e. rooted in the underlying substratum).

floating attached (rooted) (floating aquatic vegetation type): aquatic plants that are rooted in the underlying substratum but have their leaves and flowers floating on the water surface.
- NOTE: 'Floating attached' aquatic vegetation is also known as 'rooted floating' or 'floating-leaved' aquatic vegetation.

floodplain: the mostly flat or gently-sloping land adjacent to and formed by an alluvial river channel under its present climate and sediment load, which is subject to periodic inundation by overtopping of the channel bank.
- NOTE: Floodplains are typically characterised by a suite of geomorphological features associated with river-derived depositional processes, including point bars, scroll bars, oxbow lakes and levees.

floodplain depression: a depression occurring as a feature within a broader floodplain wetland complex, including 'backwater depressions', 'floodplain pans', 'meander cut-offs', 'oxbow lakes' and other depressional features typically associated with a floodplain.

floodplain flat: a non-depressional, near-level wetland area forming part of a floodplain.

floodplain wetland: a wetland area within a floodplain. Water and sediment input to these wetlands is mainly via overspill from a river channel during flooding.
- NOTE: Portions of a floodplain may not be wetland.

flow regime (as relates to a river): the frequency, timing and duration of flow.

fluvial: of or resulting from flowing water associated with a river.

forest: woody vegetation dominated by trees with a canopy cover of 75% or more (i.e. with overlapping crowns). A forest may or may not have an understorey of young trees or shrubs and a herbaceous layer below an overstorey of mature trees.
- NOTE: In the Classification System, forested Inland Systems are further divided into riparian forest and forested wetland, with the former further divided into upper and lower river types.

forested wetland (swamp forest): a community of trees occurring in soils that are permanently saturated or seasonally inundated with non-saline water. Forested wetlands are often fed primarily by groundwater that is close to or at the surface of the ground, and sometimes occur in peat soils.

- NOTE: Swamp forests are the only indigenous forested wetland type associated with Inland Systems in South Africa; they are restricted to the KwaZulu-Natal and Eastern Cape provinces, distributed in pockets and narrow ribbons extending in a narrow belt along the Indian Ocean coast.

free-floating (floating aquatic vegetation type): aquatic plants that float entirely on the water surface, including their roots.

fresh (as relates to salinity/conductivity): not salty. For purposes of the Classification System, fresh water is categorised as having a salinity (or TDS concentration) of less than 3 g/l, and/or a conductivity of less than 500 mS/m.

functional unit: for this Classification System, the combination of a Hydrogeomorphic (HGM) Unit with its hydrological regime.

geology (lithology): type of rock or sedimentary deposit underlying a particular area, forming a discrete and recognisable lithostratigraphic unit of reasonable homogeneity.

geophytes (herbaceous vegetation type): non-woody plants, generally less than 2 m tall, that propagate by underground storage organs (i.e. bulbs, tubers, corms, rhizomes or stolons).

gradient: the degree of steepness of an incline, determined by the ratio between the vertical rise and the corresponding horizontal distance between two points.

gravel (substratum type): stone particles with diameters of 2 to 4 mm [particle size bigger than a sand grain but smaller than a finger nail].

grasses (herbaceous vegetation type): tuft-forming or creeping non-woody plants without brightly coloured flowering parts and with leaves that consist of three parts—a long, narrow leaf blade, a leaf sheath and a ligule (i.e. inconspicuous membrane or ring of hairs found between the leaf blade and leaf sheath).

groundwater (*cf*. subsurface water): subsurface water in the saturated zone below the water table (i.e. the water table marks the upper surface of groundwater systems).

herbs/forbs (herbaceous vegetation type): non-woody flowering plants, generally less than 2 m tall, which are not sedges, rushes, reeds, restios, palmiet or geophytes.

herbaceous vegetation: non-woody plants with soft stems, generally less than five metres tall (includes grasses, herbs/forbs, sedges/rushes, reeds, restios, palmiet and geophytes).

hilltop (a type of bench): relatively flat area at the top of a mountain or hill, flanked by down-slopes in all directions; a crest. The gradient of the surrounding slopes may vary from gentle to steep.

hydraulic conductivity: measure of the ease with which water will pass through a layer of rock or soil.

hydrogeomorphic: a combination of hydrology (i.e. the nature of the movement of water) and geomorphology (i.e. landform characteristics and processes).

hydrogeomorphic (HGM) type: one of the seven primary HGM Units of the Classification System, as categorised at Level 4A (namely: river, floodplain wetland, channelled valley-bottom wetland, unchannelled valley-bottom wetland, depression, seep or wetland flat).

hydrogeomorphic (HGM) unit: a type of aquatic ecosystem distinguished primarily on the basis of, (i) landform (which defines the shape and localised setting of the ecosystem); (ii) hydrological characteristics (which describe the nature of water movement into, through and out of the ecosystem); and (iii) hydrodynamics (which describe the direction and strength of flow through the ecosystem). The Classification System recognises seven primary HGM Units (or HGM types) for Inland Systems.

hydrological regime: the typical cycle of water movement in an aquatic ecosystem.

hydromorphic soil: a soil that, in its undrained condition, is saturated or inundated long enough to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation. Such soils typically display distinct characteristics resulting from prolonged saturation (such as a low-chroma soil matrix or a high percentage of organic carbon).

hydroperiod: the frequency and persistence of saturation and/or inundation within an aquatic ecosystem.

hydrophytic vegetation: plants that are adapted to growing in water or in soils that are, at least periodically, deficient in oxygen (i.e. anaerobic) as a result of soil saturation or inundation; plants typically found in wet habitats.

hypersaline (as relates to salinity/conductivity): very salty. For purposes of the Classification System, hypersaline water is categorised as having a salinity (or TDS concentration) of more than 48 g/l, and/or a conductivity of more than 8 000 mS/m.

indigenous vegetation: plants that are naturally occurring in a particular area.

infiltration: downward permeation of water below the ground surface, either into the soil or into the groundwater.

inland system: an aquatic ecosystem with no existing connection to the ocean. These ecosystems are characterised by the complete absence of marine exchange and/or tidal influence.
- NOTE: While an Inland System itself does not have an existing connection to the ocean, the estuaries into which most rivers flow are by definition connected to the ocean, either permanently or temporarily.

interflow: the lateral movement of water, usually derived from precipitation, that occurs in the upper part of the unsaturated zone between the ground surface and the water table. This water generally enters directly into a wetland or other aquatic ecosystem, without having occurred first as surface runoff, or it returns to the surface at some point down-slope from its point of infiltration.

intermittent (as relates to non-perennial flow regime): water flows for a relatively short time of less than one season's duration (i.e. less than approximately 3 months), at intervals varying from less than a year to several years.

intermittently inundated: holding surface water for irregular periods of less than one season (i.e. less than approximately 3 months), at intervals varying from less than a year to several years.

intermittently saturated: with all the spaces between the soil particles filled with water for irregular periods of less than one season (i.e. less than approximately 3 months). This corresponds to the 'temporary (outer) zone' of a wetland, according to the terminology used in the DWAF (2005) wetland delineation manual.
- NOTE: In the Classification System, saturation is considered within the upper 0.5 m of the soil surface (which is the commonly accepted maximum depth to which soil saturation is considered for wetland delineation purposes).

inundated: covered by water (water is observably present at the surface).

irrigated land: areas purposefully supplied with water to aid the growth of plants (often crops), including land irrigated by controlled flooding, where the supply of water has resulted in the formation of an artificial aquatic ecosystem.

lentic (*cf*. lotic): of or relating to standing (still) waters.

limnetic (*cf*. littoral): for purposes of the Classification System, inundated to a maximum depth of 2 m or more at the average annual low-water level of an open waterbody.

lithostratigraphic (as relates to geology/lithology): pertaining to the physical characteristics of and the relations between the layers of rock forming the Earth's crust.

littoral (*cf*. limnetic): for purposes of the Classification System, inundated to a maximum depth of less than 2 m at the average annual low-water level of an open waterbody.

loamy soil (substratum type): a mineral soil consisting of a mixture of clay-, silt- and sand-sized particles, together with some organic material.

lotic (*cf*. lentic): of or relating to running (flowing) waters.

lower foothills (as relates to river zonation): 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. Floodplain often present. Characteristic gradient 0.001–0.005.

lowland river (as relates to river zonation): low-gradient, alluvial sand-bed channel, typically regime reach type. Often confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increase in silt content in bed or banks. Characteristic gradient 0.0001–0.001.

macrophyte: a plant (not algae) that grows in or near water, which can be emergent, submerged or floating.

macro-algae (*cf*. macrophyte): larger forms of algae that are visible to the naked eye.

marine system: for purposes of the Classification System, that part of the open ocean overlying the continental shelf and/or its associated coastline up to a depth of 10 m at low tide (i.e. not extending beyond the shallow photic zone as described by the marine component of the South African National Spatial Biodiversity Assessment 2004).

mineral soil (*cf*. organic soil): non-organic soil (i.e. with an average organic carbon content of less than 10% throughout a vertical distance of 200 mm) consisting primarily of rock and/or mineral particles smaller than 2 mm in diameter. Mineral soils include sandy soil, silt (mud), clayey soil and loamy soil.
- NOTE: Certain mineral soils can still have a relatively high organic carbon content (but less than 10%) and, therefore, appear to be visibly dark in colour. However, these soils are not organic soils, by definition, and should be classified according to texture as a mineral soil with a high organic carbon content.

mottles: as relates to wetland soils, spots of colour in the soil that contrast with the background (matrix) soil colour. Mottles occur where minerals in the soil that have been reduced under anaerobic conditions are re-oxidised.

mountain headwater stream (as relates to river zonation): 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. Characteristic gradient greater than 0.1.

mountain stream (as relates to river zonation): steep-gradient stream dominated by bedrock and boulders, locally cobble or coarse gravel in pools. Reach types include cascades, bedrock fall, step-pool, plane bed. Approximate equal distribution of 'vertical' and 'horizontal' flow components. Characteristic gradient 0.040–0.099.

natural: existing in, or produced by, nature; not made or caused by humankind.

never/rarely inundated: covered by water for less than a few days at a time (up to a week at most), if ever.

non-perennial (as relates to flow regime): does not flow continuously throughout the year, although pools may persist.

open reservoir: an uncovered concrete structure for storing water.

open waterbody: an inland aquatic ecosystem that contains standing water on a permanent basis (i.e. it is permanently inundated).
- NOTE: For purposes of the Classification System, rivers, streams, canals and other aquatic ecosystems where water moves from one place to another via a channel are not considered to be open waterbodies. Dams along a river (classified as artificial depressions with dammed outflow drainage) are, however, considered to be open waterbodies if they contain water permanently.

organic soil (*cf*. mineral soil): topsoil with an average organic carbon content of at least 10% throughout a vertical distance of 200 mm (after Soil Classification Working Group 1991).
- NOTE: An organic soil is *not* necessarily peat.

palmiet (herbaceous vegetation type): leafy *Prionium serratum* plants (common name 'palmiet'), typically associated with river channels and valley-bottom wetland systems.

peat (*cf*. organic soil): a sedentarily (*in situ*) accumulated material comprising of at least 30% (dry mass) of dead organic matter (after Joosten & Clark 2002), generally formed under permanently saturated conditions.

peatland: a wetland area (vegetated or unvegetated) with a naturally accumulated peat layer that has a minimum thickness of 300 mm; also known as a mire.

pebble (substratum type): a stone particle with a diameter of 4 to 64 mm [between the size of a finger nail and the length of an average-sized hand from wrist to half-way along middle finger].

perched water table: a localised zone of saturation close to the soil surface that occurs when there is a relatively impermeable layer of rock or sediment between the ground surface and the regional water table.

perennial (as relates to flow regime): flows continuously throughout the year, in most years.

permanently inundated: with surface water present throughout the year, in most years.

permanently saturated: of wetland soils, where all the spaces between the soil particles are filled with water throughout the year, in most years. This corresponds to the 'permanent (inner) zone' of a wetland, according the terminology used in the DWAF (2005) wetland delineation manual.
- NOTE: In the Classification System, saturation is considered within the upper 0.5 m of the soil surface (which is the commonly accepted maximum depth to which soil saturation is considered for wetland delineation purposes).

pH: a measurement of the negative logarithm of the hydrogen ion concentration in a water sample or waterbody.
- NOTE: The pH of pure water is 7.0 and is known as neutral. As the concentration of hydrogen ions in a solution increases, so pH decreases (below 7.0) and the solution becomes more acid. Conversely, as the concentration of hydrogen ions in a solution decreases, pH increases (above 7.0) and the solution becomes more alkaline.

plain (as relates to landscape setting): an extensive area of low relief. These areas are generally characterised by relatively level, gently undulating or uniformly sloping land with a very gentle gradient (typically less than 0.01 or 1:100) that is not located within a valley. Includes coastal plains, interior plains, and plateaus.

- NOTE (1): For purposes of the Classification System, plains are differentiated from valley floors by the absence of side-slopes within 500 m of an Inland System.
- NOTE (2): Plains are more extensive than benches in the landscape, generally being greater than 50 ha in area.

plane bed (river reach type in an alluvial channel): topographically uniform bed formed in coarse alluvium (cobble or small boulder) lacking well defined scour or depositional features.

plantation: an area in which trees have been planted, especially for commercial purposes, in contrast to a forest consisting of indigenous or alien invasive trees.

pool-rapid (river reach type in a bedrock channel): channel characterised by pools backed up behind channel-spanning bedrock intrusions forming rapids.

pool-riffle (river reach type in an alluvial channel): channel characterised by an undulating bed that defines a sequence of coarse bars (cobbles or gravel) (riffles) and scour pools.

precipitation: any form of water that falls to or condenses on the ground (including rain, snow, hail, sleet, mist, etc).

rapid: section of a river channel characterised by fast, turbulent flows over and around exposed rocks (generally consisting of bedrock and/or large boulders).

reeds (herbaceous vegetation type): tall (up to 3 m), unbranched plants with stiff (semi-woody) stems and/or long relatively stiff leaves, which generally grow at the water's edge with their roots submerged in water or saturated soil.

- NOTE: *Phragmites australis* (common reed) and *Typha* spp. (bulrush/cattail) are examples of reeds.

regime (river reach type in an alluvial channel): sand- or gravel-dominated channel characterised by low relative roughness and exhibiting a succession of bedforms with increasing flow velocity. Typical features include plane bed morphology, sand waves, mid-channel bars and/or braid bars.

rejuvenated bedrock fall (as relates to river zonation): 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. Characteristic gradient greater than 0.02.

rejuvenated foothills (as relates to river zonation): 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 floodplain may be present between the active and macro-channel. Characteristic gradient 0.001–0.02.

restios (herbaceous vegetation type): plants belonging to the family Restionaceae, which have very small leaves consisting only of scale-like sheathes that envelope the culms or stems; the sheaths are often brown, and the culms or stems green.

- NOTE: Restios grow predominantly in the southwestern Cape, and constitute one of the three main elements of Fynbos vegetation (the other two elements being proteas and ericas).

riffle: relatively short section of a river channel characterised by very shallow, flickering flow consisting of undular (non-breaking) or breaking standing waves over coarse alluvial substrata (from gravel to cobble), where the water covers most of the substrata.

riparian forest: a community of trees (i.e. a forest) occurring in the riparian zone of a river.

riparian zone or **riparian area**: area of land directly adjacent to the active channel of a river, which is influenced by river-induced or river-related processes. The South African National Water Act (Act No. 36 of 1998) defines 'riparian habitat' to include "...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 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."

- NOTE: Riparian areas, which are saturated or flooded for prolonged periods, would be considered wetlands and should be classified as such. However, many riparian areas are not wetlands (e.g. an area where alluvium is periodically deposited by a stream during floods but which is well drained).

river: a linear landform with clearly discernable bed and banks, which permanently or periodically carries a concentrated flow of water. A river is taken to include both the active channel and the riparian zone as a unit.

- NOTE: In the Classification System, a river can be further divided into longitudinal zones, according to the geomorphological river zonation scheme of Rowntree & Wadeson (2000).

river reach: a length of river characterised by a particular channel pattern and channel morphology, resulting from a uniform set of local constraints on channel form. A river reach is typically hundreds of meters in length.

river zonation: categorisation of the longitudinal variation in physical characteristics and associated biological distributions down the length of a river, which provides a classification framework that can be used to group similar river reaches while retaining the idea of a longitudinal change down the system.

- NOTE: In South Africa, the most commonly used river zonation scheme is that of Rowntree & Wadeson (2000), whereby valley form and valley floor (or river) gradient are the primary criteria for distinguishing between geomorphological river zones. Ten longitudinal zones are recognised in the scheme, seven of which are associated with a 'normal' river profile (namely: source zone, mountain headwater stream, mountain stream, transitional, upper foothills, lower foothills and lowland river), while the remaining three zones are associated with steepened rejuvenated river profiles (namely: rejuvenated bedrock fall, rejuvenated foothills and upland floodplain).

rushes (herbaceous vegetation type): stiff, non-woody plants of the genus *Juncus*, which grow in tufts of cylindrical unbranched stems with flowering parts branching off to the side of the stem near the apex.

- NOTE: The so-called bulrush, *Typha capensis*, is usually considered to be a reed, not a rush.

saddle (a type of bench): relatively flat, high-lying area flanked by down-slopes on two opposite sides in one direction and up-slopes on two opposite sides in an approximately perpendicular direction. The gradient of the surrounding slopes may vary from gentle to steep.

saline (as relates to salinity/conductivity): salty. For purposes of the Classification System, saline water is categorised as having a salinity (or TDS concentration) of 18 to 48 g/l, and/or a conductivity of 3 000 to 8 000 mS/m.

salinity: saltiness; the concentration of dissolved inorganic solids in water. Salinity and Total Dissolved Solids (TDS) concentration are virtually identical in waters with small quantities of dissolved organic matter relative to the amount of inorganic matter (as is the case for waters with a high salinity, close to that of seawater at 35 g/l). Conductivity can be used as a surrogate measure of salinity.

- NOTE: For purposes of the Classification System, the terms 'salinity' and 'TDS' are used interchangeably, although it is acknowledged that this is not technically correct due to discrepancies in these measurements where the proportion of dissolved organic matter forms a significant fraction of a water sample.

salt crust: a layer of dried alkali salts covering the substratum.

salt works: a place where salt is produced commercially, usually by evaporation of natural brines.

sand: see sandy soil.

sandy soil: soil dominated by mineral particles with diameters from 0.06 to 2.00 mm (i.e. coarse grit).

saturated (waterlogged): of soil, a condition in which the spaces between the soil particles are filled with water but surface water is not necessarily present.

- NOTE: In the Classification System, saturation is considered within the upper 0.5 m of the soil surface (which is the commonly accepted maximum depth to which soil saturation is considered for wetland delineation purposes).

seasonal (as relates to non-perennial flow regime): with water flowing for extended periods during the wet season/s (generally between 3 to 9 months duration) but not during the rest of the year.

seasonally inundated: with surface water present for extended periods during the wet season/s (generally between 3 to 9 months duration) but drying up annually, either to complete dryness or to saturation.

seasonally saturated: of wetland soils, with all the spaces between the particles filled with water for extended periods (generally between 3 to 9 months duration), usually during the wet season/s, but dry for the rest of the year. This corresponds to the 'seasonal zone' of a wetland, according to the terminology used in the DWAF (2005) wetland delineation manual.

- NOTE: In the Classification System, saturation is considered within the upper 0.5 m of the soil surface (which is the commonly accepted maximum depth to which soil saturation is considered for wetland delineation purposes).

sedges (herbaceous vegetation type): stiff, grass-like plants of the family Cyperaceae, sometimes referred to as 'nut-grasses'. Sedges are distinguished from grasses in that they do not have a leaf sheath (their leaves are attached directly to the culm or stem) or when they do, it is closed around the culm, where grasses have an open leaf sheath. The culms of many (but not all) sedges are triangular in cross section, while the culms of grasses are always cylindrical.

seep: a wetland area located on gently to steeply sloping land and dominated by the colluvial (i.e. gravity-driven), unidirectional movement of water and material down-slope. Seeps are often located on the side-slopes of a valley but they do not, typically, extend onto a valley floor. Water inputs are primarily via subsurface flows from an up-slope direction.

- NOTE (1): Seeps are often associated with diffuse overland flow ('sheetwash') during and after rainfall events.
- NOTE (2): For purposes of the Classification System, the drainage of a seep is classified (at Level 4C) according to whether water from the seepage area concentrates towards a point where it exits via channelised surface flow (i.e. 'with channelled outflow') or whether water from the seepage area exits via diffuse surface or subsurface flow (i.e. 'without channelled outflow'). It is important to note that a seep abutting a distinct river channel and feeding into the channel via diffuse surface flow or subsurface flow, but not having a channelised outlet from the seepage area to the adjacent channel, would be classified as a 'seep without channelled outflow' even though it feeds into a channel.
- NOTE (3): Seeps can occur in relatively flat or very gently-sloping landscapes where there is a unidirectional subsurface flow of water.

seepage: percolation of water through a soil layer, as subsurface flow.

shelf (a type of bench): relatively high-lying, localised flat area along a slope, representing a break in slope with an up-slope on one side and a down-slope on the other side in the same direction; a terrace or a ledge. The gradient of the surrounding slopes may vary from gentle to steep.

shrub: a self-supporting, generally multi-stemmed, woody plant less than five metres in height, including true shrubs, young trees and trees that are small or stunted as a result of environmental conditions. Shrubs that are single-stemmed always branch from the base. A dense growth of shrubs is called thicket.

silt (mud): soil dominated by mineral particles with diameters of less than 0.06 mm (i.e. very fine material).

slope (as relates to landscape setting): an inclined stretch of ground typically located on the side of a mountain, hill or valley, not forming part of a valley floor. Includes scarp slopes, mid-slopes and foot-slopes.
- NOTE: For purposes of the Classification System, as a guideline, the gradient of a slope is taken to be typically greater than or equal to 0.01 (i.e. 1:100).

soil profile: a vertical section of the soil at a specific location, from the ground surface to a certain depth, showing the different soil layers (or 'horizons').

source zone (as relates to river zonation): low-gradient, upland plateau or upland basin able to store water, which typically has spongy or peaty hydromorphic soils.

step-pool (river reach type in an alluvial channel): channel characterised by large clasts (boulders or cobbles) which are organised into discrete channel-spanning accumulations that form a series of steps separating pools containing finer material.

stormwater pond: an artificial body of water that forms part of a stormwater reticulation system, including retention ponds, detention ponds and attenuation ponds.

submerged aquatic vegetation (*cf*. emergent vegetation): aquatic plants that are rooted in the underlying substratum of a wetland or aquatic ecosystem, with their foliage below the water surface (*cf*. floating attached aquatic vegetation). Submerged aquatic plants only produce reproductive organs (i.e. flowers) above the water surface, with the rest of the plant generally remaining underwater.

substratum: the material that constitutes the bottom of an aquatic ecosystem.

subsurface water (*cf*. groundwater): all water occurring beneath the Earth's surface, including soil moisture, that in the vadose (unsaturated) zone and groundwater.

tarn: a small, often circular, steep-banked open waterbody occurring at high altitude; a mountain lakelet.

terrestrial: of or on dry land; outside the boundaries of a wetland or other aquatic ecosystem.

thicket: a very dense growth of shrubs.

total dissolved solids (TDS): a measure of the total amount of material dissolved in water, including all material that is both organic and inorganic, and both ionized and un-ionized.
- NOTE (1): For purposes of the Classification System, the terms 'salinity' and 'TDS' are used interchangeably, although it is acknowledged that this is not technically correct due to discrepancies in these measurements where the proportion of dissolved organic matter forms a significant fraction of a water sample.
- NOTE (2): Conductivity measurements can be translated into TDS estimates using a conversion factor (e.g. it has been found that $<\text{TDS in mg/l}> \approx <\text{conductivity in mS/m}> \times 6.6$ for South Africa as a whole, although a multiplicand of 5.5 is somewhat more accurate for the naturally acidic waters of the southwestern Cape). It is important to bear in mind, however, that TDS estimates based on conductivity measurements will be inaccurate if there is a large amount of un-ionised material (e.g. dissolved organic carbon) in the water because conductivity measurements only consider ionised material.

transitional (as relates to river zonation): moderately steep stream dominated by bedrock or boulders. Reach types include plane bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited floodplain development. Characteristic gradient 0.020–0.039.

transpiration: the transfer of water from plants into the atmosphere via stomata (i.e. small openings on the underside of leaves).

tree: a self-supporting, single-stemmed woody plant five metres or more in height.

unchannelled valley-bottom wetland: a valley-bottom wetland without a river channel running through it. These wetlands are characterised by their location on valley floors, an absence of distinct channel banks, and the prevalence of diffuse flows. Water inputs are typically from an upstream channel and seepage from adjacent valley side-slopes, if present.

- NOTE (1): These areas are usually characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment and the presence of vegetation.
- NOTE (2): Preferential flow paths (minor channels) are often present, particularly towards the lower end of the wetland where flow often begins to concentrate.

unvegetated: without vegetation, consisting instead of bare substratum or open water.

upland floodplain (as relates to river zonation): an upland low-gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment. Characteristic gradient less than 0.005.

upper foothills (as relates to river zonation): 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 floodplain of sand, gravel or cobble often present. Characteristic gradient 0.005–0.019.

valley: an elongated, relatively narrow region of low land between ranges of mountains, hills, or other high areas, often having a river running along the bottom.

valley-bottom wetland: a mostly flat wetland area located along a valley floor, often connected to an upstream or adjoining river channel.

- NOTE: In the Classification System, valley-bottom wetlands are categorised as channelled valley-bottom wetland or unchannelled valley-bottom wetland.

valley floor (as relates to landscape setting): the base of a valley, situated between two distinct valley side-slopes, where alluvial or fluvial processes typically dominate.

- NOTE: For the purposes of the Classification System, as a guideline, the side-slopes of a valley floor are typically within 500 m of an Inland System located thereon.

vegetated: with vegetation (as opposed to bare substratum or open water), in the form of macro-algae and/or macrophytes.

water table: the upper surface of groundwater or that level below which the soil is completely saturated with water.

wetland: for this Classification System, as defined in the National Water Act (Act No. 36 of 1998), "a wetland is land that 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."

wetland flat: a level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. The primary source of water for a wetland flat is generally precipitation, with the exception of wetland flats situated on a coastal plain where groundwater may rise to or near the ground surface. Horizontal water movements within the wetland are typically weak and multi-directional, if present at all.

- NOTE (1): It is important not to confuse 'wetland flats' (as incorporated as a primary HGM Unit at Level 4A of the Classification System) with 'floodplain flats' (which have been included at Level 4B as a type of floodplain wetland). Floodplain flats are connected to and fed by a river, while the 'wetland flats' included at Level 4A are fed only by precipitation and/or groundwater.
- NOTE (2): Closed elevation contours are not evident around the edge of a wetland flat (as would be the case for a depression).
- NOTE (3): Small ponded areas that form depressional micro-features within an extensive 'wetland flat' are considered to be part of the 'wetland flat'.

WWTW (wastewater treatment works) pond: an artificial body of water associated with a wastewater (i.e. sewage) treatment works (WWTW), including effluent ponds, settling ponds, sludge ponds, oxidation ponds and maturation ponds.

APPENDIX 3: DICHOTOMOUS KEYS FOR THE CLASSIFICATION OF INLAND AQUATIC ECOSYSTEMS (LEVELS 3 TO 5)

A series of 'dichotomous keys' have been developed to assist with the classification of inland aquatic ecosystems. A dichotomous key is simply a systematic method for deciding on the identity of something (like an animal or plant, or a biophysical feature) by being led through a series of choices that leads you to the correct name of the object.

How to use the keys

Four keys have been developed for Inland Systems—one for the classification of Landscape Units at Level 3 (Key 1), one for the classification of Hydrogeomorphic Units at Level 4 (Key 2), and two keys for the classification of the hydrological regime at Level 5 (Key 3a for river flow type and Key 3b for hydroperiod category). No keys have been developed for the categorisation of the regional setting or of descriptors, at Levels 2 and 6 of the Classification System, respectively. In the case of the regional setting, no key is necessary because this is simply ascertained by referring to the appropriate map for the chosen spatial framework. The use of descriptors is dealt with in Section 7 of the User Manual.

To classify a particular Inland System using the keys, you should generally start at the beginning of the key for the classification of Landscape Units (Key 1) and move on from there to the keys for the classification of HGM Units (Key 2) and the hydrological regime (Keys 3a and 3b). In situations where only the classification of HGM Units and/or the hydrological regime is required, you can skip the preceding keys. This is generally not advised, however, as it could lead to the incorrect or incomplete classification of the type of inland aquatic ecosystem.

What is a DICHOTOMOUS KEY?

A 'key', in this context, is a tool used to identify or classify specific objects. 'Dichotomous' means divided into two parts. It follows then that a 'dichotomous key' is a written tool for identifying/classifying unknown objects through a process of elimination, generally consisting of pairs of contrasting statements/questions (also known as 'couplets') about the characteristics of the objects being identified/classified. Essentially, a dichotomous key can be visualised as a series of branches or intersections, where choices are made between successive alternatives, eventually resulting in the isolation and identification/classification of a single object.

Each key consists of a series of numbered questions. To go through a key, you must simply answer each question with 'yes' or 'no', starting with question # 1. The yes/no answer to each question will direct you to the number of the next question that must be answered, given in round brackets in the key (e.g. (go to 2), (go to 4), etc.). Questions must be answered in this manner until, instead of a new question number, the name of the relevant category is given (i.e. Landscape Unit at Level 3, HGM Unit at Level 4, and River Flow Type or Hydroperiod Category at Level 5). For each name, a reference to the relevant section in the User Manual is given in square brackets—this guides you to the place where more detailed information and explanations can be found about the particular item. In addition, instructions are given in round brackets below the name, to direct you to the next key or to the next question number in the same key for categories that can be divided further. At this stage, you can either go to the next key (if no further division of the category is required or possible) or to the next question in the same key before moving on to the next key (if further division of the category is required and possible).

Important and/or potentially confusing terms for certain questions in the keys have been highlighted in bold and definitions for these terms are provided in the Glossary (Appendix 2). Relevant definitions should be referred to when answering questions that have these bold-highlighted terms, particularly the first time the keys are used. You should also refer to the definition and description of the category that you arrive at as the final answer when using the keys (in the User Manual and accompanying Glossary), to check that your answer is consistent with the definition and description of the particular term.

If, while using one of the keys, you reach a point where you are unable to answer a particular question, you should work your way back through the preceding questions and reconsider your answers, paying particular attention to the definitions of relevant terms. In some cases, additional information provided in the relevant section/s of the User Manual could be helpful in reaching an answer. In others, you may find that you are unable to classify the aquatic ecosystem beyond a particular level and you will have to classify it as 'unknown' beyond that point unless you can obtain more information to help you with the classification (e.g. by conducting a site visit if this has not been done yet). For certain questions in the keys, there is an in-built feedback loop to an earlier question (e.g. (go back to 4)) that requires you to reconsider an answer that was initially chosen.

Key 1: Landscape Unit (Level 3)

Start with Key 1, below, to assist you with the classification of Landscape Units (at Level 3).

Key 1: Landscape Unit (Level 3)		
LEVEL 3A		
1.	Is the inland aquatic ecosystem located on the base of a **valley**, situated between two distinct valley side-slopes (with the bottom of the **slopes** generally within 500 m of the aquatic ecosystem)?	
a)	YES	**Valley floor** [see Section 4.2.1] (go to Key 2: HGM Unit)
b)	NO	(go to **2**)
2.	Is the inland aquatic ecosystem located on an inclined stretch of ground (**gradient** >1:100, generally) that typically forms the side of a mountain, hill or valley?	
a)	YES	**Slope** [see Section 4.2.2] (go to Key 2: HGM Unit)
b)	NO	(go to **3**)
3.	Is the inland aquatic ecosystem located within an extensive area (generally >50 ha or 0.5 km^2) of low relief (**gradient** <1:100, generally)?	
a)	YES	**Plain** [see Section 4.2.3] (go to Key 2: HGM Unit)
b)	NO	(go to **4**)
4.	Is the inland aquatic ecosystem located within a discrete area (generally <50 ha or 0.5 km^2 in extent) of high ground (relative the broad surroundings) that is mostly level or nearly level (**gradient** generally <1:100)?	
a)	YES	**Bench** [see Section 4.2.4] (go to **5** or to Key 2: HGM Unit)
b)	NO	(go back to **1**)
LEVEL 3B		
5.	Is the inland aquatic ecosystem located on relatively flat ground at the top (crest) of a mountain or hill, flanked by down-slopes in all directions?	
a)	YES	**Hilltop** [see Section 4.2.4(a)] (go to Key 2: HGM Unit)
b)	NO	(go to **6**)
6.	Is the **bench** on which the inland aquatic ecosystem is located flanked by down-slopes on two opposite sides in one direction and by up-slopes on the two remaining opposite sides in an approximately perpendicular direction?	
a)	YES	**Saddle** [see Section 4.2.4(b)] (go to Key 2: HGM Unit)
b)	NO	(go to **7**)
7.	Is the **bench** on which the inland aquatic ecosystem is situated a localised flat area along a **slope**, with an up-slope on one side and a down-slope on the other side in the same direction (i.e. a terrace or a ledge)?	
a)	YES	**Shelf** [see Section 4.2.4(c)] (go to Key 2: HGM Unit)
b)	NO	(go back to **4**)

Key 2: Hydrogeomorphic Unit (Level 4)

Use Key 2, below, to assist you with the classification of HGM Units (at Level 4), preferably after having worked through Key 1 for the classification of Landscape Units.

Key 2: HGM Unit (Level 4)		
LEVEL 4A (HGM type)		
1.	Is the Inland System of a linear landform with clearly discernable bed and banks, which permanently or periodically carries a **concentrated** flow of water?	
a)	YES	**River** [see Section 5.1] (go to **Level 4B*** or to **Key 3a**: River Flow Type)
b)	NO	(go to **2**)
2.	Is the Inland System a **wetland** (or, in some cases, an **open waterbody**), which is situated adjacent or close to a distinct **active channel** of a **river** <u>and</u> likely to be subject to water input from periodic (intermittent to seasonal) overtopping of the **channel** banks?	
a)	YES	(go to **3**)
b)	NO	(go to **4**)
3.	Is the **wetland** (or **open waterbody**) located on a **valley floor** <u>and</u> likely to receive water via (surface and subsurface) runoff from one or both of the adjacent valley side-slopes, with an <u>absence</u> of river-derived depositional features that are characteristic of a **floodplain** (such as levees)?	
a)	YES	**Channelled valley-bottom wetland** [see Section 5.3.1] (go to **Key 3b**: Hydroperiod Category)
b)	NO	**Floodplain wetland** [see Section 5.2] (go to **8** or to **Key 3b**: Hydroperiod Category)
4.	Is the Inland System a **wetland** (typically **vegetated**) <u>without</u> clearly discernable **channel** banks, which is characterised by a permanent <u>or</u> periodic, **diffuse**, unidirectional through-flow of water (often dominated by subsurface flow)?	
a)	YES	(go to **5**)
b)	NO	(go to **6**)
5.	Is the **wetland** located on a **valley floor**?	
a)	YES	**Unchannelled valley-bottom wetland** [see Section 5.3.2] (go to **Key 3b**: Hydroperiod Category)
b)	NO	**Seep** [see Section 5.5] (go to **9** or to **Key 3b**: Hydroperiod Category)
6.	Is the Inland System a **wetland** <u>or</u> **open waterbody** with closed (or near-closed) elevation contours that increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates?	
a)	YES	**Depression** [see Section 5.4] (go to **10** or to **Key 3b**: Hydroperiod Category)
b)	NO	(go to **7**)
7.	Is the Inland System a level or near-level **wetland** that is <u>not</u> fed by water from a **river channel**, typically located on a **plain** or a **bench**, and which is dominated by vertical water movements (horizontal water movements are very weak and multi-directional, if present at all)?	
a)	YES	**Wetland flat** [see Section 5.6] (go to **Key 3b**: Hydroperiod Category)
b)	NO	(go back to **1**)

* A **river** can be split into longitudinal **river zones** at Level 4B (using Table 2 on p. 22 of the User Manual), each of which can be categorised separately in terms of river flow type (using Key 3a), if necessary. At Level 4C, each longitudinal zone can be split into the **active channel** and **riparian zone** components of the river, for the application of descriptors at Level 6.

LEVEL 4B (River zonation/Landform/Outflow drainage)**

** Rivers can be split into longitudinal river zones at Level 4B, based largely on the gradient and substratum characteristics of the river channel (see Table 2 in the User Manual).

8. Is the **floodplain** feature a **wetland** or **open waterbody** with closed elevation contours that increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates?

a) YES .... **Floodplain depression** [see Box 9, Section 5.2]
(go to **Key 3b**: Hydroperiod Category)

b) NO .... **Floodplain flat** [see Box 9, Section 5.2]
(go to **Key 3b**: Hydroperiod Category)

9. Does water from the **seep** concentrate towards a point where it exits as surface flow contained within a distinct **channel**?

a) YES .... **With channelled outflow** [see Section 5.5.1]
(go to **Key 3b**: Hydroperiod Category)

b) NO .... **Without channelled outflow** [see Section 5.5.1]
(go to **Key 3b**: Hydroperiod Category)

10. Is the outflow drainage of the **depression** governed by the nature or operation of an artificial barrier placed across a **river channel**, **valley-bottom wetland** or **seep**?

a) YES .... **Dammed** [see Section 5.4.1]
(go to **12** or to **Key 3b**: Hydroperiod Category)

b) NO .... (go to **11**)

11. Is the **depression** outward-draining, with water exiting via **concentrated** surface flow (in a **channel**), or as **diffuse** (surface and/or less obvious subsurface) flow?

a) YES .... **Exorheic** [see Section 5.4.1]
(go to **12** or to **Key 3b**: Hydroperiod Category)

b) NO .... **Endorheic** [see Section 5.4.1]
(go to **12** or to **Key 3b**: Hydroperiod Category)

LEVEL 4C (Landform*/Inflow drainage)**

*** Each river zone (or the entire length of a river) can be split into **active channel** and **riparian zone** landform components at Level 4C (see Section 5.1.2 of the User Manual), which would generally only be necessary for application of descriptors at Level 6 [NOTE: categorisation of the hydrological regime (using Key3a or 3b) is not applicable to the 'riparian zone' component of a river].

12. Does water enter the **depression** via **concentrated** surface flow in one or more **channels**?

a) YES .... **With channelled inflow** [see Section 5.4.2]
(go to **Key 3b**: Hydroperiod Category)

b) NO .... **Without channelled inflow** [see Section 5.4.2]
(go to **Key 3b**: Hydroperiod Category)

Keys for hydrological regime (Level 5)

There are two keys for the classification of the hydrological regime (at Level 5)—one key for the categorisation of the flow type (or flow regime) for rivers (Key 3a), and the other key for the categorisation of the hydroperiod for all other HGM types (Key 3b).

Key 3a: River flow type

Use Key 3a, below, to assist you with the categorisation of the river flow type (at Level 5) if you are dealing with the classification of a river, preferably after having worked through Key 2 for the classification of HGM Units to confirm that it is definitely a 'river' that you are dealing with.

Key 3a: River Flow Type (Level 5)		
LEVEL 5A		
1.	Do you have some knowledge of the **flow regime** within the **active channel** of the **river**?	
a)	YES	(go to **2**)
b)	NO	**Unknown flow regime**
2.	Is there a flow of water within the **active channel** of the **river** continuously throughout the year, in most years?	
a)	YES	**Perennial** [see Section 6.1.1]
b)	NO	**Non-perennial** [see Section 6.1.1] (go to **3**)
LEVEL 5B		
3.	Do you have some knowledge of the nature of **non-perennial** flow regime?	
a)	YES	(go to **4**)
b)	NO	**Unknown (seasonal/intermittent)**
4.	Is there a flow of water within the **active channel** for extended periods during the wet season/s (generally between 3 to 9 months duration) but not during the rest of the year?	
a)	YES	**Seasonal** [see Section 6.1.2]
b)	NO	(go to **5**)
5.	Is there only a flow of water within the **active channel** for a relatively short time of less than one season's duration (i.e. less than approximately 3 months), at intervals varying from less than a year to several years?	
a)	YES	**Intermittent** [see Section 6.1.2]
b)	NO	(go back to **1**)

Key 3b: Hydroperiod category

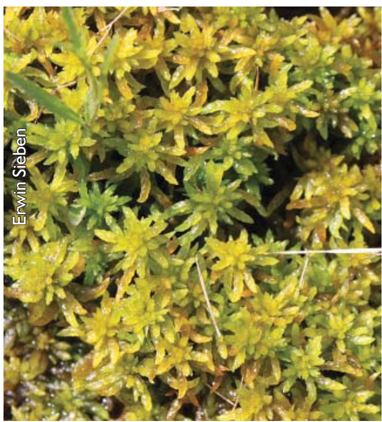
Use Key 3b, below, to assist you with the categorisation of the hydroperiod (at Level 5) if you are dealing with the classification of an inland aquatic ecosystem that is not a river, preferably after having worked through the key for the classification of HGM Units to confirm that it is definitely a non-river HGM type that you are dealing with.

Key 3b: Hydroperiod (Level 5)			
LEVEL 5A (Inundation period)			
1.	Do you have some knowledge of the frequency and duration of **inundation** within the inland aquatic ecosystem?		
a)	YES	(go to **2**)	
b)	NO	**Unknown inundation hydroperiod** (go to **6**)	
2.	Is surface water present within a portion of the inland aquatic ecosystem throughout the year, in most years (i.e. the Inland System, or a portion thereof, is an **open waterbody**)?		
a)	YES	**Permanently inundated*** [see Section 6.2.1] (go to **10**)	
b)	NO	(go to **3**)	
3.	Is surface water present within a portion of the inland aquatic ecosystem for extended periods during the wet season/s (generally between 3 to 9 months duration) but absent during the dry season/s?		
a)	YES	**Seasonally inundated*** [see Section 6.2.1] (go to **6**)	
b)	NO	(go to **4**)	
4.	Is surface water present within a portion of the inland aquatic ecosystem for irregular time periods of less than one season's duration (i.e. less than approximately 3 months), at intervals varying from less than a year to several years?		
a)	YES	**Intermittently inundated*** [see Section 6.2.1] (go to **6**)	
b)	NO	(go to **5**)	
5.	Is a portion of the inland aquatic ecosystem only ever covered by surface water for no more than a few days at a time (up to a week at most), if at all?		
a)	YES	**Never/rarely inundated*** [see Section 6.2.1] (go to **6** if you are dealing with a wetland)	
b)	NO	(go back to **1**)	
LEVEL 5B (Saturation period)			
6.	Do you have some knowledge of the frequency and duration of **saturation** within the **wetland**?		
a)	YES	(go to **7**)	
b)	NO	**Unknown saturation hydroperiod**	
7.	Does a portion of the **wetland** display visible indicators that the soil is **saturated** up to within 0.5 m of the ground surface throughout the year, in most years?		
a)	YES	**Permanently saturated*** [see Section 6.2.2]	
b)	NO	(go to **8**)	
8.	Does a portion of the **wetland** display visible indicators that the soil is regularly **saturated** up to within 0.5 m of the ground surface for extended periods (generally between 3 to 9 months duration), usually during the wet season/s, but dry for part of the year?		
a)	YES	**Seasonally saturated*** [see Section 6.2.2]	
b)	NO	(go to **9**)	

9.	Does a portion of the **wetland** display visible indicators that the soil is occasionally **saturated** up to within 0.5 m of the ground surface, for irregular periods of less than one season (i.e. less than approximately 3 months), but dry for most of the year?		
a)	YES	**Intermittently saturated*** [see Section 6.2.2]	
b)	NO	(go back to **6**)	
LEVEL 5C (Inundation depth-class)			
10.	Do you have knowledge of the typical maximum depth of permanent **inundation** within the **open waterbody** at the driest time of the year?		
a)	YES	(go to **11**)	
b)	NO	**Unknown depth-class**	
11.	Is the maximum depth of **inundation** at the annual average low-water level of the **open waterbody** (i.e. the typical maximum water depth at the end of the dry season) greater than or equal to 2 m?		
a)	YES	**Limnetic** [see Section 6.2.3]	
b)	NO	**Littoral** [see Section 6.2.3]	

* **NOTE:** For the classification of the inundation and saturation hydroperiod, you should estimate the proportion of each hydroperiod category within an inland aquatic ecosystem using the rating scale presented in Section 6.2.4 of the User Manual.

NOTES



NOTES

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Enquiries

SANBI Bookshop, Private Bag X101, Pretoria, 0001 South Africa.
Tel.: +27 12 843 5000
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E-mail: bookshop@sanbi.org.za
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