Development of Decision-support Tools for Assessment of Wetland Present Ecological Status (PES)

Volume 1

REVIEW OF AVAILABLE METHODS FOR THE ASSESSMENT OF THE ECOLOGICAL CONDITION OF WETLANDS IN SOUTH AFRICA

DJ Ollis & HL Malan

WATER RESEARCH COMMISSION

TT 608/14

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REVIEW OF AVAILABLE METHODS FOR THE ASSESSMENT OF THE ECOLOGICAL CONDITION OF WETLANDS IN SOUTH AFRICA

Report to the

WATER RESEARCH COMMISSION

by

DJ Ollis* and HL Malan

*The Freshwater Consulting Group

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Obtainable from
Water Research Commission
Private Bag X03
Gezina, Pretoria
0031 SOUTH AFRICA

orders@wrc.org.za or download from www.wrc.org.za

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PREFACE

This report is one of the outputs of a directed Water Research Commission (WRC) project originally entitled "Consolidation and optimization of wetland health assessment methods through development of a Decision-support Tree (DST) that will provide guidelines" (WRC Project K5/2192). The stated overall objective of the project was "To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands".

This report forms Volume 1 of 2 in the pair of Final Reports compiled for WRC Project K5/2192. The two Final Reports are as follows:

- **Volume 1 (this report):** *Review of available methods for the assessment of the ecological condition of wetlands in South Africa* (by DJ Ollis and HL Malan) **(WRC Report No. TT 608/14)**.
- **Volume 2:** *Development of a decision-support framework for wetland assessment in South Africa and a Decision-support Protocol for the rapid assessment of wetland ecological condition* (by DJ Ollis, JA Day, HL Malan, JL Ewart-Smith and NM Job) **(WRC Report No. TT 609/14)**.

The following 'tools' have also been produced through WRC Project K5/2192 include (both of which have been packaged with Final Report Volume 2):

- A generic decision-support Framework for Wetland Assessment in South Africa, which is a flow-chart showing the various steps in the process of identifying, delineating, classifying, assessing, managing and monitoring wetlands, and how these different aspects typically relate to one another; and
- A Decision-support Protocol (DSP) specifically for the rapid assessment of Wetland Present Ecological Status (PES), in the form of a series of electronic spreadsheets compiled in a Microsoft Excel (.xls) format.

EXECUTIVE SUMMARY

AIMS AND OBJECTIVES

The stated overall objective of this project was "To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands". The specific aims of the project were stated as follows in the directed call for proposals:

(1) to compare and contrast the available mainstream wetland health assessment tools with a particular focus on identifying potential duplication and/or overlaps;
(2) to identify the limitations and report on gaps of existing wetland health assessment tools or methods available in the country;
(3) to recommend further research on wetland health assessment methods;
(4) to develop a Decision-support Tree (DST) to guide users in the application of these tools for use in various types of wetlands and assessments;
(5) to test the application and scientific viability of the DST on selected case study sites; and
(6) to train the core group of users and students from appropriate disciplines on the application of the DST."

The aims of the project that have been addressed in the current review document (Final Report: Volume 1) are the first three listed above. The other aims are addressed in Final Report: Volume 2.

RATIONALE

Government agencies (and other parties responsible for the management of wetlands) typically take the Present Ecological State (PES) of a wetland, as represented by the PES Score and associated Ecological Category, into account when making management decisions relating to the sustainable use and protection of wetlands. It is thus important for government agencies to ensure that appropriate methods, which generate reliable and comparable results, are used for wetland PES assessments.

The rationale for the project was to:

(i) identify key areas for future research and development with regard to the assessment of wetland PES in South Africa (dealt with in Final Report: Volume 1); and
(ii) provide interim decision-support tools to assist government agencies and wetland assessors in selecting appropriate wetland PES assessment methods and reporting the results in a transparent and consistent manner (dealt with in Final Report: Volume 2).

APPROACH TAKEN IN THE REVIEW (METHODS)

The focus of this review, and of the overall project, was on existing methods or tools that have been developed for the assessment of wetland *condition* in South Africa, in particular for determining the PES of a wetland. Methods or tools relating to the assessment of other aspects have only been given peripheral treatment in this review. Whilst the focus of the review is on South African PES assessment methods, as a point of comparison, consideration has also been given to some of the more prominent wetland assessment methods used internationally.

The definition of “wetland” that has been adopted for this review is that of the South African National Water Act (Act No. 36 of 1998), whereby a wetland is defined as “land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated soil”.

The following approach was taken in the appraisal of methods for the assessment of the ecological condition of inland wetlands:

- A literature review of wetland assessment methods that have been developed/used in South Africa was conducted.
- A literature review was conducted of the more prominent international approaches to wetland assessment and the methods that have been developed for such assessments.
- The key findings of a comparative review of the WET-Health and Wetland-IHI methods that was undertaken by Malan (2008) were summarised.
- The results and documentation emanating from the survey on wetland assessment methods undertaken by DWA in 2010 were carefully reviewed.
- A detailed analysis was undertaken of the three most widely-used existing tools for wetland PES assessments that were identified to be of relevance nationally, by carefully reading through the available documentation relating to the tools and reviewing reports in which the tools were applied to particular wetlands.
- Comparative testing of the most important methods currently available for the rapid assessment of wetland PES was conducted by applying the selected methods to a number of wetlands in the South Western Cape that were visited by members of the project team during 2012 and 2013.
- Presentations on this project were delivered at the National Wetlands Indaba (October 2012 and October 2013) and the annual conference of the Southern African Society of Aquatic Scientists (SASAQS) (June/July 2013), and at a meeting of the national Wetlands Task Group (November 2013). In addition, a workshop was held at the SASAQS 2013 conference to specifically discuss wetland PES assessment methods in South Africa. During these conferences, valuable discussions were held with attendees (e.g. about their experience of using the existing wetland assessment methods in South Africa) and all the input that was received has contributed to the findings presented in the current review.
- A number of key stakeholders in the South African wetland community (including government officials, consultants and academics) were individually consulted to try and find out what wetland assessment methods are generally used or advocated by various organisations and groups across the country.
- Based on the comparison of the available wetland PES assessment methods and the findings of the gap analysis, areas requiring further research and development were identified in relation to tools for the assessment of the ecological condition of inland wetlands in South Africa.

DISCUSSION

Review of international wetland assessment methods

The literature review of wetland assessment methods used outside South Africa primarily covers the United States of America (USA), as most of the publicly available literature on wetland assessment methods originates from there. Some literature concerning wetland assessment methods in Europe and in Australia and New Zealand has, however, been included in the review. The main purpose of this appraisal was to gain an understanding of the approaches to wetland assessment used in other countries, compared to the approach followed in South Africa, and to glean information about any novel methods or approaches that could be used to guide future research and development relating to wetland assessment in South Africa.

North America

In the USA the majority of wetland assessment methods that are in use have been developed for the assessment of wetland functions (i.e. “ecosystem services” such as flood prevention and water quality improvement) and values, as opposed to, but sometimes incorporating, elements relating to an assessment of wetland ecological condition. This is largely due to the legislative context for wetland assessment established by the Clean Water Act in the USA.

Some of the more prominent methods that have been developed in the USA are:

- the Habitat Evaluation Procedure (HEP) for wetlands of the US Fish and Wildlife Service (1980), which is used to evaluate the quality and quantity of available habitat for selected wetland fauna based on species-specific conceptual models for habitat use;
- the Wetland Evaluation Technique (WET) of the US Army Corps of Engineers (Adamus et al., 1987, 1991), which identifies the broad groups of functions a wetland is likely to perform based on the presence or absence of specified wetland characteristics;
- the hydrogeomorpic (HGM) approach to wetland classification and assessment of the US Army Corps of Engineers (after Brinson, 1993; Smith et al., 1995), serving as the basis for so-called “functional assessments”;
- bioassessment and the development of multimetric Indices of Biological Integrity (IBI) for wetlands based on macrophytes, algae/diatoms, macroinvertebrates, amphibians, birds or fish, spearheaded by the US Environmental Protection Agency;
- mixed methods that attempt to integrate the HGM and IBI approaches; and
- so-called wetland Rapid Assessment Methods (RAMs) such as the Ohio Rapid Assessment Method (ORAM) for Wetlands ((Mack, 2001a) and the California Rapid Assessment Method (CRAM) for Wetlands (CWMW, 2013b), which have been developed for certain regions to provide rapid, scientifically defensible, standardised, cost-effective assessments of the wetland ecological condition.

Functional assessments based on the HGM approach have become especially prolific in the United States, as this approach was developed in direct response to the legal requirements pertaining to wetland assessment, using the best science available. In the past ten years or so, however, there seems to have been a shift in the focus of wetland assessment research in the United States from functional assessment, and the development and testing of methods to support this approach, to the assessment of wetland condition. For example, the USEPA recently initiated the “National Wetland Condition Assessment” to address the need for a coordinated, national programme for the assessment of the ecological condition of wetlands in the United States. One of the more well-established, regional-scale wetland ecological condition assessment methods in the United States is the California Rapid Assessment Method for Wetlands (CRAM), now in version 6.

A number of assessment methods have also been developed in the United States to categorise the degree of human disturbance to a wetland. These have arisen largely out of the need to relate biological data from wetlands to the level of anthropogenic disturbance in the development and testing of wetland IBIs.

Europe

Until approximately ten years ago, no rapid assessment methods existed for the assessment of European wetlands, and the assessment of wetland condition and implementation of wetland management strategies in Europe was highly fragmented. This has, to some extent, been addressed by the implementation of the Water Framework Directive (WFD) of the European Union.

The WFD requires member states to establish ‘integrated river basin management plans’ to achieve ‘good ecological status’ of river, lake, estuary and coastal water bodies by 2015. Annex V of the Directive lists the specific quality elements to be measured for the determination of ecological status. The WFD does not set independent ecological objectives for wetlands other than where those wetlands, or parts of them, fall under what would be defined as a surface water body (i.e. a river, lake, estuary, or coastal water body). The Directive does, however, contain a complex set of provisions applicable to all member states that implicitly require the functional role of wetlands to be taken into account.

A method to assess wetland functioning throughout Europe, in the context of the WFD, has recently been developed by Maltby et al. (2009). The method sets out Functional Assessment Procedures (FAPs) for application in European countries, which are founded upon an HGM-based approach to wetland classification and assessment.

Australia

In recent years, all jurisdictions within Australia have applied some form of wetland assessment. These have been carried out for varied reasons and under different organisational contexts, over different scales and on a wide variety of wetlands. WetlandCare Australia produced a Wetland Assessment Techniques Manual for Australian Wetlands (Price et al., 2007), in an attempt to standardise wetland assessment techniques across the country. Another, rather novel initiative in Australia is the Framework for the Assessment of River and Wetland Health (FARWH), which was developed to facilitate comparable reporting of river and wetland condition across all parts of Australia (Alluvium Consulting, 2011). The FARWH allows for existing river and wetland condition data from across Australia to be normalised and integrated, without replacing existing assessment methods.

The State of Victoria in Australia is in the process of developing an Index of Wetland Condition (IWC) that will conform with the FARWH. This ongoing development of this index appears to have been informed by a wetland condition index for the rapid field-based assessment of permanent floodplain wetlands in the Murray Darling Basin (after Spencer et al., 1998). The IWC is designed for the general surveillance of wetland condition, for assigning wetlands to general condition categories and for detecting significant changes in wetland condition. It takes the form of a hierarchical index, with six sub-indices based on the primary characteristics that are thought to define wetlands, namely: (1) wetland catchment; (2) physical form; (3) hydrology; (4) soils; (5) water properties; and (6) biota. One or two "key ecological components" have been identified for each sub-index, and for each of these components a number of specific measures have been included for evaluation.

New Zealand

Two methods have been developed to assess wetland condition within New Zealand – the Wetland Condition Index (WCI) (Clarkson et al., 2003) and the Index of Ecological Integrity (IEI) (after Ausseil et al., 2008; cited by Suren et al., 2011). Both these methods primarily assess the landscape and catchment factors that influence wetland plant communities. The WCI method is based on field observations of five factors that are considered to affect wetland condition: (1) hydrological integrity; (2) physicochemical parameters; (3) ecosystem intactness; (4) browsing predation and harvesting regimes; and (5) dominance of native plants. The IEI method, on the other hand, involves the combining of six spatial indicators of human activities (termed ''pressure measures'') known to degrade wetland biodiversity and function. These indicators are derived from national GIS databases and applied across three spatial units, i.e. the wetland catchment, a 30 m buffer around the wetland, and the wetland itself. The six indicators used for the IEI are: (1) proportion of natural vegetation cover; (2) proportion of human-made impervious cover; (3) number of introduced fish species; (4) percentage cover by woody weeds; (5) artificial drainage; and (6) a surrogate measure of land-use intensity (nitrate leaching risk).

Comparison of wetland assessment tools used in South Africa

Legislative context

The South African legal framework for wetland assessment (and inland aquatic ecosystem assessment, more generally), as contained mainly in the National Water Act (Act No. 36 of 1998) (NWA), is rather distinctive. For example, it is quite different to the legislative framework created by the Clean Water Act in the USA and the Water Framework Directive in Europe.

In South Africa the NWA lays down a series of regulatory measures that are, together, intended to facilitate the protection of water resources throughout the country, with "water resources" defined to include rivers, wetlands, estuaries and aquifers. More specifically, this Act (in section 12, under Chapter 3) sets out the legal requirement for the Minister to prescribe a system for classifying water resources into management classes, which is to serve as the basis for the setting of "the Reserve" and the "Resource Quality Objectives (RQOs)" for all significant water resources in the country. Chapter 14 of the NWA places a duty on the Minister to, as soon as reasonably practicable, establish national monitoring and information systems for water resources (in sections 137 and 139 of the Act, respectively).

Regulations for the establishment of a national Water Resource Classification System (WRCS) were gazetted in September 2010, which set out a 7-step procedure for determining the class of a water resource (with three classes prescribed), an 8-step procedure for determining the Reserve, and a 6-step procedure for determining RQOs. The significance of the water resource classification process is that the higher the management class, the less water that may be abstracted and the more stringent the RQOs, because the water body must be maintained in a state that is closer to natural than resources classified into a lower management class. Of most relevance to the current review is Step 3 of the 8-step procedure set out in the WRCS for the determination of the Reserve, which specifically makes reference to the determination of the reference condition and PES (and ecological importance and sensitivity) of each of the selected study sites. Central to the determination of the PES of an aquatic ecosystem (and to the assignment of a Recommended Ecological Category), within the national WRCS framework, is the categorisation of the (present and/or desired future) biophysical state/condition of a water resource, relative to the natural (pre-development), minimally-impacted reference conditions.

Since the publication of the original RDM methods for various kinds of aquatic ecosystems by the Department of Water Affairs in 1999, a six-class (A to F) rating system (see Table ES1) has been widely used to categorise and describe the ecological condition for water resource management purposes in South Africa.

Table ES1: Ecological Categories for assessment of the Present Ecological State (PES) of inland aquatic ecosystems (after **Kleynhans, 1996**)

ECOLOGICAL CATEGORY	PES % SCORE	DESCRIPTION
A	90-100%	Unmodified, natural.
B	80-90%	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	60-80%	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D	40-60%	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	20-40%	The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-20%	Modifications have reached a critical level and the ecosystem has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

The determination of Ecological Categories to describe the PES of water resources (including wetlands) and the assignment of Recommended Ecological Categories as a basis for the ongoing management of water resources form major components of the procedures for RDM, particularly with respect to the water resource classification requirements of the NWA. This information is ultimately used by government officials to make management decisions that relate to the sustainable utilisation and protection of wetlands and other water resources in the country. Interestingly, the South African legislation does not set out any specific requirements for the assessment of ecosystem functioning or the provision of ecosystem services by aquatic ecosystems, as in the case of the USA for example where the focus of the legislation is on functional assessments. Presumably, this is based on an implicit assumption that if the ecological condition of a water resource is good, the functioning will also be good.

Whilst there is a clear, rather prescriptive legal mandate for the determination of the PES of significant wetlands (and other types of aquatic ecosystems) in the NWA, through the national WRCS, it is important to take cognisance of the fact that not all wetland assessments undertaken in the country form part of a RDM process. There is, for example, also the legal requirement for national monitoring of and reporting on the "health" of aquatic ecosystems, including wetlands, in terms of Chapter 14 of the NWA. There is also a legal imperative to conduct PES assessments of water resources for which a "water use" licence (or registration of a General Authorisation) is required in terms of sections 21 and 22 of the NWA, forming part of the so-called Source-Directed Controls for water resource management. In addition, other legislation besides the NWA exists in South Africa that triggers the need for wetland assessments to be undertaken, such as the Environmental Impact Assessment (EIA) Regulations of the National Environmental Management Act (Act No. 107 of 1998) (NEMA).

It is important to note that not all wetland assessments in South Africa are conducted to merely fulfil legal requirements, either in terms of the NWA or other environmental legislation. Examples of situations and contexts within which wetland assessments are undertaken include, *inter alia*, wetland rehabilitation planning and the evaluation of the success of wetland rehabilitation interventions; conservation planning; strategic environmental assessments and the compilation of Environmental Management Frameworks; compilation of State-of-Environment Reports; and compilation of wetland inventories that contain attribute information about the wetlands.

It is also important to note that not all wetland assessment methods provide for the categorisation of the PES of a wetland. Furthermore, some assessment methods have specifically been designed to fulfil legal requirements and/or to be rapid, while others have been designed with the intention of providing a means of gaining a better understanding of the characteristics of wetlands.

Historical overview of wetland assessment methods developed in South Africa

A list of the most influential, nationally applicable wetland assessment methods that have been developed in South Africa was compiled. For completeness and to gain a better understanding of the evolution of method development in this country, the list includes methods that were developed for purposes other than the assessment of wetland PES. For example, methods for the assessment of wetland ecosystem service provision (i.e. functional assessment methods) and for the categorisation of the Ecological Importance and Sensitivity (EIS) of a wetland ecosystem are included. A brief description of each of the methods is provided.

In addition to the nationally applicable wetland assessment methods that exist in South Africa, a number of regional or more localised adaptations of these methods have been developed for specific areas or for specific applications. A number of wetland PES assessment methods have also been developed for specific purposes, which do not represent a modification of any of the more prominent, nationally-applicable methods. Brief descriptions of some of the more localised or purpose-specific methods that have been developed are provided.

The historical overview of the development and use of wetland assessment methods in South Africa (as presented in this review) revealed that there are only three main methods that have been developed to date that are potentially applicable across all regions in South Africa for assessing the present ecological condition of wetland ecosystems. These are the PES method for floodplain and other palustrine wetlands developed by Duthie (1999b) as part of the package of methods included in the original RDM Manual for Wetland Ecosystems (DWAF, 1999c), the Wetland-IHI for floodplain and valley-bottom wetlands developed by DWAF (2007b), and the WET-Health assessment tool (Macfarlane et al., 2007).

Comparison of the original RDM-99 PES assessment method for wetland ecosystems, Wetland-IHI and WET-Health

The Wetland-IHI and WET-Health assessment methods are undoubtedly the most advanced wetland PES assessment methods currently available for the assessment of wetland PES throughout South Africa. Both of these methods were developed by highly competent teams of wetland scientists over a number of years, based on the research findings accumulated over many years by the broader aquatic science community, and thus incorporate up-to-date scientific approaches to the determination of wetland PES. The Wetland-IHI and WET-Health methods consist of individual ‘modules’ representing the primary components of wetland PES (namely hydrology, geomorphology, vegetation and, in the case of Wetland-IHI, water quality), which are separately scored. The individual scores are then combined (if necessary), using specified weightings for the individual component scores, to derive an overall wetland PES score and category.

While Wetland-IHI and WET-Health are clearly the most recent and appropriate methods to compare in more detail in this review, the relatively simple wetland PES assessment method of Duthie (1999b), developed as one of the main tools in the original set of Resource Directed Measures for the protection of wetland ecosystems back in 1999 and hereinafter referred to as the “RDM-99 method”, has also been included in the detailed comparison. The RDM-99 method is not modular, but rather consists of a number of criteria that are rated to derive an overall (averaged) wetland PES score and category. The main reasons for including this method in the detailed comparison are that, despite its shortcomings and lack of sophistication, the method is still used today (both in its original form and in modified versions) and because the assessment follows a somewhat different approach to that of Wetland-IHI and WET-Health.

The three methods were compared in terms of their purpose and applicability; the criteria that are taken into consideration; the scoring procedures and the importance of reference conditions; and the amount of time, level of experience required, and user-friendliness. In addition, comparative testing was undertaken of the results generated by the three methods, only considering the rapid “Level 1” assessment in the case of WET-Health (the more comprehensive “Level 2” assessment option in WET-Health is not directly comparable to the rapid RDM-99 or Wetland-IHI methods). This testing involved the application of these three methods to a selection of 18 case-study wetlands from the South Western Cape region by a number of assessors. A total of nine individuals were involved in the testing, with between 3 and 8 assessors for each case-study wetland. For each case study wetland, the PES percentage scores and the respective Ecological Categories derived by the different assessors for the various components of wetland PES (i.e. hydrology, geomorphology, vegetation, and water quality) and for Overall Wetland PES using the three assessment methods were compared.

The comparative testing revealed relatively high levels of inconsistency between the PES% scores derived by different assessors and using the three different methods. Only for case-study wetlands that were in relatively pristine ecological condition were these differences minimal, and it is assumed that this would also be the case for severely transformed wetlands (none of the case-study wetlands were severely transformed). Most of the variability between assessors and between the different methods was not statistically significant ($p<0.05$), according to the non-parametric statistical tests that were used, but this was mostly because of the generally large variability between replicate scores and was not a reflection of consistency between scores. For many of the case-study wetlands, there were differences of one or more Ecological Categories in the derivation of PES scores by different assessors and through the application of the different assessment methods, and this was the case for all the different components of wetland PES (i.e. hydrology, geomorphology, vegetation, and water quality) and for the Overall PES. The inconsistencies that were observed did not, except in a few cases, appear to be related to the relative level of experience of the assessor or to the type of wetland.

The main reasons for the observed inconsistencies between assessors in the testing that was undertaken are thought to be related to differences in the perception of the natural reference state of the case-study wetlands, differences in the delineation of the “assessment unit”, and differences in the assessment of impact intensity and/or extent by different assessors, rather than inherent problems with any of the assessment methods that were compared. All three of the methods have strong points and shortcomings, and none of the assessment methods were found to yield more consistent results than any of the other methods. A similar amount of time and level of expertise is also required to apply the three assessment methods, bearing in mind that the comparative testing only involved the application of “Level 1” assessments for WET-Health (and not the more time-consuming and comprehensive “Level 2” assessment).

In the absence of any other nationally applicable wetland PES assessment methods currently being available, and based on the finding that none of the methods seem to provide more consistent results than the others, the ongoing use of all three Wetland PES assessment methods that were compared is deemed to be acceptable, providing the inherent limitations of the methods are taken into account. Training in the use of a particular tool, a basic level of understanding of wetland science and some experience in wetland assessment is required for the proper application of all three methods. Of the three methods that were evaluated, the RDM-99 method is the most simplistic and least comprehensive, and is also more prone to subjectivity than the other two methods. Discouragement of the ongoing use of this particular, rather dated PES assessment method in its current form is thus warranted. The more recent Wetland-IHI and WET-Health (Level 1) assessment methods both have limitations and weaknesses in their current form, but both methods have also been built on a relatively solid scientific foundation and should thus be developed further and, ideally, integrated into a single, nationally-applicable rapid Wetland PES assessment method.

GAP ANALYSIS OF EXISTING WETLAND PES ASSESSMENT METHODS IN SOUTH AFRICA (CONCLUSIONS)

The overarching findings of the gap analysis, which are of relevance to all three of the existing nationally-applicable wetland PES assessment methods (i.e. the RDM-99 method, Wetland-IHI, and WET-Health), were as follows:

- More guidance is required for the determination of the natural reference state, which is a critical but underplayed step in the application of most of the wetland PES assessment methods.
- Photographic field-guides need to be developed that contain written and pictorial guidelines for rating the extent and intensity of impacts, to facilitate consistency between assessors.
- Guidelines are needed for the reporting of results and, to facilitate consistency between reports, report templates should be developed for each method.
- Better explanations of the scoring systems associated with the assessment methods are needed, with additional guidance as to how to apply the scoring system to various scenarios that typically occur (e.g. rating the extent and intensity of land-use impacts where the different land-uses occur as a mosaic within and around a wetland).
- None of the existing methods are really appropriate, in their present form, for application to depressions or wetland flats.
- A shift in the composition of (indigenous) plant species within a wetland, which can in some cases represent a relatively significant impact, is not explicitly taken into account in the vegetation component of any of the existing assessment methods.
- No (or very little) explanation is given in the exiting methods as to how an assessor should deal with the effects of wild fires, natural grazing, floods, droughts and other natural disturbances.
- All of the existing tools were released for widespread usage before they were thoroughly tested and refined. This situation must be avoided in the development of any new or integrated wetland assessment tools.
- Structured, hands-on training in the use of the assessment tools is important for all of the methods, and the development of standardised training procedures should be developed for this purpose.
- Besides the confusion that exists as to which wetland PES assessment tool may be applicable and most appropriate for a particular situation, there is much confusion and difference in opinion as to when a PES assessment should be undertaken in the first place. There is thus a clear need for the development of a decision-support framework for the whole wetland assessment process in general.

For each of the three assessment methods that were compared, a number of specifically relevant limitations and gaps were also identified and discussed.

RECOMMENDATIONS FOR FUTURE RESEARCH

The following recommendations for further research and development are made specifically in relation to the tools and methods for wetland PES assessment in South Africa:

1) The existing assessment tools (particularly WET-Health and Wetland-IHI) should be combined into a single assessment tool or an integrated suite of assessment tools for the categorisation of wetland PES.
2) In the interim, a decision-support tool of some sort should be developed to assist in the determination of which of the existing wetland PES assessment methods (or specific components of the existing methods) would be most appropriate for particular situations and/or particular wetland types. [The Decision-support Protocol (DSP) for the rapid assessment of wetland PES in South Africa that has been developed through the current project (see Volume 2 report) is such a tool]
3) A method for assessing the ecological condition of depressions and wetland flats (and seeps that are not connected to a drainage network) should be formulated as a matter of urgency, or one of the existing methods should be adapted to account for these wetland types. [The DSP that has been produced through the current project includes comprehensive lists of potential impacts for each component of Wetland PES, which could serve as the starting point for the development of a PES assessment method for depressions and wetland flats (and for seeps that are not connected to a drainage network)]
4) Written guidelines should be produced to assist with the determination of the perceived natural reference state for wetlands. [The inclusion of a datasheet for entering the perceived natural reference state of a wetland in the DSP for the rapid assessment of Wetland PES that has been developed through the current project (see Volume 2 report), which has a list of important criteria to consider, represents a start to the production of the recommended guidelines for determining and describing the perceived natural reference state of a wetland]
5) The characteristics of reference wetlands in different geographical areas should be documented, following a standardised approach and reporting format.
6) Photographic field-guides should be developed for the rating of wetland impacts.
7) Reporting guidelines and report templates should be produced for wetland PES assessments.
8) An overarching decision-support framework for wetland assessment in South Africa should be developed. [The decision-support Framework for Wetland Assessment in South Africa that has been developed through the current project (see Volume 2 report) is such a framework]

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LIST OF ABBREVIATIONS

CRAM	California Rapid Assessment Method (for Wetlands)
DEAT	Department of Environmental Affairs & Tourism
DSP	Decision-support Protocol
DSS	Decision-support System
DST	Decision-support Tree
DWA	Department of Water Affairs
DWAF	Department of Water Affairs & Forestry
EIA	Environmental Impact Assessment
EIS	Ecological Importance & Sensitivity
FARWH	Framework for the Assessment of River and Wetland Health
GIS	Geographical Information System
HDS	Human Disturbance Score
HGM	Hydrogeomorphic
IBI	Index of Biological Integrity
IEI	Index of Ecological Integrity
IHI	Index of Habitat Integrity
IWC	Index of Wetland Condition
KZN	KwaZulu-Natal
LDI	Landscape Development Intensity
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ORAM	Ohio Rapid Assessment Method (for Wetlands)
PES	Present Ecological State
RAM	Rapid Assessment Method
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
SANBI	South African National Biodiversity Institute
UKZN	University of KwaZulu-Natal
US	United States (of America)
USA	United States of America
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WCI	Wetland Condition Index
Wet-HAT	Wetland Health Assessment Technique
WFD	Water Framework Directive
WHI	Wetland Health and Importance (Research Programme)
WRC	Water Research Commission
WRCS	Water Resource Classification System
WULA	Water Use Licence Application

1 INTRODUCTION AND OBJECTIVES

1.1 Background and context

This review emanates from a solicited Water Research Commission (WRC) project originally entitled "Consolidation and optimization of wetland health assessment methods through development of a Decision-support Tree (DST) that will provide guidelines" (WRC Project K5/2192). The project was awarded to the Freshwater Consulting Group, in collaboration with the then Freshwater Research Unit at the University of Cape Town, and officially commenced in July 2012. The stated overall objective of the project was, "To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands".

The specific aims of the WRC project were stated as follows in the directed call for proposals:

1) "To compare and contrast the available mainstream wetland health assessment tools with a particular focus on identifying potential duplication and/or overlaps;
2) To identify the limitations and report on gaps of existing wetland health assessment tools or methods available in the country;
3) To recommend further research on wetland health assessment methods;
4) To develop a Decision-support Tree (DST) to guide users in the application of these tools for use in various types of wetlands and assessments;
5) To test the application and scientific viability of the DST on selected case study sites; and
6) To train the core group of users (DWA/SANBI) and students from appropriate disciplines on the application of the DST."

The primary deliverable of the project was initially envisaged to be the DST referred to in the stated aims of the project and accompanying guidelines/instructions for use. Through the review of existing wetland assessment methods that was undertaken for the project, however, it became apparent that slightly modified deliverables would be more appropriate. The main deliverables that have been produced through this project are a Decision-support Protocol (DSP) for the rapid assessment of wetland Present Ecological State (PES), and an overarching Framework for Wetland Assessment, together with a report describing and explaining these two 'tools' (see Volume 2 report).

1.2 Aims of the project addressed in this review

The aims of WRC Project K5/2192 that have been addressed in this review document are the first three listed above, namely: 1) to compare and contrast the available mainstream wetland health assessment tools; 2) to identify the limitations and report on gaps of existing wetland health assessment tools/methods available in the country; and 3) to make recommendations for further research on wetland health assessment methods. The other aims are addressed in Volume 2 of this series.

1.3 Rationale

The PES of a wetland refers to its present ecological condition relative to the perceived natural reference condition (pre-development/historical). The ability of a wetland to continue providing ecosystem goods and services is determined, to a large degree, by its present ecological condition. Government agencies (and other parties responsible for the management of wetlands) take the present ecological condition of a wetland (as represented by the PES Score and associated Ecological Category) into account when making management decisions relating to the sustainable use and protection of wetlands. It is thus important for government agencies to ensure that appropriate methods, which generate reliable and comparable results, are used for wetland PES assessments. Through their use over a number of years, gaps have been identified in the existing methods that are available for wetland PES assessment in South Africa. These shortcomings have been addressed through the *ad hoc* modifications of the existing assessment 'tools' by users, or through the development of additional (non-standardised) 'tools' for specific situations. This has created significant problems for government agencies in maintaining consistent standards of data collection and reporting, leading to a lack of confidence in the comparability of wetland PES assessment results generated by different assessors.

It is important for authorities (and assessors) to understand the limitations and gaps affecting the use of existing wetland assessment tools, as these have significant implications for decisions that are made with respect to the sustainable use and protection of wetland ecosystems. Furthermore, it has become evident that there is a dire need for clear guidelines and decision-support tools for the appropriate selection, use and reporting of results generated by the existing wetland assessment methods in South Africa. This was the motivation for the current project. In particular, the rationale for the project was to:

(iii) identify key areas for future research and development with regard to the assessment of wetland PES in South Africa, so as to pave the way towards improving the existing methods (dealt with Final Report: Volume 1, i.e. the current report); and

(iv) to provide interim decision-support tools to assist government agencies and wetland assessors in selecting appropriate wetland PES assessment methods and reporting the results in a transparent and consistent manner (dealt with in Final Report: Volume 2).

It is anticipated that the research and development needs identified, and the guidelines and decision-support tools produced through this project, should assist in demystifying what is currently an area of great confusion and uncertainty for South African government agencies and wetland assessors alike.

2 APPROACH TAKEN IN THIS REVIEW AND STRUCTURE OF REPORT

2.1 Approach

The focus of this review, and of the overall project, was on existing methods or tools that have been developed for the assessment of wetland *condition* in South Africa, in particular for determining the *Present Ecological State* (PES) of a wetland. Methods or tools relating to the assessment of other aspects such as social and/or economic importance, ecological importance and sensitivity, ecosystem service provision, and conservation importance, to name a few, have only been given peripheral treatment in this review, as have methods developed for bioassessment using particular taxa, or groups of taxa, within wetlands (such as wetland plants, invertebrates and algae). Whilst the focus of the review is on South African PES assessment methods, as a point of comparison, consideration has also been given to some of the more prominent wetland assessment methods used internationally.

In this review, the terms “wetland health” and “ecological health” have been specifically avoided, due to differences in opinion as to what such terms mean and the potential confusion that their usage may introduce (e.g. see Suter, 1993; Callicott, 1995; Wicklum and Davies, 1995; Scrimgeour and Wicklum, 1996; Boulton, 1999; Lackey, 2001). A similar decision was taken with regard to the use of such terminology in the tools developed in the Wetland Health and Importance (WHI) Research Programme, despite the name of the programme, and a good discussion of the potential controversies associated with the use of the term “health” with reference to ecosystem condition is provided by Day and Malan (2010).

The definition of “wetland” that has been adopted for this review is that of the South African National Water Act (Act No. 36 of 1998), whereby a wetland is defined as “land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated soil”. According to this definition, rivers and lakes are not regarded to be wetlands, as they are in the case of less restrictive wetland definitions such as that of the Ramsar Convention. Furthermore, only assessment methods relating to *inland* wetlands have been considered in this review, and not those relating to marine or estuarine systems.

The following approach was taken in this appraisal of methods for the assessment of the ecological condition of inland wetlands:

- A literature review of wetland assessment methods that have been developed/used in South Africa was conducted. Both peer-reviewed scientific sources and (mostly) ‘grey-literature’ reports were consulted, including all the relevant documentation that has been produced by the Department of Water Affairs (DWA) in relation to the currently applicable Reserve Determination and EcoClassification/EcoStatus methods for wetlands.
- A literature review was conducted of the more prominent international approaches to wetland assessment and the methods that have been developed for such assessments.

- The key findings of a comparative review of the WET-Health and Wetland-IHI methods that was undertaken by Malan (2008) were summarised.
- The results and documentation emanating from the survey on wetland assessment methods undertaken by DWA in 2010 were carefully reviewed.
- A detailed analysis was undertaken of the three most widely-used existing tools for wetland PES assessments that were identified to be of relevance nationally, by carefully reading through the available documentation relating the tools and reviewing reports in which the tools were applied to particular wetlands.
- Comparative testing of the most important methods currently available for the rapid assessment of wetland PES was conducted by applying the selected methods to a number of wetlands in the South Western Cape that were visited by members of the project team during 2012 and 2013. The testing included a comparison of the outputs of the different methods in terms of the PES categories that were derived by different assessors for the various components of wetland condition and for the overall PES of each wetland. The PES categories generated by the various methods were also compared, for each wetland, with the 'gut-feel' PES categories that were independently estimated by the assessors.
- Presentations on this project (WRC Project K5/2192) were delivered at the National Wetlands Indaba (in October 2012 and October 2013) and the annual conference of the Southern African Society of Aquatic Scientists (SASAQS) (in June/July 2013), and at a meeting of the national Wetlands Task Group (in November 2013). In addition, a workshop was held at the SASAQS 2013 conference to specifically discuss wetland PES assessment methods in South Africa. During these conferences, valuable discussions were held with attendees (e.g. about their experience of using the existing wetland assessment methods in South Africa) and all the input that was received has contributed to the findings presented in the current review.
- A number of key stakeholders in the South African wetland community (including government officials, consultants and academics) were individually consulted (via phone calls, email and face-to-face conversations) to try and find out what wetland assessment methods are generally used or advocated by various organisations and groups across the country. An attempt was also made, through these consultations, to find out why the various stakeholders prefer one method over another.
- Based on the comparison of the available wetland PES assessment methods and the findings of the gap analysis, areas requiring further research and development were identified in relation to tools for the assessment of the ecological condition of inland wetlands in South Africa.

A draft final version of the current was independently reviewed by three external consultants, two of whom were centrally involved in the development of the more important wetland assessment tools that are currently in use in South Africa (i.e. WET-Health and Wetland-IHI), to help ensure that the descriptions and comparisons of the different methods that have been presented in this document are accurate and unbiased. The Reference Group for this project were also all provided with an opportunity to review the draft final report, and additional internal peer-review was provided by members of the project team.

The main findings of the review of wetland assessment methods presented in this document were used to guide the development of the Decision-support Protocol (DSP) for rapid wetland PES assessment and an overarching Framework for Wetland Assessment in South Africa that were produced as the primary deliverables of WRC Project K5/2192.

2.2 Structure of report

The main findings of the review have been presented in the current report, as follows:

- Chapter 3 provides a summary of the literature review of international methods that was undertaken, covering North America (Section 3.1), Europe (Section 3.2), and Australia and New Zealand (Section 3.3)
- Chapter 4 presents the comparison of South African wetland assessment tools that was completed, starting with an explanation of the legislative context for wetland assessment (Section 4.1) and a historical overview of the wetland assessment methods that have been developed to date (Section 4.2), followed by a detailed comparison of the most prominent wetland PES assessment methods of national applicability that are currently available for use in South Africa (Section 4.3)
- Chapter 5, which is intricately related to Chapter 4, presents the key findings of the gap analysis that was undertaken with regard to the existing methods for the assessment of wetland PES in South Africa
- Chapter 6 provides recommendations for further research relating to wetland PES assessment tools in South Africa

3 LITERATURE REVIEW OF INTERNATIONAL METHODS

The literature review of wetland assessment methods used outside of South Africa primarily covers the United States of America (USA), as most of the publicly available literature on wetland assessment methods originates from there. Some literature concerning wetland assessment methods in Europe and in Australia and New Zealand has, however, been included in the review. The main purpose of this appraisal was to gain an understanding of the approaches to wetland assessment used in other countries, compared to the approach that has been followed in South Africa (as outlined in Section 3.2), and to glean information about any novel methods or approaches that could be used to guide future research and development relating to wetland assessment in South Africa.

3.1 North America

In the USA, the majority of wetland assessment methods that are in use have been developed for the assessment of wetland functions (i.e. "ecosystem services" such as flood prevention and water quality improvement) and values, as opposed to but sometimes incorporating elements relating to an assessment of wetland ecological condition. This (as noted by DWAF, 2004) is largely due to the legislative context for wetland assessment established by the Clean Water Act in the USA. In terms of Section 404 of the Clean Water Act, a permit must be obtained from the US Army Corps of Engineers for the placement of fill material into wetlands and other waters if such infilling results in wetland loss. As explained by Thiesing (2001), "The §404 regulations direct that, for a permit to be granted, it must be demonstrated that the placement of fill is unavoidable and that it has been minimised to the maximum extent possible. If these criteria have been met, the permit applicant must mitigate for any unavoidable impacts that the fill may have on the aquatic ecosystem. This typically involves some form of wetland creation, enhancement, or restoration within the affected ecosystem; its purpose is to compensate for wetland value lost to the system as a result of fill. In order to objectively determine whether wetland loss can be compensated by mitigation, the *functions* performed by the wetland proposed to be impacted must be determined." [italics and underlining added].

The development and application of wetland assessment methods in the United States has generally been undertaken in reaction to possible impacts to wetlands, rather than as a part of a strategic and holistic inventory of the status of the resource (Larson, 2009). Due to the legal setting, wetland assessments in the United States are indeed most commonly triggered by the possible impact to or loss of wetlands through a proposed development (Thiesing, 2001). In these situations, the relevant legislation requires that consideration be given to the ecological value and functions associated with the wetland in the decision-making process. Most of the wetland assessment methods that have been developed in the country, therefore, relate to the assessment of wetland functions and values.

A multitude of wetland assessment methods have been developed in the USA over the years, driven largely by the regulatory assessment requirements. A number of reviews of the available methods have also been completed through the years (e.g. see Bartoldus, 1999; Thiesing, 2001; Carletti et al., 2004; Fennessy et al., 2004, 2007).

Some of the more prominent methods that have been developed are:

(1) the Habitat Evaluation Procedure (HEP) for wetlands of the US Fish and Wildlife Service (1980), which is used to evaluate the quality and quantity of available habitat for selected wetland fauna based on species-specific conceptual models for habitat use;
(2) the Wetland Evaluation Technique (WET) of the US Army Corps of Engineers (Adamus et al., 1987, 1991), which identifies the broad groups of functions a wetland is likely to perform based on the presence or absence of specified wetland characteristics;
(3) the hydrogeomorpic (HGM) approach to wetland classification and assessment of the US Army Corps of Engineers (after Brinson, 1993; Smith et al., 1995), serving as the basis for so-called “functional assessments”;
(4) bioassessment and the development of multimetric Indices of Biological Integrity (IBI) for wetlands based on macrophytes, algae/diatoms, macroinvertebrates, amphibians, birds or fish, spearheaded by the US Environmental Protection Agency (see USEPA (2002) and accompanying documents in the series on ‘methods for evaluating wetland condition’);
(5) mixed approaches such as the proposed method of integrating the HGM and IBI approaches presented by Stevenson and Hauer (2002); and
(6) so-called wetland Rapid Assessment Methods (RAMs) such as the Ohio Rapid Assessment Method (ORAM) for Wetlands ((Mack, 2001a) and the California Rapid Assessment Method (CRAM) for Wetlands (CWMW, 2013a), which have been developed for certain regions to provide rapid, scientifically defensible, standardised, cost-effective assessments of the wetland ecological condition.

Functional assessments based on the HGM approach have become especially prolific in the United States, as this approach was developed in direct response to the legal requirements pertaining to wetland assessment, using the best science available. The primary objective of the HGM approach is to determine how alterations to wetlands affect their ecological condition and their ability to perform functions. This is based on the premise that a wetland is in good condition if its ability to perform functions has not been significantly altered through anthropogenic impacts (Brinson, 2009). <u>The establishment of reference conditions is central to the HGM approach to wetland assessment</u> (Brinson and Rheinhardt, 1996), through the use of existing, relatively unaltered ecosystems that represent a particular wetland type (or usually sub-type) within a particular region as the benchmark for comparison.

The use of functional performance to imply ecological integrity (i.e. condition) and vice-versa, as followed in the HGM approach to wetland assessment in the United states, may not always yield accurate results (Kusler, 2006) and does, therefore, require validation. In South Africa, some preliminary work has been undertaken by Ellery et al. (2010) to infer the extent to which certain functions are being provided by wetlands, at the catchment or landscape scale. This was based on theoretical relationships between specific ecosystem services and particular aspects of ecological condition, rather than quantitative measurements. Many more investigations like this would need to be carried out, and at finer spatial scales, to ascertain whether there are strong enough relationships between wetland condition and wetland function to allow for the inference of functional importance on the basis of the outcomes of assessments of present ecological condition. Given the difficulties in quantifying ecosystem services supplied by wetlands, both internationally and especially in a developing country like South Africa (Turpie et al., 2010), functional assessments may not be the most pragmatic approach to pursue.

In the past ten years or so, there seems to have been a shift in the focus of wetland assessment research in the United States from functional assessment, and the development and testing of methods to support this approach, to the assessment of wetland condition. According to Wardrop et al. (2007), one of the requirements of the Clean Water Act is that the condition/quality of all waters of the US should be assessed every two years but this has been historically ignored for wetlands, even though they are included in the definition of 'waters of the US'. To this end, Fennessy et al. (2004, 2007) conducted a review of the available methods for wetland assessment to identify those methods that could be used for the rapid assessment of ecological condition. They concluded that most of the available methods do not provide a proper assessment of ecosystem condition, mainly because they have largely been developed for functional assessments. A recent initiative by the USEPA, which went through a rigorous research and development phase between 2007 and 2011, is aiming to address the need for a coordinated, national programme for the assessment of the ecological condition of wetlands in the United States, namely the "National Wetland Condition Assessment" (USEPA, 2008).

The National Wetland Condition Assessment intends to build upon the "Wetland Status and Trends Reports" that are already produced by the United States Fish and Wildlife Service (USFWS), to provide a national baseline of wetland quality. The USFWS Wetland Status and Trends Reports, which have documented trends in wetland acreage since the 1950's, are considered to be the most commonly cited and scientifically valid source of national-scale wetland information in the USA, but they do not provide any data on wetland condition (Scozzafava, 2009). In an attempt to fill this gap, one of the primary aims of the National Wetland Condition Assessment is to produce a national report that describes the quality of the wetlands of the USA. To date, a list of recommended 'indicator classes' was derived for the national assessment (namely vegetation, algae, soils, water chemistry and stressors), a statistically-valid sampling design and associated sampling procedures were developed (USEPA, 2011), and extensive field sampling has been undertaken. <u>The approach taken in the National Wetland Condition Assessment is to use data collected from minimally disturbed reference sites to establish the criteria for wetland condition</u>.

One of the more well-established, regional-scale wetland ecological condition assessment methods in the United States is the California Rapid Assessment Method for Wetlands (CRAM), now in version 6 (CWMW, 2013a). CRAM has been developed as a cost-effective and scientifically defensible rapid assessment method for evaluating the present ecological condition of six major types of wetland (riverine wetlands, lacustrine wetlands, depressional wetlands, slope wetlands, playas, and estuarine wetlands) throughout California. Application of the method involves the scoring of several metrics of wetland condition, organised into four overarching attributes, namely (1) landscape context and buffer, (2) hydrology, (3) physical structure, and (4) biotic structure. The main output of the method is an overall CRAM score for each "Assessment Area", which is derived from the component scores for the four overarching attributes and their metrics. The overall score provides an indication of the present ecological condition of a wetland relative to the best achievable conditions for that wetland type in the State of California. CRAM also provides guidelines for identifying stressors that might account for low scores, and requires an assessor to go through a stressor checklist to facilitate an exploration of the possible relationships between ecological condition and stress.

The CRAM tool has been designed in such a way that it can be used to assess wetland ecological condition on a variety of scales, ranging from individual wetlands to catchments and larger regions (CWMW, 2013a). In line with the generic approach to RAM development in the USA (e.g. see Sutula et al., 2006), CRAM was formulated according to a set of explicitly-stated underlying conceptual models and assumptions relating to the most appropriate framework for managing wetlands, the driving forces that account for wetland condition, and the spatial relationships among the driving forces. The method has been subject to extensive technical and peer review, and iterative refinement for the various CRAM wetland types. In addition, for certain wetland types (riverine, estuarine and depressional wetlands), the results that are generated by CRAM have been validated against independent, detailed measures of ecological condition involving the collection of biotic data. This has resulted in refinement of the metrics for these wetland types, providing for a higher level of confidence in the ecological meaning of CRAM scores. Similar validation efforts are planned for other wetland types (CWMW, 2009).

While CRAM is a relatively rapid method, it is not necessarily easy to apply. Its application involves a systematic, detailed examination of wetland structure at various spatial scales, which requires the assessor to have a certain level of expertise. A training programme has been developed for instructors and practitioners, and it is recommended that all CRAM practitioners should complete at least one CRAM training course (CWMW, 2009). A "CRAM photo dictionary" (Central Coast Wetlands Group, 2013) has been produced to assist users in the application of the tool.

A number of assessment methods have also been developed in the United States to categorise the degree of human disturbance to a wetland. These have arisen largely out of the need to relate biological data from wetlands to the level of anthropogenic disturbance in the development and testing of wetland IBIs. For example, Gernes and Helgen (2002) developed a method for assessing the degree of disturbance to wetlands based on landscape, physical and chemical stressors. Their method generates a human disturbance gradient score, known as the Human Disturbance Score (HDS), which ranges from zero (for the least disturbed site) to 100 (for the most disturbed site). Five factors are evaluated to derive the final score, namely: (1) the degree of disturbances within the 50 meter buffer area around the wetland edge; (2) the degree of disturbances within the near-wetland landscape, generally within less than 500 meters; (3) habitat, substrate and vegetation disturbances; (4) hydrologic alteration; and (5) the degree of chemical pollution from chloride, phosphorus and nitrogen in water and from copper and zinc in sediments. An additional four points are reserved for features of disturbance not included in these five factors. Another example of a scoring system that has been used to rate the degree of human disturbance to wetlands is the Ohio Rapid Assessment Method for Wetlands (ORAM, v. 5.0) (Mack, 2001a) – the final score generated by this method, which provides a qualitative assessment of the ecological integrity of a wetland, has been applied as the disturbance scale in the development of a vegetation IBI for wetlands developed for Ohio (Mack, 2001b).

A related approach to estimating the degree of human disturbance is to generate an index of land-use intensity from remote sensing data, and/or from an analysis of aerial photographs and field data. An example of this approach used in the USA is the index of Landscape Development Intensity (LDI) that was formulated by Brown and Vivas (2005). The LDI is a quantitative, land-use based index of the intensity of human disturbance within a catchment, derived from the estimation of the use of energy per unit area. According to Brown and Vivas (2005), the LDI can be used at the scale of river, stream or lake catchments, or at the smaller scale of individual isolated wetland catchments.

The LDI index of Brown and Vivas (2005) was evaluated by Mack (2006) using a large reference wetland data set from Ohio, based on land use percentages within a 1 km radius of the wetlands. Mack (2006) found that the LDI index had interpretable and significant relationships with another human disturbance gradient – in this case, ORAM scores, after Mack (2001a) – and with most metrics and scores from the Vegetation IBI developed for use in the State of Ohio (Mack, 2001b). He concluded that the LDI has many advantages over more qualitative measures of human disturbance, given its theoretical underpinnings and the fact that it uses quantified land-use percentages. He predicted that using land-use percentages from increasingly smaller distances from the wetland edge (100-200 m) may improve the resolution of the LDI and its ability to detect on-site disturbances to a wetland.

3.2 Europe

According to Carletti et al. (2004), until approximately ten years ago, no rapid assessment methods existed for the assessment of European wetlands, and the assessment of wetland condition and implementation of wetland management strategies in Europe was highly fragmented. This has, to some extent, been addressed by the implementation of the Water Framework Directive (WFD) of the European Union (Directive 2000/60/EC) established in October 2000. This legal framework requires member states to establish integrated river basin management plans to achieve ‘good ecological status’ of river, lake, estuary and coastal water bodies by 2015. Annex V of the directive lists the specific quality elements to be measured for the determination of ecological status, and it sets out the five categories to be used for the consistent classification of the ecological status of surface water bodies (i.e. high, good, moderate, poor, bad), as explained in European Commission (2005).

While the WFD does clearly identify the protection, restoration and enhancement of the water needs of wetlands as part of its purpose (in Article 1(a) of the Directive), it does not provide any specific definition of what a wetland is, nor does it clearly state the extent to which wetlands should be used for the achievement of environmental objectives (European Commission, 2003a). The WFD considers wetlands to be distinct from other water bodies, but they are implicitly dealt with and are not the primary focus. As explained in a guidance document on the role of wetlands in the WFD published by the European Commission (European Commission, 2003a), the WFD does not set independent ecological objectives for wetlands other than where those wetlands, or parts of them, fall under what would be defined as a surface water body (i.e. a river, lake, estuary, or coastal water body – see European Commission, 2003b). The focus on water bodies and their relationships in the WFD, however, helps to highlight the functional role of wetland systems within the hydrological cycle and the river basin, as reflected in the Directive by means of a complex set of provisions that implicitly take the functional role of wetlands into account (European Commission, 2003a).

A method to assess wetland functioning throughout Europe, in the context of the WFD, has recently been developed by Maltby et al. (2009), representing the culmination of a long-term, interdisciplinary, pan-European scientific research effort. The method sets out Functional Assessment Procedures (FAPs) for application in European countries, which are founded upon an HGM-based approach to wetland classification and assessment.

3.3 Australia and New Zealand

3.3.1 Australia

According to the situation analysis for the development of a framework for the assessment of wetland ecological integrity in South Africa undertaken by DWAF (2004), approximately ten years ago there were no nationally applicable wetland condition assessment methods in Australia (at least according to published records). Some initial testing of multivariate macroinvertebrate-based bioassessment methods for wetlands (developed from the AUSRIVAS bioassessment method for rivers) had, however, been undertaken at that stage. In recent years, all jurisdictions within Australia have applied some form of wetland assessment (with at least 17 significant wetland assessment programs having been implemented across the different states in the country). These have been carried out for varied reasons and under different organisational contexts, over different scales and on a wide variety of wetlands (Alluvium Consulting, 2011).

WetlandCare Australia produced a Wetland Assessment Techniques Manual for Australian Wetlands (Price et al., 2007), which was designed to standardise and re-structure wetland assessment techniques. The aim of this initiative was to allow for the formation of regionally comparable databases that could be used for inclusion in a Decision-support Database to assist with prioritisation of wetlands for management through Catchment Management Authorities. In its current form, the field-based wetland condition assessment technique outlined in the Manual is only suitable for use in swamp forests ("paperbark wetlands"), reed and rush marshes, open freshwater wetlands, and estuarine wetlands. For the applicable wetland types, there are seven high-level "health indices" that must always be derived, namely: (1) Connectivity Index; (2) Human Disturbance Index; (3) Acid Sulfate Soils Index; (4) Vegetation Index (Freshwater or Estuarine); (5) Habitat Potential Index; (6) Tidal Restriction or Hydrological Change Index; and (7) Bank Condition Index (where applicable). Additional specific "health indices" need to be derived, dependent on the wetland type. For example, for Freshwater Marsh dominated by reeds and/or rushes and for Open Freshwater Bodies, the prescribed additional "health indices" are Water Quality and Fringing Vegetation. For each "health index", there are a number of measures that are to be evaluated to derive the final index value (expressed as a percentage). The wetland assessment technique of

Price et al. (2007) appears to be a rigorous, albeit somewhat complex, method and the Manual includes relatively detailed guidance for the required field assessment.

A rather novel initiative in Australia is the Framework for the Assessment of River and Wetland Health (FARWH), which is a system that was developed to facilitate comparable reporting of river and wetland condition across all parts of Australia (Alluvium Consulting, 2011). The FARWH allows for existing river and wetland condition data from across Australia to be normalised and integrated, without replacing existing assessment methods, so that results obtained using different assessment methods can be rationally compared and to facilitate consistent reporting. The design of the assessment framework was initially based on a hierarchical model of river function, with six indices: (1) Catchment Disturbance Index; (2) Hydrological Disturbance Index; (3) Fringing Zone Index; (4) Water Quality and Soils Index; (5) Physical Form Index; and (6) Aquatic Biota Index. The inclusion of a seventh index providing a measure of wetland extent (the Wetland Extent Index) to enable the identification of wetlands that have been fundamentally altered in size or destroyed, and the adoption of a tiered assessment approach that uses desktop assessments to inform where more detailed field assessments should occur, has been recommended to effectively extend the applicability of the assessment framework from rivers to include wetland ecosystems (Alluvium Consulting, 2011).

The conceptual basis of the FARWH is that several unspecified sub-indices are used to derive each of the seven prescribed indices, with the selection of sub-indices to be guided by the characteristics of the local environment and the available data from existing jurisdictional programs. Trials undertaken in different parts of Australia to test the FARWH on rivers and wetlands demonstrated that each of the indices have different levels of importance in different areas, with the identification of the appropriate sub-indices for each index varying considerably between regions. As such, one of the key findings of the FARWH trials was that sub-index selection should be underpinned by a relevant conceptual model (i.e. a set of explicit assumptions that outline the relationship between the chosen sub-indices and the index), with a different conceptual model (and therefore different sub-indices) likely to be needed for each type of system being assessed in each region. It has thus been recommended that future FARWH assessments and reporting should be supported by a research program to continually test the underlying conceptual models (Alluvium Consulting, 2011).

The State of Victoria in Australia is in the process of developing an Index of Wetland Condition (IWC) [and an Index of Estuary Condition] that will conform with the FARWH (Alluvium Consulting, 2011). Wetland condition has been defined for the IWC as the state of the '*biological, physical, and chemical components of the wetland ecosystem and their interactions*', based on a former Ramsar Convention definition of ecological character. The method aims to differentiate natural from human-induced changes in condition, and it is applicable to naturally occurring, non-flowing wetlands that do not have a marine hydrological influence. The IWC is designed for the general surveillance of wetland condition, for assigning wetlands to general condition categories and for detecting significant changes in wetland condition. Currently, the IWC is considered to be a provisional method requiring systematic use and testing as part of a continuing process of development (Department of Sustainability and Environment, 2005).

The IWC takes the form of a hierarchical index, with six sub-indices based on the primary characteristics that are thought to define wetlands, namely: (1) wetland catchment; (2) physical form; (3) hydrology; (4) soils; (5) water properties; and (6) biota. One or two "key ecological components" have been identified for each sub-index, and for each of these components a number of specific measures have been included for evaluation (see Table 1). The selected measures are either the ecological components themselves, impacts on the component or threats to the component (with the latter two being a type of surrogate measure). All sub-indices have an equal maximum possible score of twenty points, so the maximum total score for wetland condition is thus 120. Within sub-indices that have more than one measure, each measure is given equal weighting. The guiding principal behind the scoring of each measure is the comparison with reference condition. For each component-based measure, the greater the departure from the reference condition the lower the score (for threat-based measures, the reference condition will be the absence of the activity with the potential to cause a change in condition or, in some cases, the absence of a risk factor likely to cause a change in condition). The four final reporting categories for the IWC, based on scoring classes that are equally distributed across the total scoring range, are simply "well below reference", "moderately below reference", "slightly below reference", and "reference" (Department of Sustainability and Environment, 2005).

Table 1: List of sub-indices included in the Index of Wetland Condition (IWC), and the key ecological components and respective measures to be considered for each sub-index, together with an indication of the type of measure in each case (from **Department of Sustainability and Environment, 2005**)

IWC sub-index	Key ecological component	Measure	Measure type
Wetland catchment	Wetland catchment	Percentage of land in different land use intensity classes adjacent to the wetland	Threat
	Wetland buffer	Average width of the buffer	Component
		Percentage of wetland perimeter with a buffer	Component
Physical form	Area of the wetland	Percentage reduction in wetland area	Component
	Wetland form	Percentage of wetland where activities (excavation and landforming) have resulted in a change in bathymetry	Threat
Hydrology	Water regime	Severity of activities that change the water regime	Threat
Water properties	Macronutrients (such as N and P)	Activities leading to an input of nutrients to the wetland	Threat
	Electrical conductivity (salinity)	Factors likely to lead to wetland salinisation • input of saline water to the wetland • wetland occurs in a salinity risk area	Threat
Soils	Soil physical properties (structure, texture, consistency and profile)	Percentage and severity of wetland soil disturbance	Impact
Biota	Wetland plants	Wetland vegetation quality assessment based on: • critical lifeforms • presence of weeds • indicators of altered processes • vegetation structure and health	Component Impact Impact Component

As part of the ongoing development of the IWC, a review of wetland assessment methods reported in the literature from Australia, New Zealand and the USA was undertaken (Department of Sustainability and Environment, 2006). The conclusion of the review was that there are significant differences between methods and their objectives, and that no single method can be easily adapted as a Victorian state-wide method. The review did, however, identify and highlight important aspects of the existing methods considered to be of possible relevance to the development of a wetland condition assessment method for the State of Victoria, including aspects relating to the framework for the development of indicators or measures and the practical requirements of a robust assessment method.

Spencer et al. (1998) previously developed a wetland condition index for the rapid field-based assessment of permanent floodplain wetlands in the Murray Darling Basin, which appears to have informed the ongoing development of the more recent IWC to some degree. This index was composed of 13 indicators related to wetland function, based on four primary wetland attributes (namely: soils, fringing vegetation, aquatic vegetation, and water quality). Each indicator was scored from 0 to 4, whereby the highest scores reflect the best condition and the lowest scores reflect the most degraded condition. Each sub-index score was normalised to produce a score out of 10. A final score of 10 represented excellent condition and a score of zero represented extremely poor condition. Spencer et al. (1998) tested the index in the field for scientific validity relative to an independent long-term monitoring data-set, replicability of indicator scores by different investigators, and the seasonality of wetland processes. They concluded that wetland condition index is a valuable and reliable tool for the rapid surveying of the condition of permanent floodplain wetlands in the Murray Darling Basin, but that reference wetlands and further validation would be required if the tool were to be applied to floodplain wetlands in other regions of the country.

3.3.2 New Zealand

Two methods have been developed to assess wetland condition within New Zealand (Suren et al., 2011) – the Wetland Condition Index (WCI) (Clarkson et al., 2003) and the Index of Ecological Integrity (IEI) (after Ausseil et al., 2008; cited by Suren et al., 2011). Both these methods (described briefly below) primarily assess the landscape and catchment factors that influence wetland plant communities (Suren et al., 2011).

The WCI method for New Zealand is based on field observations of five factors that are considered to affect wetland condition: 1) hydrological integrity; 2) physicochemical parameters; 3) ecosystem intactness; 4) browsing predation and harvesting regimes; and 5) dominance of native plants. Each indicator component is scored on a subjective scale from zero to five, with zero representing the most degraded condition and five representing the unmodified or best condition. These component scores are then summed to derive the final WCI score, which ranges from 0 to 25. According to Clarkson et al. (2003), the selection of indicators followed the international trend of using soil and vegetation characteristics as the most important indicators of wetland condition. The wetland classification system adopted by the WCI assessment method is the national typology for New Zealand wetlands developed by Johnson and Gerbeaux (2004), which is a classification system based largely on structural features (i.e. not an HGM-based classification system).

The documentation for the WCI method (Clarkson et al., 2003) includes concise, yet comprehensive, user-friendly score-sheets and scoring guidelines. As noted in the review by the Department of Sustainability and Environment (2006), the score-sheets include a ‘Specify and Comment’ column, which provides information on the reason a particular score has been given so it can be recalled at a later date.

According to Suren et al. (2011), the IEI method for New Zealand wetlands involves the combining of six spatial indicators of human activities (termed ‘‘pressure measures’’) known to degrade wetland biodiversity and function, which are derived from national GIS databases and applied across three spatial units, i.e. the wetland catchment, a 30 m buffer around the wetland, and the wetland itself. The six indicators used for the IEI are: 1) proportion of natural vegetation cover; 2) proportion of human-made impervious cover; 3) number of introduced fish species; 4) percentage cover by woody weeds; 5) artificial drainage; and 6) a surrogate measure of land-use intensity (nitrate leaching risk). After appropriate weighting, the pressure measures are summed to derive the final IEI, which ranges from 0 (totally degraded, with no remaining ecological integrity, native biodiversity or ecological function) to 1 (pristine, no human-induced impacts).

4 COMPARISON OF WETLAND ASSESSMENT TOOLS USED IN SOUTH AFRICA

4.1 Legislative context

The South African legal framework for wetland assessment (and inland aquatic ecosystem assessment, more generally), as contained mainly in the National Water Act (Act No. 36 of 1998) (NWA), is rather distinctive. For example, it is quite different to the legislative framework created by the Clean Water Act in the USA and the Water Framework Directive in Europe.

In South Africa, the NWA lays down a series of regulatory measures that are, together, intended to facilitate the protection of water resources throughout the country (particularly in Chapters 3 and 14), with "water resources" defined to include rivers, wetlands, estuaries and aquifers. More specifically, this Act (in section 12, under Chapter 3) sets out the legal requirement for the Minister to prescribe a system for classifying water resources into management classes, which is to serve as the basis for the setting of "the Reserve" and the "Resource Quality Objectives (RQOs)" for all significant water resources in the country. Chapter 14 of the NWA places a duty on the Minister to, as soon as reasonably practicable, establish national monitoring and information systems for water resources (in sections 137 and 139 of the Act, respectively).

The term "Reserve", as defined by the NWA, refers to the quantity *and* quality of water required to, (a) satisfy basic human needs such as drinking, food preparation and personal hygiene (the so-called "basic human needs Reserve"), and (b) protect aquatic ecosystems (the so-called "ecological Reserve"). The quantity and quality of water which remains in excess of the Reserve is considered to be the "total allocatable resource", which may be distributed amongst competing users guided by the objectives of social equity and economic efficiency. The water requirements of the ecosystem must thus be met before any allocation of resource quality or quantity for productive use may be made (e.g. see Van Wyk et al., 2006).

RQOs serve to establish clear goals relating to the quality of the water resources that have been classified (into a management class) in terms of the prescribed water resource classification system. According to section 13(3) of the NWA, the RQOs of a particular water resource may relate to (a) the Reserve; (b) the instream flow; (c) the water level; (d) the presence and concentration of particular substances in the water; (e) the characteristics and quality of the water resource and the instream and riparian habitat; (f) the characteristics and distribution of aquatic biota; (g) the regulation or prohibition of instream or land based activities which may affect the quantity of water in or quality of the water resource; and (h) any other characteristic, of the water resource in question. In determining RQOs, a balance must be sought between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other.

The ecological Reserve that is established and the accompanying RQOs that are set for a water resource will vary, depending on the designated management class of the resource.

The Minister is required to determine the Reserve and the RQOs for all or part of any significant water resource in the country, on the basis of the designated management class of each water resource deemed to be "significant". Once the Reserve and the RQOs of a water resource have been determined and published in the Government Gazette, adherence to them becomes legally binding.

Regulations for the establishment of a national Water Resource Classification System (WRCS) were gazetted in September 2010 (Government Notice No. R. 810 of 17 September 2010), which set out a 7-step procedure for determining the class of a water resource (with three classes prescribed[1]), an 8-step procedure for determining the Reserve, and a 6-step procedure for determining RQOs. The officially gazetted Regulations were developed from a comprehensive series of five volumes containing detailed technical information about the development of the WRCS that were published by the Department of Water Affairs some three-and-a-half years earlier (see DWAF, 2007a). The significance the water resource classification process is that the higher the management class, the less water that may be abstracted and the more stringent the RQOs, because the water body must be maintained in a state that is closer to natural than resources classified into a lower management class.

The 8-step procedure set out in the WRCS for the determination of the Reserve for a particular water resource is as follows:

- STEP 1: Initiate the basic human needs and ecological water requirements assessment.
- STEP 2: Determine eco-regions, delineate resource units, and select study sites.
- **STEP 3: Determine the reference condition, present ecological status (PES), and the ecological importance and sensitivity of each of the selected study sites.**
- STEP 4: Determine the basic human needs and ecological water requirements for each of the selected study sites.
- STEP 5: Determine operational scenarios, and their socio-economic and ecological consequences.
- STEP 6: Evaluate the scenarios with stakeholders.
- STEP 7: Design an appropriate monitoring programme.
- STEP 8: Gazette and implement the Reserve.

The original 10-step process for the implementation of Resource Directed Measures (RDM) for the protection of water resources developed by the Department of Water Affairs in 1999 (as presented in DWAF, 1999a) included aspects relating to the setting of management classes and RQOs, which are dealt with as separate but related procedures to the Reserve in the WRCS[2].

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[1] Class I: minimally used water resources with an overall condition that is minimally altered from the pre-development condition; Class II: moderately used water resources with an overall condition that is moderately altered from the pre-development condition; Class III: heavily used water resources with an overall condition that is significantly altered from the pre-development condition.

[2] As pointed out by Rountree et al. (2013), the Resource Directed Measures (RDM) of the Department of Water Affairs collectively comprises of the determination of the management class, the Reserve and the RQOs for significant water resources, as per the prescribed WRCS.

Of most relevance to the current review is Step 3 of the 8-step procedure set out in the WRCS for the determination of the Reserve (as highlighted in bold above), which is the equivalent to Steps 3 and 4 of the original 10-step RDM process (as outlined in DWAF, 1999a) where the determination of reference conditions was included as a separate step before the determination of PES and Ecological Importance and Sensitivity (EIS). In recent years, the Department of Water Affairs has adopted the term "EcoClassification" (after Kleynhans and Louw, 2008) to refer to the inter-related actions of determining the PES (relative to the perceived reference condition), the EIS and the Recommended Ecological Category [previously known as the Ecological Management Class] of a water resource (e.g. see the generic procedure for Reserve Determination studies provided by Rountree et al., 2013 as the basis for the methods recommended for conducting rapid Ecological Reserve Determinations for inland wetlands).

Central to the determination of the PES of an aquatic ecosystem (and to the assignment of a Recommended Ecological Category), within the national WRCS framework, is the categorisation of the (present and/or desired future) biophysical state/condition of a water resource, relative to the natural (pre-development), minimally-impacted reference conditions. Since the publication of the original RDM methods for various kinds of aquatic ecosystems by the Department of Water Affairs in 1999, a six-class (A to F) rating system (see Table 2) has been widely used to categorise and describe the ecological condition for water resource management purposes in South Africa. The six Ecological Categories (also known as PES Categories or Habitat Integrity Categories) were originally conceived for an Index of Habitat Integrity (IHI) for rivers that was developed by Neels Kleynhans of the Department of Water Affairs in the mid-1990's (Kleynhans, 1996). These categories were then adopted as the framework for Habitat Integrity (PES) assessments for Ecological Reserve Determination processes for river (DWAF, 1999b) and wetland (DWAF, 1999c) ecosystems, and they have now become the standard language for describing the ecological condition (present / recommended / predicted) of inland and estuarine aquatic ecosystems in South Africa.

Table 2: Ecological Categories for assessment of the Present Ecological State (PES) of inland aquatic ecosystems (after **Kleynhans, 1996**)

ECOLOGICAL CATEGORY	PES % SCORE	DESCRIPTION
A	90-100%	Unmodified, natural.
B	80-90%	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	60-80%	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D	40-60%	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	20-40%	The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-20%	Modifications have reached a critical level and the ecosystem has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

According to section 137(2) of the NWA (under Chapter 14), monitoring systems must be established at a national level to provide for the collection of appropriate data and information necessary to specifically assess, among other matters, (a) the quantity of water in the various water resources; (b) the quality of water resources; (c) the use of water resources; (d) the rehabilitation of water resources; (e) compliance with resource quality objectives; [and] (f) the health of aquatic ecosystems. As such, there is a legal mandate for the Department of Water Affairs to ensure that there is a system in place to monitor and report on the "health" (i.e. present ecological condition, or PES) of aquatic ecosystems in the country, including wetlands. An example of an existing national monitoring programme that has been established in terms of Chapter 14 of the NWA (specifically, section 137 of the Act) is the River Health Programme. A project has been initiated by the WRC to develop and pilot-test a framework for a National Wetland Monitoring Programme for South Africa (WRC Project K5/2269).

From the above summary of some of the key legal provisions stemming from the NWA, it is clear that the determination of Ecological Categories to describe the PES of water resources (including wetlands) and the assignment of Recommended Ecological Categories as a basis for the ongoing management of water resources form major components of the procedures for RDM, particularly with respect to the water resource classification requirements of the NWA. This information is ultimately used by government officials to make management decisions that relate to the sustainable utilisation and protection of wetlands and other water resources in the country. Interestingly, the South African legislation does not set out any specific requirements for the assessment of ecosystem functioning or the provision of ecosystem services by aquatic ecosystems, as in the case of the USA and a number of other countries where the focus of the legislation is on functional assessments. Presumably, this is based on an implicit assumption that if the ecological condition of a water resource is good, the functioning will also be good.

Whilst there is a clear, rather prescriptive legal mandate for the determination of the PES of significant wetlands (and other types of aquatic ecosystems) in the NWA, through the national WRCS, it is important to take cognisance of the fact that not all wetland assessments undertaken in the country form part of a RDM process. There is, for example, also the legal requirement for national monitoring of and reporting on the "health" of aquatic ecosystems, including wetlands, in terms of Chapter 14 of the NWA – this would typically require, amongst other things, the periodic determination of the PES of selected wetlands across the country. In addition, other legislation besides the NWA exists in South Africa that triggers the need for wetland assessments to be undertaken, such as the Environmental Impact Assessment (EIA) Regulations of the National Environmental Management Act (Act No. 107 of 1998) (NEMA) and the National Environmental Management: Waste Act (Act No. 59 of 2008) whereby specialist freshwater ecological input (including wetland delineation and assessment) is generally required to assess the potential impact of certain listed activities relating to or within a specified distance of any "watercourses". In these cases, there are no legally binding procedures or assessment methods that have to be followed to categorise the PES of wetlands and other watercourses. A scientifically defensible assessment of the predicted significance of the potential impacts of proposed development activities has to be presented, however, which would generally require an assessment of the PES and the ecological importance and/or sensitivity of potentially affected wetlands.

There is also a legal imperative to conduct PES assessments of water resources for which a water use licence (or registration of a General Authorisation) is required in terms of sections 21 and 22 of the NWA, forming part of the so-called Source-Directed Controls for water resource management. According to section 27(1) of the NWA, “In issuing a general authorisation or licence a responsible authority must take into account all relevant factors, including ... (f) the likely effect of the water use to be authorised on the water resource and on other water users; [and] (g) the class and the resource quality objectives of the water resource”, where the RQOs would also include information about the Reserve. Section 17 of the Act, read together with section 22(5), stipulates that the Minister must establish a preliminary Reserve before authorising the use of water within a water resource in cases where a Reserve has not yet been determined for a particular water resource. This means that the PES, the Recommended Ecological Category and the RQOs for a water resource must all be given due consideration when completing or evaluating a Water Use Licence Application (WULA) or the registration of a General Authorisation. These requirements also apply to non-consumptive “water uses” such as those listed in Section 21(c) and (i) of the NWA, namely “impeding or diverting the flow of water in a watercourse” (Section 21(a) water use) and “altering the bed, banks, course or characteristics of a watercourse” (Section 21(i) water use). For these non-consumptive water uses, the Supplementary Water Use Information Form that must be submitted with applications to DWA specifically requires that an assessment must also be made of the extent to which the potential impacts of a proposed “water use” activity will bring about changes in respect of the PES (after mitigation).

It is important to note that not all wetland assessments in South Africa are conducted to merely fulfil legal requirements, either in terms of the NWA or other environmental legislation. Examples of situations and contexts within which wetland assessments are undertaken, at various levels of detail, include *inter alia*:

- Wetland rehabilitation planning and the evaluation of the success of wetland rehabilitation interventions (such as that undertaken by the Working for Wetlands Programme);
- Conservation planning (such as the compilation of systematic biodiversity plans that incorporate inland aquatic ecosystems);
- Strategic environmental assessments and the compilation of Environmental Management Frameworks;
- Compilation of State-of-Environment Reports; and
- Compilation of wetland inventories where the inventory contains attribute information about the wetlands.

It is also important to note that not all wetland assessment methods provide for the categorisation of the PES of a wetland. Furthermore, some assessment methods have specifically been designed to fulfil legal requirements and/or to be rapid, while others have been designed with the intention of providing a means of gaining a better understanding of the characteristics of wetlands. These differences are explored in more detail in the following subsection.

4.2 Historical overview of wetland assessment methods developed in South Africa

A list of the most influential, nationally applicable wetland assessment methods that have been developed in South Africa is presented in Table 3. For completeness and to gain a better understanding of the evolution of method development in this country, the list includes methods that were developed for purposes other than the assessment of wetland PES. For example, methods for the assessment of wetland ecosystem service provision (i.e. functional assessment methods) and for the categorisation of the Ecological Importance and Sensitivity (EIS) of a wetland ecosystem are included. A brief description of each of the methods is provided below, in chronological order.

Wetland-Use, Version 1 (Kotze et al., 1994): This was one of the first attempts at the development of a rapid, systematic wetland assessment method in South Africa, although it was initially developed specifically for use on privately-owned, large-scale commercial farms in the KwaZulu-Natal Midlands. Wetland-Use was essentially a tool for assessment of the functional value of a wetland, the development of which drew heavily on the Wet Evaluation Technique (WET) of Adamus et al. (1987) in the United States. The initial (1994) version of Wetland-Use provided a rather complex decision tree for predicting the effect of the impact of a variety of particular land-uses on the functional values of a wetland, as a basis for determining the acceptability of those land-uses.

Index of Habitat Integrity (IHI) for river ecosystems (Kleynhans, 1996): This was a method developed originally for assessment of the habitat integrity status of the Levuvhu River ecosystem (a tributary of the Limpopo River, with a section that flows through the Kruger National Park). It introduced the A to F categories for describing the PES Class or Ecological Category of a water resource, now established as the *lingua franca* for assessments of the ecological condition of inland and estuarine aquatic ecosystems in South Africa[3]. Most of the wetland PES assessment methods that have been developed by or for DWA have been based on this river assessment method, which could partly explain why the wetland assessment methods developed to date are not applicable or difficult to apply to non-riverine wetlands such as depressions (including pans) and seeps (see Section 3.3).

Wetland Fix assessment forms (Wyatt, 1997): Wetland Fix was an illustrated set of step-by-step field guides on the assessment, management and rehabilitation of wetlands, produced by the Rennies Wetlands Project (which later became the Mondi Wetlands Programme). A set of assessment forms accompanied the Wetland Fix series of documents, which aimed to provide a simple method of wetland evaluation for use by land-agency extension officials and others who are not necessarily wetland specialists. The assessment forms were intended to be used for education, simple impact assessment, the formulation of management or restoration guidelines, and wetland

[3] In the original (Kleynhans, 1996) paper, the six categories were named Class 1 to Class 6 and were called "habitat integrity classes". Later on (in 1999, after the publication of the National Water Act No. 36 of 1998), these classes were renamed A to F, and also became known as "PES classes" or "PES categories". More recently (since the adoption by DWA of the EcoClassification procedures of Kleynhans and Louw, 2008) they are more commonly referred to as "Ecological Categories".

inventory purposes. The key question that the Wetland Fix assessment forms attempted to address was whether or not wetland functioning has been significantly altered, based on the assumption that the degree of impairment to the provision of wetland functions is directly related to the type and magnitude of impact. There is no scoring of impacts or of impairment of wetland functions, nor an overall categorisation of the present ecological condition or functional importance of a wetland. Instead, the assessment forms simply allow for the categorisation of the land-uses impacting on a wetland, the landscape setting of the wetland, and the vegetation cover type within each hydrological zone of the wetland.

DEAT Wetland Classification System, Draft 1 (Dini et al., 1998): One of the first concerted attempts by a government agency to develop a nationally applicable classification system to differentiate between different types of wetlands. While a wetland classification system is not an assessment method, it provides the wetland typology needed as the basis for wetland assessment. This version was based on the well-known classification system for wetlands and deepwater habitats of the United States Fish and Wildlife Service (Cowardin et al., 1979), accounting for all aquatic ecosystem types defined as wetlands in terms of the Ramsar Convention. The DEAT Wetland Classification System (Draft 1) tried to introduce HGM wetland types at the lower levels of the hierarchical classification framework, using the HGM types that were being explored by a number of wetland scientists in the country at the time (e.g. in Wetland-Use and in the work of Kotze, 1999).

National Water Act (Act No. 36 of 1998): This key piece of legislation is also not an assessment method, nor does it make reference to any specific assessment methods, but it contains the first nationally applicable legal definition of "wetland" and it sets out the requirements for Resource Directed Measures (RDM) to protect water resources in the country. Part of the RDM process, as outlined earlier in this review, is to determine the PES of all significant water resources (including wetlands) and to use this as the basis for the setting of the ecological management class for each resource, which in turn informs the determination of the Reserve and the RQOs for significant water resources. The NWA also sets out the legal mandate to establish a national system to monitor and report on the "health" (i.e. present ecological condition, or PES) of aquatic ecosystems in the country, including wetlands.

System for Supporting Wetland Management Decisions (Kotze, 1999): A seminal piece of work, representing some of the earliest focussed research on wetland assessment in South Africa, conducted over a period of approximately 5 years in KwaZulu-Natal. This PhD thesis includes a refined version of the assessment method and decision-support tree initially presented in Wetland-Use (Kotze et al., 1994), and one of the first HGM-based wetland classification systems proposed for use in South Africa.

Procedure for Intermediate Determination of RDM for Wetland Ecosystems (Duthie, 1999a): Part of the DWAF (1999c) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). It outlines the generic RDM process to be followed for an Intermediate Reserve determination. For the determination of ecoregional types, the prescribed procedure was to use the DWAF (1999b) ecotyping scheme for rivers to categorise Ecoregion Levels I and II, and to use the Lacustrine, Palustrine and Endorheic classification in the proposed national wetland classification of Dini et al. (1998) for Ecoregion Level III. The ecotyping was then used as the basis for the selection of the most appropriate methods for determining the PES, EIS and Ecological Management Class. For Lacustrine or Endorheic wetlands (e.g. lakes or pans), the methods developed for lakes (i.e. Harding, 1999a, b) were specified for use or adaptation according to site conditions; for Palustrine wetlands, the methods for floodplain/palustrine wetlands (i.e. Duthie, 1999b, c) were to be used or adapted according to site conditions.

Intermediate Ecological Reserve PES method for [floodplain] wetlands (Duthie, 1999b): Part of the DWAF (1999c) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). The aim of this particular document was to provide a method for determining, at an Intermediate level of determination, the PES of palustrine wetlands (after Dini et al., 1998) according to a modified Habitat Integrity approach (after the river methods of Kleynhans, 1996; Kemper, 1999). Although the method was, in the first instance, developed for floodplain wetlands (due to its origin in a river PES method), it was to be used for all palustrine wetland types identified by Dini et al. (1998) (i.e. Flats, Slopes, Valley Bottoms, and Floodplains) but not for endorheic wetlands (pans).

Intermediate Ecological Reserve EIS method for [floodplain] wetlands (Duthie, 1999c): Part of the DWAF (1999c) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). Outlines a method originally developed for determining the EIS of floodplain wetlands, based on and very similar to the river EIS method of Kleynhans (1999), which was to be used for all palustrine wetland types (after Dini et al., 1998) but not for endorheic wetlands (pans).

Comprehensive determination of RDM for freshwater lake ecosystems (Harding, 1999a): Also part of the DWAF (1999c) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). This is a section of the main RDM Manual for Wetland Ecosystems that simply contains a summary of the process followed for a comprehensive Ecological Reserve determination for the Mhlathuze Lakes. An appendix (Harding, 1999b) provides a worked example for Lake Cubhu. The methods recommended for determining the PES, EIS and Ecological Management Class of Lacustrine and Endorheic ‘wetlands’ (i.e. lakes and pans) for an Intermediate RDM process in the RDM Manual for Wetland Ecosystems (Duthie, 1999a) were the tools/methods developed for lakes (with specific reference to Harding, 1999a, b). No generic tools or methods were actually developed, however. The habitat assessment criteria that were used to rate the PES of coastal lakes in the Mhlathuze Study (Harding, 1999a) were eutrophication and water quality, water level regulation, loss of rooted submerged aquatic vegetation, siltation and/or suspensoids, loss of fringing wetlands, loss of estuarine character, loss of ecological function / connectivity, exotic macrophytes, salinization (not-estuarine related), and exotic fauna. Many of these criteria would not really be applicable to endorheic wetlands (pans), and no guidance is provided in the RDM Manual for Wetland Ecosystems (DWAF, 1999c) as to how the lake examples of Harding (1999a, b) were meant to be adapted for determining the PES of endorheic wetlands.

Guidelines for delineation of wetland boundaries and wetland zones (Marneweck and Kotze, 1999): Part of the DWAF (1999c) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). The aim of this document was to provide a set of guidelines which could be used nationally for the delineation of wetlands. As such, this is not a wetland assessment method. The identification and delineation of wetlands is, however, generally required as a precursor to a wetland assessment. The document outlines a framework that was developed for the cost-effective delineation of wetlands, which includes criteria for using soil morphology and vegetation as an indicators of hydric conditions, and a list of other indicators of wetland condition (besides vegetation and soil morphology). Most of the guidelines presented by Marneweck and Kotze (1999) were based on information taken from the Wetlands Delineation Manual of the U.S. Army Corps of Engineers (Environmental Laboratory, 1987).

Wetland-Use, Version 2 (Kotze et al., 2000): The prototype version of Wetland-Use (Kotze et al., 1994) was refined and expanded to make the original system more widely applicable, using funding from the Department of Environmental Affairs & Tourism (DEAT). The assessment component of the revised version of Wetland-Use (called “IMPACT-ASSESS”) allows for the rating of the effect of a variety of impacts on six specific wetland functions (e.g. the impact of medium and high levels of soil disturbance on the function of erosion control and on the other specified functions). It is important to note, for purposes of this review, that neither version of Wetland-Use provides for the categorisation of the overall PES of a wetland or of the different aspects of wetland condition (e.g. hydrology, geomorphology, water quality, vegetation/land-use); instead, it provides for an assessment of the functional value/importance of a wetland.

DEAT Wetland Classification System, Draft 2 (Dini and Cowan, 2000): A modified version of the wetland classification system originally developed by Dini et al. (1998) for distinguishing between different types of wetlands in South Africa. One of the main modifications was the inclusion of Pans (i.e. endorheic wetlands) as a type of Palustrine Sub-system (instead of having Endorheic Systems as a separate, primary wetland type at the first level of the hierarchy). This classification system was still based on the Cowardin et al. (1979) approach to wetland classification, with an attempt to incorporate HGM elements at a lower (sub-system) level of the hierarchy.

Wetland-Assess (Kotze et al., 2004): A tool for the qualitative assessment of the functional value of wetlands, which seems to have been partly built on some of the ideas initially introduced in the assessment methods developed for Wetland-Use (Kotze et al., 1994, 2000) and through the UKZN research project on the development of decision-support tools for wetland management (Kotze, 1999). This was essentially an earlier version of WET-EcoServices (Kotze et al., 2007).

Wetland Habitat Integrity Assessment (Macfarlane, 2004): A tool for the rapid assessment of wetland habitat integrity, initially developed by Sappi for the forestry industry. The initial method (Macfarlane, 2004) was refined and expanded by the KZN Wetland Assessment Working Group (consisting of academics, consultants and NGO representatives) and became known as the Wetland Health Assessment Technique (Wet-HAT). It was a modular-based approach for evaluating and monitoring the PES of South African wetlands, on the basis of ‘hydrological functioning’ and ‘vegetation structure and functioning’ initially, with ‘geomorphology’ added later. This technique essentially represented an earlier version of the WET-Health assessment tool (Macfarlane et al., 2007).

Wetland Identification and Delineation Guidelines (DWAF, 2005): An update of the wetland identification and delineation guidelines of Marneweck and Kotze (1999), published by DWA as a stand-alone document. These guidelines were, again, based largely on information taken from the Wetlands Delineation Manual of the US Army Corps of Engineers (Environmental Laboratory, 1987).

Wetland Water Quality and the Ecological Reserve (Malan and Day, 2005a): A document and accompanying database providing the ranges of expected values for a number of water quality parameters, as recorded from different types of wetlands (following an approach to classification based on Cowardin et al., 1979) and different regions within the country. The ranges of recorded values provided by Malan and Day (2005a) for various water quality parameters, and the “best-guess” water quality objectives estimated for each of the parameters, can be used to assist with the determination of the PES category for a wetland in terms of water quality.

Proposed National Wetland Classification System, Version 1 (Ewart-Smith et al., 2006): Wetland classification system (for distinguishing between different wetland types in South Africa) developed for the National Wetland Inventory. The proposed wetland classification system was intended for widespread national usage, not just application to the National Wetland Inventory. It was based fundamentally on an HGM approach to classification and on a broad definition of ‘wetland’ (following the definition of the Ramsar Convention).

Wetland Index of Habitat Integrity for floodplain and channelled valley-bottom wetlands (DWAF, 2007a): A rapid assessment tool developed for the determination of the overall PES of floodplain and channelled valley-bottom wetlands. It is based on an assessment of the PES of the hydrology, geomorphology, vegetation and water quality of a wetland.

WET-Health (Macfarlane *et al.*, 2007; Kotze et al., 2012): A tool developed for the rapid (Level 1) or comprehensive (Level 2) assessment of the PES of the hydrology, geomorphology and vegetation cover of a wetland, and of the anticipated trajectory of change in these components of wetland integrity. Combining the three components to derive an overall PES rating for a wetland is not recommended, but a means of doing this is provided for. The assessment method is based on an HGM approach to wetland classification and the documentation includes a description of the adopted wetland classification system.

WET-EcoServices (Kotze et al., 2007): An updated version of the Wetland-Assess tool for the qualitative assessment of the functional value of wetlands. The assessment method is centred on an HGM approach to wetland classification, using the same classification system as WET-Health.

Proposed National Wetland Classification System, Version 2 (SANBI, 2009): An updated and refined version of the proposed classification system for aquatic ecosystems initially developed for the National Wetland Inventory (Ewart-Smith et al., 2006), intended for widespread use nationally. The HGM types in this classification system are similar to those of the classification system adopted by WET-Health and WET-EcoServices, except that it makes provision for the classification of marine and estuarine systems, in addition to inland aquatic ecosystems, and that it includes rivers as an inland aquatic ecosystem type.

Outputs of the Wetlands Health and Importance (WHI) research programme (Day and Malan, 2010): A series of documents providing a summary of the outcomes of research into the development of tools for bio-assessment of wetlands, broad-scale assessment of impacts and ecosystem services, and evaluation of the socio-economic importance of wetlands and the sustainability of wetland use. The outputs of this research programme are of relevance to the determination of the present ecological condition (and importance) of wetlands and to the assessment of impacts on wetland condition and functionality.

Water quality and wetlands: defining Ecological Categories and links with land-use (Malan and Day, 2012): An updated report and accompanying database that attempts to establish, for a variety of water quality parameters, the typical ranges of values that occur in different wetland types and in different regions of the country. Wetland types were categorised on the basis of Version 2 of the proposed National Wetland Classification System (SANBI, 2009). The relationships between land-use, water quality and ecosystem condition are also explored.

Manual for the Rapid Ecological Reserve Determination of Inland Wetlands, Version 2 (Rountree et al., 2013): An update of the DWAF (1999c) RDM Manual for Wetland Ecosystems, specifically for *rapid* Ecological Reserve Determinations of wetlands. The Manual does not provide any new PES assessment methods for wetlands but, rather, outlines the procedures that should be followed and the tools that should be used for determining the PES of different wetland HGM types and for different ecosystem components within each wetland (i.e. hydrology, geomorphology, water quality, vegetation, diatoms, fish, and groundwater). For example, the recommended assessment methods for the rapid determination of the hydrological and geomorphological PES of floodplain and channelled valley-bottom wetlands are the hydrology and geomorphology modules of Wetland-IHI (DWAF, 2007a), while the recommended methods for all other HGM types are the Level 1 hydrology and geomorphology modules of WET-Health (Macfarlane et al., 2007).

EIS method for wetlands (for Reserve determinations) (Rountree and Kotze, 2013): An appendix to the Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Rountree et al., 2013), which presents a newly-proposed method for rapidly categorising the EIS of a wetland based on an amalgamation of the previous wetland EIS assessment tool developed by DWA (Duthie, 1999c) and the WET-EcoServices functional assessment tool (Kotze et al., 2007). The new tool provides for an assessment of three suites of wetland importance criteria, namely: 1) traditional EIS criteria, as used in

EIS assessments of other water resources by DWA; 2) hydro-functional importance, which considers the water quality, flood attenuation and sediment trapping ecosystem services that a wetland may provide; and 3) importance in terms of basic human benefits, taking into consideration the subsistence uses and cultural benefits of a wetland system. The recommended approach is to use the highest of these three suites of scores to determine the overall Importance and Sensitivity category of a wetland.

Water quality assessment method for wetlands (for Reserve determinations) (Malan et al., 2013): An appendix to the Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Rountree et al., 2013), which presents a relatively simple, rapid method for determining the water quality component of the Ecological Reserve for different wetland types. The method provides guidance as to how to establish the present water quality condition (in terms of categories from A-E/F), how to establish wetland sensitivity to potential changes in water quality, and how to identify likely changes in water quality under different future development scenarios. Three basic complementary approaches are recommended for determining the water quality component of the Rapid Ecological Reserve for wetlands, namely: (1) Measurements of water quality parameters (either historical or new data); (2) The use of diatoms for inferring water quality; and (3) An impacts-based approach based on land-use in the catchment surrounding the wetland. A Landuse/WQ model was developed for the third approach. With only limited testing of the model having been undertaken on different types of wetlands to date, the model does still require extensive testing and validation, but it does represent a promising approach to estimating the water quality PES of a wetland.

Guideline for identifying appropriate levels of Resource Protection Measures for Inland Wetlands (DWA, 2013): A guideline to assist with the selection of the appropriate level of RDM assessment, based primarily on the wetland HGM type (using an HGM-based classification system similar to that of SANBI, 2009). For each wetland type, the document presents a decision tree that serves to guide the DWA official or representative to the appropriate level of RDM assessment for the specific wetland and related water uses under consideration. In addition to the type of wetland, the recommended level of RDM study is determined by the national importance and sensitivity of the wetland, and the type of risks of proposed developments within the wetland and/or the catchment. In each case, except for lakes where reference is made to the DWAF (1999c) approach, it is recommended that the reference conditions, PES, EIS and Recommended Ecological Category should be described according to the methods prescribed in Rountree et al. (2013).

Classification System for wetlands and other inland aquatic ecosystems (Ollis et al., 2013): The final version of the Inland component of the proposed Classification System for Wetlands and other Aquatic Ecosystems in South Africa that was developed for widespread national use (Ewart-Smith et al., 2006; SANBI, 2009), including application to the National Wetland Inventory, published by SANBI in the form of a User Manual (Ollis et al., 2013).

Table 3: A chronology of key, nationally-applicable wetland assessment methods and associated tools developed in South Africa (wetland PES assessment methods highlighted in bold)

Year	Name of method	Key reference/s	Type of assessment	Backing institution	Purpose	Comments
1994	Wetland-Use (Version 1)	Kotze et al., 1994	Functional value	WRC	A wetland management decision-support system to assist agricultural and nature conservation extension personnel in KZN in providing wetland management and land-use planning guidelines.	Tool developed as part of a PhD project on wetland management in KZN by Donovan Kotze (Kotze 1999), at UKZN. Provides an assessment of functional value, rather than an assessment of ecological condition. Based on HGM classification.
1996	**River Index of Habitat Integrity (IHI)	Kleynhans 1996	Rapid PES (rivers)	DWA	River PES assessment method developed for comprehensive Ecological Reserve determinations	The source of the A-F PES categories and the method that forms the basis of many of the wetland PES methods
1997	Wetland Fix assessment forms	Wyatt 1997	Land-use impacts	Rennies Wetlands Project (now the Mondi Wetlands Programme)	To provide a simple method of wetland evaluation for use by land agency extension officials and others who are not necessarily wetland specialists, forming part of a set of illustrated field guides on the assessment, management and rehabilitation of wetlands	The design and intention of "Wetland Fix" was not to embark on any detailed impact assessment but to merely record whether a land use is present and to highlight those activities considered to be potentially serious and detrimental to wetland functioning. Besides rating the land-uses affecting a wetland and/or its catchment, the landscape setting of the wetland is recorded, together with the estimated extent of cover for a variety of vegetation types.
1998	DEAT Wetland Classification System (Draft 1)	Dini et al., 1998	[not an assessment method]	DEAT	To provide a nationally applicable wetland classification system	Based on the Cowardin system with HGM elements introduced
	National Water Act (Act No. 36 of 1998)	Republic of South Africa 1998	[not an assessment method]	DWA	To ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account, amongst other factors, protecting aquatic and associated ecosystems and their biological diversity, and reducing and preventing pollution and degradation of water resources	The National Water Act of 1998 established the legal imperative to determine a recommended ecological management class for all significant water resources in the country (including wetlands). This Act also contains the nationally applicable legal definition of "wetland".
1999	System for Supporting Wetland Management Decisions	Kotze 1999	Functional value	UKZN	To provide guidelines and tools for the assessment and management of wetlands, especially for rural areas in KZN	Donovan Kotze's PhD thesis, which contains the thinking behind many of the wetland assessment methods (incl. an HGM-based classification system)

Year	Name of method	Key reference/s	Type of assessment	Backing institution	Purpose	Comments
	Procedure for Intermediate Determination of RDM for Wetland Ecosystems	Duthie 1999a	[suite of methods for EWR assessment]	DWA	To outline the procedures that should be followed and tools that should be used for determining the PES, EIS, Ecological Management Class, Reserve, and RQOs of different wetland types.	Prescribes the use of the methods developed for either floodplain wetlands (Duthie 1999b) or freshwater lakes (Harding 1999a, b) to determine the PES class, EIS category and Ecological Management Class of all wetland types
	Intermediate Ecological Reserve PES method for floodplain wetlands	**Duthie 1999b**	Rapid PES (wetlands)	DWA	To provide a method for determining, at an Intermediate level of determination, the present ecological status of palustrine wetlands.	Method applicable to all palustrine wetlands (following the wetland classification of Dini et al., 1998) but may need to be adapted for non-floodplain wetlands, according to Duthie (1999a)
	Intermediate Ecological Reserve EIS method for floodplain wetlands	Duthie 1999c	Rapid EIS (wetlands)	DWA	To assess the ecological importance and sensitivity of a floodplain as the basis for determining the Ecological Management Class [now termed the Recommended Ecological Category]	Method applicable to all palustrine wetlands (following the wetland classification of Dini et al., 1998) but may need to be adapted for non-floodplain wetlands, according to Duthie (1999a)
	Comprehensive determination of RDM for freshwater lake ecosystems	Harding 1999a	PES (lakes)	DWA	A summary of the CER determination for the Mhlathuze lakes is provided to serve as a guideline for RDM determination for freshwater lakes.	According to Duthie (1999a), the method is also applicable to endorheic wetlands (pans) (following the wetland classification of Dini et al., 1998)
	Guidelines for delineation of wetland boundaries and wetland zones	Marneweck & Kotze 1999	[not an assessment method]	DWA	To provide a set of guidelines which could be used nationally to delineate wetlands	Basis of the DWAF (2005) wetland delineation manual
2000	Wetland-Use (Version 2)	Kotze et al., 2000	Functional value	DEAT	Modification of 1994 method for widespread national use	Developed after the completion of Kotze's (1999) PhD thesis. Based on HGM classification.
	DEAT Wetland Classification System (Draft 2)	Dini & Cowan 2000	[not an assessment method]	DEAT	To provide a nationally applicable wetland classification system	Update of Dini et al. (1998)
2004	Wetland Assess	Kotze et al., 2004	Functional value (rapid)	Mondi Wetlands Project	Functional wetland assessment tool	An earlier version of WET-EcoServices
	Wetland Habitat Integrity Assessment (morphed into Wet-HAT)	**Macfarlane 2004**	Rapid PES (wetlands)	Sappi	To provide a simple and user-friendly wetland habitat assessment technique that meets the requirements of the Forestry industry	Essentially an early version of WET-Health, which was at one stage called Wetland Habitat Assessment Technique (Wet-HAT)
2005	Wetland Identification and Delineation Guidelines	DWAF 2005	[not an assessment method]	DWA	To provide guidelines for the identification and delineation of wetlands and riparian areas	Based largely on Marneweck & Kotze 1999

Year	Name of method	Key reference/s	Type of assessment	Backing institution	Purpose	Comments
	Wetland Water Quality and the Ecological Reserve	Malan & Day 2005	[not an assessment method]	WRC	To provide guidelines for determining the water quality component of the Ecological Reserve for wetland ecosystems	Includes ranges of values to expect for different water quality parameters, by region and by wetland type
2006	Proposed National Wetland Classification System (Version 1)	Ewart-Smith et al., 2006	[not an assessment method]	WRC/SANBI	To provide an HGM-based national classification system for aquatic ecosystems	Not an assessment method, but provides wetland types that should inform the methods that are developed
2007	**Wetland-IHI**	**DWAF 2007**	Rapid PES (wetlands)	DWA	To derive an Ecological Category (= PES category) for a wetland through a rapid assessment of the hydrology, geomorphology, water quality and (within wetland) landuse changes of the wetland	Tool currently only applicable to floodplain and channelled valley-bottom wetland types (intention is to develop similar tools for other wetland types)
	WET-Health	**Macfarlane et al., 2007, Kotze et al., 2012**	PES (wetlands, comprehensive & rapid)	WRC/ DEAT/SANBI	Assessment method for determining the PES of wetland ecosystems	Includes rapid 'Level 1' and more comprehensive 'Level 2' assessment options
	WET-EcoServices	Kotze et al., 2007	Functional value (rapid)	WRC/ DEAT/SANBI	Assessment method for qualitatively evaluating ecosystem service provision by wetlands	Finalised version of Wetland Assess (Kotze et al., 2004)
2009	Proposed National Wetland Classification System (Version 2)	SANBI 2009	[not an assessment method]	SANBI	To provide an HGM-based national classification system for aquatic ecosystems	Refinement of classification system presented in Ewart-Smith et al., 2006
2010	Wetlands Health and Importance (WHI) research programme	Day & Malan 2010 (and others)	Bioassessment; socio-economic valuation; sustainability of wetland use	WRC	Research into the development of tools for the assessment of wetland environmental condition and socio-economic importance	Includes documents and tools relating to bio-assessment of wetlands, broad-scale assessment of impacts and ecosystem services, socio-economic valuation, and assessment of sustainability of wetland use
2012	Water quality and wetlands: defining Ecological Categories and links with land-use	Malan & Day 2012	Water quality PES (wetlands, rapid)	WRC	Establishing ranges of water quality variables in wetlands and their relationship to land-use and ecosystem response: towards refining the ecological reserve.	Update of the 2005 report on wetland water quality and the ecological reserve. Includes a database of water quality data for wetlands
2013	Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2)	Rountree et al., 2013	[suite of methods for rapid EWR assessment]	DWA/WRC	To provide the technical information (or references to the appropriate methods, where published) for the Rapid level of Reserve determination for all wetland types	Does not provide new PES assessment methods, but outlines the procedures that should be followed and tools that should be used for determining the PES of different wetland HGM types (incl. specific procedures for various PES components)
	EIS method for wetlands (for Reserve determinations)	Rountree & Kotze 2013	Rapid EIS (wetlands)	DWA/WRC	To categorise the ecological importance and sensitivity of wetlands (all HGM types)	Replacement for original method of Duthie 1999c, revised to accommodate all wetland HGM types and to incorporate criteria from WET-EcoServices

Year	Name of method	Key reference/s	Type of assessment	Backing institution	Purpose	Comments
	Water quality PES assessment method for wetlands	Malan et al., 2013	Water quality PES (wetlands, rapid)	DWA/WRC	To categorise the PES of the water quality component of wetland condition	Assessment based on rating of dominant land-use surrounding a wetland
	Guideline for identifying appropriate levels of Resource Protection Measures for Inland Wetlands	DWA 2013	[not an assessment method]	DWA/WRC	To provide a simple guideline that enables the appropriate level and type of Resource Directed Measures to be identified and applied where RDM input or studies are commissioned	Structured primarily according to wetland HGM type, based on a wetland classification system similar to that of SANBI (2009)
	Classification System for wetlands and other inland aquatic ecosystems	Ollis et al., 2013	[not an assessment method]	SANBI	User Manual for the Classification System developed for SANBI	Final version of the NWCS (after Ewart-Smith et al., 2006, SANBI 2009)

** a river PES assessment method that was pivotal to the development of many of the wetland PES assessment methods in South Africa

WRC = Water Research Commission; DWA = Department of Water Affairs [now part of Department of Water and Environmental Affairs (DWEA), previously the Department of Water Affairs & Forestry (DWAF)]; DEAT = Department of Environmental Affairs & Tourism [now the Department of Environmental Affairs forms part of DWEA]; UKZN = University of KwaZulu-Natal; SANBI = South African National Biodiversity Institute

In addition to the above-mentioned nationally applicable wetland assessment methods, a number of regional or more localised adaptations of these methods have been developed for specific areas or for specific applications. One of the earliest examples was a modification of DWA's original PES assessment method for floodplain and other palustrine wetlands (Duthie, 1999b) by Southern Waters (Harding et al., 2001) to make the method more suitable for the assessment of urban systems in the Cape Town metropolitan area and to allow it to be used for the assessment of all palustrine and lacustrine wetland types (including open water "vleis"). More recently, the WET-Health assessment method (after Macfarlane *et al.*, 2007) has been modified for use within the Working for Wetlands Programme (pers. comm., Mr Umesh Bahadur, SANBI), for application by CapeNature personnel in the Western Cape (pers. comm., Ms Nancy Job, Mondi Wetlands Programme), to address identified shortcomings for consulting purposes (pers. comm., Craig Cowden, Ground Truth), and for rapidly assessing the condition of mapped wetlands during a ground-truthing exercise undertaken for the City of Cape Town's Wetlands Map (Snaddon et al., 2009).

A number of wetland PES assessment methods have also been developed for specific purposes, which do not represent a modification of any of the above-mentioned methods. Examples include the following:

- A wetland classification and risk assessment method developed for the monitoring of wetlands on Eskom properties on the Highveld, which incorporates a scoring system to categorise the PES of a wetland in terms of the A-F ecological categories used by DWA (Oberholster and McMillan, no date).
- A tool developed for the rapid desktop-based estimation of the average PES and EIS of all wetlands within a Quaternary catchment (pers. comm., Mark Rountree, Fluvius Environmental Consulting).
- A checklist developed to aid in the rapid assessment of wetland condition for linear development projects (e.g. the construction of pipelines) that potentially impact on numerous wetlands along the proposed route/s, and where different assessors often need to assess the condition of wetland ecosystems (and identify the major impacts and issues of concern) in a consistent manner (pers. comm., Retief Grobler, Imperata Consulting).
- A rapid PES assessment system based on the land-use disturbances within and surrounding a wetland, termed the Human Disturbance Score (HDS) index, was developed by the WHI Programme to facilitate "testing" of the feasibility of detecting human-related disturbances to wetlands through the use of aquatic invertebrates (Bird, 2010) and aquatic macrophytes (Corry, 2012). This HDS index was based on the indices developed by Mack (2001a) for Ohio and by Gernes and Helgen (2002) for Minnesota in the United States, modified for the local (Western Cape) situation using the datasheet for the Western Cape Wetlands Inventory (Dallas et al., 2006) as a starting point. The scoring system consists of two main components, namely a land-use characterisation component and a component relating to indicators of plant community integrity. The land-use characterisation component provides for the rating of the expected effects of immediate and surrounding land-uses (within a wetland, and within a 100 m and 500 m radius of the wetland edge) on the water quality, hydrology and physical structure of a

wetland, using a rating scale from 0 (least disturbance) to 5 (most disturbance). The maximum scores for each distance band and impact category are then summed, and this total score is added to the sum of the plant community indicator scores to produce the final HDS. The HDS is divided by the maximum possible score (70) to obtain the HDS % score for each wetland. Corry (2012) used HDS % scores to divide wetlands into three categories of disturbance intensity (i.e. reference condition, moderate condition, and poor condition). Malan and Day (2012) present a simple way of grouping HDS % scores into the commonly used A-E PES categories.

The historical overview of the development and use of wetland assessment methods in South Africa (as presented above) revealed that there are only three main methods that have been developed to date that are potentially applicable across all regions in South Africa for assessing the present ecological condition of wetland ecosystems. This represents an improvement in the *status quo* of 2005, when a strategic overview of the research needs relating to the assessment of wetland condition and importance (Malan and Day, 2005b) revealed that there was at the time no definitive, well-developed method, or suite of methods, for assessing the ecological condition ("health") of wetlands. The three nationally applicable methods currently available for the assessment of wetland condition are the PES method for floodplain and other palustrine wetlands developed by Duthie (1999b) as part of the package of methods included in the original RDM Manual for Wetland Ecosystems (DWAF, 1999c), the Wetland-IHI for floodplain and valley-bottom wetlands developed by DWAF (2007b), and the WET-Health assessment tool (Macfarlane et al., 2007). A detailed comparison of these methods has thus been undertaken (see Section 4.3, below), to serve as a basis for the identification of gaps in the existing methods (Chapter 5), and for the formulation of recommendations for further research and development relating to wetland assessment methods in South Africa (Chapter 6).

4.3 Comparison of the original RDM-99 PES assessment method for wetland ecosystems, Wetland-IHI and WET-Health

The Wetland-IHI and WET-Health assessment methods are undoubtedly the most advanced wetland PES assessment methods currently available for the assessment of wetland PES throughout South Africa. Both of these methods were developed by highly competent teams of wetland scientists over a number of years, based on the research findings accumulated over many years by the broader aquatic science community, and thus incorporate up-to-date scientific approaches to the determination of wetland PES. It is important, upfront, to acknowledge the significance of the milestones that were attained by the developers of these tools, the foresight of the institutions that initiated the development of the tools, and the ground-breaking research done by the scientists whose work paved the way for the development of the tools. These tools have been extremely influential in the rapid advancement of wetland science that we have experienced in this country in the last decade.

While Wetland-IHI and WET-Health are clearly the most recent and appropriate methods to compare in more detail in this review, the wetland PES assessment method of Duthie (1999b), developed as one of the main tools in the original set of Resource Directed Measures for the protection of wetland ecosystems back in 1999 and hereinafter referred to as the “RDM-99 method”, has also been included in the detailed comparison. The main reasons for this are that, despite its shortcomings and lack of sophistication, the method is still used today (both in its original form and in modified versions) and because the assessment follows a somewhat different approach to that of Wetland-IHI and WET-Health, making for an interesting comparison.

4.3.1 Purpose and applicability

The overall purpose of all three methods is broadly similar in that they are all intended to be used for the categorisation of the PES of wetland ecosystems. The RDM-99 method (Duthie (1999b) was specifically developed for the purpose of determining the PES of wetlands within an intermediate Ecological Reserve determination process. The Wetland-IHI for floodplain and valley-bottom wetlands was, on the other hand, initially developed specifically for the purpose of determining the PES of certain wetland types as a monitoring tool within the wetland component of the National Aquatic Ecosystem Health Monitoring Programme of DWA. Since its development, however, the Wetland-IHI has been used for wetland Reserve determination studies and has been incorporated into the formal Reserve determination processes for wetlands (e.g. Rountree et al., 2013).

The WET-Health tool was, in contrast to the RDM-99 and Wetland-IHI methods, developed outside of the institutional setting of DWA. It was designed the purpose of serving as a rapid, nationally applicable method for assessing the ecological condition of a wetland based on the impacts of human stressors on hydrogeomorphic processes and vegetation responses (Kotze et al., 2012). The WET-Health tool was adopted by the Working for Wetlands Programme as the prescribed method for assessing the ecological condition of a wetland and identifying the major impacts, but the method was not specifically developed for this purpose. For example, an important partner in the development of WET-Health was KZN Wildlife, who were seeking a method for assessing the ecological condition of wetlands (pers. comm., Dr D Kotze), and two of the authors of WET-Health (Goodman and Goge), were both working for KZN Wildlife at the time. Here it is important to recognise that the development of WET-Health started, in the form of Wet-HAT and its predecessors, quite some time before the initiation of the Wetland Rehabilitation research programme that culminated in the publication of the WET-Management series that includes WET-Health.

The RDM-99 method of Duthie (1999b) is most applicable to floodplain wetlands, as this is the wetland type that it was originally developed for. According to the procedures set out for the Intermediate determination of RDM for wetland ecosystems (Duthie, 1999a), however, this PES assessment method could actually be applied to all palustrine wetlands (with some adaptation in certain cases). Pans (endorheic depressions) are the only inland wetland type for which it was specifically stipulated that this method could not be used; instead, the comprehensive approach that was followed for the determination of the PES of lakes was prescribed for this wetland type.

The Wetland-IHI of DWAF (2007b) is, as the full name of the PES assessment method clearly states, only applicable to floodplain and channelled valley-bottom wetlands because the tool was specifically developed for these two HGM wetland types. WET-Health, on the other hand, is supposed to be applicable to all HGM wetland types, according to the primary documentation (Macfarlane *et al.*, 2007; Kotze et al., 2012). In reality, however, this method is most appropriate for the assessment of floodplain and valley-bottom wetlands (channelled and unchannelled), and (to a lesser degree) for hillslope seeps, while it is not particularly well suited to the assessment of depressions (especially endorheic pans) and wetland flats. For example, the WET-Health manual (Macfarlane et al., 2007) explicitly states that the geomorphological module focuses on wetlands that are connected to the drainage network in some way and that it therefore excludes endorheic pans.

4.3.2 Criteria taken into consideration

The WET-Health and Wetland-IHI assessment methods both examine the degree of deviation from the natural reference condition for three components of wetland PES, namely: hydrology, geomorphology and vegetation. Water quality is explicitly included as a fourth component for assessment in Wetland-IHI, which is not the case for WET-Health (although the WET-Health manual does provide a framework for adding a water quality module to a Level 2 assessment). The components considered by the RDM-99 method are similar, also with four in total, except that faunal criteria (which are not taken into account by WET-Health or Wetland-IHI) are grouped together with vegetation criteria in a category referred to as 'biota'

A comparison of the specific criteria that are taken into consideration in the assessment of impacts and the determination of PES scores by the RDM-99 method (Duthie, 1999b), Wetland-IHI (DWAF, 2007a) and WET-Health (Macfarlane et al., 2007) is presented in Table 4, below. The criteria are listed under five overarching categories, namely hydrological impacts, geomorphological impacts, water quality impacts, land-use related vegetation alteration, and faunal impacts.

Table 4: Comparison of hydrological, geomorphological, water quality, vegetation and faunal criteria for the assessment of Present Ecological Status (PES) taken into account by Duthie's (1999b) PES method ("RDM-99"), Wetland-IHI and WET-Health [Y = explicitly included; N = not assessed; ~ = factored into the assessment, but not explicitly]

PES assessment criteria	PES assessment method		
	RDM-99	Wetland-IHI	WET-Health
HYDROLOGICAL IMPACTS			
A. Catchment effects			
A1] Flow modification	Y	~	~
- Changes in flood peaks/frequencies	~	Y	Y
- Changes in base flows	~	Y	~
- Changes in seasonality	~	Y	~
- Zero flows	N	Y	~
- Increased/decreased water inputs	~	~	Y
B. Within-wetland effects			
B1] Connectivity - altered channel size/competency (channel modification)	~*[1]	Y	Y
B2] Increased/decreased water retention in the wetland	~	Y	~
- artificial drainage of wetlands	~	~	Y
- reduced surface roughness	~	~	Y
- impeding features - upstream effects	~	~	Y
- impeding features - downstream effects	~	~	Y
- increased on-site water use	~	~	Y
- deposition/infilling or excavation	~	~	Y
B3] Alteration of inundation patterns	Y	~	~
GEOMORPHOLOGICAL IMPACTS			
A. Catchment effects			
A1] Increased/decreased sediment supply	~*[2]	Y	~
- upstream dams	N	~	Y*[3]
A2] Increased/decreased sediment transport capacity	~*[2]	Y	~
- increased water yield & flood peaks (increased runoff)	~*[2]	~	Y*[4]
B. Within-wetland effects			
B1] Erosional features (increased erosion)	~	Y	Y*[4]
B2] Depositional features (increased deposition)	~	Y	Y*[4]
B3] Topographical alteration	Y	N	~
- infilling	~	N	Y*[5]
- ploughing	~	N	N
- excavation	~	N	N
B4] Stream shortening (diversion)	N	N	Y*[5]
B5] Loss of organic matter	N	N	Y*[6]
B6] (Canalisation)	Y*[7]	~	~

Table 4 continued on following page...

...continuation of Table 4 from previous page

PES assessment criteria	PES assessment method		
	RDM-99	Wetland-IHI	WET-Health
WATER QUALITY IMPACTS			
1] Water quality modification	Y	Y	N*8
- pH	~	Y	N*8
- dissolved salts (TDS/salinity/EC)	~	Y	N*8
- nutrients	~	Y	N*8
- water temp	~	Y	N*8
- turbidity / sedimentation	~	Y	N*8
- dissolved oxygen	~	Y	N*8
- toxics	~	Y	N*8
2] (Sediment load modification)	Y*9	N	N
LAND-USE RELATED VEGETATION ALTERATION			
1] Indigenous vegetation loss/alteration	Y	~	~*10
- agricultural crops	~	~	Y
- pastures	~	N	Y
- grazing/trampling by livestock	~	~	N
- mining/excavation	~	Y	Y
- infrastructure	~	~	Y
- urban development (housing, etc)	~	~	~*11
- harvesting	~	~	N*10
- afforestation (plantations)	~	~	Y
- firewood collection	~	~	N*10
- vegetation clearing	~	Y	N*10
- erosion	~	N	Y
- sports fields	~	~	Y
- gardens	~	~	Y
- flooding by dams	~	N	Y
- seepage below dams (increased perm-zone)	N	N	Y
2] Infilling/backfilling	~	Y	Y
3] Terrestrial encroachment	Y	N	N
4] Alien/invasive plant encroachment	Y	Y	Y
FAUNAL IMPACTS			
1] Domination by alien fauna	Y	N	N
2] Over-utilisation of indigenous fauna	Y	N	N

NOTES:

*1 canalisation included under 'hydraulic/geomorphic' impacts

*2 partly dealt with through inclusion of 'canalisation' under hydraulic/geomorphic impacts

*3 only for floodplain wetlands

*4 for non-floodplain wetlands

*5 only for floodplain and channelled valley-bottom wetlands

*6 only for non-floodplain HGM units with peat

*7 should really be included under hydrological impacts

*8 WET-Health provides a framework for adding a WQ module to a Level 2 assessment

*9 should really be included under geomorphological impacts

*10 veg impact assessment in WET-Health based on land-use categories, not activities

*11 considered under 'infrastructure'

The comparison presented in Table 4 shows that, of the three methods, the RDM-99 method takes into account the fewest specific criteria, primarily because it uses a more generic approach to the derivation of PES scores (with a one-page score-sheet versus at least four pages of datasheets for the other two methods). Specific criteria that are not dealt with by each of the methods are discussed in the gap analysis undertaken for this review (see Section 3.3). At a very coarse level, however, it can be seen from the results presented in Table 4 that one of the major gaps of WET-Health (especially Level 1) is the lack of an explicit module for water quality, and that neither WET-Health nor Wetland-IHI take into account any faunal impacts (although this may be more appropriate for a habitat-based wetland PES assessment tool, as explained later).

4.3.3 Scoring procedures and the importance of reference conditions

The RDM-99 wetland PES assessment method has a simple scoring procedure that involves the rating of each criterion or attribute on a scale of 0 (critically modified) to 5 (natural, unmodified), relative to the presumed natural state, and then calculating the mean score without any differential weighting of the criteria to derive the overall PES category for a wetland (using the A-F categories shown in Table 2 of this review). This represents a simplification the 0-25 scale, with differential weighting of the various criteria, used for the River IHI (Kleynhans, 1996; Kemper, 1999), from which the RDM-99 wetland PES method was derived. The following guidelines are provided for determining the PES category:

- Mean score >4 = Category A;
- Mean score >3 to 4 = Category B;
- Mean score>2 to 3 = Category C;
- Mean score of 2 = Category D;
- Mean score of >0 and <2 = Category E; and
- Mean score of zero = Category F.

If any of the attributes are given a score of less than 2 (i.e. it is considered to be seriously or critically modified), the documentation for the RDM-99 method (Duthie (1999b) stipulates that this score and not the mean should be used to derive the PES category. This approach is based on the assumption that such extensive degradation of any of the wetland attributes would typically override the other criteria and determine the overall ecological condition of the wetland.

The scoring procedures for WET-Health and Wetland-IHI are a lot more complex than that of the RDM-99 wetland PES assessment method, especially in the case of WET-Health, although the final outputs of both these methods are also the categorisation of the PES in terms of the standard A-F ecological categories originally developed by DWA (as presented in Table 2).

In WET-Health, a wetland must be divided into its constituent HGM units and each of the HGM units making up the wetland must be assessed individually because different HGM units are likely to respond in different ways to stressors (Kotze et al., 2012). Once all HGM units have been assessed, a rating of the condition of the wetland as a whole is derived by calculating a combined score for each component by area-weighting the scores calculated for each HGM unit.

The WET-Health assessment tool attempts to standardise the way that impacts are scored and presented for each of the component modules (i.e. hydrology, geomorphology, and vegetation). The spatial extent of an HGM unit that has been affected by a particular stressor must first be estimated (as a percentage of the total area). The intensity of the impact in the affected area is then scored on a scale of 0 (no impact or deviation from natural) to 10 (complete transformation from natural). Extent and intensity of impact are combined (multiplied by one another) to determine the overall magnitude-of-impact score, which is an area-weighted impact score that also ranges from 0 to 10.

Once the magnitude-of-impact scores of individual activities and/or indicators have been calculated, these are combined in a structured way (using weightings in some cases) to provide a measure of overall impact on a scale of 1-10, which is then related to the six A-F categories for describing the present ecological condition to derive an Ecological Category or "health class" for each module. For each module, an assessment must also be made of the likely trajectory of change within the wetland, using a combination of threat and/or vulnerability. Trajectory of change is determined qualitatively based on guidance provided for each of the three modules in the Manual. Five categories of likely change are recognized depending on the direction and/or degree of anticipated change in the next 5 years (↑↑ = large improvement, ↑ = slight improvement, → = remain the same, ↓ = slight decline, ↓↓ = large decline). The overall "health score" is presented in each module by jointly representing the Ecological Category and likely trajectory of change.

While the WET-Health documentation explicitly discourages aggregation of the scores for the three components (hydrology, geomorphology and vegetation), a procedure is provided whereby the results can be integrated into a single score that can be used to categorise the overall present ecological condition of a wetland. The formula that is recommended is: Overall Health = ((Hydrology score) x3 + (Geomorphology score) x2 + (Vegetation score) x2)) ÷ 7, but users can adjust these default weightings for the three components if they consider this to be necessary, provided written justification for such an adjustment is given.

The scoring procedure for Wetland-IHI is slightly less complex than that of WET-Health, partly because the assessment results for different HGM units do not need to be combined together (only one HGM unit is assessed at a time when using the Wetland-IHI tool). A similar scoring system is used, however, whereby the extent of an impact on an HGM unit is multiplied by the rating of the intensity of the impact to derive a magnitude-of-impact score (simply termed the 'Impact Score' in Wetland-IHI) for most of the impacts that are assessed (certain impacts are assessed on the basis of the rating of intensity alone). The rating of intensity is on a scale of 0 to 5 (versus the scale of 0-10 in WET-Health). In some cases, as in WET-Health, the Impact Score is multiplied by a prescribed default weighting (to generate a Weighted Impact Score), to account for the differential influence of the factors being evaluated, before deriving an overall PES score.

The integration of scores from the four component modules of the assessment is strongly encouraged by the developers of Wetland-IHI, in contrast to the situation for WET-Health, and this process is automated (using default weightings for the different modules) in the Excel spreadsheets that accompany the documentation for the assessment tool. When applying Wetland-IHI, as in the case of WET-Health, the default weightings that have been prescribed in the datasheets can be adjusted if this is deemed to be necessary, provided that good written justification for such changes is given.

A comparison between the default weightings used for the different components in the derivation of the overall PES score and category by the WET-Health and Wetland-IHI methods is presented in Table 5, below. Although the RDM-99 method groups the evaluation criteria that are considered under four headings that are similar to the components that are separately evaluated in WET-Health and Wetland-IHI, separate component scores are not generated by the RDM-99 method and the overall Wetland PES Score is simply calculated as the mean of all the criteria that are evaluated (i.e. there is no weighting of any of the criteria). The comparison of weightings shows that the Wetland-IHI method accords a significantly higher weighting to the vegetation component than WET-Health (~45% in Wetland-IHI versus ~28% in WET-Health), while hydrology is given the highest weighting in WET-Health (~43%, versus ~26% in Wetland-IHI). The geomorphology component is given a similar weighting in the derivation of an overall PES score/category by WET-Health and Wetland-IHI (~28% and ~21%, respectively).

Table 5: Comparison of the weightings (as a percentage) given to component scores when deriving the overall Wetland PES Score (and Category) using the Wetland-IHI and WET-Health methods

Component	Weightings allocated to each component by different assessment methods (as a %)	
	Wetland-IHI	WET-Health
Hydrology	26.4%	42.8%
Geomorphology	21.2%	28.6%
Vegetation/Biota	44.4%	28.6%
Water quality	8.0%	n/a

For all three methods, an indication of the degree of confidence in the rating of each criterion needs to be given, to highlight areas of uncertainty in the assessment. The score-sheets provided with the documentation for the RDM-99 method (Duthie, 1999b) and the Wetland-IHI method (DWAF, 2007a) include columns for recording confidence ratings, while this is an omission in the case for the score-sheets provided with the WET-Health manual (Macfarlane et al., 2007).

For the RDM-99 method, Wetland-IHI and a Level 1 WET-Health assessment, the assessor must ascertain and describe the reference conditions of a wetland, which represent the presumed/probable natural (unimpacted) characteristics of the wetland to be used as the baseline against which impacts are evaluated. The determination of reference conditions needs to be done as one the first steps in the assessment process, as it establishes the benchmark against which the entire assessment is conducted. The importance of this aspect of PES assessment is highlighted by its explicit inclusion as a fundamental component of the procedures for RDM and Reserve determinations (e.g. DWAF, 2007a; Rountree et al., 2013) (see Section 4.1 of this review).

Generally, the presumed *natural* state of a wetland prior to human impact is used to establish the reference conditions for a PES assessment. If this approach is not followed, then the baseline against which impacts are assessed would be a shifting target, and it would result in outcomes that are inconsistent and non-comparable. As highlighted by MacKay (1999), this would ultimately lead to a situation where the grounds on which management decisions are made relating to the protection of water resources would always be shifting. There may, however, be certain (very rare) situations where a non-pristine reference state could be used as the baseline for a PES assessment. For example, if a wetland has been modified to such an extent, and in such a manner, that ecosystem structure, functions and processes have been irreversibly changed (through human intervention or catastrophic natural events), such an ecosystem can still be "healthy" and require protection in its present, highly modified state, although it may bear little resemblance to the ecosystem which was present under natural unimpacted conditions. If a new stable ecological state has been reached and there is no practical way of restoring the original ecological characteristics of a particular wetland ecosystem, then there may be justification for using non-pristine reference conditions to more accurately reflect the new ecological characteristics (MacKay, 1999; Duthie, 1999a). This type of situation would be the exception, rather than the rule, and expert judgement would be required to ascertain whether the "resetting" of reference conditions is indeed appropriate. The adoption of a non-pristine reference state for PES assessments is utilised a lot less now than it was in the "early days" of applying the RDM procedures in South Africa (in the late 1990's to early 2000's), as a result of the recognition that this approach precludes any consistent scoring or comparable monitoring of water resources (pers. comm., Mark Rountree, Fluvius Environmental Consultants).

In the case of a comprehensive WET-Health Level 2 assessment, the determination and description of the natural reference state of the wetland that is being assessed is less critical, except for the vegetation component where some understanding of the natural (unimpacted) vegetation is required. This is because the impact scores that are generated, and the PES scores that are ultimately derived, are based on the evaluation of numerous specific aspects (for example, the density and size of drains within a wetland) that have been formulated around an in-built assumption of what the typical characteristics of an unimpacted wetland are.

4.3.4 Amount of time, level of experience required, and user-friendliness

The documentation for the RDM-99 wetland PES method (Duthie, 1999b) does not indicate how long an assessment should take, but does state that the tasks to be undertaken for an assessment should include a literature review of relevant aspects, analysis and interpretation of maps and aerial photographs, a site visit and use of local knowledge, rating of the assessment criteria and generation of preliminary PES scores, and reporting. For most wetlands, it should be possible to complete the site visit, rating of criteria and generation of PES scores within half a day.

For the Wetland-IHI method, data and information required for the assessment should also be obtained through a rapid site visit (taking approximately 3 hours, according to DWAF, 2007b) and, possibly, from remotely sensed imagery (including aerial photographs, maps and/or satellite imagery).

In the case of WET-Health, the option is provided of either undertaking a rapid "Level 1" assessment or a more comprehensive "Level 2" assessment. The Level 1 assessment is intended to be primarily a desktop evaluation with limited field verification, while the Level 2 assessment requires the structured collection of data from the catchment and the wetland. According to the manual (Macfarlane et al., 2007), the Level 1 assessment has been designed for use when many wetlands need to be assessed over a broad geographical area, whereas the Level 2 assessment has been developed for the more detailed assessment of a single wetland. The time required to undertake a Level 2 assessment could be anything from 2 to 20 hours, depending on the size and complexity of the wetland and its catchment, and on the number and level of complexity of the impacts to which the wetland has been subjected but most assessments should be completed in less than 8 hours (Macfarlane et al., 2007). According to Kotze et al. (2012), a WET-Health Level 2 assessment should take no more than two people half-a-day in the field, and no more than another half-a-day of office preparation and data analysis should be required to obtain a result. The review by Malan (2008), however, concluded that application of a Level 2 assessment to a single, small wetland is more likely to take an average of 2 days (3-4 hours preparing maps, 1 day in the field, 4-5 hours completing datasheets)[4]. For a Level 1 WET-Health assessment, it should be possible to complete the site visit, rating of criteria and generation of PES scores within half a day, which is similar to the amount of time required for the completion of the same steps using the RDM-99 method or the Wetland-IHI.

According to the relevant documentation, Wetland-IHI was specifically designed for application by non-wetland experts (although prior experience with other EcoStatus models is preferable to facilitate easier application of the model by the end-user) (DWAF, 2007a), while it is stated that WET-Health was designed for use by competent scientists with appropriate background and training in wetland evaluation, together with field-based experience (Macfarlane et al., 2007). In reality, based on personal experience and discussion with wetland practitioners who have used both tools, the amount of experience required for both a Wetland-IHI assessment and a WET-Health Level 1 assessment is the same, with at least some basic working knowledge of wetland ecosystems being necessary. For both these methods, some training in the use of the assessment tool is considered to be essential by the respective developers. Although it is not stipulated in the relevant documentation, for the RDM-99 wetland PES method of Duthie (1999b) some degree of knowledge and experience of wetland ecosystems is also required for the proper application of this tool.

In terms of user-friendliness, the RDM-99 method provides a relatively self-explanatory one-page scoresheet with the documentation, which is relatively easy to fill in. Although the

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[4] The evaluation by Malan (2008) was based on a draft version of WET-Health, which was less refined than the finalised version presented by Macfarlane et al. (2007).

scoring system is relatively simple and transparent (see description above), compared to Wetland-IHI and WET-Health, the datasheet for the RDM-99 method is not provided in an electronic format (such as Microsoft Excel) that automatically derives the overall PES score and category for a wetland. In the case of Wetland-IHI, field forms are provided with the Manual (DWAF, 2007a). These consist of six pages on which information needs to be recorded during the site visit and a final summary page for the results of the assessment. The interface of the Wetland-IHI is in a format similar to that of DWA's River EcoStatus models, which are currently used for the assessment of PES in riverine environments. In the case of WET-Health, standardized datasheets have been developed for each module of the assessment. For a Level 2 assessment, there are a total of 4 datasheets per HGM Unit for the hydrology module, 5 datasheets per HGM Unit for the geomorphology module and 3 datasheets per HGM Unit for the vegetation module, plus a one-page summary datasheet for each module. For a Level 1 assessment, there are 3 pages of datasheets per HGM Unit plus one summary page for the assessment. For both Wetland-IHI and WET-Health, electronic spreadsheets (in Microsoft Excel format) are provided for capturing all the data that are collected. The spreadsheets automatically calculate the PES scores and categories, based on the ratings that are entered and the internal weightings of the respective scoring systems. The spreadsheets produced for Wetland-IHI are, however, more refined and user-friendly than the rather cumbersome set of spreadsheets produced for WET-Health.

4.3.5 Comparative testing of results generated

A comparative evaluation of Wetland-IHI and WET-Health ("Level 1" and "Level 2") was conducted by Malan (2008), as part of the WHI research programme (see Day and Malan, 2010), which involved the field-based application of both tools (neither of which were finalised at the time) to a number of wetlands from around the country. This initial testing was mostly undertaken by one assessor or a group of assessors working together, applying the methods to each case-study wetland. The detailed results of this testing are not presented in the current report, but the main findings were taken into account in the gap analysis (see Section 5).

Additional, largely field-based, comparative testing of the Wetland-IHI, WET-Health ("Level 1" only) and RDM-99 wetland PES assessment methods was undertaken for the current investigation (see detailed report attached as an Annexure), to complement the previous evaluation by Malan (2008). This testing involved the application of these three methods – identified to be the most prominent, nationally-applicable rapid Wetland PES assessment methods that currently exist in South Africa – to a selection of 18 case-study wetlands from the South Western Cape region by a number of assessors. A total of nine individuals were involved in the testing, with between 3 and 8 assessors for each case-study wetland.

Two key aspects that were tested as far as possible were the degree of consistency in the results generated between (a) different assessors and (b) different assessment methods, for the same wetlands. These tests were conducted separately for the different components of wetland condition (i.e. hydrology, geomorphology, vegetation, and water quality) and for the overall Wetland PES Scores/Categories. Another important aspect that was tested was the applicability of the three methods, or of the component 'modules' of each of the three methods, to different wetland HGM types, and the reliability of the results generated for different HGM types. Only by applying the existing methods to a wide range of wetland types and land-use settings, and by a number of independent assessors, could the tools be tested robustly and in a way that could provide a reasonable evaluation of the degree of consistency in the results that are generated. The comparative testing also included a preliminary, desktop-based analysis of the relative sensitivity of the three methods (WET-Health "Level 1", Wetland-IHI, and RDM-99) to small differences in scores that are entered leading to relatively large changes in the overall results.

For each case study wetland, the PES percentage scores and the respective Ecological Categories derived by the different assessors for the various components of wetland PES (i.e. hydrology, geomorphology, vegetation, and water quality) and for Overall Wetland PES using the three assessment methods were compared. Assessors also provided "gut-feel" PES Categories for the Hydrology, Geomorphology, Vegetation, Water Quality, and Overall Wetland PES of each wetland, and these results were also compared. The "gut-feel" PES is an intuitive estimate of the PES Category for a given wetland by a particular assessor, or group of assessors. Recording this intuitive estimate is a valuable exercise, especially when one bears in mind that there is no way to actually measure the absolute PES of a wetland and that all estimates (even those generated by semi-quantitative tools) are to a greater or lesser extent subjective.

The detailed results of the comparative testing of the RDM-99, WET-Health (Level 1) and Wetland-IHI assessment methods are presented in the "Testing Report" included as an Annexure to the current Volume. This includes detailed analysis and discussion of the main reasons behind different PES results being recorded for certain of the case-study wetlands.

a) Consistency between different assessors

Taking all the results into consideration, the general trend was for the degree of consistency in PES% scores and Ecological Categories between assessors to decrease as the number of impacts increased or as the intensity and/or complexity of the impacts increased[5]. For example, there was a very high degree of consistency in the results generated by different assessors in the case of the Middelberg and Kleinplaatz Dam wetlands, both of which had relatively negligible impacts. On the other hand, there was a great deal of inconsistency between the results of the different assessors in the case of the Mfuleni wetland, which was subject to a fairly large number of peri-urban impacts. Also, the PES of the Salmonsdam wetland, which has been impacted in a complex manner by relatively severe gully erosion affecting approximately half the wetland and creating a number of knock-on effects, was evaluated differently by the different assessors, regardless of their level of experience.

Despite the above-noted inconsistencies, statistically significant differences ($p < 0.05$) between the results of the different assessors were detected for only two of the case-study wetlands, based on the Kruskal-Wallis non-parametric test. These were for Khayelitsha Pool

[5] No seriously to critically altered wetlands were included in the case studies, but it is assumed that at very high levels of transformation there would (as in the case of minimal impacts) be a high degree of consistency in the results of different assessors.

(hydrology and geomorphology components, but not the vegetation component or the overall PES) and Belsvlei (geomorphology component only). Despite the general lack of statistically significant differences, there was an unsatisfactory degree of consistency in the relative PES scores obtained by different assessors for the majority of the case-study wetlands, with variations of one Ecological Category or more frequently being recorded.

There was also a relatively high degree of inconsistency between the "gut-feel" Ecological Categories recorded by assessors and the categories obtained by the same assessor using one or more of the formal PES assessment methods, except for wetlands with very few impacts (such as the Middelberg and Kleinplaas wetlands). Such differences were observed for all four components of wetland condition (i.e. hydrology, geomorphology, vegetation, and water quality), irrespective of the level of experience of the assessor, but were less obvious in the Overall PES. This indicates that there could be certain impacts that are not being factored in by the assessment methods, which the assessors were taking into account in their assignment of "gut-feel" categories, or that the methods weight certain impacts too strongly in the scoring. It should be noted in this regard that the assessors, in all cases, made a concerted effort to apply the assessment methods without 'tweaking' the results generated to agree more with their "gut-feel". Alternatively, the discrepancies between assessors' "gut-feel" categories and the categories generated by the assessment methods could be due to a lack of adequate 'calibration' in an assessor's perception of the degree of deviation from the natural reference state for certain impacts.

b) Consistency between different assessment methods

As in the case of the differences between the PES scores of assessors, more inconsistency was observed between the PES scores recorded for the different methods as the number or intensity of impacts increased.

The only statistically significant differences between the PES% scores of WET-Health versus Wetland-IHI for individual components of Wetland PES, based on non-parametric pair-wise Wilcoxon rank sum tests, were for the Vegetation component of the Mfuleni ($p = 0.005$) and Goukou ($p = 0.001$) wetlands. In both these cases, the Wetland-IHI method generated vegetation PES scores that were one or two categories (or more) higher than the scores generated by the WET-Health (Level 1) method. For most of the statistical comparisons between the overall PES% scores recorded using the RDM-99 method and those recorded using the WET-Health or Wetland-IHI methods, the differences were also statistically insignificant. The few case-study wetlands for which the overall PES% scores derived using the RDM-99 method were found to be significantly different ($p<0.05$) to the overall scores derived using the WET-Health or Wetland-IHI methods generally had PES scores for the RDM-99 method that were one Ecological Category lower than the respective WET-Health or Wetland-IHI overall scores.

For some case study wetlands, similar Ecological Categories were derived for the Overall PES by different assessors, despite relatively large differences between some or all of the component scores. For example, in the case of the Goukou wetland, similar overall PES% scores were derived by two of the assessors using both WET-Health and Wetland-IHI, despite significantly different PES% scores being recorded for the hydrology and/or geomorphology components by these assessors using the same methods. These discrepancies can largely be explained by the disparate weightings of the components by the two assessment methods (as shown in Table 5).

c) Preliminary sensitivity analysis of assessment methods

The detailed findings of the preliminary analysis of the relative sensitivity of the WET-Health, Wetland-IHI and RDM-99 PES assessment methods are presented in the "testing report" included as an Annexure. In general, all three methods are highly sensitive to 'missing impacts' (i.e. impacts that are not taken into account in the derivation of PES scores by a particular assessment method). This is because the inputting of no scores for 'missing impacts' that are applicable to a wetland leads to results that indicate that the wetland is in better condition than it actually is (or worse condition in the case of the RDM-99 method), and there is no formalised means to overcome this problem by including additional impacts that have not been accounted for in the score-sheets. The typical solution to this issue is that an assessor "tweaks" certain scores in an assessment to factor in any 'missing impacts'.

In terms of the derivation of overall Wetland PES Scores by the three methods, WET-Health would be particularly sensitive to the PES% score for hydrology and Wetland-IHI would be particularly sensitive to the PES% score for vegetation, due to the respective weightings of these components being the highest (see Table 5). The overall PES score for the RDM-99 method, on the other hand, would be particularly sensitive to any criteria that are given a score of less than 2 due to the "override" that is applied in such instances when using the prescribed scoring system for this method.

d) Overall conclusions of comparative testing and implications of findings

The comparative testing of the three most nationally prominent Wetland PES assessment methods that currently exist in South Africa revealed relatively high levels of inconsistency between the PES% scores derived by different assessors and using the different methods. Only for case-study wetlands that were in relatively pristine ecological condition were these differences minimal, and it is assumed that this would also be the case for severely transformed wetlands (none of the case-study wetlands were severely transformed). Most of the variability between assessors and between the different methods was not statistically significant ($p<0.05$), according to the non-parametric statistical tests that were used, but this was mostly because of the generally large variability between replicate scores and was not a reflection of consistency between scores. For many of the case-study wetlands, there were differences of one or more Ecological Categories in the derivation of PES scores by different assessors and through the application of the different assessment methods, and this was the case for all the different components of wetland PES (i.e. hydrology, geomorphology, vegetation, and water quality) and for the Overall PES. The inconsistencies that were observed did not, except in a few cases, appear to be related to the relative level of experience of the assessor or to the type of wetland.

Based on the findings of the comparative testing of existing wetland PES assessment methods, there appears to be a less than satisfactory degree of consistency between the results generated by different assessors and between the results generated using different Wetland PES assessment tools, when comparing the RDM-99, Wetland-IHI and WET-Health (Level 1) methods. The main reasons for the observed inconsistencies are thought to be related to differences in the perception of the natural reference state of the case-study wetlands, differences in the delineation of the "assessment unit", and differences in the assessment of impact intensity and/or extent by different assessors, rather than inherent problems with any of the assessment methods that were compared. All three of the methods have strong points and shortcomings, and none of the assessment methods were found to yield more consistent results than any of the other methods. A similar amount of time and level of expertise is also required to apply the three assessment methods.

One of the interesting, and rather unexpected, findings of the "testing" was that the use of the Vegetation and Water Quality modules of the Wetland-IHI method for wetlands that are not floodplain or channelled valley-bottom wetlands seems to be acceptable. The application of these PES assessment modules to different wetland types in the testing that was undertaken did not present any particular problems or areas of confusion to the assessors who were involved. A number of problems were encountered, however, in the application of all three assessment methods, especially WET-Health and Wetland-IHI, to depressions and wetland flats, particularly for the Geomorphology and (to less degree) Hydrology modules.

In the absence of any other appropriate PES assessment methods currently being available, and based on the finding that none of the existing methods seem to provide more consistent results than the others, the ongoing use of all three Wetland PES assessment methods that were compared is deemed to be acceptable, providing the inherent limitations of the methods are taken into account. Training in the use of a particular tool, a basic level of understanding of wetland science and some experience in wetland assessment is required for the proper application of all three methods. Of the three methods that were evaluated, the RDM-99 method is the most simplistic and least comprehensive, and is also more prone to subjectivity than the other two methods. Discouragement of the ongoing use of this particular, rather dated PES assessment method in its current form is thus warranted. The more recent WET-Health (Level 1) and Wetland-IHI assessment methods both have limitations and weaknesses in their current form, but both methods have also been built on a relatively solid scientific foundation and should thus be developed further and, ideally, integrated into a single, nationally-applicable rapid Wetland PES assessment method.

5 GAP ANALYSIS OF EXISTING WETLAND PES ASSESSMENT METHODS IN SOUTH AFRICA

Limitations associated with the main existing wetland PES assessment methods in South Africa and gaps in the methods were identified through (1) a comparative analysis of the methods (as presented above and in the earlier comparative review by Malan, 2008), including case-study testing; (2) a review of the findings of a survey on this topic that was conducted by DWA a few years ago; and (3) consultation and discussion with wetland assessment practitioners from around the country about their experiences with the application of the various methods.

5.1 Generic findings applicable to all existing assessment methods

The overarching findings of the gap analysis, which are of relevance to all three of the existing nationally-applicable methods (i.e. the RDM-99 method, Wetland-IHI, and WET-Health), were as follows:

- More guidance is required for the determination of the natural reference state, which is a critical but underplayed step in the application of most of the wetland PES assessment methods. For example, there is a need for a list of specific characteristics for which the probable/presumed natural reference state should be determined (e.g. reference HGM type, hydroperiod, dominant vegetation structure, broad water quality characteristics, etc.). Another gap in this regard is the lack of documented guidelines as to how and where the necessary information about the likely reference state of a wetland can be obtained, and for documentation about the typical characteristics of the unimpacted (or minimally impacted) wetlands in various regions.
- Photographic field-guides need to be developed that contain written and pictorial guidelines for rating the extent and intensity of impacts, to facilitate consistency between assessors. A good example of such a guide is the Model Photo Guide for the rating of instream and riparian modifications to river ecosystems (Graham and Louw, 2008) that accompanies the Technical Manual for the latest (EcoClassification / EcoStatus) version of the IHI for river ecosystems (Kleynhans et al., 2008). It may be useful to include additional photographs of (and information about) various wetland features in the photographic field-guides (e.g. erosion gullies, different HGM types, alluvial fans, dykes, typical wetland vegetation in different regions, etc.), as suggested by Malan (2008), to ensure that assessors have a better understanding of the criteria that need to be taken into consideration when applying the assessment tools.
- Guidelines are needed for the reporting of results and, to facilitate consistency between reports, report templates should be developed for each method. These guidelines should include recommendations about *inter alia* the length of the report, the critically important information that should be included in all reports as a minimum requirement, which summary tables and output scores to include from the assessment, and the important aspects that should typically be highlighted or emphasised.
- Better explanations of the scoring systems associated with the assessment methods are needed, with additional guidance as to how to apply the scoring system to various scenarios that typically occur (e.g. rating the extent and intensity of land-use impacts where the different land-uses occur as a mosaic within and around a wetland).

- None of the existing methods are really appropriate, in their present form, for application to depressions or wetland flats.
- A shift in the composition of (indigenous) plant species within a wetland, which can in some cases represent a relatively significant impact, is not explicitly taken into account in the vegetation component of any of the existing assessment methods. The rating of this kind of impact would, however, probably require specialist botanical knowledge or input. Nevertheless, a means of factoring this impact into an assessment should be formulated, for situations where it is known to be relevant.
- Another shortcoming pertaining to all three of the existing methods is that no (or very little) explanation is given as to how an assessor should deal with the effects of wild fires, natural grazing, floods, droughts and other natural disturbances. Such disturbances often result in impacts that may not constitute an alteration of the natural cycles of change for certain wetlands (for example, a large 1:100 year flood could denude a floodplain wetland of its vegetation as part of a natural cycle, but the PES of the vegetation within the wetland would still be in "good condition" relative to the naturally cyclical reference state). The issue of understanding the natural burning regime is of particular relevance to fire-adapted regions, such as the Fynbos Biome of the South Western (and Southern) Cape and the Grassland Biome of the eastern interior. While not entirely addressing this issue, the WET-SustainableUse tool for assessing the sustainability of wetland use (Kotze, 2010) does include very useful guidelines and a scoring system for assessing how far removed a burning regime for a wetland is from the naturally-expected frequency and timing of fire (for both Fynbos and two broad types of Grassland vegetation).
- All of the existing tools were released for widespread usage before they were thoroughly tested and refined. This situation must be avoided in the development of any new or integrated wetland assessment tools.
- Structured, hands-on training in the use of the assessment tools is important for all of the methods, and the development of standardised training procedures should be developed for this purpose. Importantly, sustainable sources of funding should be accessed to run training courses, or to at least subsidise the costs of running training courses, so as to ensure that potential users of the assessment methods are not prevented from attending training courses due to prohibitive costs.
- Besides the confusion that exists as to which wetland PES assessment tool may be applicable and most appropriate for a particular situation, there is much confusion and difference in opinion as to when a PES assessment should be undertaken in the first place. For example, when is a PES assessment required, versus an assessment of the ecosystem service provision, the ecological importance and sensitivity, the economic value, or the socio-cultural importance of a wetland, or some other factor? There is thus a clear need for the development of a decision-support framework for the whole wetland assessment process in general, which should include linkages to the available tools and methods for the assessment of various aspects (not just wetland condition).

5.2 Specific findings relating to individual assessment methods

The specific findings of the gap analysis that was undertaken for the three wetland PES assessment methods are presented below.

5.2.1 RDM-99 wetland PES assessment method

The gap analysis identified the following limitations and gaps in the wetland PES assessment method of Duthie (1999b):

- It is not entirely clear from the accompanying documentation what wetland types this assessment tool can be applied to, which is further complicated by the fact that the wetland classification system that was in use at the time was itself rather ambiguous (and still in draft form). For example, the title of the primary document (Duthie, 1999b) refers to it as a PES method for floodplain wetlands, whereas the related document on the procedure to be followed for RDM processes (Duthie, 1999a) stipulates that the method is appropriate for all palustrine wetlands but not for endorheic pans.
- The criteria that must be scored are, generally, rather vague and ambiguous, and the wording that is used is not always entirely clear (for example, reference is made to 'flow' in some cases where it would be more accurate or appropriate to refer to 'hydroperiod' or to the depth and/or proportional area of 'inundation').
- The scoring system is very simplistic and does not distinguish between the extent and the intensity of impacts (as in the case of Wetland-IHI and WET-Health), although this does sometimes make it easier for a user to understand the rating of certain impacts. This potential source of variability between the results generated by different assessors is exacerbated by a lack of guidance in the documentation on how to rate criteria that only affect a portion of a wetland.
- The list of criteria included in the score-sheet is not very comprehensive (e.g. only two criteria are included for some of the PES components, such as hydrology and geomorphology), with no provision made for the addition of 'missing' criteria. This makes the method very sensitive to variations in the rating scores assigned to individual criteria, especially with the use of unweighted averaging to derive an overall PES score and category.
- All criteria are given equal weighting in the calculation of PES scores by simply using mean scores, which tends to 'dilute' more significant impacts (this is, of course, ameliorated to some degree by the "overriding" of the average score by any criteria that have a score of <2, but this approach has its own issues, as discussed below). In reality, there are certain criteria that generally do have a greater influence than others on the overall ecological condition of a wetland.
- The use of a very low PES score (<2) for any individual criterion to determine the overall PES category for a wetland, as per the prescribed scoring system, is too extreme. There may, however, be some merit in taking this approach for the derivation of the PES scores and categories for over-arching PES components within the assessment (i.e. hydrology, water quality, geomorphology and biota).
- No guidance is provided as to how impacts that are not applicable should be scored (e.g. should these be left blank, which results in the overall score treating them as a zero, or should they be given the maximum score of 5 that indicates natural/unmodified conditions?). Such guidance is critical because of the large influence that the score for any one criterion can have on the overall results.
- Catchment-related impacts are not explicitly separated from within-wetland impacts, and no guidance is given on how to rate criteria (such as 'flow modification') that include both catchment effects and within-wetland effects.

- No guidance is provided as to how to select the wetland units for inclusion in a particular assessment (for example, it is not clear whether a wetland that consists of a number of different HGM units should be assessed as a single entity or split into separate HGM units for individual assessment of each HGM unit).
- Some of the criteria are confusing or have been placed under the wrong heading. For example, the criterion of “sediment load modification” is included under water quality, instead of under geomorphology, and it is not clear how the criterion of “canalisation” (included under the hydraulic/geomorphic component) should be rated.
- The inclusion of faunal criteria (“alien fauna” and “over-utilisation of biota”) is questionable for a rapid, habitat-based PES assessment method. The approach of the Habitat Integrity assessment method (after Kleynhans, 1996, 1999b) is that abiotic and structural factors (including certain vegetation characteristics) are evaluated as a means of broadly indicating how closely the present state of an aquatic ecosystem resembles the natural situation that would have been prevalent before human intervention. The premise is that if the habitat conditions within an aquatic ecosystem are similar to what they would have been in the natural state, then the ecosystem should be able to support the naturally-occurring fauna. One of the main reasons for typically excluding faunal criteria from a rapid PES assessment method is that the collection of the required data is generally time-consuming and resource-intensive.
- The application of the tool is dependent on the formulation of a clear “picture” of the natural reference state of the wetland in the mind of the assessor before any of the prescribed impacts can be rated, yet there is very little guidance provided as to how the perceived natural reference state should be determined or even of what factors should be taken into consideration.

5.2.2 Wetland-IHI assessment method

The following limitations and gaps were identified for the Wetland-IHI (DWAF, 2007a) assessment method:

- The tool is only strictly applicable to floodplain and channelled valley-bottom wetlands, although the testing undertaken for the current project showed that the Vegetation and Water Quality ‘modules’ of Wetland-IHI can actually be applied to all wetland HGM types.
- The tool is site-specific and can only accommodate the assessment of one HGM unit at a time. As such, a single assessment of multiple wetlands at a broad scale cannot be conducted with this tool and no clear instructions are provided for the combining of individual scores for different HGM units.
- There is no version of the tool that provides for a comprehensive assessment (like WET-Health Level 2), which would enable more detailed information to be obtained about the causes of degradation to a wetland.
- The assessment method does not, in its present form, make provision for an assessment of the “trajectory of change” of the various components of wetland condition.
- It is confusing, and presents a possible source of inconsistency between the results generated by different assessors, that certain weightings need to be entered by the assessor. For example, in the Hydrology module an appropriate weighting must be selected for "zero flows" and it is unclear whether there is a default weighting for this criterion or not.

- Only four land-use activities are listed for assessment in the Vegetation Alteration module, with a number of important land-use activities excluded from this list (such as terrestrial vegetation encroachment and flooding by dams).
- For the Hydrology module, the scoring of within-wetland effects is very confusing, as it is difficult to differentiate between the "extent" and "intensity" of the listed impacts, especially when the total "extent" for all the impacts must add up to 100%.
- There is not enough emphasis in the Hydrology module on the potential impacts of erosion gullies on the hydrological functioning of a wetland.
- In the Geomorphology module, the presence of vegetation within a channel (and the robustness of this vegetation) is not explicitly taken into account on the ‘transport capacity’ side of the 'sediment budget' calculation, which is very important in the case of wetlands with vegetated channels.
- There is no provision for the rating of topographical alterations in the Geomorphology module, which is a major omission, also relevant to WET-Health.
- The overall scores for the Geomorphology module have to be entered manually in the relevant spreadsheet, with reference to a look-up table, which introduces a potential area for user-error when the score-sheets are filled in. The derivation of these final scores should be automated in the spreadsheet.
- For the Geomorphology module in general, more criteria are needed to make the rating of geomorphological impacts more robust and easier to score.
- The Water Quality module is rather rudimentary and very confusing to apply in its current form, and its application requires a relatively good understanding of the effects of different land-uses on specific water quality variables (which a non-specialist is very unlikely to have).
- The Water Quality module is very sensitive to whether an assessor enters zeros or leaves the relevant cells blank for non-applicable cells in the scoring matrix, with different mean, median and mode ratings generated in each case. No guidance is provided in the documentation for Wetland-IHI as to how to deal with the filling-in of the Water Quality score-sheet for non-applicable criteria.
- The prescribed use of some kind of average (mean, median or mode) to derive the overall rating score for each parameter taken into consideration in the Water Quality module is potentially problematic in that it could mask water quality impacts. The use of maximum scores is recommended to derive the overall rating score for each water quality parameter, instead, as a means of alleviating this potential issue.
- The application of the tool is dependent on the formulation of a clear “picture” of the perceived natural reference state of the wetland in the mind of the assessor, before any of the prescribed impacts can be rated.

5.2.3 WET-Health assessment method

The following limitations and gaps were identified for the WET-Health (Macfarlane et al., 2007) assessment method:

- The tool is not really applicable to depressions or wetland flats (especially those occurring on coastal plains that are driven largely by fluctuations in the groundwater level), or to seeps that are not integrally connected to a drainage network, despite the documentation only acknowledging this for depressions in the case of the Geomorphology module. There are a number of aspects that need to be rated in a WET-Health assessment that are not generally relevant to depressions or wetland flats, or to seeps that are not integrally connected to a drainage network. For example, in the Hydrology module, the scoring of “modification of existing channels” for evaluating changes to water distribution and retention patterns within a wetland, and the scoring of “reduced floodpeaks” as a criterion in the evaluation of changes to water input characteristics from the catchment are not relevant for systems that do not form an intrinsic part of a drainage network.

- The tool does not include a Water Quality module, although a framework for the inclusion of such a module is provided in a Level 2 assessment.
- The integrated assessment of all the HGM units that make up a wetland, on the basis of the proportional extent of each HGM unit, can be confusing (especially to first-time users of the tool) and introduces an element of complexity into the assessment method.
- The completion of a Level 2 assessment is time-consuming and complex. This more detailed assessment does, however, yield valuable information about the causes of degradation to a wetland and helps guide the assessor as to exactly what they need to consider for each criterion that is rated (such detailed guidance is lacking in a Level 1 assessment).
- There is no explicit inclusion of a confidence rating for the assessment of the various criteria in the WET-Health score-sheets, which is included in the RDM-99 and Wetland-IHI score-sheets. This is considered to be a major omission.
- For the detailed Level 2 assessment, there are certain features explicitly included that are only relevant to wetlands in certain parts of the country (e.g. scores for sugar cane, which are particularly relevant in KwaZulu-Natal), whereas other features that are of relevance in other parts of the country are missing (e.g. the relative water consumption of vineyards and wheat, which are relevant to the Western Cape).
- For the Hydrology module (when conducting both Level 1 and Level 2 assessments), ‘changes in flow seasonality’ and ‘periods of non-flow’ are implicitly taken into account by the assessor when evaluating changes in inflows and/or alterations to floodpeaks, whereas in the Hydrology module for Wetland-IHI these criteria are included as specific aspects that need to be rated. It probably would be better to explicitly include ‘changes in flow seasonality’ as a separate hydrological criterion to score, especially for the more arid parts of the country.
- In the Hydrology module (for Level 1 and Level 2 assessments), there is the need for a clear explanation and additional guidance as to how the criteria for assessing changes to water distribution and retention patterns within the wetland should be scored when there are several different land-uses (disturbance units) within a wetland.
- The Geomorphology module is, generally, complicated and rather confusing to apply.
- In the Geomorphology module, the inclusion of a (indirect) diagnostic assessment and a (direct) indicator-based assessment to determine the overall geomorphological condition could possibly lead to the “double-scoring” of impacts.
- The rating of a number of the criteria included in the Geomorphology module (e.g. the identification of signs of excessive sediment deposition, such as alluvial fans that have formed as a result of impacts in the catchment of a wetland) is difficult for assessors who

are not expert geomorphologists, or who don't have at least some knowledge and experience of earth science.

- A number of the criteria included in the Geomorphology module are only rated for certain, specified HGM types, but the criteria are sometimes relevant to other HGM types and it is not clear whether they should be scored in such cases. For example, the impact of upstream dams on sediment transport is only meant to be scored for floodplain wetlands but this impact is often also of relevance to channelled valley-bottom wetlands.
- There is no provision for the explicit rating of topographical alterations in the Geomorphology module (for both Level 1 and Level 2 assessments), which is a major omission that is also relevant to Wetland-IHI. Rather confusingly, 'infilling' (a type of topographical alteration) is considered for floodplain and channelled valley-bottom wetlands in the Geomorphology module, but not for other HGM types.
- In the Vegetation module (for a Level 1 assessment), the use of a default intensity score of 1 for 'untransformed areas' in the scoring table for disturbance classes means that a wetland that is 100% untransformed will be given a Vegetation PES of Ecological Category B, when a category of A or A/B would generally be more appropriate.
- The tool and its accompanying datasheets are not very user-friendly (for both Level 1 and Level 2 assessments), with a lot of cross-referencing to a multitude of tables required throughout the assessment.
- For a Level 1 assessment, it is unclear from the documentation and the score-sheets themselves whether the total extent for within-wetland hydrological and geomorphological impacts, or vegetation 'disturbance classes' can add up to more than 100% (the score-sheets do not, for example, have an in-built mechanism to prevent the entry of values that add up to more than 100% in total). If extent-estimates are entered that result in total extents of greater than 100% for any of these criteria, it could (depending on the intensity scores associated with each extent estimate) result in overall magnitude-of-impact scores of greater than the maximum of 10 being obtained which could, in turn, lead to the 'over-weighting' of these impact scores and make combined scores further on in the assessment process particularly sensitive to these 'inflated' scores. No guidance is provided in the WET-Health manual as to how an assessor should deal with situations where a particular portion of a wetland is affected by more than one of the impacts taken into consideration within a particular assessment module.
- At a number of points throughout the assessment (especially for Level 2), two or more scores are manually combined to derive an overall score for a particular aspect, by referring to the relevant look-up tables. This process should be automated in the relevant spreadsheets, to reduce the potential for user-error in the recording of derived final scores and to make the application of this aspect of the assessment more user-friendly.
- The application of a Level 1 assessment is dependent on the formulation of a clear "picture" of the perceived natural reference state of the wetland in the mind of the assessor, before any of the prescribed impacts can be rated. This is not as critical in the application of a Level 2 assessment, except for the vegetation component where some understanding of the natural (unimpacted) vegetation is required, because the presumed reference conditions are to some degree built into the scoring of the detailed criteria that need to be evaluated.

6 RECOMMENDATIONS FOR FURTHER RESEARCH RELATING TO WETLAND PES ASSESSMENT TOOLS IN SOUTH AFRICA

Based on the findings of this review of wetland assessment methods in South Africa, a number of recommendations for further research and development have been identified. The following **recommendations for further research and development** are made **specifically in relation to the tools and methods for wetland PES assessment in South Africa**:

1) The existing assessment tools (particularly WET-Health and Wetland-IHI) should be combined into a single assessment tool or an integrated suite of assessment tools for the categorisation of wetland PES.

The two main tools that are currently used around the country both have good features but both also have weaknesses, as highlighted in the current review. For example, on the positive side, WET-Health provides the option of conducting a rapid Level 1 assessment or a comprehensive Level 2 assessment, and the method generates a PES category and an anticipated trajectory of change for each component that is assessed (i.e. hydrology, geomorphology and vegetation) and for the wetland as a whole if required. This tool is, however, lacking a water quality component and it is not particularly user-friendly to apply. Wetland-IHI, on the other hand, does include a prototype water quality module and is relatively user-friendly in terms of the manual and accompanying spreadsheet-model, but this method does have some missing elements and is currently only strictly applicable to floodplain and channelled valley-bottom wetland types.

The ultimate goal should be to develop a robust, rigorously tested tool (or suite of tools) that can be used to categorise the present ecological condition of all HGM wetland types (in terms of hydrology, geomorphology, water quality and vegetation alteration, and for a wetland as a whole). It should also generate the anticipated trajectory of change, and provide the option of conducting a rapid assessment or a more comprehensive assessment (such as the Level 1 and Level 2 assessment options currently provided by WET-Health). The Framework for Assessment of River and Wetland Health (FARWH) in Australia (Alluvium Consulting, 2011) could be explored as a possible approach to the development of an integrated method for South Africa. In the FARWH, a two-tiered approach is followed whereby rapid desktop-based assessment precedes the detailed field-based assessment of more critical systems. The derivation of prescribed index scores in the FARWH is through the use of flexible sub-indices that are selected on the basis of the type of aquatic ecosystem and the region within which it occurs.

Once a single, robust assessment tool has been developed, an easy-to-read, well-illustrated User Manual should be professionally published, and a user-friendly set of datasheets should be produced to accompany the Manual. Electronic versions of the datasheets, which automatically do as many of the required calculations as possible, should also be developed and provided with the Manual. Rigorous error-checking and debugging of the electronic datasheets should be completed before they are officially released for widespread use.

The development of a single method for the *rapid* assessment of wetland PES is of particular urgency, due to the confusion created by the existence of two tools that essentially do the same thing. Wetland-IHI and WET-Health Level 1 both provide for a rapid, modular-based assessment of wetland PES, generate similar outputs (i.e. PES scores and Ecological Categories for different components of wetland condition, and for the overall condition of a wetland), and require a similar amount of time and level of expertise to apply. The main differences between these tools are that Wetland-IHI is only applicable to floodplain and channelled valley-bottom wetland types, whereas WET-Health Level 1 was developed to be applicable to all wetland types, and Wetland-IHI includes a water quality module but WET-Health Level 1 does not.

The procedure that has been followed in the development of the wetland RAM tools in the USA, such as CRAM (described in Section 3.1), could be explored as a possible means of developing a scientifically defensible rapid assessment method for the determination of wetland PES in South Africa. The six basic stages that are typically followed in the RAM development process are as follows (Sutula et al., 2006):

(1) Identify the intended applications, assessment endpoints, and geographic scope of the RAM, and form appropriate teams to advise the development process and review its products;
(2) Build a scientific foundation for method development by conducting a literature review, choosing a wetland classification system, building conceptual models, and identifying the major assumptions underlying the model;
(3) Assemble the method as a system of attributes and metrics that describe a full range of possible ecological conditions;
(4) Verify the ability of the method to distinguish between the ecological condition of wetlands along a continuum of disturbance;
(5) Calibrate and validate the method against sets of quantitative data representing more intensive measures of wetland condition; and
(6) Implement the method through outreach and training of the intended users.

2) In the interim, a decision-support tool of some sort should be developed to assist in the determination of which of the existing wetland PES assessment methods (or specific components of the existing methods) would be most appropriate for particular situations and/or particular wetland types[6].

The development of such a tool is seen as a temporary stop-gap measure, until an integrated tool is developed (as recommended above). It is important to contextualise this particular tool by showing how it should fit into a broader framework for the entire process of wetland assessment in the country (as explained below). Besides indicating which of the existing PES assessment methods are most appropriate for particular situations, the decision-support tool should also identify and highlight gaps where none of the existing methods are particularly suitable (e.g. for categorising the Geomorphology PES of endorheic depressions and wetland flats).

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[6] The Decision-support Protocol (DSP) for the rapid assessment of wetland PES in South Africa that has been developed through WRC Project K5/2192 (see Volume 2 report) is such a tool.

3) ***A method for assessing the ecological condition of depressions and wetland flats (and seeps that are not connected to a drainage network) should be formulated as a matter of urgency, or one of the existing methods should be adapted to account for these wetland types.***

This is a critical aspect, requiring proper research to ensure that a robust and scientifically rigorous method (or suite of methods) is developed, or that one of the existing wetland PES assessment tools (e.g. WET-Health) is appropriately adapted to adequately deal with these wetland types. The method could be developed as part of (or as the starting point for) the recommended initiative to develop an integrated tool from the existing methods, which should account for all wetland types. Alternatively, an interim method could be developed to complement the existing methods and fill the gap that currently exists, or one of the existing tools could be appropriately modified.

As indicated by Malan (2008), some of the factors that would need to be considered in an assessment of depressions (and possibly wetland flats) include water quality, excessive siltation due to activities in the catchment and encroachment of macrophytes[7]. The incorporation of such factors into WET-Health would not require major adjustment of the existing modules in WET-Health, if this tool was to be used as the starting point for the development of such a method, but a water quality module would need to be added because depressions (especially endorheic depressions) are particularly vulnerable to pollution. The Index of Wetland Condition (IWC) that is under development in Australia (Department of Sustainability and Environment, 2005) includes components (and an approach) that could be considered in the formulation of an assessment method for depressions, as it was specifically developed for non-flowing systems and followed a scientifically rigorous approach. Another tool that could be consulted for ideas as to how a rapid assessment method for depressions can be structured and what some of the aspects are that need to be taken into account is the CRAM Field Book for the assessment of depressional wetlands in California (CWMW, 2013b).

4) ***Written guidelines should be produced to assist with the determination of the perceived natural reference state for wetlands.***

This recommendation should also be carried out as a matter of urgency, irrespective of whether or not an integrated assessment method is developed, since it will promote more consistency between assessors in this critical step of wetland PES assessment. The production of these guidelines should be based on thorough research into the concept of reference conditions for wetland ecosystems, including the review of international literature and consultation with wetland assessment practitioners (and academics) from other countries to gain a better understanding of how this issue is dealt with elsewhere. The guidelines should include practical advice as to what aspects should be considered[8] and

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[7] The DSP that has been produced through WRC Project K5/2192 includes comprehensive lists of potential impacts for each component of Wetland PES, which could serve as the starting point for the development of a PES assessment method for depressions and wetland flats (and for seeps that are not connected to a drainage network).

[8] The inclusion of a datasheet for entering the perceived natural reference state of a wetland in the DSP for the rapid assessment of Wetland PES that has been developed through WRC Project

where potentially relevant information can be obtained when trying to establish the natural reference state of a wetland.

5) The characteristics of reference wetlands in different geographical areas should be documented, following a standardised approach and reporting format.

For particular geographical areas (e.g. a municipal area, a province, the catchment of a particular river system, an ecoregion, a geomorphic province, or an area delineated by the NFEPA project as a wetland vegetation group), documentation should be produced to describe the range of wetland types in the area and the typical characteristics of reference wetlands representing the most dominant wetland types. A standardised approach to the selection of reference wetlands and identification of their typical characteristics should be developed, together with guidelines for the documentation that should be produced, along the lines of the regional guidebooks that are developed for particular wetland types in the United States (after Smith et al., 1995). These guidebooks form the backbone of the application of the HGM-based assessment of wetland functions in different regions of the United States. The production of such documentation for particular regions of South Africa would provide benchmarks that can be used for the determination of appropriate reference characteristics for wetland PES assessments in those regions. Ideally, a research programme should be initiated to strategically identify areas where there is the greatest need for the description of natural reference wetland characteristics and to systematically produce documentation across the country, starting with these key areas.

6) Photographic field-guides should be developed for the rating of wetland impacts.

These field-guides would facilitate consistency between assessors in the rating of impact intensity. They could be structured along the lines of the Model Photo Guide for the rating of instream and riparian modifications to river ecosystems (Graham and Louw, 2008), which was produced as an accompaniment to the Technical Manual for the latest version of the IHI for river ecosystems (Kleynhans et al., 2008). The CRAM Photo Dictionary (Central Coast Wetlands Group, 2013), developed to assist with the assessment of wetland condition in California (USA), could also be consulted for ideas as to how a photographic field guide can be structured and what sort of information can be included. Separate field-guides could be produced for each of the existing methods, or (preferably) a more generic field-guide could be produced for the rating of impacts that typically affect wetlands.

7) Reporting guidelines and report templates should be produced for wetland PES assessments.

The production of reporting guidelines and report templates would result in much greater levels of consistency in the quality and content of the reports that are compiled for wetland PES assessments. The reporting guidelines for wetland assessments conducted under the Working for Wetlands Programme could be examined as a starting point for the production of such guidelines and templates. Specific report templates may need to be produced for

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K5/2192 (see Volume 2 report), which has a list of important criteria to consider, represents a start to the production of the recommended guidelines for determining and describing the perceived natural reference state of a wetland.

each of the existing assessment methods, or for assessments undertaken for specific agencies (e.g. DWA versus Working for Wetlands) or specific purposes (e.g. for an EIA versus a Reserve determination process; for a once-off assessment versus ongoing monitoring). An attempt should, however, be made to produce some sort of generic report template for wetland PES assessments. In the reporting guidelines and report templates (and in the further development of wetland PES assessment methods in South Africa), a clear distinction should be made between measures/indicators of impact and threat to wetland ecosystems, and the ecological characteristics of the wetlands (as per the description of the scoring system for the IWC in Australia, e.g. see Department of Sustainability and Environment, 2005) to ensure that these inter-related but vastly different aspects are not confused with one another in reports that are produced.

8) An overarching decision-support framework for wetland assessment in South Africa should be developed.

In addition to the specific recommendations listed above in relation to the research and development needs for wetland PES assessment methods in South Africa, more broadly, it is strongly recommended that a decision-support framework for wetland assessment is developed. This framework should identify what the main facets of the wetland assessment process are, and show how these facets relate to one another[9]. Examples of the facets of wetland assessment include wetland identification and delineation, classification of wetland type, assessment and determination of the PES, assessment of the functional value, assessment of the ecological importance and sensitivity, assessment of the socio-cultural importance and/or economic value, and so on. The framework should also provide references or linkages to the currently available tools and/or procedures for each of the facets, where these exist. The envisaged framework would be similar to, but less prescriptive and more generally applicable than, the RDM process of DWA that has been incorporated into the national WRCS.

The development of a decision-support framework for wetland assessment, as recommended above, would show where the assessment of wetland PES fits into the broader picture of wetland assessment more generally, and thereby provide an indication of when the application of the tools that are available for the assessment of wetland PES would be most appropriate. It is anticipated that this would go a long way towards preventing the current problem of the totally wrong type of wetland assessment tool being applied to a particular situation – for example, inappropriately attempting to use a wetland PES assessment tool such as WET-Health to ascertain the ecological importance or socio-cultural value of a wetland, when the use of an alternative tool (or series of tools) to evaluate the overall *importance* (versus ecological condition) of a wetland would have been more appropriate.

[9] The decision-support Framework for Wetland Assessment in South Africa that has been developed through WRC Project K5/2192 (see Volume 2 report) is such a framework.

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ANNEXURE:

REPORT ON COMPARATIVE TESTING OF EXISTING METHODS FOR THE RAPID ASSESSMENT OF WETLAND PRESENT ECOLOGICAL STATE (PES)

ANNEXURE:

REPORT ON COMPARATIVE TESTING OF EXISTING METHODS FOR THE RAPID ASSESSMENT OF WETLAND PRESENT ECOLOGICAL STATE (PES)

--- FINAL REPORT ---

Prepared for:
The Water Research Commission
Pretoria

Prepared by:
Dean Justin Ollis *Pr.Sci.Nat.*
The Freshwater Consulting Group
Email: dean.ollis@gmail.com

The Freshwater Consulting Group

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TABLE OF CONTENTS

1. INTRODUCTION

1.1. Background

The results presented in this document emanate from a solicited Water Research Commission (WRC) project originally entitled "Consolidation and optimization of wetland health assessment methods through development of a Decision-support Tree (DST) that will provide guidelines" (WRC Project K5/2192). The stated overall objective of the project was, "To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands".

The specific aims of the WRC project were stated as follows in the directed call for proposals:

1) To compare and contrast the available mainstream wetland health assessment tools with a particular focus on identifying potential duplication and/or overlaps;
2) To identify the limitations and report on gaps of existing wetland health assessment tools or methods available in the country;
3) To recommend further research on wetlands health assessment methods;
4) To develop a Decision-support Tree (DST) to guide users in the application of these tools for use in various types of wetlands and assessments;
5) To test the application and scientific viability of the DST on selected case study sites; and
6) To train the core group of users (DWA/SANBI) and students from appropriate disciplines on the application of the DST.

The primary deliverables that have been produced for WRC Project K5/2192 are a review of available methods for the assessment of wetland condition in South Africa (i.e. Final Report: Volume 1), and a Decision-support Protocol (DSP) for the rapid assessment of the Present Ecological State (PES) of wetlands (included with Final Report: Volume 2). The DSP represents a variation of the initially envisaged Decision-support *Tree* (DST) or Decision-support *System* (DSS) that was referred to in the initial aims for this project, with the name having been changed to convey a more accurate description of the final product that has been produced[i]. An additional product that has been produced is a Framework for Wetland Assessment in South Africa (also included with Final Report: Volume 2). The Framework was produced to contextualise the DSP and to provide users of the 'tool' with a better understanding of how the rapid assessment of wetland PES relates to other aspects of wetland assessment.

The DSP that has been produced for this project (in place of the initially envisaged DSS or DST) includes a relatively simple decision-support matrix that allows users of the 'tool' to select their preferred choice of applicable assessment method for each component of wetland PES (namely, Hydrology, Geomorphology, Vegetation, and Water Quality), and to select the set of weightings deemed to be most appropriate for the derivation of an overall Wetland PES score and category. The

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[i] During the review that was undertaken (see Final Report: Volume 1), it became apparent to the project team that none of the existing Wetland PES assessment methods are more suited to certain situations, compared with other methods (except for the obvious limitation that the Wetland-IHI method is only strictly applicable to floodplain and channelled-valley bottom wetland types, and the observation that a detailed "Level 2" WET-health assessment provides a more comprehensive assessment than the other, more rapid methods). As such, the development of a sophisticated DSS or DST was considered to be unfeasible and inappropriate.

‘tool’ is in the form of an electronic spreadsheet (compiled in Microsoft Excel format), which has hyperlinks to the data-entry forms for the selected assessment method in each case. For each component of Wetland PES, there is also a hyperlink to a comprehensive list of potential impacts relating to that component. This list can be used, for a particular wetland that is being assessed, to check whether there are any specific impacts affecting the wetland that the selected assessment method does not take into consideration (thus highlighting the need to possibly ‘tweak’ the score that is generated by the selected method, or to select another method that does take the specific impact into account).

The DSP that has been produced as the primary deliverable for WRC Project K5/2192 (as briefly described above), and the accompanying Framework for Wetland Assessment, cannot be “tested” in the way that it was originally envisaged that the DST/DSS that was to be produced would have been tested. Therefore, instead of conducting case-study-based testing of the DSP itself, the more direct “testing” of the DSP was completed by sending a draft version of the ‘tool’ to a number of reviewers for input and comment (including the Review Group members for this project, relevant government officials, specialist external review consultants, and internal peer-reviewers on the project team). The main existing methods for the rapid assessment of Wetland PES in South Africa – i.e. WET-Health “Level 1” (Macfarlane *et al.,* 2007), Wetland-IHI (DWAF 2007), and the DWA RDM-99 method (Duthie 1999) – have, however, been tested through dedicated comparative application to a number of case-study wetlands by a number of assessors. This was considered by the project team to be a more appropriate and useful way of indirectly “testing” the ‘tool’ that has been produced because the DSP is, ultimately, comprised of existing methods and is based on the assumption that their outputs are comparable. The results of the testing of existing methods were used to guide the development and refinement of the DSP.

The current document provides a description of the comparative testing of existing rapid Wetland PES assessment methods that was undertaken and presents the results of the testing.

1.2. Scope of work

The scope of work for the testing dealt with in the current report was to conduct a comparative assessment of the most prominent, nationally-applicable rapid Wetland PES assessment methods that were available as publicly-accessible publications at the time of undertaking WRC Project K5/2192 (i.e. mid-2012 to the end of 2013). The main objectives of the comparative testing were to identify gaps and potential shortcomings in the existing methods, and to enable an evaluation to be made of the appropriateness of including modules/components of existing methods in the DSP as alternative options for the assessment of the different components of wetland condition (i.e. hydrology, geomorphology, vegetation, and water quality). The three methods that were compared in the testing were WET-Health “Level 1” (Macfarlane *et al.,* 2007), Wetland-IHI (DWAF 2007), and the more dated but influential DWA RDM-99 method (Duthie 1999).

Two of the key aspects that were tested, as far as possible, were the degree of consistency in the results generated between different assessors and between the different assessment methods, for the same wetlands. These tests were conducted separately for the different components of wetland condition (i.e. hydrology, geomorphology, vegetation, and water quality) and for the overall Wetland

PES Scores/Categories. Another important aspect that was tested was the applicability of the three methods, or of the component 'modules' of each of the three methods, to different wetland hydro-geomorphic (HGM) types, and the reliability of the results generated for different HGM types. This was done by selecting case study wetlands that represent different HGM types, including a floodplain wetland, channelled and unchannelled valley-bottom wetlands, a seep, a number of depressions (mostly endorheic), and two possible wetland flats (following the classification system of Ollis *et al*., 2013 developed for SANBI).

Finally, the comparative testing of existing Wetland PES assessment methods undertaken for the current project included a preliminary, desktop-based analysis of the relative sensitivity of the three methods (WET-Health "Level 1", Wetland-IHI, and RDM-99) to small differences in scores that are entered leading to relatively large changes in the overall results.

An attempt has been made, in the current report to synthesise the findings of the comparative testing by explaining the potential implications of the findings for future use and development of the existing methods, and for the DSP produced as the primary deliverable for WRC Project K5/2192.

2. APPROACH TO AND LIMITATIONS OF THE TESTING

2.1. Approach

The approach that was taken to the comparative testing of WET-Health (Level 1), Wetland-IHI and the RDM-99 method was to get a number of assessors to independently apply these three rapid PES assessment methods to a number of case-study wetlands and, for each wetland, to compare the results generated by the different assessors for the different methods. In addition to this, a preliminary, desktop-based analysis of the intrinsic sensitivity of the three PES assessment methods was undertaken.

2.1.1. Completion of assessments

A total of 18 wetlands were selected as case-study sites, all located in the South Western Cape. All but one of the selected wetlands were study sites for another WRC-funded project to investigate the trajectories of change in the ecological condition of wetlands in the Fynbos biome that were previously studied by the Freshwater Research Unit of the University of Cape Town in the 1980's (WRC Project K5/2183). Brief descriptions of the case-study wetlands are provided in **Section 3** of the current report. Linking the selection of case-study wetlands with WRC Project K5/2183 provided an opportunity for collaboration between that project and WRC Project K5/2192, and allowed for the inclusion of more study sites and more field-based testing than would have been possible within the limited budget of Project K5/2192 on its own. In addition, this approach to the selection of case study sites made the process less subjective and ensured that there were a number of assessors for each wetland that was selected.

Nine assessors, in total, were involved in the comparative testing, with a minimum of 3 assessors (and a maximum of 8) per wetland. The experience of the assessors in the study and practical assessment of wetlands ranged from less than 2 years to more than 20 years, with two distinct groups (<5 years and >10 years) (see **Section 4.1** for more details). Three of the assessors were post-graduate students (at Honours and Masters level) at the time of conducting the assessments. At least three of the assessors had never previously used the assessment methods that were being tested, while at least two of the assessors were involved in the review of draft versions of one or more of the methods when they were in the development stages. There was thus a good range of experience levels amongst the assessors who did the testing for the current project, although there were no assessors without a science degree or with no experience at all in working with wetlands.

For each case study, most of the assessors involved in the testing conducted at least one site visit. For those wetlands for which some of the assessors did not conduct a site visit, information-sharing sessions were held where the assessors who had visited the particular wetlands provided information about the wetlands to the assessors who had not conducted any site visits, including relevant maps, aerial photographs, Google Earth imagery, and site photographs. For each wetland that was assessed, a discussion was held between the assessors about the perceived natural reference state of the wetland, although there was, in certain cases, disagreement between some assessors as to what the natural reference state of a particular wetland is likely to have been.

The application of each of the three assessment methods under consideration simply involved the completion of the relevant score-sheets by the assessors involved in the comparative assessment of a particular case-study wetland. In most cases, the score-sheets were filled in electronically by the assessors, but for those cases where the score-sheets were completed by hand on hard copies, the data were transferred to electronic score-sheets for processing of the results. For WET-Health (Level 1), the score-sheets for Version 2.0 of the method were used (as provided with the manual of Macfarlane *et al*., 2007). For Wetland-IHI, the score-sheets for Version 1.1 of this method were used (a June 2013 update of the original score-sheets provided with the manual of DWAF 2007). The score-sheets for Wetland-IHI include a built-in calculation of the overall Wetland PES score (and Ecological Category), based on the default weightings for the different components included in the assessment (see **Table 1**, below), while the WET-Health (Level 1) score-sheets do not provide for the automated calculation of an overall Wetland PES score. Therefore, an overall Wetland PES Score was calculated for the WET-Health assessments on a wetland-by-wetland basis, using the default weightings suggested in the WET-Health manual for the derivation of overall scores[ii] (see **Table 1**). In the case of the Department of Water Affairs' RDM-99 method, an electronic version of the score-sheet provided with the original documentation (Duthie 1999) was compiled in Microsoft Excel for use in the testing, which automatically calculates mean scores for each of the sections (i.e. hydrology, water quality, geomorphology/hydraulics, and biota) and for the overall PES of a particular wetland.

[ii] The WET-Health score-sheets do not include an automated calculation of the overall Wetland PES Score because the derivation of an overall wetland condition score is specifically discouraged in this method, although suggested default weightings are provided in the manual (Macfarlane *et al*., 2007) for the derivation of an overall score if it is required.

Table 1: Comparison of the weightings (as a percentage) given to component scores in the derivation of the overall Wetland PES Score (and category) by the Wetland-IHI and WET-Health methods

Component	Weightings allocated to each component by different assessment	
	Wetland-IHI	WET-Health
Hydrology	26.4%	42.8%
Geomorphology	21.2%	28.6%
Vegetation/Biota	44.4%	28.6%
Water quality	8.0%	n/a

2.1.2. Comparison of results

For each case study wetland, the impact scores and/or PES scores obtained by each of the assessors using the different assessment methods were converted to PES percentage scores (i.e. a score representing how close the ecological condition is to the perceived natural reference state, expressed as a percentage). PES percentage scores were calculated for the Hydrology, Geomorphology, Vegetation, and Water Quality components in each case, and for the overall ecological condition of the wetland (as derived from the component scores, applying the relevant default weightings). Ecological Categories (or PES Categories) from A to F, including intermediate categories, were then determined using the rating scale presented in DWAF (2008) (see **Table 2**, below), which is a refinement of the original A to F rating scale developed by Kleynhans (1996) and adopted by the Department of Water Affairs as the standard format for describing the PES of an aquatic ecosystem in the application of Resource Directed Measures (RDM) (e.g. see DWAF 1999).

Table 2: Range of PES percentage scores used to derive an Ecological Category from A to F, including intermediate categories (from DWAF 2008, adapted from Kleynhans 1996), and colour-coding used to represent the different categories

Ecological Category (PES Category)	Range of PES% scores	Colour
A	92% - 100%	
A/B	87% - 91%	
B	82% - 86%	
B/C	77% - 81%	
C	62% - 76%	
C/D	57% - 61%	
D	42% - 56%	
D/E	37% - 41%	
E	22% - 36%	
E/F	17% - 21%	
F	0 - 16%	

For each case study wetland, the PES percentage scores from the different assessors were presented in tables, with colour-coding (following **Table 2**) used to show the respective Ecological Categories. This format of presenting the results allows for a relatively easy and quick means of graphically evaluating the degree of consistency in results between different assessors and between the three assessment methods that were tested. Assessors additionally provided "gut-feel" PES Categories for the Hydrology, Geomorphology, Vegetation, Water Quality, and Overall Wetland PES of each wetland, and these results were also presented in the comparative tables. The “gut-feel” PES is an intuitive estimate of the PES Category for a given wetland by a particular assessor, or group of assessors. Recording this intuitive estimate is a valuable exercise, especially when one bears in mind that there is no way to actually measure the absolute PES of a wetland and that all estimates (even those generated by semi-quantitative tools) are to a greater or lesser extent subjective.

Statistical analyses were also undertaken, to supplement the tabular comparison of results. For each wetland, pair-wise comparisons were made between the results generated by the different assessment methods (with assessors taken as replicates) using the non-parametric[iii] Wilcoxon rank sum test for unpaired samples (also known as the Mann-Whitney U test), to determine if there were statistically significant differences between the results of the different methods. Separate analyses were run for Overall Wetland PES, Hydrology PES, Geomorphology PES, Vegetation PES and, in the case of Wetland-IHI versus RDM-99, Water Quality PES (the WET-Health assessment method does not include a Water Quality component). The non-parametric Kruskal-Wallis test was used to determine whether there was a statistically significant difference in the PES percentage scores recorded by the various assessors (with the three assessment methods taken as replicates in this case). Again, for each wetland, separate analyses were run for Overall Wetland PES, Hydrology PES, Geomorphology PES, and Vegetation PES. No analyses were run for the Water Quality scores because these were only applicable to two of the three methods, not providing sufficient replication for the statistical test to be completed. All statistical analyses were conducted using the free open-source software package R (version 2.15.0), taking $p<0.05$ to indicate a statistically significant result.

In addition to the objective comparison of the results of the testing, as described above, a number of informal workshops were held with the assessors to discuss the application of the different assessment methods to the case-study wetlands. During these workshops, specific problems and confusing aspects that were encountered by the assessors in the application of the assessment methods were discussed and noted. The main points that emerged from the workshop discussions served as key informants in identifying the potential implications of the findings of the testing that was conducted (as documented in **Section 5** of the current report).

2.1.3. Preliminary sensitivity analysis

The preliminary analysis of the inherent sensitivity of the WET-Health (Level 1), Wetland-IHI and RDM-99 methods that was undertaken for the current study simply involved a desktop evaluation of the score-sheets for the respective methods, including an examination of the in-built formulae and look-up tables that are used to derive composite scores. The main aim of the evaluation was to identify areas where small differences in scores that are entered could lead to relatively large changes in the overall results.

2.2. Limitations

The following limitations were identified for the testing of existing wetland PES assessment methods that was undertaken:

[iii] The small sample sizes and non-normal distribution of the data made the use of parametric statistics invalid. Non-parametric statistical tests, which have lower statistical power than the parametric equivalents, were thus used.

- All of the case-study wetlands were located in the South Western Cape. While this may have precluded certain types of wetlands (e.g. grassland pans) and certain types of land-uses that could impact on wetlands (e.g. a general lack of small-scale cultivation in wetlands of the SW Cape) from being included in the testing, it is considered unlikely that significantly different results would have been obtained by selecting case-study wetlands from other regions.
- Only a few of the case-study wetlands were floodplain or definite channelled valley-bottom wetland types, which to some degree limited the comparison that could be made between the WET-Health and Wetland-IHI methods.
- There was a lack of sufficient replication to conduct rigorous statistical analyses, but this was not considered to be a major limitation because a sufficient level of analysis was obtained through the (statistical and non-statistical) analyses that were undertaken.
- The desktop-based sensitivity analysis of the three existing methods was very preliminary in nature, but it does highlight potential issues relating to the sensitivity of the scoring systems associated with the methods that were tested and serves as a good starting point for a detailed sensitivity analysis of the assessment methods.

3. BRIEF DESCRIPTION OF CASE STUDY WETLANDS

Table 3, on the following page, provides contextual information for the 18 case-study wetlands that were used in the testing of wetland PES assessment methods. For each wetland, the following information is provided:

- DWA Level I Ecoregion (after Kleyhans *et al*., 2005) that the wetland falls within;
- NFEPA WetVegGroup (after Nel *et al*., 2011) that the wetland falls within;
- Natural terrestrial vegetation types mapped in and immediately surrounding the wetland (according to the National Vegetation Map of Mucina & Rutherford 2006) and any azonal vegetation types (as mapped by Mucina & Rutherford 2006) that encompass the wetland;
- DWA Quaternary Catchment that the wetland falls within;
- Landscape setting of the wetland – valley floor / slope / plain / bench, following SANBI's Classification System for Wetlands and Other Aquatic Ecosystems (Ollis *et al*., 2013); and
- Hydro-geomorphic (HGM) wetland type and HGM sub-type that each case study wetland was categorised as, in its presumed natural reference state, according to the HGM wetland types of SANBI's Classification System for Wetlands and Other Aquatic Ecosystems (Ollis *et al*., 2013).

In **Table 4**, for each of the case-study wetlands a brief description is provided of the dominant land-uses in and around the wetland, and the main impacts on the present ecological condition of the wetland.

Detailed descriptions of the wetlands are not given in the current report, as it is only the overall findings of the comparative testing that are of importance to this project. More detailed descriptions of most of the case-study wetlands will, however, be available in the reports to be produced as part of WRC Project K5/2183 relating to the trajectories of change of selected wetlands in the South Western Cape.

Table 3: Contextual information for the 18 case-study wetlands

Wetland name	Ecoregion (DWA Level I)	NFEPA WetVeg Group	Natural vegetation type/s (terrestrial)[#]	DWA Quaternary Catchment/s	Landscape setting	HGM type* (presumed natural state)	HGM sub-type*
Middelberg wetland	Western Folded Mountains	Northwest Sandstone Fynbos	Cederberg Sandstone Fynbos	E10G	Valley floor	CVB wetland	n/a
Goukou wetland	Southern Coastal Belt	East Coast Shale Renosterveld	Cape Lowland Alluvial Vegetation (azonal veg type) within Mossel Bay Shale Renosterveld	H90A and H90C	Valley floor	UVB wetland**	n/a
Mfuleni wetland	South Western Coastal Belt	Western Strandveld	Cape Flats Dune Strandveld	G22E	Plain	Depression / Wetland flat	endorheic, without channelled inflow
Khayelitsha Pool	South Western Coastal Belt	West Coast Granite Renosterveld	Cape Lowland Freshwater Wetlands (azonal veg type) within Cape Flats Dune Strandveld	G22E	Plain	Floodplain wetland	floodplain depression
Kleinplaatz Dam wetland	Southern Folded Mountains	Southwest Sandstone Fynbos	Peninsula Sandstone Fynbos	G22A	Slope	Seep	with channelled outflow
Rooipan	South Western Coastal Belt	Southwest Sand Fynbos	Cape Inland Salt Pans (azonal veg type) within Langebaan Dune Strandveld and Saldanha Flats Strandveld	G21A	Plain	Depression / Wetland flat	endorheic, without channelled inflow
Yzerfontein salt pan	South Western Coastal Belt	Southwest Sand Fynbos	Cape Inland Salt Pans (azonal veg type) within Hopefield Sand Fynbos and Saldanha Flats Strandveld	G21A	Plain	Depression	endorheic, with channelled inflow
Burgerspan	South Western Coastal Belt	Southwest Sand Fynbos	Cape Inland Salt Pans (azonal veg type) within Swartland Granite Renosterveld	G10L	Plain	Depression	endorheic, with channelled inflow
Kiekoesvlei	South Western Coastal Belt	West Coast Shale Renosterveld	Cape Inland Salt Pans (azonal veg type) within Swartland Shale Renosterveld	G10L	Plain	Depression	endorheic, without channelled inflow
	South Western	West Coast Shale	Swartland Shale	G21A	Valley floor	CVB wetland***	n/a

Wetland name	Ecoregion (DWA Level I)	NFEPA WetVeg Group	Natural vegetation type/s (terrestrial)[#]	DWA Quaternary Catchment/s	Landscape setting	HGM type* (presumed natural state)	HGM sub-type*
Modder River wetland	Coastal Belt	Renosterveld	Renosterveld				
Agulhas Soutpan	Southern Coastal Belt	Southwest Ferricrete Fynbos	Cape Inland Salt Pans (azonal veg type) within Elim Ferricrete Fynbos	G50C	Plain	Depression	endorheic, with channelled inflow
Soetendalsvlei	Southern Coastal Belt	South Coast Limestone Fynbos	Cape Inland Salt Pans (azonal veg type) within Agulhas Sand Fynbos and Central Ruens Shale Renosterveld	G50C	Plain	Depression	endorheic, with channelled inflow
Rhenosterkop Pan	Southern Coastal Belt	? (surrounded by South Strandveld Western Strandveld)	Cape Inland Salt Pans (azonal veg type) within Overberg Dune Strandveld and Agulhas Limestone Fynbos	G50C and G50F	Plain	Depression	endorheic, without channelled inflow
Vermont Pan	Southern Coastal Belt	Southwest Sandstone Fynbos	Cape Lowland Freshwater Wetlands (azonal veg type) within Hangklip Sand Fynbos and Overberg Sandstone Fynbos	G40H	Plain	Depression	endorheic, without channelled inflow
Hemel-en-Aarde wetland	Southern Folded Mountains	Southwest Ferricrete Fynbos	Elim Ferricrete Fynbos	G40H	Valley floor	UVB wetland**	n/a
Belsvlei	Southern Folded Mountains	Southwest Ferricrete Fynbos	Elim Ferricrete Fynbos	G40H	Valley floor	UVB wetland**	n/a
Eliasgat wetland	Southern Coastal Belt (near change to Southern Folded Mountains)	East Coast Shale Renosterveld	Cape Lowland Freshwater Wetlands (azonal veg type) within Western Ruens Shale Renosterveld	G40J	Valley floor	CVB wetland***	n/a
Salmonsdam wetland	Southern Folded Mountains (near change to Southern Coastal Belt)	East Coast Shale Renosterveld	Cape Lowland Freshwater Wetlands (azonal veg type) within	G40M	Valley floor	UVB wetland**	n/a

[#] After Mucina & Rutherford (2006). Azonal vegetation types included, where relevant, together with the terrestrial vegetation type/s within which the azonal vegetation unit falls.

* After Ollis *et al*. (2013). CVB = channelled valley-bottom; UVB = unchannelled valley-bottom.

** Portions of this wetland have a distinct channel in their present-day state.

*** Possibly a UVB wetland in its natural state.

Table 4: Dominant land-uses and main impacts associated with each case-study wetland

Wetland name	Dominant land-uses within and surrounding the wetland	Main impacts affecting the ecological condition of the wetland
Middelberg wetland	Nature conservation, wilderness recreation	Historical buildings and a few alien trees, hiking paths
Goukou wetland	Agriculture (cultivation)	Channelisation, erosion, road crossings, agricultural impacts (abstraction, diffuse pollution, etc.), encroachment of invasive alien plant species
Mfuleni wetland	Peri-urban (informal settlement)	Houses, livestock (grazing/trampling), roads, infilling
Khayelitsha Pool	Peri-urban (informal settlement), urban nature conservation (Khayelitsha Wetland Park)	Channel modification, roads, livestock (grazing/trampling), encroachment by terrestrial and alien invasive plant species, water pollution and increased inflows (treated sewage effluent & stormwater runoff)
Kleinplaatz Dam wetland	Nature conservation, water storage and treatment, recreation (hiking)	Dam, footpaths, some trampling of natural vegetation
Rooipan	Urban (residential), vacant land	Excavation (historical gypsum mining), vehicle tracks, encroachment by housing
Yzerfontein salt pan	Gypsum mining (in the wetland), vacant (alien invaded) land	Dredging (mining), alien invasive plant encroachment, reduced inflows
Burgerspan	Agriculture (cultivation), natural veld	Inflowing channel modification, encroachment by cultivated fields (loss of fringing vegetation), agricultural impacts (runoff of pollutants, etc.)
Kiekoesvlei	Agriculture (cultivation, grazing)	Encroachment of terrestrial and alien plant species (agricultural weeds), trampling by livestock, water pollution (agricultural runoff)
Modder River wetland	Agriculture (cultivation, grazing), vacant land	Encroachment of terrestrial and alien plant species, sedimentation (from roads and agricultural land), road crossings, water pollution (agricultural runoff), reduced inflows, increased flood peaks
Agulhas Soutpan	Nature conservation (previous agricultural land)	Excavation (historical salt mining), impeding and diverting of inflows, historical buildings (old salt mine), roads
Soetendalsvlei	Agriculture (cultivation), vacant (alien invaded) land	Inflowing channel modification, encroachment of terrestrial and alien invasive plant species, roads, abstraction,
Rhenosterkop Pan	Agriculture (pastures/grazing), vacant (alien invaded) land	Livestock (grazing/trampling), roads, fences through wetland, encroachment of alien invasive plant species, water pollution (agricultural runoff)
Vermont Pan	Urban (residential), recreation (camp site), nature conservation (mountains to north of R43 freeway)	Water pollution (urban runoff, septic tanks, roosting birds), hardening of surrounding catchment, footpaths, encroachment of houses, gardens and alien invasive plants
Hemel-en-Aarde wetland	Agriculture (cultivation)	Channelisation, agricultural impacts (abstraction, diffuse pollution, etc.), encroachment of alien invasive plant species, reduced inflows
Belsvlei	Agriculture (cultivation), resort development	Channelisation, erosion, road crossings, agricultural impacts (abstraction, diffuse pollution, etc.), encroachment of alien invasive plant species, reduced inflows
Eliasgat wetland	Agriculture (cultivation)	Channel modification, road crossings, agricultural impacts (abstraction, diffuse pollution, etc.), encroachment of alien invasive plant species, reduced inflows

Wetland name	Dominant land-uses within and surrounding the wetland	Main impacts affecting the ecological condition of the wetland
Salmonsdam wetland	Nature conservation, recreation (camp site, hiking trails, 4X4 trail)	Channelisation, gully erosion, road crossings, encroachment of terrestrial and alien invasive plant species

4. RESULTS OF TESTING

4.1. Number of assessors and their relative experience

As mentioned previously, a total of nine people were involved in the testing undertaken for the current project, with between 3 and 8 assessors for each case-study wetland. The relative experience of the assessors was compared by simply categorising the number of years of experience in wetland assessment and/or wetland science into two groups – one group for those with more than 10 years of experience and another group for those with less than 10 years of experience (see **Table 5**, below). Of the nine people involved in the testing, five had more than 10 years of experience (up to more than 30 years), while four had less than 10 years of experience (mostly less than 5 years). For each case study wetland, there was at least one assessor from each group.

Table 5: Number of assessors involved in the application of wetland PES assessment methods to each of the case-study wetlands, broken down according to relative experience in number of years

Wetland name	Number of assessors		
	>10 years experience	<10 years experience	Total
Middelberg wetland	5	2	7
Goukou wetland	5	3	8
Mfuleni wetland	5	2	7
Khayelitsha Pool	2	2	4
Kleinplaatz Dam wetland	2	1	3
Rooipan	2	1	3
Yzerfontein salt pan	3	1	4
Burgerspan	2	1	3
Kiekoesvlei	2	1	3
Modder River wetland	2	1	3
Agulhas Soutpan	2	3	5
Soetendalsvlei	2	2	4
Rhenosterkop Pan	2	2	4
Vermont Pan	3	1	4
Hemel-en-Aarde wetland	3	1	4
Belsvlei	3	1	4
Eliasgat wetland	3	1	4
Salmonsdam wetland	3	1	4

4.2. Consistency between different assessors

Comparative tables showing the PES% scores and Ecological Categories derived by the different assessors are presented in **Appendix 1**, with a separate table for each case-study wetland. Ecological Categories are shown by means of colour-coding, according to the colour scheme presented in **Table**

2. The comparative tables in **Appendix 1** also show the "gut-feel" Ecological Categories determined by the different assessors for the overall PES of each wetland, and for the hydrology, geomorphology, vegetation and water quality PES of each wetland. In the comparative tables, Assessors 1 to 5 are those with more than 10 years of experience, while Assessors 6 to 9 are those with less than 10 years of experience. In the tables, grey shading shows where a particular wetland was not assessed by a particular assessor.

Although the RDM-99 PES assessment method of Duthie (1999) was not originally developed for application to depressional wetlands, it has been used for such wetland types in previous studies (e.g. Harding *et al*., 2001). This method was, therefore, applied to all the case-study wetlands, including depressions. A comparison was made between the results obtained through application of the RDM-99 assessment method using the "override" of the average score if any criterion is given a rating of <2 (as per the prescribed scoring system) and the results obtained without the use of such an "override" of the average score.

The Wetland-IHI method was developed exclusively for floodplain and channelled valley-bottom wetland HGM types, making it strictly applicable to only four of the case-study wetlands (namely Middelberg wetland, Khayelitsha Pool, Modder River wetland, and Eliasgat wetland). In the current study, however, this method was applied to certain case-study wetlands comprising other HGM types (i.e. Goukou unchannelled valley-bottom wetland, Mfuleni depression, Kleinplaatz Dam seep, Vermont Pan, Hemel-en-Aarde unchannelled valley-bottom wetland, Belsvlei unchannelled valley-bottom wetland, and Salmonsdam unchannelled valley-bottom wetland), by at least some of the assessors in each of these cases. This was done, partly, to allow for an evaluation to be made of how much adaptation of the assessment method would be required to make it suitable to other wetland types.

Taking all the results into consideration (see comparative tables in **Appendix 1**), the general trend was for the degree of inconsistency in PES% scores and Ecological Categories between assessors to increase as the number of impacts increased or as the intensity and/or complexity of the impacts increased[i]. For example, there was a very high degree of consistency in the results generated by different assessors in the case of the Middelberg wetland (see **Table 6**, below) and the Kleinplaatz Dam wetland, both of which had relatively negligible impacts. There was also a relatively high degree of consistency in the results generated by different assessors for the Soutpan and Rhenosterkop Pan wetlands in the Agulhas area (see results in **Appendix 1**), both of which are minimally impacted wetlands.

[i] It is important to note that no seriously to critically altered wetlands were included in the case studies, but it is assumed that at very high levels of transformation there would (as in the case of minimal impacts) be a high degree of consistency in the results of different assessors.

Table 6: PES% scores and Ecological Categories recorded by the different assessors for the Middelberg wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	100%	100%	100%	100%	100%	100%	100%		
	Wetland IHI	100%	100%	100%	100%	96%	100%	100%		
	RDM-99 (with 'override')	100%	100%	100%	100%	90%	90%	90%		
	RDM-99 (without 'override')	100%	100%	100%	100%	90%	90%	90%		
	"Gut-feel"	A	A	A	A	A	A	A		
Geomorphology	WET-Health (Level 1)	99%	100%	100%	100%	100%	100%	100%		
	Wetland IHI	100%	90%	100%	100%	92%	70%	100%		
	RDM-99 (with 'override')	100%	100%	90%	90%	100%	90%	90%		
	RDM-99 (without 'override')	100%	100%	90%	90%	100%	90%	90%		
	"Gut-feel"	A	A/B	A	A	A	A	A		
Vegetation*	WET-Health (Level 1)	89%	90%	90%	100%	100%	100%	100%		
	Wetland IHI	100%	100%	100%	100%	100%	100%	100%		
	RDM-99* (with 'override')	96%	96%	96%	96%	96%	92%	96%		
	RDM-99* (without 'override')	96%	96%	96%	96%	96%	92%	96%		
	"Gut-feel"	A	A	A	A	A	B	A		
Water quality**	Wetland IHI	100%	100%	100%	100%	100%	100%	100%		
	RDM-99 (with 'override')	90%	100%	100%	80%	100%	90%	100%		
	RDM-99 (without 'override')	90%	100%	100%	80%	100%	90%	100%		
	"Gut-feel"	A	A	A	A	A	A	A		
Overall PES	WET-Health (Level 1)	97%	97%	97%	100%	100%	100%	100%		
	Wetland IHI	100%	98%	100%	100%	98%	94%	100%		
	RDM-99 (with 'override')	96%	98%	96%	92%	96%	90%	94%		
	RDM-99 (without 'override')	96%	98%	96%	92%	96%	90%	94%		
	"Gut-feel"	A	A	A	A	A	A	A		

On the other hand, there was a great deal of inconsistency between the results of the different assessors for the Mfuleni and Salmonsdam wetlands. In the case of the Mfuleni wetland, for example (see **Table 7**, below), Assessors 3 and 7 generally rated the wetland to be in a poorer condition relative to the other assessors for most components. This was reflected in the respective PES scores generated by the different methods and in the "gut-feel" PES categories that were assigned. Upon discussion, it became evident that the main reason for this discrepancy was that the natural reference state of the wetland, as perceived by Assessors 3 and 7, was very different to that assumed by the other assessors. These two assessors considered the natural reference state to be a flat wetland area subject to seasonal saturation through the rising of the regional water table during the wet (winter) season, whereas the other assessors were of the opinion that the natural reference state was a wetland area that consisted of depressional areas subject to seasonal inundation. As the Mfuleni wetland currently consists of at least one recently infilled and subsequently excavated depressional area, Assessors 3 and 7 rated the present ecological condition to be substantially transformed from its natural reference state, compared to the other assessors. Another reason that came to light for some of the discrepancies between the results of assessors, in the case of the Mfuleni wetland, was a difference in the "assessment unit" for which the PES scoring was undertaken. Some assessors only considered a relatively large depressional wetland area, which forms part of a broader wetland consisting of a mosaic of depressions and wetland flats, whereas others considered the entire broader wetland area in their assessments.

Table 7: PES% scores and Ecological Categories recorded by the different assessors for the Mfuleni wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	90%	65%	35%	65%	70%	100%	30%		
	Wetland IHI	78%		12%	82%	86%	90%	52%		
	RDM-99 (with 'override')	50%	90%	20%	70%	90%	40%	20%		
	RDM-99 (without 'override')	50%	90%	30%	70%	90%	40%	20%		
	"Gut-feel"	B	B	D	C	B	C	D		
Geomorphology	WET-Health (Level 1)	66%	92%	6%	80%	78%	98%	22%		
	Wetland IHI	92%		54%	76%	80%	90%	60%		
	RDM-99 (with 'override')	60%	60%	20%	70%	70%	50%	20%		
	RDM-99 (without 'override')	60%	60%	60%	70%	70%	50%	30%		
	"Gut-feel"	C	D	E	C	B	D	E		
Vegetation*	WET-Health (Level 1)	67%	38%	5%	41%	39%	20%	34%		
	Wetland IHI	82%		56%	68%	74%	92%	64%		
	RDM-99* (with 'override')	76%	70%	20%	40%	44%	56%	48%		
	RDM-99* (without 'override')	76%	70%	60%	40%	44%	56%	48%		
	"Gut-feel"	D	C/D	D	D	C	D	D		
Water quality**	Wetland IHI	62%		40%	90%	72%	60%	44%		
	RDM-99 (with 'override')	66%	60%	20%	50%	60%	60%	20%		
	RDM-99 (without 'override')	66%	60%	20%	50%	60%	60%	20%		
	"Gut-feel"	C	C	C	D	C	D	E		
Overall PES	WET-Health (Level 1)	77%	65%	18%	62%	61%	77%	29%		
	Wetland IHI	82%		46%	74%	78%	90%	60%		
	RDM-99 (with 'override')	66%	72%	20%	52%	60%	52%	20%		
	RDM-99 (without 'override')	66%	72%	48%	52%	60%	52%	34%		
	"Gut-feel"	C/D	C/D	D	C/D	C	D	D/E		

In the case of the Salmonsdam wetland (see **Table 8**, below), which has been impacted by one particularly severe impact (gully erosion) affecting approximately half the wetland and creating a number of knock-on effects, the least experienced assessor (Assessor 6) consistently rated the impacts on this wetland to be less severe than the ratings assigned by the other three assessors. For example, for the hydrology PES assessment in WET-Health, Assessor 6 rated the intensity of the impact of gully erosion on the hydrological condition of the wetland to only be a score 2 (out of a possible maximum of 10), whereas the other assessors rated the intensity of this impact to be 7 or more. The PES scores derived by Assessor 2 for the Salmonsdam wetland were mostly significantly lower than those derived by the other assessors, except for the water quality PES. It transpired that the main reason for this was that the "assessment unit" used by Assessor 2 was different to that used by the other three assessors. The scores recorded in **Table 8** for Assessor 2 were for the severely eroded portion of the wetland within the Salmonsdam Reserve, while the upper portion of the wetland that has not been subject to severe gully erosion was taken as a separate "assessment unit". The other three assessors, on the other hand, used the entire portion of wetland within the Reserve (including the relatively pristine upper portion and the severely eroded lower portion) as their "assessment unit". There were stark differences between some of the PES scores generated by Assessor 1 and Assessor 5, most notably for the WET-Health hydrology and geomorphology PES results (and the overall PES score derived using the WET-Health weightings), despite both these assessors using the same "assessment unit". The main reason for this appears to be that Assessor 5 generally rated the extent to which the wetland was affected by the various impacts to be substantially higher than the extent ratings given by Assessor 1 (with the total extent for all relevant impacts within both the hydrology and geomorphology components adding up to more than 100% in the case of the WET-Health assessment by Assessor 5[ii]).

Table 8: PES% scores and Ecological Categories recorded by the different assessors for the Salmonsdam wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	50%	10%			15%	90%			
	Wetland IHI	74%				82%	80%			
	RDM-99 (with 'override')	70%	40%			60%	60%			
	RDM-99 (without 'override')	70%	40%			60%	60%			
	"Gut-feel"	C	D			C	A			
Geomorphology	WET-Health (Level 1)	55%	0%			12%	80%			
	Wetland IHI	26%				28%	70%			
	RDM-99 (with 'override')	60%	20%			60%	70%			
	RDM-99 (without 'override')	60%	40%			60%	70%			
	"Gut-feel"	D	D			D	B			
Vegetation*	WET-Health (Level 1)	55%	31%			58%	60%			
	Wetland IHI	86%				96%	98%			
	RDM-99* (with 'override')	78%	84%			52%	68%			
	RDM-99* (without 'override')	78%	84%			52%	68%			
	"Gut-feel"	C/D	D			C	B			
Water quality**	Wetland IHI	92%				94%	92%			
	RDM-99 (with 'override')	76%	90%			50%	70%			
	RDM-99 (without 'override')	76%	90%			50%	70%			
	"Gut-feel"	A	B			A	B			
Overall PES	WET-Health (Level 1)	53%	15%			26%	79%			
	Wetland IHI	70%				76%	88%			
	RDM-99 (with 'override')	72%	20%			54%	68%			
	RDM-99 (without 'override')	72%	64%			54%	68%			
	"Gut-feel"	C/D	D			C	B			

The only statistically significant differences between the results of the different assessors that were detected, based on the Kruskal-Wallis non-parametric test (see full results in **Appendix 2**), were for Khayelitsha Pool (hydrology and geomorphology components, but not the vegetation component or the overall PES) and Belsvlei (geomorphology component only).

In the case of Khayelitsha Pool (see **Table 9**, below) , the hydrology PES% scores recorded by the two experienced assessors (Assessors 1 and 2, with >10 years experience each) were at least one to two categories lower than the scores recorded by the two less experienced assessors (Assessors 6 and 7, with <5 years experience each). The main reason for these differences, at least for the WET-Health and Wetland-IHI assessment methods, was that the two more experienced assessors gave much higher ratings for the extent and intensity of "within-wetland hydrological impacts" than the less experienced assessors. At the same time, the more experienced assessors gave substantially lower scores (indicating greater impacts) for the hydrological criteria in the RDM-99 method, compared to the scores given by the less experienced assessors. There was thus clearly a significant difference in the way that the two more experienced assessors rated the hydrological impacts affecting the Khayelitsha Pool wetland than the two less experienced assessors, which could be attributed to the less experienced assessors not taking into account the broader hydrogeomorphic setting of the wetland. Although the Khayelitsha Pool wetland, as implied by its name, is a clearly depressional

[ii] It is not clear from the WET-Health manual (Macfarlane *et al*., 2007) whether total extents of >100% are 'allowed' in a "Level 1" assessment.

feature, it forms part of a much broader floodplain wetland system that has been significantly modified through urban development and the construction of major roads (including the N2 freeway). Mapping of the 'assessment unit' in relation to the broader wetland HGM Unit that it forms part of may have reduced the discrepancies between the results of different assessors for this particular case study. For the geomorphology component of Khayelitsha Pool wetland, the geomorphology PES% scores (and the "gut-feel" PES category) recorded by one of the experienced assessors (Assessor 1) were significantly lower than the respective scores recorded by the other three assessors. The main reason for this was that Assessor 1 was of the opinion that the stream channel associated with the floodplain depression had been substantially modified relative to the reference state, with stream diversion/shortening and infilling having taken place, whereas the other three assessors did not regard these to be major impacts to the present geomorphological condition of the wetland itself.

Table 9: PES% scores and Ecological Categories recorded by the different assessors for the Khayelitsha Pool wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	35%	35%				80%	70%		
	Wetland IHI	48%	56%				66%	90%		
	RDM-99 (with 'override')	30%	40%				70%	60%		
	RDM-99 (without 'override')	56%	40%				70%	60%		
	"Gut-feel"	D/E	D				D	C		
Geomorphology	WET-Health (Level 1)	48%	98%				70%	84%		
	Wetland IHI	52%	90%				68%	60%		
	RDM-99 (with 'override')	30%	70%				70%	80%		
	RDM-99 (without 'override')	46%	70%				70%	80%		
	"Gut-feel"	D	B				C	B		
Vegetation*	WET-Health (Level 1)	43%	76%				62%	86%		
	Wetland IHI	84%	72%				74%	76%		
	RDM-99* (with 'override')	60%	60%				60%	68%		
	RDM-99* (without 'override')	60%	60%				60%	68%		
	"Gut-feel"	D	C				C	C		
Water quality**	Wetland IHI	68%	68%				80%	92%		
	RDM-99 (with 'override')	50%	60%				40%	70%		
	RDM-99 (without 'override')	50%	60%				40%	70%		
	"Gut-feel"	D	D				D	C/D		
Overall PES	WET-Health (Level 1)	41%	65%				72%	79%		
	Wetland IHI	68%	72%				72%	76%		
	RDM-99 (with 'override')	30%	58%				60%	70%		
	RDM-99 (without 'override')	52%	58%				60%	70%		
	"Gut-feel"	D	C				C/D	C		

In the case of the Belsvlei wetland (see **Table 10**, below), generally higher geomorphology PES% scores were recorded by one of the less experienced assessors (Assessor 6) and, for the WET-Health method only, by one of the more experienced assessors (Assessor 2). These higher PES% scores were attributable to lower ratings being given for the extent and intensity of 'erosional features' (in WET-Health and Wetland-IHI) and (in WET-Health only) for the intensity and extent of the 'loss of organic matter'. At the same time, significantly lower PES% scores were recorded for the geomorphology component by one of the more experienced assessors (Assessor 5), compared to the other three assessors, especially when using the WET-Health and Wetland-IHI methods. These discrepancies were due to a relatively high magnitude-of-impact score of 6 (out of 10) being given for 'increased runoff' in the WET-Health assessment by Assessor 5 (this impact was considered to be not applicable by the other three assessors) and to the maximum rating of 5 being given for 'erosional features' in the Wetland-IHI assessment by this assessor. The higher geomorphology PES% scores recorded by Assessor 6 for the RDM-99 assessments were simply due to ratings of 3 being given for the geomorphological criteria, compared to ratings of 2 or 2.5 being given by the other assessors.

Table 10: PES% scores and Ecological Categories recorded by the different assessors for the Belsvlei wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	25%	35%			40%	65%			
	Wetland IHI	66%	60%			64%	66%			
	RDM-99 (with 'override')	60%	60%			40%	50%			
	RDM-99 (without 'override')	60%	60%			40%	50%			
	"Gut-feel"	D	C			C	C			
Geomorphology	WET-Health (Level 1)	55%	74%			3%	94%			
	Wetland IHI	24%	56%			10%	60%			
	RDM-99 (with 'override')	46%	40%			40%	60%			
	RDM-99 (without 'override')	46%	40%			40%	60%			
	"Gut-feel"	D/E	C			D	D			
Vegetation*	WET-Health (Level 1)	34%	68%			39%	47%			
	Wetland IHI	62%	86%			74%	78%			
	RDM-99* (with 'override')	58%	68%			56%	64%			
	RDM-99* (without 'override')	58%	68%			56%	64%			
	"Gut-feel"	D	B/C			D	C			
Water quality**	Wetland IHI	62%	62%			86%	84%			
	RDM-99 (with 'override')	50%	60%			50%	50%			
	RDM-99 (without 'override')	50%	60%			50%	50%			
	"Gut-feel"	C	B			B	C			
Overall PES	WET-Health (Level 1)	36%	56%			29%	68%			
	Wetland IHI	54%	72%			58%	72%			
	RDM-99 (with 'override')	54%	58%			50%	58%			
	RDM-99 (without 'override')	54%	58%			50%	58%			
	"Gut-feel"	D	C			D	C/D			

The above results indicate that some, but not all, of the statistically significant inconsistencies between the PES scores/categories of different assessors could be related to the relative level of experience of the assessors. There was, however, a general lack of consistency between the PES scores recorded by assessors for the different assessment methods (as dealt with in the section below), leading to very few statistically significant differences between the scores generated by different assessors. As such, despite the low degree of statistically significant differences, there was a substantial degree of inconsistency in the relative PES scores obtained by different assessors for the majority of the case-study wetlands, with variations of one Ecological Category or more being recorded relatively frequently. It was found that much of the inconsistency between the PES scores of different assessors could be attributed to one or more of the following factors:

(1) **Differences in the perceived natural reference state of a wetland** (e.g. Mfuleni wetland)[iii];

[iii] One of the case-study wetlands that highlighted the importance of ascertaining the natural reference state was Rooipan. In its present state, this wetland consists of a series of depressions behind a cordon of beach foredunes. Discussions with a manager of the Reserve within which the wetland is located, however, revealed that the depressions had been excavated through gypsum mining operations in the 1960's. This showed that, in its natural reference state, this wetland is likely to have been much flatter than it is today and subject to far less inundation. As an aside, the seasonally inundated depressions have become important sites for migratory wading birds and are now of high conservation importance.

(2) **Differences in the "assessment unit" taken into consideration** (e.g. Salmonsdam wetland)[iv];
(3) **Differences in the estimation of the extent to which a wetland has been affected by a particular impact** (e.g. Khayelitsha Pool floodplain wetland), especially where estimates have not been based on the mapping of the extent-of-impact (e.g. using GIS); and
(4) **Differences in the rating of impact intensity** (e.g. Belsvlei wetland), especially where inadequate (or no) rating guidelines have been provided in the documentation for an assessment method.

There was also a relatively high degree of inconsistency between the "gut-feel" Ecological Categories recorded by assessors and the categories obtained by the same assessor using one or more of the formal PES assessment methods, except for wetlands with very few impacts (such as the Middelberg and Kleinplaas wetlands). Such differences were observable for all four components of wetland condition (i.e. hydrology, geomorphology, vegetation, and water quality), irrespective of the level of experience of the assessor, but were less obvious in the Overall PES. This indicates that there could be certain impacts that are not being factored in by the assessment methods, which the assessors were taking into account in their assignment of "gut-feel" categories, or that the methods weight certain impacts too strongly in the scoring. It should be noted in this regard that the assessors, in all cases, made a concerted effort to apply the assessment methods without 'tweaking' the results generated to agree more with their "gut-feel". Alternatively, the discrepancies between assessors' "gut-feel" categories and the categories generated by the assessment methods could be due to a lack of adequate 'calibration' in an assessor's perception of the degree of deviation from the natural reference state for certain impacts.

4.3. Consistency between different assessment methods

As in the case of the differences between the PES scores of assessors, more inconsistency was observed between the PES scores recorded for the different methods as the number or intensity of impacts increased (see comparative tables in **Appendix 1**)[v]. For example, there was a much higher degree of consistency in the PES scores recorded using the different methods for the relatively natural Middelberg wetland than there was in the case of the significantly more degraded Mfuleni wetland (see **Table 6** vs. **Table 7**, respectively).

The only statistically significant differences between the PES% scores of WET-Health versus Wetland-IHI, based on pair-wise Wilcoxon rank sum tests (see full results in **Appendix 2**), were for the Vegetation component of the Mfuleni ($p = 0.005$) and Goukou ($p = 0.001$) wetlands, where the Wetland-IHI method generated vegetation PES scores that were one or two categories (or more) higher than the scores generated by the WET-Health (Level 1) method. In the case of the Mfuleni wetland (see **Table 7**), where there were a multitude of impacts affecting the condition of the

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[iv] The Kleinplaatz Dam wetland case study clearly highlighted the importance of identifying and specifying the unit of assessment. Kleinplaatz Dam was established by constructing a barrier across a seepage wetland, which destroyed much of the original seep, except for a portion on the slopes above the dam. For the current project, only the relatively intact portion of wetland above the dam was considered in the assessments that were undertaken. Very different results would have been obtained if the "assessment unit" was taken to be the natural extent of seepage wetland, including the area where the dam is now located.

[v] Again, it is important to note here that no seriously to critically altered wetlands were included in the case studies, but it is assumed that at very high levels of transformation there would be a high degree of consistency in the results of different assessment methods.

vegetation, the 'forced' use of a total extent of 100% in the Wetland-IHI method and the listing of far fewer (broader) potential vegetation impacts than there are in the WET-Health (Level 1) score-sheet, together with the application of a weighting to each impact score in Wetland-IHI, seemed to be the main reasons behind these differences. The use of only a few broad categories of impact and the application of weightings in Wetland-IHI could result in the "dilution" of impact scores and an under-estimation of the overall magnitude of impact on vegetation condition. On the other hand, the rating of overlapping impacts in WET-Health, with a total extent that could exceed 100%, could lead to "double-scoring" and an over-estimation of the overall magnitude of impact on vegetation condition. More research and focussed testing would be required to determine which of these approaches to the derivation of the vegetation PES% is the most robust.

In the case of the Goukou wetland (see **Table 11**), the derivation of higher vegetation PES% scores through the use of Wetland-IHI compared to WET-Health could be attributed to the use of the default intensity scores for the various 'disturbance classes' in the WET-Health (Level 1) score-sheets by all the assessors. In an attempt to minimise the variability between the scoring by different assessors in the testing that was undertaken, it was agreed that, the default scores (including those for the vegetation 'disturbance classes' in WET-Health) would be used by all the assessors for all the wetland case-studies. A large proportion (80% or more) of the Goukou wetland was considered by all the assessors to be in a relatively near-natural state in terms of its vegetation. The default intensity rating for 'untransformed areas' in WET-Health is, however, a score of 1, whereas in the Wetland-IHI method an intensity rating of zero is assumed for the portion of a wetland with vegetation that is in a near-pristine ('reference') state. Many of the assessors also rated a significant portion (up to 10%) of the Goukou wetland to be affected by 'dense alien vegetation patches'. This 'disturbance class' has a relatively high default intensity score of 7, whereas the equivalent category in the vegetation component of Wetland-IHI ('vegetation clearing/loss/alteration') does not have a default intensity rating but does have a ranking of 3 and a default weighting of 60 that tends to lead to lower overall weighted impact scores than the case for the scoring of 'dense alien vegetation patches' in WET-Health. Adjustment of the default intensity ratings in WET-Health and/or of the default weightings in Wetland-IHI for the relevant criteria would, of course, reduce the differences between the vegetation PES scores that would be generated by the two methods.

For both the Mfuleni and Goukou case-study wetlands, relatively big differences were also observed between the PES scores recorded by the two different methods (WET-Health vs. Wetland-IHI) for the hydrology and geomorphology components (see **Tables 7 and 11**). The differences in these scores were, however, less consistent between the different assessors, compared with the vegetation PES scores – some assessors recorded much higher hydrology/geomorphology PES scores using the Wetland-IHI method, while others recorded much higher respective scores using WET-Health. The main reasons for the inconsistency between the scores derived by different assessors for the Mfuleni wetland were discussed in **Section 4.2**, above. In the case of the Goukou wetland, the relatively high variability in hydrology and geomorphology PES scores between different assessors (see **Table 11**), for both WET-Health and Wetland-IHI, could be largely attributed to differences in the rating of the extent and intensity to which this naturally unchannelled valley-bottom wetland has been affected by channelisation. Some of the assessors considered this impact and its knock-on effects to be relatively serious (e.g. Assessor 1), whereas others considered it to be far less of an issue (e.g. Assessor 6).

Table 11: PES% scores and Ecological Categories recorded by the different assessors for the Goukou wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	35%	65%	35%	80%	80%	90%	85%		80%
	Wetland IHI	78%	72%	68%	86%	86%	82%	56%		82%
	RDM-99 (with 'override')	70%	80%	80%	70%	80%	80%	70%		70%
	RDM-99 (without 'override')	70%	80%	80%	70%	80%	80%	70%		70%
	"Gut-feel"	B/C	B/C	C	B/C	B	C	C		A
Geomorphology	WET-Health (Level 1)	87%	67%	74%	56%	59%	92%	91%		83%
	Wetland IHI	54%	66%	60%	66%	80%	60%	60%		60%
	RDM-99 (with 'override')	70%	70%	70%	60%	80%	80%	80%		70%
	RDM-99 (without 'override')	70%	70%	70%	60%	80%	80%	80%		70%
	"Gut-feel"	C	B/C	C	C	B	B	B		B
Vegetation*	WET-Health (Level 1)	76%	76%	74%	82%	67%	72%	75%		67%
	Wetland IHI	92%	94%	94%	94%	94%	96%	90%		86%
	RDM-99* (with 'override')	74%	76%	72%	68%	84%	72%	64%		76%
	RDM-99* (without 'override')	74%	76%	72%	68%	84%	72%	64%		76%
	"Gut-feel"	B	B	B	B/C	B	B	C		C
Water quality**	Wetland IHI	72%	72%	66%	98%	60%	92%	90%		92%
	RDM-99 (with 'override')	66%	70%	50%	40%	60%	60%	70%		80%
	RDM-99 (without 'override')	66%	70%	50%	40%	60%	60%	70%		80%
	"Gut-feel"	B/C	B/C	B	B	B	C	C		A
Overall PES	WET-Health (Level 1)	62%	69%	57%	74%	70%	90%	84%		77%
	Wetland IHI	78%	82%	80%	86%	88%	86%	76%		80%
	RDM-99 (with 'override')	70%	74%	70%	62%	78%	72%	70%		74%
	RDM-99 (without 'override')	70%	74%	70%	62%	78%	72%	70%		74%
	"Gut-feel"	B/C	B/C	B/C	B/C	B	B/C	C		B

The statistical comparisons between the RDM-99 method versus the WET-Health and Wetland-IHI methods were only conducted using overall PES scores (see **Appendix 2**) because the PES scores for the different categories in the case of the RDM-99 method (i.e. hydrology, water quality, geomorphology/hydraulics, and biota) are based on the average of only a few criteria, making the validity of any statistical analyses questionable and the power of any such analyses very weak. The few case-study wetlands for which the overall PES% scores derived using the RDM-99 method were found to be statistically significantly different ($p<0.05$) to the overall scores derived using the WET-Health or Wetland-IHI methods generally had PES scores for the RDM-99 method that were one Ecological Category lower than the respective WET-Health or Wetland-IHI overall scores. Specifically, this was the finding for Vermont Pan in the case of both WET-Health and Wetland-IHI (see comparative table in **Appendix 1**), and for the Goukou (see **Table 11**), Hemel-en-Aarde and Eliasgat (see **Table 12**) wetlands in the case of the RDM-99 method versus Wetland-IHI but not for the statistical comparison between the WET-Health and the RDM-99 method. It is not possible to determine the main 'driving factors' behind these differences because the simple scoring system of the RDM-99 method (based on the use of the overall average score, or the lowest score if any score of <2 is recorded) is so different to the relatively complex scoring systems of the WET-Health and Wetland-IHI methods for the derivation of the overall wetland PES score/category.

Table 12: PES% scores and Ecological Categories recorded by the different assessors for the Eliasgat wetland case study (Ecological Categories colour-coded according to Table 2; grey shading indicates where no assessment was completed by a particular assessor)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	30%	50%			65%	35%			
	Wetland IHI	52%	68%			66%	68%			
	RDM-99 (with 'override')	60%	40%			40%	50%			
	RDM-99 (without 'override')	60%	40%			40%	50%			
	"Gut-feel"	D	C			C	C			
Geomorphology	WET-Health (Level 1)	40%	98%			24%	94%			
	Wetland IHI	64%	70%			58%	50%			
	RDM-99 (with 'override')	46%	70%			50%	50%			
	RDM-99 (without 'override')	46%	70%			50%	50%			
	"Gut-feel"	D/E	C			C	D			
Vegetation*	WET-Health (Level 1)	34%	70%			37%	30%			
	Wetland IHI	66%	86%			66%	78%			
	RDM-99* (with 'override')	50%	60%			60%	52%			
	RDM-99* (without 'override')	50%	60%			60%	52%			
	"Gut-feel"	D	C			C	D			
Water quality**	Wetland IHI	66%	66%			88%	76%			
	RDM-99 (with 'override')	46%	60%			50%	40%			
	RDM-99 (without 'override')	46%	60%			50%	40%			
	"Gut-feel"	C	C			C	C			
Overall PES	WET-Health (Level 1)	34%	70%			45%	50%			
	Wetland IHI	64%	78%			66%	68%			
	RDM-99 (with 'override')	50%	58%			54%	50%			
	RDM-99 (without 'override')	50%	58%			54%	50%			
	"Gut-feel"	D	C			C	C/D			

Taking the results for all the case-study wetlands into account, the inconsistencies that were observed between assessors' "gut-feel" categories and the categories derived using the various assessment methods (as discussed in **Section 4.2**, above) appeared to be applicable to all three assessment methods. Generally, in the limited number of cases where the 'override' was applied for the RDM-99 method (i.e. for any PES score of <2 recorded, where the lowest score and not the average is taken as the overall score), there tended to be a greater discrepancy between an assessor's "gut-feel" category and the category derived by the RDM-99 method than there was for the application of the method simply using average scores. There were one or two exceptions to this observation. In all the other cases, the category derived using the RDM-99 method 'with override' was at least one category lower than an assessor's "gut-feel" category, and generally at least one category lower than the categories derived using the other assessment methods, especially for overall PES scores. This suggests that the prescribed 'override' of the average score in the RDM-method when any condition score of less than 2 is recorded is too extreme.

In two of the three cases where the Wetland-IHI method was applied to non-pristine floodplain or channelled valley-bottom wetlands (i.e. Khayelitsha Pool and the Modder River wetland), there was more consistency between the PES scores for WET-Health and Wetland-IHI than there was generally for the case-study wetlands that are not floodplain or channelled valley-bottom wetlands but to which Wetland-IHI was applied anyway, especially in the scores recorded by more experienced assessors (i.e. Assessors 1 to 5). This was particularly true for the hydrology and geomorphology PES scores and less so for the vegetation PES scores. In the other case (Eliasgat wetland), however, a relatively high level of inconsistency was observed between the WET-Health and Wetland-IHI PES scores recorded by most of the assessors, for all three PES components (i.e. hydrology, geomorphology and vegetation) and for the Overall PES (see **Table 12**). For this channelled valley-bottom wetland, the PES% scores recorded using the Wetland-IHI method were generally higher than the respective scores recorded using WET-Health (Level 1), often differing by one Ecological Category or more. In the case of the hydrology PES scores, this was mostly due to higher overall ratings being assigned to 'within-wetland effects' when WET-Health was applied, compared to the ratings given in Wetland-IHI. The main reason for such discrepancies was that there are more within-wetland impacts listed in WET-Health, many of which were considered to be relevant to the Eliasgat wetland by most of the assessors and were thus scored, and because the total extent of all the within-wetland impacts often exceeded 100% in the WET-Health assessments for this wetland (which seems to be allowed when using this method), whereas the Wetland-IHI method has fewer within-wetland impacts to rate and requires the total of all the extent estimates to add up to exactly 100%. For the vegetation PES component of the scoring for this wetland, the generation of significantly higher PES% scores by all of the assessors when applying Wetland-IHI compared to WET-Health seems to be related to more impacts being listed in the WET-Health score-sheet and to the use of the default intensity ratings for the various 'disturbance classes' in WET-Health and of the default rankings and weightings for the various vegetation impacts listed in Wetland-IHI (similar to the situation for the Goukou wetland, as discussed above).

For the geomorphology PES scores of the Eliasgat wetland, two assessors (Assessors 1 and 5) recorded higher PES% scores using Wetland-IHI compared to WET-Health. These assessors rated the relevant geomorphological impacts in WET-Health (e.g. 'erosional features', 'depositional features', 'loss of organic matter') to be of relatively high intensity (5 or more) and estimated extents that added up to >100%. The other two assessors (Assessors 2 and 6) who, on the other hand, recorded higher PES% scores using WET-Health compared to Wetland-IHI, gave relatively low ratings for the intensity and extent of the geomorphological impacts listed in WET-Health. In the Wetland-IHI assessments, however, these assessors gave higher ratings for the 'erosional features' impact than the other two assessors (Assessors 1 and 5) gave using the same method. As such, the differences in geomorphology PES% scores were largely dictated by the way in which the various assessors scored erosion-related impacts, with two of the assessors having been more cautious than the other two assessors about the possible 'double-scoring' of impacts in WET-Health, and having ensured that the sum of all the extent estimates did not exceed 100%.

For some case study wetlands, similar Ecological Categories were derived for the Overall PES by different assessors, despite relatively large differences between some or all of the component scores by the same assessors. For example, in the case of the Goukou wetland (see **Table 11**), similar overall PES% scores were derived by Assessors 1 and 2 using WET-Health and Wetland-IHI, despite significantly different PES% scores being recorded for the hydrology and/or geomorphology components by these assessors using the same methods. These discrepancies can largely be explained by the disparate weightings of the components by the two methods (as presented in **Table 1**).

4.4. Preliminary sensitivity analysis of assessment methods

The findings of the preliminary analysis of the relative sensitivity of the WET-Health, Wetland-IHI and RDM-99 PES assessment methods are outlined, separately for the three methods, in the sub-sections below. For all three methods, it was noted that they are all highly sensitive to 'missing impacts' (i.e. impacts that are not taken into account in the derivation of PES scores by a particular assessment method). This is because the inputting of no scores for 'missing impacts' that are applicable to a wetland leads to results that indicate that the wetland is in better condition than it actually is (or worse condition in the case of the RDM-99 method), and there is no formalised means to overcome this problem by including additional impacts that have not been accounted for in the score-sheets. The typical solution to this issue is that an assessor "tweaks" certain scores in an assessment to factor in any 'missing impacts'.

In terms of the derivation of overall PES scores by the three methods that have been compared, WET-Health is particularly sensitive to the PES% score for hydrology and Wetland-IHI is particularly sensitive to the PES% score for vegetation, due to the respective weightings of these components being highest (see **Table 1**). The overall PES score for the RDM-99 method is particularly sensitive to any criteria that are given a score of less than 2, due to the "override" that is applied in such instances when using the prescribed scoring system for this method.

4.4.1. WET-Health (Level 1)

The following observations were made about the inherent sensitivity of the score-sheets for the hydrology module of WET-Health (Level 1 assessment):

- The combining of catchment-effect scores to get an overall magnitude of impact score (using Table 5.3 of the WET-Health manual) could lead to big 'jumps', especially in the case of floodplain wetlands and channelled valley-bottom wetlands driven primarily by overbank flooding (i.e. Table 5.3a). This is because there are 'jumps' of ≥2 units between certain categories; for example, for a 'change in inflows' score of -0.9 to +0.9, there is a 'jump' of 4 units (from a magnitude-of-impact score of 1 to a score of 5) when going from a 'small decrease' for 'altered floodpeaks' (score range of -1.6 to 3.9) to a 'moderate decrease' for this criterion (score range of -4 to -6).
- The table used to get the overall magnitude-of-impact score for the hydrology PES (Table 5.12 of the WET-Health manual) also has some big 'jumps' (of up to 2.5) in the middle portion of the table. Specifically, this applies to 'small to moderate' scores for 'water distribution/retention', when going from 'moderate' to 'large' scores for 'water input' scores, and for small to moderate 'water input' scores, when going from moderate to large 'water distribution/retention' scores.

For the score-sheets of the geomorphology module of WET-Health (Level 1 assessment), the following observation was made:

- The look-up table used to derive an overall magnitude-of-impact score for 'increased runoff' (Table 5.16 of the WET-Health manual) has a particularly big 'jump' (of 3 units) for a 'small increase' in the 'increased flows' score, when going from a 'small increase' to a 'moderate increase' for the 'increased floodpeaks' score. The inclusion of the 'increased runoff' criterion in the geomorphology module is also possibly leading to the double-scoring of a factor that was already taken into account in the hydrology module; it may be more appropriate to include a criterion that results from increased runoff but is more directly related to the geomorphology of the wetland.

For the vegetation module of WET-Health (Level 1 assessment), it was noted that the use of a default intensity score of 1 for 'untransformed areas' in the scoring table for disturbance classes (during Step 4C of the Level 1 assessment) means that a wetland that is 100% untransformed will be given a Vegetation PES of Ecological Category B, when a category of A or A/B would generally be more appropriate for such a situation.

An issue that was noted in the score-sheets for all three modules of WET-Health (Level 1 assessment) was that it is not clear from the documentation or the score-sheets themselves whether the total extent for within-wetland hydrological impacts at Step 2B, geomorphological impacts at Step 3A, and/or vegetation 'disturbance classes' at Step 4C can add up to more than 100% (the score-sheets do not, for example, have an in-built mechanism to prevent the entry of values that add up to more than 100% in total). If total extents of greater than 100% are allowed at these steps in the assessment process, it could (depending on the intensity scores associated with each extent estimate) result in overall magnitude-of-impact scores of greater than the maximum of 10 being obtained which could, in turn, lead to the 'over-weighting' of these impact scores and make combined scores further on in the assessment process particularly sensitive to these 'inflated' scores. No guidance is provided in the WET-Health manual as to how an assessor should deal with situations where a particular portion of a wetland is affected by more than one of the impacts taken into consideration within a particular assessment module.

4.4.2. Wetland-IHI

In general, the use of an impact rating scale of 0 to 5 in Wetland-IHI makes it more sensitive to small differences in input scores than WET-Health with its impact rating scale of 0 to 10.

The following observations were made about the inherent sensitivity of the score-sheets for the hydrology module of Wetland-IHI:

- Under the 'catchment effects' section, there is more sensitivity to changes in the scores for 'changes in flood peaks' than for the other criteria under this section (e.g. 'changes in base flows') because this criterion has a higher default weighting.
- The derivation of an overall Hydrology PES score is more sensitive to the combined 'catchment effects' score than the combined 'within-wetland effects' score because the 'catchment effects' score has a higher default weighting. For the derivation of an overall Hydrology PES score in WET-Health, on the contrary, it seems that more weight is given to within-wetland scores than catchment-related scores (although the combining of scores is dealt with differently in WET-Health than it is in Wetland-IHI, so it is difficult to do a proper comparison without proper sensitivity testing).

For the score-sheets of the geomorphology module of Wetland-IHI, the following observations were made:

- The derivation of an overall Geomorphology PES score is sensitive to the weighting that is selected for 'catchment' under 'importance of catchment vs. on-site effects', which is dependent on the assessor's interpretation of whether catchment soils are sand- or clay-dominated (with respective suggested weightings of 100 and 70, respectively).

- For 'catchment effects', the matrix table that is used to derive a 'change in sediment budget' score from the 'change in sediment supply' and 'change in transport capacity' scores is more sensitive to certain changes than others, with the 'jumps' between adjacent scores on one axis varying from 0.25 to 1.5. It also appears as though there are some errors in the matrix table, with some overall impact scores decreasing as a particular impact increases – for example, the overall score that would be derived for a 'change in sediment supply' score of 1 (on the y-axis of the matrix) changes from 1.5 to 1 going from a 'change in transport capacity' score of 0 to 1 (on the x-axis), when it should presumably increase.
- The scoring of 'within-wetland effects' is much more sensitive to the value that is recorded for 'erosional features' than it is to the value recorded for 'depositional features' (weighting of 100 versus 10). This is based on the assumption that wetlands are naturally depositional features that should aggrade rather than degrade (pers. comm., M. Rountree, Fluvius Environmental Consultants).

The Overall PES score that is derived for a wetland using Wetland-IHI is very *in*sensitive to the PES score that is calculated for the water quality module because the score for this module has such a low default weighting of less than 10% (see **Table 1**). Within the water quality module itself, the use of the mean, median or mode of the impact ratings for each of the water quality parameters to derive an overall rating for each parameter reduces the sensitivity of the module to particularly acute water quality impacts (e.g. effluent from industries affecting the concentration of toxics in a wetland). The use of the *maximum* impact rating for each water quality parameter would probably thus be more appropriate for deriving an overall rating for each parameter in the water quality module, especially for wetlands that are more sensitive to water quality impacts (such as most wetlands in the SW Cape).

4.4.3. DWA RDM-99 method

In general, as in the case of Wetland-IHI, the use of an impact rating scale of 0 to 5 in the RDM-99 method makes it generally more sensitive to small differences in input than WET-Health with its impact rating scale of 0 to 10. The score-sheet for the RDM-99 assessment method is also particularly sensitive to whether a cell is left blank (taken as a score of zero) or given a score of 5 for impacts that are not relevant because, in the scoring system for this method, a score of 5 represents an unimpacted state (instead of a score of zero). This sensitivity to non-relevant criteria being scored as a 5 or being left blank is particularly acute for the case of the hydrology, water quality and geomorphology/hydraulics sections, each of which only have two component criteria that need to be evaluated.

The derivation of separate scores for the different sections on the score-sheet for the RDM-99 method is highly sensitive to the values entered for individual criteria. This is because there are so few criteria under each section, especially in the case of the hydrology, geomorphology/hydraulics and water quality sections (each of which only have two criteria that are scored).

As noted previously, the RDM-99 method is especially sensitive to any criteria that are given a score of <2 (i.e. seriously to critically modified) when the "override" of the average score is applied and the lowest score is used for the overall rating instead, as per the scoring protocol. This sensitivity applies to the derivation of individual scores for each section of the score-sheet, if this is done, and (even more so) to the derivation of an overall PES score.

4.5. Specific issues identified by assessors during testing

Some of the specific problem areas and confusing aspects identified by the assessors in the application of the three PES assessment methods to the case-study wetlands are outlined below, separately for each assessment method. For all of the methods, it was found that insufficient guidance is provided on the determination of the reference state of a wetland, which is a critical step in the PES assessment process. The Wetland-IHI score-sheets do at least provide a space for entering a written description of the perceived reference state of the wetland that is being assessed, which is not provided for in the score-sheets for the WET-Health or RDM-99 methods. Another shortcoming pertaining to all three of the existing methods that was identified during the testing is that no explanation is given as to how an assessor should deal with the effects of wild fires and natural grazing, which result in natural, short-term changes to wetlands that do not constitute an alteration of the natural cycles of change for certain wetlands. This issue is of particular relevance to the fire-adapted Fynbos Biome of the South Western Cape. A major gap that was identified is that none of the three existing wetland PES assessment methods that were tested are suitable for determining the present ecological condition of depression or wetland flat HGM types.

RDM-99 method:

- The criteria that must be scored are, generally, very vague and ambiguous, and the wording that is used is not always entirely clear (for example, references to ‘flow’ in some cases should refer to ‘hydroperiod’ or ‘inundation’ or ‘saturation’).
- The list of criteria included in the score-sheet is not very comprehensive, with no provision made for the addition of ‘missing’ criteria.
- All criteria are given equal weighting in the calculation of PES scores by simply using mean scores, which tends to ‘dilute’ more significant impacts (this is, of course, ameliorated to some degree by the “overriding” of the average score by any criteria that have a score of <2, but this approach has its own issues).
- The “overriding” of the average score with the lowest score for wetlands with impact scores of <2 seems to be too extreme in most cases.
- There is no explicit separation of catchment effects from within-wetland effects.
- No guidance is given on how to rate criteria that include catchment effects and within-wetland effects, or for which only a portion of a wetland may be affected (there is no separate rating of intensity and extent in this assessment method), which makes the scoring system very subjective. The ‘permanent inundation’ criterion under the hydrology section is, for example, particularly difficult to score with a single rating.
- In the biota section, ‘alien fauna’ and ‘over-utilisation of biota’ are difficult to score and are inappropriate criteria for a habitat-based PES assessment method.

Wetland-IHI method:

- It is confusing, and a possible source of inconsistency, that certain weightings need to be entered by the assessor. For example, in the Hydrology module an appropriate weighting must be selected for "zero flows" and it is unclear whether there is a default weighting for this criterion. Another example is in the Geomorphology module, where a weighting needs to be selected for 'catchment' under ‘importance of catchment vs. on-site effects’ on the basis of the assessor’s interpretation of whether catchment soils are sand- or clay-dominated (as discussed previously in **Section 4.4.2**).

- There appears to be a typographical error in the Hydrology score-sheet of Wetland-IHI Version 1.1, for the default weighting of "change in seasonality" where there is a zero weighting by default (this criterion had a weighting of 60 in the score-sheet of Version 1.0, which is the weighting that was used in the testing that was undertaken).
- In the Geomorphology module, the presence of vegetation within a channel (and the robustness of this vegetation) is not explicitly taken into account on ‘transport capacity’ side of the 'sediment budget' calculation, which is very important in the case of wetlands with vegetated channels.
- It is not clear whether half-scores can be entered for the overall 'change in sediment budget' score in the Geomorphology module.
- No provision has been made in the score-sheet of the Geomorphology module for the rating of topographical alterations.
- The overall scores for the Geomorphology module have to be entered manually in the relevant score-sheet, with reference to a look-up table, which introduces a potential area for user-error when the score-sheets are filled in. The derivation of these final scores should be automated in the spreadsheet.
- For the Geomorphology module in general, more criteria are needed to make the rating of geomorphological impacts more robust and easier to score.
- In the Vegetation Alteration module, only four land-use activities are listed for assessment, with a number of important land-use activities excluded from this list (such as terrestrial vegetation encroachment and flooding by dams).
- The Water Quality module is rather rudimentary and very confusing to apply in its current form, and its application requires a relatively good understanding of the effects of different land-uses on specific water quality variables (which a non-specialist is very unlikely to have). This module also takes too long to fill in relative to the value that it adds, especially taking into account the very low weighting given to the Water Quality PES score in the derivation of the Overall PES score for a wetland (see **Table 1**).
- The Water Quality module is very sensitive to whether an assessor enters zeros or leaves the relevant cells blank for non-applicable cells in the scoring matrix, with different mean, median and mode ratings generated in each case. No guidance is provided in the documentation for Wetland-IHI as to how to deal with the filling-in of the Water Quality score-sheet for non-applicable criteria.
- The experience of the assessors involved in the testing was, not surprisingly, that the Hydrology and Geomorphology modules of Wetland-IHI were very difficult to apply to systems that were not floodplain or channelled valley-bottom wetlands (especially in the case of depressions), but the Vegetation Alteration and Water Quality modules did seem to be applicable to all the different wetland HGM types that were included as case studies.

WET-Health (Level 1) method:

- There is no explicit inclusion of a confidence rating for the assessment of the various criteria in the WET-Health score-sheets, which is included in the RDM-99 and Wetland-IHI score-sheets. This is considered to be a major omission.
- The overall scores for the Hydrology module have to be entered manually in the relevant section of the score-sheet, with reference to two look-up tables, which introduces a potential area for user-error when the score-sheet is filled in. The derivation of these final scores should be automated in the spreadsheet.
- In the Geomorphology module, the inclusion of a (indirect) diagnostic assessment and a (direct) indicator-based assessment to determine the overall geomorphological condition could possibly lead to the "double-counting" of impacts.
- A number of the criteria included in the Geomorphology module are only rated for certain, specified HGM types, but the criteria are sometimes relevant to other HGM types and it is not clear whether they should be scored in such cases. For example, the impact of upstream dams on sediment transport is only meant to be scored for floodplain wetlands but this impact is often also of relevance to channelled valley-bottom wetlands.
- The Geomorphology module is, generally, too complicated and rather confusing to apply.
- The Geomorphology module and, in some cases, the Hydrology module, was difficult to apply to wetlands not connected to the drainage network (especially depressions).
- For all three modules, it is not clear whether it is acceptable to enter extent estimates that add up to >100%.
- Of the three assessment methods that were tested, the score-sheets for WET-Health were generally found to be the least user-friendly to apply. This is largely due to the need to continually refer back to a multitude of look-up tables in the manual, instead of including most of the information in the score-sheets themselves (as in the case of the Wetland-IHI score-sheets).

5. DISCUSSION OF FINDINGS

The comparative testing of the three most nationally prominent Wetland PES assessment methods that currently exist in South Africa that was undertaken for WRC Project K5/2192 revealed that there were relatively high levels of inconsistency between the PES% scores and Ecological Categories derived by different assessors and by the different methods, except for case-study wetlands that were in relatively pristine ecological condition. Most of the variability between assessors and between the different methods was not statistically significant ($p<0.05$), according to the non-parametric statistical tests that were used, but this was mostly because of the generally large variability between replicate scores and was not a reflection that there was consistency between the scores. Indeed, as can be seen from a cursory examination of the comparative tables (see **Appendix 1**), for many of the case-study wetlands there were differences of one or more Ecological Categories in the derivation of PES scores by different assessors and through the application of the different assessment methods. This was the finding for all the different components of wetland PES (i.e. hydrology, geomorphology, vegetation, and water quality), and for the Overall PES. The inconsistencies that were observed did not, except in a few cases, appear to be related to the relative level of experience of the assessors or to the type of wetland.

Clearly, these findings highlight that consequential differences could be obtained in the results generated through the application of the three assessment methods by different assessors. This is far from ideal and is an issue of concern with respect to the general use of the assessment methods for Wetland PES assessment by various users throughout the country. One of the biggest problems is that none of the existing assessment methods seems to consistently provide more 'accurate' results than any of the other methods. Instead, all of the methods have strong points and shortcomings. This highlights the dire need for the development of a single method for wetland PES assessment in South Africa (or of a suite of similar methods for different wetland types), building on and improving the methods that already exist.

One of the important questions to address is, "What are the main sources of variability between the results that are generated by different assessors and through the use of different assessment methods?" In a recent study undertaken by Bodmann (2011) on the variation in scores from different users of the WET-Health 'Level 2' tool, some of the main sources of variation between assessors were identified to be the participant's occupation and qualifications (with less variability between more experienced assessors), group work versus individual work (with less variability where assessment was done in groups), attendance at a training course (with less variability between assessors who have completed a training course specifically relating to the assessment method), and the duration of the assessment (with more consistency between assessors if a longer time is spent assessing a wetland). In his study, Bodmann (2011) also found that there was more variability between the scores recorded by different assessors for the hydrology module of WET-Health than there was for the other modules, and attributed this to the hydrology module for a 'Level 2' assessment requiring greater knowledge and more intense assessment to complete than the other modules. It was concluded that the assessment and scoring of the hydrology module takes much longer than that for the vegetation and geomorphology modules, and the hydrology module has more factors to consider in an assessment, making the scoring more tedious and the hydrology PES more difficult to assess.

The findings of the current study did not agree with all the findings of Bodmann (2011), for the WET-Health method or for the other two assessment methods. Instead, in our study, no strong relationship was found between the level of experience of the assessors and the variability of PES scores (with a relatively high degree of variability, generally, even between the scores of assessors with more than 10 years of experience), or between group work and the variability of PES scores (with a relatively high degree of variability between assessors for both wetlands that were assessed as group work exercises and those that were assessed more individually). It should be noted, however, that the current study evaluated the rapid 'Level 1' version of WET-Health, whereas the study by Bodmann (2011) focussed on the more comprehensive 'Level 2' WET-Health assessment. The effect of the duration of an assessment and of the participation in relevant training courses could not be evaluated from the testing done for the current study.

The conclusion of the testing that was undertaken for the current study, with regard to the sources of variability in the PES scores recorded by different users or derived using different assessment methods, was that one of the main sources of variability was differences between assessors in their perception of the natural reference state of a particular wetland. This highlights the critical importance of ascertaining and describing the reference state (or reference conditions) of a wetland as one the first steps in the assessment process, for all the rapid Wetland PES assessment methods that were evaluated. The reference state represents the presumed/probable natural (unimpacted) characteristics of the wetland, which is to be used as the baseline or benchmark against which impacts are evaluated. The determination of the reference state is the pivot point around which the entire PES assessment revolves. It is important to, generally, use the presumed *natural* state of a wetland prior to human impact for the establishment of the reference conditions for a PES assessment. If this approach is not followed, then the baseline against which impacts are assessed would be a shifting target, and it would result in outcomes that are inconsistent and non-comparable. As highlighted by MacKay (1999), this would ultimately lead to a situation where the grounds on which management decisions are made relating to the protection of water resources would always be shifting.

Other major sources of variability in the PES scores recorded by different assessors that were identified in the current study were differences in the "assessment unit" taken into consideration, differences in the estimation of the extent to which a wetland has been affected by a particular impact, and differences in the rating of impact intensity (partly due to a lack of adequate guidelines for the scoring of impacts relative to the perceived natural reference state).

One of the interesting, rather serendipitous findings of the current study was that the use of the Vegetation and Water Quality modules of the Wetland-IHI method for wetlands that are not floodplain or channelled valley-bottom wetlands seems to be acceptable. The application of these PES assessment modules to different wetland types in the testing that was undertaken did not present any particular problems or areas of confusion to the assessors who were involved. A number of problems were encountered, however, in the application of all three assessment methods, especially WET-Health and Wetland-IHI, to depressions and wetland flats, particularly for the Geomorphology and (to less degree) Hydrology modules.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the current report, there appears to be a less than satisfactory degree of consistency between the results generated by different assessors and between the results generated using different Wetland PES assessment methods, when comparing the RDM-99, WET-Health (Level 1) and Wetland-IHI methods. The main reasons for the observed inconsistencies are thought to be related to differences in the perception of the natural reference state of the case-study wetlands, differences in the delineation of the "assessment unit", and differences in the assessment of impact intensity and/or extent by different assessors, rather than inherent problems with any of the assessment methods that were compared. All of the methods that were compared have strong points and shortcomings, and none of the assessment methods were found to yield more consistent results than any of the other methods. A similar amount of time and level of expertise is also required to apply the three assessment methods.

In the absence of any other potentially appropriate Wetland PES assessment methods that exist at present, the ongoing use of all of three of the existing methods and their inclusion in the proposed Decision-support Protocol (DSP) for WRC Project K5/2192 is thus deemed to be acceptable, providing the inherent limitations of the methods are taken into account. Of the three methods that were evaluated, the RDM-99 method is the most simplistic and least comprehensive, and is also more prone to subjectivity than the other two methods. The exclusion of this method from the DSP (except for deriving the overall PES score for depressions and wetland flats) and the discouragement of its ongoing use in its current form is, therefore, considered to be warranted. The development of a simple, but more comprehensive and less subjective rapid assessment method along the lines of the RDM-99 method is, however, something that should be pursued in the future development of Wetland PES assessment methods in South Africa. In the interim, the DSP that has been produced includes comprehensive lists of potential impacts for each component of Wetland PES, which can be used to identify the impacts affecting the present ecological condition of a wetland that is being assessed and could serve as the starting point for the development of a “new” PES assessment method in the future.

The separate modules from WET-Health and Wetland-IHI are explicitly included in the DSP that has been developed for the rapid assessment of Wetland PES, according to their relevance to different wetland types (including the option to use the Vegetation and Water Quality modules of Wetland-IHI for all wetland types). The DSP also allows for the selection of the preferred weightings for the derivation of the overall Wetland PES by an assessor (i.e. the WET-Health default weightings or the Wetland-IHI default weightings, or customised weightings if neither of these are considered to be appropriate), except for depressions and wetland flats because the geomorphology PES cannot be determined for these wetland types using either WET-Health or Wetland-IHI. There is clearly the need for a project to be completed to determine what weightings should be used for the different components of wetland condition when deriving an Overall PES score/category for a wetland. It is likely that the weightings for the derivation of Overall PES scores would need to be different for different wetland types.

While the use of the DSP, and of the primary methods included in the DSP (i.e. WET-Health and Wetland-IHI), are considered to be the best available options for the rapid assessment of wetland PES at present, there is clearly a dire need for the development of a single Wetland PES assessment method (or a suite of similar assessment methods for different wetland types). Extensive testing/validation and consultation with the wetland community in South Africa will be vital in the development of an adequately robust method that will be acceptable for widespread use throughout the country.

Until a “new” and widely accepted method is developed for the rapid assessment of Wetland PES in South Africa, the following guidelines should be developed as a matter of urgency to improve the consistency between different assessors using WET-Health and Wetland-IHI:

- More guidance is required for the determination of reference conditions, which is a critical but underplayed step in the application of most of the assessment methods. One aspect of this is the need for a list of specific characteristics for which the probable/presumed natural reference state should be determined (e.g. reference HGM type, hydroperiod, dominant vegetation structure, broad water quality characteristics, etc.)[vi]. The other aspect is the need for

[vi] This aspect has been addressed, to some degree, by the inclusion of a ‘reference state’ datasheet in the DSP produced for WRC Project K5/2192 but more guidelines are still needed.

documented guidelines as to how and where the necessary information about the likely natural reference state of a wetland can be obtained, and for documentation about the typical characteristics of the unimpacted (or minimally impacted) wetlands in various regions.

- Guidelines are required for the selection and mapping of the "assessment unit/s" when a wetland PES assessment is undertaken. These guidelines should not only address the selection and mapping of assessment units, but also the mapping of the HGM unit and the entire wetland that an "assessment unit" is located within[vii].
- Photographic field-guides should be developed that contain guidelines for rating the intensity and extent of impacts, to facilitate consistency between assessors. A good example of such a guide is the Model Photo Guide for the rating of instream and riparian modifications to river ecosystems (Graham and Louw 2008) that accompanies the Technical Manual for the latest (EcoClassification / EcoStatus) version of the IHI for river ecosystems (Kleynhans *et al*., 2008). It may be useful to include additional photographs of (and information about) various wetland features in the photographic field-guides (e.g. erosion gullies, different HGM types, alluvial fans, dykes, typical wetland vegetation in different regions, etc.), as suggested by Malan (2008), to ensure that assessors have a better understanding of the criteria that need to be taken into consideration when applying the existing assessment tools.
- Once guidelines for the determination and documentation of the perceived natural reference state of a wetland, and for the rating of impacts have been developed, training in the use of these guidelines and their application to the existing wetland PES assessment methods should be given in the various regions across the country. This would facilitate a certain degree of national standardisation in wetland PES assessment, which would go a long way towards addressing some of the inconsistencies between different assessors and different assessment methods that were raised in the current report. Generic training material should be produced to enable different organisations (with relevant experience) to be involved in the delivery of the training.

[vii] The inclusion of a worksheet for the identification and delineation of HGM Units and "assessment units" in the DSP produced for WRC Project K5/2192 has, to some degree, addressed this issue but more guidelines are still needed.

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APPENDIX 1:

Comparison of PES scores and categories recorded by different assessors for each case-study wetland

Wetland name: Middelberg
HGM type (presumed natural state): Channelled valley-bottom wetland

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	100%	100%	100%	100%	100%	100%	100%		
	Wetland IHI	100%	100%	100%	100%	96%	100%	100%		
	RDM-99 (with 'override')	100%	100%	100%	100%	90%	90%	90%		
	RDM-99 (without 'override')	100%	100%	100%	100%	90%	90%	90%		
	"Gut-feel"	A	A	A	A	A	A	A		
Geomorphology	WET-Health (Level 1)	99%	100%	100%	100%	100%	100%	100%		
	Wetland IHI	100%	90%	100%	100%	92%	70%	100%		
	RDM-99 (with 'override')	100%	100%	90%	90%	100%	90%	90%		
	RDM-99 (without 'override')	100%	100%	90%	90%	100%	90%	90%		
	"Gut-feel"	A	A/B	A	A	A	A	A		
Vegetation*	WET-Health (Level 1)	89%	90%	90%	100%	100%	100%	100%		
	Wetland IHI	100%	100%	100%	100%	100%	100%	100%		
	RDM-99* (with 'override')	96%	96%	96%	96%	96%	92%	96%		
	RDM-99* (without 'override')	96%	96%	96%	96%	96%	92%	96%		
	"Gut-feel"	A	A	A	A	A	B	A		
Water quality**	Wetland IHI	100%	100%	100%	100%	100%	100%	100%		
	RDM-99 (with 'override')	90%	100%	100%	80%	100%	90%	100%		
	RDM-99 (without 'override')	90%	100%	100%	80%	100%	90%	100%		
	"Gut-feel"	A	A	A	A	A	A	A		
Overall PES	WET-Health (Level 1)	97%	97%	97%	100%	100%	100%	100%		
	Wetland IHI	100%	98%	100%	100%	98%	94%	100%		
	RDM-99 (with 'override')	96%	98%	96%	92%	96%	90%	94%		
	RDM-99 (without 'override')	96%	98%	96%	92%	96%	90%	94%		
	"Gut-feel"	A	A	A	A	A	A	A		

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Goukou

HGM type (presumed natural state): Unchannelled valley-bottom wetland

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	35%	65%	35%	80%	80%	90%	85%		80%
	Wetland IHI	78%	72%	68%	86%	86%	82%	56%		82%
	RDM-99 (with 'override')	70%	80%	80%	70%	80%	80%	70%		70%
	RDM-99 (without 'override')	70%	80%	80%	70%	80%	80%	70%		70%
	"Gut-feel"	B/C	B/C	C	B/C	B	C	C		A
Geomorphology	WET-Health (Level 1)	87%	67%	74%	56%	59%	92%	91%		83%
	Wetland IHI	54%	66%	60%	66%	80%	60%	60%		60%
	RDM-99 (with 'override')	70%	70%	70%	60%	80%	80%	80%		70%
	RDM-99 (without 'override')	70%	70%	70%	60%	80%	80%	80%		70%
	"Gut-feel"	C	B/C	C	C	B	B	B		B
Vegetation*	WET-Health (Level 1)	76%	76%	74%	82%	67%	72%	75%		67%
	Wetland IHI	92%	94%	94%	94%	94%	96%	90%		86%
	RDM-99* (with 'override')	74%	76%	72%	68%	84%	72%	64%		76%
	RDM-99* (without 'override')	74%	76%	72%	68%	84%	72%	64%		76%
	"Gut-feel"	B	B	B	B/C	B	B	C		C
Water quality**	Wetland IHI	72%	72%	66%	98%	60%	92%	90%		92%
	RDM-99 (with 'override')	66%	70%	50%	40%	60%	60%	70%		80%
	RDM-99 (without 'override')	66%	70%	50%	40%	60%	60%	70%		80%
	"Gut-feel"	B/C	B/C	B	B	B	C	C		A
Overall PES	WET-Health (Level 1)	62%	69%	57%	74%	70%	90%	84%		77%
	Wetland IHI	78%	82%	80%	86%	88%	86%	76%		80%
	RDM-99 (with 'override')	70%	74%	70%	62%	78%	72%	70%		74%
	RDM-99 (without 'override')	70%	74%	70%	62%	78%	72%	70%		74%
	"Gut-feel"	B/C	B/C	B/C	B/C	B	B/C	C		B

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Mfuleni

HGM type (presumed natural state): Depression (endorheic, without channelled inflow) / Wetland flat

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	90%	65%	35%	65%	70%	100%	30%		
	Wetland IHI	78%		12%	82%	86%	90%	52%		
	RDM-99 (with 'override')	50%	90%	20%	70%	90%	40%	20%		
	RDM-99 (without 'override')	50%	90%	30%	70%	90%	40%	20%		
	"Gut-feel"	B	B	D	C	B	C	D		
Geomorphology	WET-Health (Level 1)	66%	92%	6%	80%	78%	98%	22%		
	Wetland IHI	92%		54%	76%	80%	90%	60%		
	RDM-99 (with 'override')	60%	60%	20%	70%	70%	50%	20%		
	RDM-99 (without 'override')	60%	60%	60%	70%	70%	50%	30%		
	"Gut-feel"	C	D	E	C	B	D	E		
Vegetation*	WET-Health (Level 1)	67%	38%	5%	41%	39%	20%	34%		
	Wetland IHI	82%		56%	68%	74%	92%	64%		
	RDM-99* (with 'override')	76%	70%	20%	40%	44%	56%	48%		
	RDM-99* (without 'override')	76%	70%	60%	40%	44%	56%	48%		
	"Gut-feel"	D	C/D	D	D	C	D	D		
Water quality**	Wetland IHI	62%		40%	90%	72%	60%	44%		
	RDM-99 (with 'override')	66%	60%	20%	50%	60%	60%	20%		
	RDM-99 (without 'override')	66%	60%	20%	50%	60%	60%	20%		
	"Gut-feel"	C	C	C	D	C	D	E		
Overall PES	WET-Health (Level 1)	77%	65%	18%	62%	61%	77%	29%		
	Wetland IHI	82%		46%	74%	78%	90%	60%		
	RDM-99 (with 'override')	66%	72%	20%	52%	60%	52%	20%		
	RDM-99 (without 'override')	66%	72%	48%	52%	60%	52%	34%		
	"Gut-feel"	C/D	C/D	D	C/D	C	D	D/E		

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Khayelitsha pool

HGM type (presumed natural state): Floodplain wetland (floodplain depression adjacent to floodplain flat)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	35%	35%				80%	70%		
	Wetland IHI	48%	56%				66%	90%		
	RDM-99 (with 'override')	30%	40%				70%	60%		
	RDM-99 (without 'override')	56%	40%				70%	60%		
	"Gut-feel"	D/E	D				D	C		
Geomorphology	WET-Health (Level 1)	48%	98%				70%	84%		
	Wetland IHI	52%	90%				68%	60%		
	RDM-99 (with 'override')	30%	70%				70%	80%		
	RDM-99 (without 'override')	46%	70%				70%	80%		
	"Gut-feel"	D	B				C	B		
Vegetation*	WET-Health (Level 1)	43%	76%				62%	86%		
	Wetland IHI	84%	72%				74%	76%		
	RDM-99* (with 'override')	60%	60%				60%	68%		
	RDM-99* (without 'override')	60%	60%				60%	68%		
	"Gut-feel"	D	C				C	C		
Water quality**	Wetland IHI	68%	68%				80%	92%		
	RDM-99 (with 'override')	50%	60%				40%	70%		
	RDM-99 (without 'override')	50%	60%				40%	70%		
	"Gut-feel"	D	D				D	C/D		
Overall PES	WET-Health (Level 1)	41%	65%				72%	79%		
	Wetland IHI	68%	72%				72%	76%		
	RDM-99 (with 'override')	30%	58%				60%	70%		
	RDM-99 (without 'override')	52%	58%				60%	70%		
	"Gut-feel"	D	C				C/D	C		

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Kleinplaas (/Kleinplaatz) Dam wetland
HGM type (presumed natural state): Seep (with channelled outflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	100%	100%				100%			
	Wetland IHI	98%					100%			
	RDM-99 (with 'override')	90%	90%				90%			
	RDM-99 (without 'override')	90%	90%				90%			
	"Gut-feel"	A/B	A				A			
Geomorphology	WET-Health (Level 1)	100%	97%				100%			
	Wetland IHI	100%					100%			
	RDM-99 (with 'override')	96%	90%				90%			
	RDM-99 (without 'override')	96%	90%				90%			
	"Gut-feel"	A	A				A			
Vegetation*	WET-Health (Level 1)	87%	86%				87%			
	Wetland IHI	96%					98%			
	RDM-99* (with 'override')	100%	100%				92%			
	RDM-99* (without 'override')	100%	100%				92%			
	"Gut-feel"	A/B	A				A			
Water quality**	Wetland IHI	100%					98%			
	RDM-99 (with 'override')	100%	100%				100%			
	RDM-99 (without 'override')	100%	100%				100%			
	"Gut-feel"	A	A				A			
Overall PES	WET-Health (Level 1)	96%	95%				96%			
	Wetland IHI	98%					98%			
	RDM-99 (with 'override')	96%	96%				92%			
	RDM-99 (without 'override')	96%	96%				92%			
	"Gut-feel"	A	A				A			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Rooipan
HGM type (presumed natural state): Wetland flat (or 'dune slack' depression)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	50%	50%				40%			
	Wetland IHI									
	RDM-99 (with 'override')	20%	20%				90%			
	RDM-99 (without 'override')	60%	60%				90%			
	"Gut-feel"	C/D	C				B			
Geomorphology	WET-Health (Level 1)	100%	100%				90%			
	Wetland IHI									
	RDM-99 (with 'override')	30%	70%				80%			
	RDM-99 (without 'override')	30%	70%				80%			
	"Gut-feel"	C/D	A				C			
Vegetation*	WET-Health (Level 1)	44%	44%				25%			
	Wetland IHI									
	RDM-99* (with 'override')	78%	92%				68%			
	RDM-99* (without 'override')	78%	92%				68%			
	"Gut-feel"	D	B				B			
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	90%	90%				80%			
	RDM-99 (without 'override')	90%	90%				80%			
	"Gut-feel"	A/B	B				B			
Overall PES	WET-Health (Level 1)	62%	62%				50%			
	Wetland IHI									
	RDM-99 (with 'override')	20%	20%				76%			
	RDM-99 (without 'override')	64%	78%				76%			
	"Gut-feel"	C	B				B			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Yzerfontein salt pan

HGM type (presumed natural state): Depression (endorheic, with channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	35%	60%	10%			90%			
	Wetland IHI									
	RDM-99 (with 'override')	66%	60%	90%			60%			
	RDM-99 (without 'override')	66%	60%	90%			60%			
	"Gut-feel"	C	B	B			B			
Geomorphology	WET-Health (Level 1)	100%	100%	79%			100%			
	Wetland IHI									
	RDM-99 (with 'override')	66%	66%	50%			70%			
	RDM-99 (without 'override')	66%	66%	50%			70%			
	"Gut-feel"	C	B	C			B			
Vegetation*	WET-Health (Level 1)	59%	86%	100%			100%			
	Wetland IHI									
	RDM-99* (with 'override')	80%	82%	100%			56%			
	RDM-99* (without 'override')	80%	82%	100%			56%			
	"Gut-feel"	B	B	n/a			B			
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	80%	80%	70%			60%			
	RDM-99 (without 'override')	80%	80%	70%			60%			
	"Gut-feel"	B	B	B			B			
Overall PES	WET-Health (Level 1)	61%	79%	55%			96%			
	Wetland IHI									
	RDM-99 (with 'override')	72%	72%	84%			60%			
	RDM-99 (without 'override')	72%	72%	84%			60%			
	"Gut-feel"	B/C	B	B			B			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Burger's Pan
HGM type (presumed natural state): Depression (endorheic, with channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	70%	70%				50%			
	Wetland IHI									
	RDM-99 (with 'override')	66%	50%				60%			
	RDM-99 (without 'override')	66%	50%				60%			
	"Gut-feel"	C	B				C			
Geomorphology	WET-Health (Level 1)	100%	100%				100%			
	Wetland IHI									
	RDM-99 (with 'override')	86%	96%				60%			
	RDM-99 (without 'override')	86%	96%				60%			
	"Gut-feel"	B/C	B				B			
Vegetation*	WET-Health (Level 1)	82%	85%				47%			
	Wetland IHI									
	RDM-99* (with 'override')	76%	80%				68%			
	RDM-99* (without 'override')	76%	80%				68%			
	"Gut-feel"	B	C				B			
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	76%	80%				60%			
	RDM-99 (without 'override')	76%	80%				60%			
	"Gut-feel"	C	B				C			
Overall PES	WET-Health (Level 1)	82%	83%				63%			
	Wetland IHI									
	RDM-99 (with 'override')	76%	76%				64%			
	RDM-99 (without 'override')	76%	76%				64%			
	"Gut-feel"	C	B/C				B/C			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Kiekoesvlei

HGM type (presumed natural state): Depression (endorheic, without channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	65%	100%				80%			
	Wetland IHI									
	RDM-99 (with 'override')	76%	76%				100%			
	RDM-99 (without 'override')	76%	76%				100%			
	"Gut-feel"	A/B	B				B			
Geomorphology	WET-Health (Level 1)	100%	100%				100%			
	Wetland IHI									
	RDM-99 (with 'override')	80%	96%				90%			
	RDM-99 (without 'override')	80%	96%				90%			
	"Gut-feel"	C	A				B			
Vegetation*	WET-Health (Level 1)	40%	30%				76%			
	Wetland IHI									
	RDM-99* (with 'override')	20%	30%				68%			
	RDM-99* (without 'override')	56%	66%				68%			
	"Gut-feel"	C/D	D				C			
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	76%	76%				60%			
	RDM-99 (without 'override')	76%	76%				60%			
	"Gut-feel"	C	C				C			
Overall PES	WET-Health (Level 1)	68%	80%				85%			
	Wetland IHI									
	RDM-99 (with 'override')	20%	30%				76%			
	RDM-99 (without 'override')	72%	78%				76%			
	"Gut-feel"	C	C				B/C			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Modder River

HGM type (presumed natural state): Channelled valley-bottom wetland (possibly unchannelled)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	60%	60%				100%			
	Wetland IHI	74%	78%				76%			
	RDM-99 (with 'override')	70%	70%				60%			
	RDM-99 (without 'override')	70%	70%				60%			
	"Gut-feel"	B/C	C				C			
Geomorphology	WET-Health (Level 1)	72%	98%				100%			
	Wetland IHI	68%	86%				60%			
	RDM-99 (with 'override')	76%	76%				60%			
	RDM-99 (without 'override')	76%	76%				60%			
	"Gut-feel"	D	C				B			
Vegetation*	WET-Health (Level 1)	75%	82%				46%			
	Wetland IHI	86%	94%				76%			
	RDM-99* (with 'override')	58%	30%				56%			
	RDM-99* (without 'override')	58%	68%				56%			
	"Gut-feel"	C/D	C				B			
Water quality**	Wetland IHI	66%	72%				88%			
	RDM-99 (with 'override')	56%	60%				60%			
	RDM-99 (without 'override')	56%	60%				60%			
	"Gut-feel"	C	C				C			
Overall PES	WET-Health (Level 1)	68%	77%				85%			
	Wetland IHI	78%	88%				74%			
	RDM-99 (with 'override')	64%	30%				58%			
	RDM-99 (without 'override')	64%	68%				58%			
	"Gut-feel"	C	C				B/C			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Agulhas Soutpan

HGM type (presumed natural state): Depression (endorheic, with channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	90%				90%	100%		65%	60%
	Wetland IHI									
	RDM-99 (with 'override')	86%				80%	80%		80%	40%
	RDM-99 (without 'override')	86%				80%	80%		80%	40%
	"Gut-feel"	A/B				A	B		A/B	D
Geomorphology	WET-Health (Level 1)	100%				100%	100%		89%	85%
	Wetland IHI									
	RDM-99 (with 'override')	70%				100%	70%		70%	40%
	RDM-99 (without 'override')	70%				100%	70%		70%	40%
	"Gut-feel"	B				A	B		B	D
Vegetation*	WET-Health (Level 1)	82%				90%	90%		68%	76%
	Wetland IHI									
	RDM-99* (with 'override')	88%				76%	68%		90%	80%
	RDM-99* (without 'override')	88%				76%	68%		90%	80%
	"Gut-feel"	A/B				A	A		n/a	C
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	70%				90%	70%		80%	60%
	RDM-99 (without 'override')	70%				90%	70%		80%	60%
	"Gut-feel"	A				A	B		B	C
Overall PES	WET-Health (Level 1)	91%				93%	97%		73%	72%
	Wetland IHI									
	RDM-99 (with 'override')	80%				84%	70%		82%	62%
	RDM-99 (without 'override')	80%				84%	70%		82%	62%
	"Gut-feel"	A/B				A	B		B	D

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Soetendalsvlei

HGM type (presumed natural state): Depression (endorheic, with channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	70%				70%	100%		40%	
	Wetland IHI									
	RDM-99 (with 'override')	80%				80%	60%		20%	
	RDM-99 (without 'override')	80%				80%	60%		50%	
	"Gut-feel"	B				B	C		C	
Geomorphology	WET-Health (Level 1)	90%				56%	95%		62%	
	Wetland IHI									
	RDM-99 (with 'override')	80%				100%	70%		80%	
	RDM-99 (without 'override')	80%				100%	70%		80%	
	"Gut-feel"	B				B	C		D	
Vegetation*	WET-Health (Level 1)	78%				82%	56%		62%	
	Wetland IHI									
	RDM-99* (with 'override')	72%				80%	68%		20%	
	RDM-99* (without 'override')	72%				80%	68%		68%	
	"Gut-feel"	B				A	C		B	
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	60%				70%	60%		20%	
	RDM-99 (without 'override')	60%				70%	60%		40%	
	"Gut-feel"	B				B	C		B	
Overall PES	WET-Health (Level 1)	78%				70%	86%		53%	
	Wetland IHI									
	RDM-99 (with 'override')	74%				82%	66%		62%	
	RDM-99 (without 'override')	74%				82%	66%		62%	
	"Gut-feel"	B				B	C		C/D	

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Rhenosterkop Pan

HGM type (presumed natural state): Depression (endorheic, without channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	65%				100%	30%		100%	
	Wetland IHI									
	RDM-99 (with 'override')	96%				100%	80%		90%	
	RDM-99 (without 'override')	96%				100%	80%		90%	
	"Gut-feel"	A/B				A	A		A/B	
Geomorphology	WET-Health (Level 1)	97%				94%	100%		100%	
	Wetland IHI									
	RDM-99 (with 'override')	80%				100%	70%		90%	
	RDM-99 (without 'override')	80%				100%	70%		90%	
	"Gut-feel"	A/B				A	A		A/B	
Vegetation*	WET-Health (Level 1)	82%				80%	90%		74%	
	Wetland IHI									
	RDM-99* (with 'override')	88%				100%	80%		88%	
	RDM-99* (without 'override')	88%				100%	80%		88%	
	"Gut-feel"	A				A	B		n/a	
Water quality**	Wetland IHI									
	RDM-99 (with 'override')	76%				90%	80%		90%	
	RDM-99 (without 'override')	76%				90%	80%		90%	
	"Gut-feel"	A				A	A		A/B	
Overall PES	WET-Health (Level 1)	90%				93%	97%		88%	
	Wetland IHI									
	RDM-99 (with 'override')	86%				98%	78%		90%	
	RDM-99 (without 'override')	86%				98%	78%		90%	
	"Gut-feel"	A/B				A	A		A/B	

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Vermont Pan

HGM type (presumed natural state): Depression (endorheic, without channelled inflow)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	100%	90%			100%	100%			
	Wetland IHI	90%				92%	78%			
	RDM-99 (with 'override')	80%	60%			80%	60%			
	RDM-99 (without 'override')	80%	60%			80%	60%			
	"Gut-feel"	A/B	C			A	C			
Geomorphology	WET-Health (Level 1)	98%	100%			100%	95%			
	Wetland IHI	100%				100%	90%			
	RDM-99 (with 'override')	90%	100%			100%	70%			
	RDM-99 (without 'override')	90%	100%			100%	70%			
	"Gut-feel"	A	B			A	B			
Vegetation*	WET-Health (Level 1)	88%	100%			90%	90%			
	Wetland IHI	98%				100%	94%			
	RDM-99* (with 'override')	88%	84%			92%	56%			
	RDM-99* (without 'override')	88%	84%			92%	56%			
	"Gut-feel"	A/B	C			A	C			
Water quality**	Wetland IHI	76%				78%	82%			
	RDM-99 (with 'override')	70%	60%			70%	60%			
	RDM-99 (without 'override')	70%	60%			70%	60%			
	"Gut-feel"	B	B/C			A	C			
Overall PES	WET-Health (Level 1)	96%	96%			97%	96%			
	Wetland IHI	96%				96%	90%			
	RDM-99 (with 'override')	84%	76%			88%	60%			
	RDM-99 (without 'override')	84%	76%			88%	60%			
	"Gut-feel"	A/B	C			A	C			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Hemel-en-Aarde

HGM type (presumed natural state): Unchannelled valley-bottom wetland

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	60%	30%			70%	40%			
	Wetland IHI	70%				74%	74%			
	RDM-99 (with 'override')	50%	70%			60%	60%			
	RDM-99 (without 'override')	50%	70%			60%	60%			
	"Gut-feel"	C/D	C			B	C			
Geomorphology	WET-Health (Level 1)	95%	88%			78%	95%			
	Wetland IHI	70%				70%	80%			
	RDM-99 (with 'override')	66%	60%			70%	60%			
	RDM-99 (without 'override')	66%	60%			70%	60%			
	"Gut-feel"	C/D	B			B	B			
Vegetation*	WET-Health (Level 1)	56%	64%			65%	76%			
	Wetland IHI	74%				84%	96%			
	RDM-99* (with 'override')	68%	64%			68%	64%			
	RDM-99* (without 'override')	68%	64%			68%	64%			
	"Gut-feel"	C	B/C			A	B			
Water quality**	Wetland IHI	66%				88%	88%			
	RDM-99 (with 'override')	50%	60%			60%	60%			
	RDM-99 (without 'override')	50%	60%			60%	60%			
	"Gut-feel"	C	B/C			B	C			
Overall PES	WET-Health (Level 1)	69%	56%			71%	66%			
	Wetland IHI	72%				80%	88%			
	RDM-99 (with 'override')	62%	64%			66%	62%			
	RDM-99 (without 'override')	62%	64%			66%	62%			
	"Gut-feel"	C/D	B/C			B	B/C			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Belsvlei

HGM type (presumed natural state): Unchannelled valley-bottom wetland (possibly channelled)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	25%	35%			40%	65%			
	Wetland IHI	66%	60%			64%	66%			
	RDM-99 (with 'override')	60%	60%			40%	50%			
	RDM-99 (without 'override')	60%	60%			40%	50%			
	"Gut-feel"	D	C			C	C			
Geomorphology	WET-Health (Level 1)	55%	74%			3%	94%			
	Wetland IHI	24%	56%			10%	60%			
	RDM-99 (with 'override')	46%	40%			40%	60%			
	RDM-99 (without 'override')	46%	40%			40%	60%			
	"Gut-feel"	D/E	C			D	D			
Vegetation*	WET-Health (Level 1)	34%	68%			39%	47%			
	Wetland IHI	62%	86%			74%	78%			
	RDM-99* (with 'override')	58%	68%			56%	64%			
	RDM-99* (without 'override')	58%	68%			56%	64%			
	"Gut-feel"	D	B/C			D	C			
Water quality**	Wetland IHI	62%	62%			86%	84%			
	RDM-99 (with 'override')	50%	60%			50%	50%			
	RDM-99 (without 'override')	50%	60%			50%	50%			
	"Gut-feel"	C	B			B	C			
Overall PES	WET-Health (Level 1)	36%	56%			29%	68%			
	Wetland IHI	54%	72%			58%	72%			
	RDM-99 (with 'override')	54%	58%			50%	58%			
	RDM-99 (without 'override')	54%	58%			50%	58%			
	"Gut-feel"	D	C			D	C/D			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Eliasgat

HGM type (presumed natural state): Channelled valley-bottom wetland (possibly unchannelled)

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	30%	50%			65%	35%			
	Wetland IHI	52%	68%			66%	68%			
	RDM-99 (with 'override')	60%	40%			40%	50%			
	RDM-99 (without 'override')	60%	40%			40%	50%			
	"Gut-feel"	D	C			C	C			
Geomorphology	WET-Health (Level 1)	40%	98%			24%	94%			
	Wetland IHI	64%	70%			58%	50%			
	RDM-99 (with 'override')	46%	70%			50%	50%			
	RDM-99 (without 'override')	46%	70%			50%	50%			
	"Gut-feel"	D/E	C			C	D			
Vegetation*	WET-Health (Level 1)	34%	70%			37%	30%			
	Wetland IHI	66%	86%			66%	78%			
	RDM-99* (with 'override')	50%	60%			60%	52%			
	RDM-99* (without 'override')	50%	60%			60%	52%			
	"Gut-feel"	D	C			C	D			
Water quality**	Wetland IHI	66%	66%			88%	76%			
	RDM-99 (with 'override')	46%	60%			50%	40%			
	RDM-99 (without 'override')	46%	60%			50%	40%			
	"Gut-feel"	C	C			C	C			
Overall PES	WET-Health (Level 1)	34%	70%			45%	50%			
	Wetland IHI	64%	78%			66%	68%			
	RDM-99 (with 'override')	50%	58%			54%	50%			
	RDM-99 (without 'override')	50%	58%			54%	50%			
	"Gut-feel"	D	C			C	C/D			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

Wetland name: Salmonsdam

HGM type (presumed natural state): Unchannelled valley-bottom wetland

Component	Assessment method	PES scores / categories								
		Assessor 1	Assessor 2	Assessor 3	Assessor 4	Assessor 5	Assessor 6	Assessor 7	Assessor 8	Assessor 9
Hydrology	WET-Health (Level 1)	50%	10%			15%	90%			
	Wetland IHI	74%				82%	80%			
	RDM-99 (with 'override')	70%	40%			60%	60%			
	RDM-99 (without 'override')	70%	40%			60%	60%			
	"Gut-feel"	C	D			C	A			
Geomorphology	WET-Health (Level 1)	55%	0%			12%	80%			
	Wetland IHI	26%				28%	70%			
	RDM-99 (with 'override')	60%	20%			60%	70%			
	RDM-99 (without 'override')	60%	40%			60%	70%			
	"Gut-feel"	D	D			D	B			
Vegetation*	WET-Health (Level 1)	55%	31%			58%	60%			
	Wetland IHI	86%				96%	98%			
	RDM-99* (with 'override')	78%	84%			52%	68%			
	RDM-99* (without 'override')	78%	84%			52%	68%			
	"Gut-feel"	C/D	D			C	B			
Water quality**	Wetland IHI	92%				94%	92%			
	RDM-99 (with 'override')	76%	90%			50%	70%			
	RDM-99 (without 'override')	76%	90%			50%	70%			
	"Gut-feel"	A	B			A	B			
Overall PES	WET-Health (Level 1)	53%	15%			26%	79%			
	Wetland IHI	70%				76%	88%			
	RDM-99 (with 'override')	72%	20%			54%	68%			
	RDM-99 (without 'override')	72%	64%			54%	68%			
	"Gut-feel"	C/D	D			C	B			

* For the RDM-99 assessment method, the 'vegetation' component deals more broadly with 'biota' (incl. fauna)

** There is no formal water quality module for the WET-Health assessment method

APPENDIX 2:

Detailed results of statistical analyses

Kruskal-Wallis test: Differences between assessors (WET-Health & Wetland-IHI & RDM-99 methods as replicates)

Wetland	Component	KW chi-squared	df	p
Goukou	Hydrology	7	7	0.4289
	Geomorph	4.4357	7	0.7284
	Vegetation	1.4126	7	0.9852
	Overall	5.1402	7	0.6429
Mfuleni	Hydrology	10.8332	5	0.05479
	Geomorph	9.2444	5	0.0997
	Vegetation	4.7417	5	0.4482
	Overall	11.0576,	5	0.05025
Khayelitsha pool	**Hydrology**	**8.4178**	**3**	**0.03812**
	Geomorph	**7.9314**	**3**	**0.04745**
	Vegetation	2.5184	3	0.472
	Overall	6.0591	3	0.1088
Modder River	Hydrology	0.7188	2	0.6981
	Geomorph	2.0565	2	0.3576
	Vegetation	2.7556	2	0.2521
	Overall	0.8739	2	0.646
Vermont Pan	Hydrology	1.1362	2	0.5666
	Geomorph	5.5046	2	0.06378
	Vegetation	1.3785	2	0.5019
	Overall	1.1879	2	0.5521
Hemel-en-Aarde	Hydrology	1.1462	2	0.5638
	Geomorph	0.1623	2	0.922
	Vegetation	0.9636	2	0.6177
	Overall	0.4294	2	0.8068
Belsvlei	Hydrology	1.925	3	0.5881
	Geomorph	**7.8627**	**3**	**0.04894**
	Vegetation	4.1427	3	0.2465
	Overall	6.9274	3	0.07425
Eliasgat	Hydrology	0.583	3	0.9003
	Geomorph	5.7153	3	0.1263
	Vegetation	2.9566	3	0.3984
	Overall	4.1868	3	0.242
Salmonsdam	Hydrology	1.3669	2	0.5049
	Geomorph	5.5819	2	0.06136
	Vegetation	0.8	2	0.6703
	Overall	2.4889	2	0.2881

WET-Health vs Wetland-IHI (Wilcoxon rank sum test, assessors as replicates)

Wetland	Component	W	p	n (WH, WIHI)
Goukou	Hydrology	27	0.635	8, 8
	Geomorph	48	0.101	8, 8
	Vegetation	**0**	**0.001**	**8, 8**
	Overall	14	0.066	8, 8
Mfuleni	Hydrology	19.5	0.8861	7, 6
	Geomorph	22	0.943	7, 6
	Vegetation	**40**	**0.005**	**7, 6**
	Overall	12	0.224	7, 6
Khayelitsha pool	Hydrology	6	0.686	4, 4
	Geomorph	10	0.686	4, 4
	Vegetation	6.5	0.772	4, 4
	Overall	6	0.657	4, 4
Modder River	Hydrology	3	0.658	3, 3
	Geomorph	8	0.2	3, 3
	Vegetation	1	0.2	3, 3
	Overall	3	0.7	3, 3
Vermont Pan	Hydrology	10.5	0.138	4, 3
	Geomorph	6	1	4, 3
	Vegetation	2.5	0.28	4, 3
	Overall	9	0.27	4, 3
Hemel-en-Aarde	Hydrology	0.5	0.072	4, 3
	Geomorph	11	0.105	4, 3
	Vegetation	1	0.114	4, 3
	Overall	0	0.057	4, 3
Belsvlei	Hydrology	2	0.11	4, 4
	Geomorph	10	0.686	4, 4
	Vegetation	1	0.057	4, 4
	Overall	3	0.191	4, 4
Eliasgat	Hydrology	1	0.059	4, 4
	Geomorph	8	1	4, 4
	Vegetation	2	0.11	4, 4
	Overall	3	0.2	4, 4
Salmonsdam	Hydrology	3	0.4	4, 3
	Geomorph	5	0.857	4, 3
	Vegetation	0	0.057	4, 3
	Overall	2	0.229	4, 3

WET-Health vs RDM-99 (Overall PES, Wilcoxon rank sum test, assessors as replicates)

Wetland	RDM-99 scoring	W	p	n (WH, RDM-99)
Goukou	without override	34.5	0.833	8, 8
	with override	n/a	n/a	n/a
Mfuleni	without override	29	0.609	7, 7
	with override	31	0.442	7, 7
Khayelitsha pool	with override	12	0.343	4, 4
	without override	11	0.486	4, 4
Rooipan	without override	6	0.653	3, 3
	with override	0	0.077	3, 3
Yzerfontein pan	without override	8	1	4, 4
	with override	n/a	n/a	n/a
Burgers pan	without override	6	0.658	3, 3
	with override	n/a	n/a	n/a
Kiekoesvlei	without override	8	0.2	3, 3
	with override	6	0.7	3, 3
Modder River	without override	9	0.1	3, 3
	with override	8.5	0.121	3, 3
Agulhas Soutpan	without override	19	0.222	5, 5
	with override	n/a	n/a	n/a
Soetendalsvlei	without override	9	0.886	4, 4
	with override	n/a	n/a	n/a
Rhenosterkop	without override	10.5	0.561	4, 4
	with override	n/a	n/a	n/a
Vermont Pan	**without override**	**16**	**0.027**	**4, 4**
	with override	n/a	n/a	n/a
Hemel-en-Aarde	without override	11.5	0.381	4, 4
	with override	n/a	n/a	n/a
Belsvlei	without override	6	0.663	4, 4
	with override	n/a	n/a	n/a
Eliasgat	without override	5	0.46	4, 4
	with override	n/a	n/a	n/a
Salmonsdam	without override	4	0.343	4, 4
	with override	6	0.686	4, 4

Wetland-IHI vs. RDM-99 (Overall PES, Wilcoxon rank sum test, assessors as replicates)

Wetland	RDM-99 scoring	W	p	n (WIHI, RDM-99)
Goukou	**without override**	**62.5**	**0.002**	**8, 8**
	with override	n/a	n/a	n/a
Mfuleni	without override	34.5	0.062	6, 7
	with override	33.5	0.086	6, 7
Khayelitsha pool	without override	15	0.059	4, 4
	with override	15	0.059	4, 4
Modder River	without override	9	0.1	3, 3
	with override	9	0.1	3, 3
Vermont Pan	**without override**	**12**	**0.05**	**3, 4**
	with override	n/a	n/a	n/a
Hemel-en-Aarde	**without override**	**12**	**0.05**	**3, 4**
	with override	n/a	n/a	n/a
Belsvlei	without override	12.5	0.231	4, 4
	with override	n/a	n/a	n/a
Eliasgat	**without override**	**16**	**0.029**	4, 4
	with override	n/a	n/a	n/a
Salmonsdam	without override	11	0.114	3, 4
	with override	11	0.114	3, 4