A comparative study of the Wet-Health tool and the citizen-science land-cover based wetland assessment method

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ABSTRACT

Citizen science approach has a role to play in the determination of the wetland condition in South Africa (SA). Public participation in wetland health assessment and monitoring can help them interact with authorities, and also provide participants with an understanding and insight that can allow them to contribute meaningfully to management of wetlands closest to them. The purpose of the study was to perform a comparative analysis of a more commonly used method, Wet-Health, and the newly developed Citizen Science (CS) tool that is used for the rapid assessment of wetland health in SA. The new tool was designed to infer impacts on wetlands and their upslope catchments by using land cover types. The Wet-Health method performs an integrated assessment of impacts on four components namely hydrology, geomorphology, water quality and vegetation. To achieve the objectives of the study, the researcher selected a sample of six wetlands that were previously assessed using the Wet-Health tool, and employed the newly developed tool to assess the health of those wetlands. A comparative analysis of the two methods was performed in Gauteng and the North-West provinces. There was a fair match between the overall magnitudes of impact scores that translates into the condition of the wetland. The overall magnitude of impact scores for all wetlands assessed fell within a range of between 0.4-3.9, i.e. PES category is from A-C compared to a range of between 0.4-4.2 (PES A-D) obtained by the independent assessor. The findings indicated that the CS tool is able to obtain fairly similar results compared to that of the independent assessor. Four of the six wetlands assessed yielded similar PES category. Differences in the overall impact scores ranges for categories that were similar were found to be negligible, and the exact overall impact score similarity was obtained for one wetland (Kgaswane) using both methods. The study is therefore, promising in elucidating the wetland present state based on land cover impacts. These findings will enable the public at large to be empowered with skills and knowledge that can aid environmental specialists in data gathering and identification of wetland at risks.

Keywords

Rapid Assessment, Wetland ecological condition, Conservation.

LIST OF ABBREVIATIONS AND ACRONYMS

AFI	Average Functional Index
CARA:	Conservation of Agricultural Resources Act
CM:	Coastal Method
CS:	Citizen Science
CWAC:	Coordinated Waterbird Counts
DEA:	Department of Environmental Affairs
DECAP:	Delaware Comprehensive Assessment Procedure
DERAP:	Delaware Rapid Assessment Procedure
DWAF:	Department of Water Affairs and Forestry
DWS:	Department of Water and Sanitation
ECA:	Environmental Conservation Act
FCI:	Functional Capacity Index
GIS:	Geographic Information System
HA:	Hectare
HGM:	Hydrogeomorphic
IBI:	Index of Biological Integrity
ICI:	Invertebrate Community Index
IEM:	Integrated Environmental Management
IWC:	Index of Wetland Condition
KZN:	Kwa-Zulu Natal
LDI:	Landscape Development Index
MCTM:	Maine Citizens Tidal Method
MAP:	Mean Annual Precipitation
MAE:	Mean Annual Evaporation
MS:	Microsoft
NGO:	Non-Governmental Organisations
NWMP:	National Wetland Monitoring Programme
NEMA:	National Environmental Management Act
NWA:	National Water Act
ORAM:	Ohio Rapid assessment Method
PES:	Present Ecological State
RDM:	Resource Directed Measures
SA:	South Africa
SANBI:	South African Biodiversity Institute

SCWPP:	Stone Creek Wetland Protection Plan
US:	United States
USA:	United States of America
US EPA:	United States Environmental Protection Agency
USFWS:	United States Fish & Wild Life Service
Wet-IHI:	Wetland Index of Habitat Integrity
WMA:	Water Management Areas
WRAP:	Wetland Rapid Assessment Procedure
WRC:	Water Research Commission

TABLE OF CONTENTS

ACKNOWLEDGEMENTS I

ABSTRACT II

LIST OF ABBREVIATIONS AND ACRONYMS III

LIST OF TABLES IX

LIST OF FIGURES X

CHAPTER 1 INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 2

1.3 Justification 3

1.4 Aim and Objectives 3

1.5 Scope of the study 4

1.6. Report outline 4

CHAPTER 2 LITERATURE REVIEW 5

2.1. Introduction 5

2.1.1. Wetland Definition 5

2.1.2. Wetland characteristics in SA 6

2.1.3. Wetland legislation in SA 6

2.1.4. Types of wetland ecosystems 8

2.1.5. Importance of wetlands 9

2.1.6. Wetland Classification 10

2.2. Major threats to wetland ecosystems in SA 11

2.3. Effects of land cover types of the wetland and catchment. 11

2.4. Wetland assessment tools 12

2.4.1. International wetland assessment tools 12

2.4.1.1. International rapid assessment methods 12

Hydrogeomorphic (HGM) and Index of Biotic Integrity (IBI) method 12

Landscape Development Index (LDI) 13

Delaware Rapid Assessment Procedure (DERAP) 14

Florida Wetland Rapid Assessment Procedure (WRAP) 14

2.4.1.2. International rapid assessment methods for non-experts 18

2.4.2. Wetland assessment tools in SA 18

Wet-Index of Habitat Integrity (Wet–IHI) 18

Wet-Health assessment tool 19

2.5. Citizen-Science tools in SA 21

2.5.1. Benefits of citizen-science tools 22

CHAPTER 3 MATERIALS AND METHOD 23

3.1. Approach and method used in the assessment 23

3.2. Study sites 24

3.2.1. North-West province 24

3.2.1.1. Rietfontein 24

Catchment description 24

3.2.1.2. Bokkraal 25

Catchment description....25

3.2.1.3. Kgaswane Nature Reserve Wetland complex....26

Catchment description....26

3.2.2. Gauteng province 27

3.2.2.1. Doornrandjie Wetland: Pretoria Rural 27

Catchment description....27

3.2.2.2. Sokhulumi 29

Catchment description....29

3.2.2.3. Tweefontein....30

Catchment description....30

3.3. Wetland assessment method using the Citizen Science tool....31

3.3.1. Wetland delineation....31

3.3.2. Step 1: Mapped/delineated wetlands....32

3.3.3. Step 2: Desktop assessment....33

3.3.4. Step 3: Fieldwork....33

3.3.5. Step 4: Recording of the data sheets (Citizen Science tool)....33

3.4. Wetland and upslope-catchment condition assessment 36

CHAPTER 4 RESULTS 37

4.1. Wetlands assessed in North-West province....37

4.1.1. Rietfontein wetland 38

4.1.2. Bokkraal wetland....41

4.1.3. Kgaswane Nature Reserve 43

4.2. Wetlands assessed in Gauteng province....46

4.2.1. Doornrandjie wetland....46

4.2.2. Sokhulumi wetland....48

4.2.3. Tweefontein wetland 51

CHAPTER 5 DISCUSSION....55

5.1. North-West Wetlands 56

5.2. Gauteng Wetlands 56

5.3. Land use activities as a challenge....58

5.4. Assumptions....58

5.5. Limitations of the research....59

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS 60

6.1. Conclusion with respect to the study objectives 60

6.2. Recommendations 62

BIBLIOGRAPHY....63

LEGISLATION AND REGULATIONS 72

PUBLISHED AMENDMENTS TO THE NEMA: EIA REGULATIONS AND LISTING NOTICES 72

1. APPENDIX A 1

2. APPENDIX B 1

LIST OF TABLES

Table 3-1: Wetlands already assessed with Wet-Health by Imperata Consulting (Imperata Consulting, 2013-2016). 23

Table 3-2: Ancillary data utilised to capture wetland boundaries. 32

Table 3-3: Overall impact score categories and corresponding Present Ecological State (PES) categories (modified from MacFarlane *et al*. 2007). 35

Table 3-4: Example of the percentile land use of the catchment of the study area 36

Table 4-1: Overall magnitude of impact scores and PES scores derived from the current study compared to the scores derived by the dependent assessor from Imperata Consulting (Imperata Consulting, 2013, 2014a-c & 2016). 37

Table 4-2: PES results – Rietfontein wetland and its upslope catchment assessment results. 40

Table 4-3: PES results – Bokkraal wetland and its upslope catchment assessment results. 42

Table 4-4: PES results – Kgaswane Nature Reserve wetland and its upslope catchment assessment results. 45

Table 4-5: PES results – Doornrandjie wetland and its upslope catchment assessment results. 47

Table 4-6: PES results – Sokhulumi wetland and its upslope catchment assessment results. 50

LIST OF FIGURES

Figure 2-1: National Wetland Classification System of SA (source: (Ollis *et al.* 2013)..... 9
Figure 3-1: Illustration of Rietfontein wetland in relation to its catchment. 25
Figure 3-2: Illustration of Bokkraal wetland in relation to its catchment. 26
Figure 3-3: Illustration of Kgaswane Nature Reserve wetland in relation to its catchment. 27
Figure 3-4a: Illustration of Doornranjie wetland in close proximity to the Juskei River. 28
Figure 3-4b: Illustration of Doornranjie wetland zoomed in. 29
Figure 3-5: Illustration of Sokhulumi wetland in relation to its catchment. 30
Figure 3-6: Illustration of Tweefontein Wetland in close proximity to the Tweefonteinspruit. 31
Figure 3-7: A guideline for scoring the extent of a buffer zone of natural vegetation around a wetland (source: Kotzé 2015). 34
Figure 4-1 a-d: Illustrates surrounding land use units within the Rietfontein wetland and its catchment area (Date taken 29/12/2017). (a- represent a wetland that is still pristine with a gravel road traversing it; b- represent wetland excavation; c- represents flagstone mining upslope of the catchment; d- catchment that is still natural except for flagstone mining). 39
Figure 4-2: Illustrates the natural area surrounding the Rietfontein wetland as well as agricultural activities on the upslope catchment of the wetland. 40
Figure 4-3 a-c: Illustrates surrounding land use units within the Bokkraal wetland and its catchment area. (Date taken 29/12/2017). (a- represent water abstraction for irrigation purposes; b- wetland that is still pristine and water flowing from the headwater; c- catchment that is still natural)..... 42
Figure 4-4: Land-use units (cultivation practices and furrows) on the upslope catchment area of the Bokkraal wetland. 43
Figure 4-5 a-d: Illustrates surrounding land use units within the Kgaswane Nature Reserve wetland and its catchment area. (Date taken 05/1/2018). (a- weir erected to slow down the velocity of water; b- represent a wetland that is still pristine; c and d - catchment that is still natural). 44
Figure 4-6: Illustration of Kgaswane wetland and its upslope catchment that is still in a natural condition. 45
Figure 4-7 a-c: Illustrates surrounding land use units within the Doornrandjie wetland and its catchment area. (Date taken 06/1/2018). (a- represents animal trampling within a

wetland; b- represent foot-paths within a wetland; c- catchment that is still natural with minor development). 47

Figure 4-8: Illustration of furrows (wetland drainage) on the upslope catchment of the Doornrandjie wetland, wetland impoundment and alien vegetation in close proximity to the wetland. 48

Figure 4-9 a-d: Illustrates surrounding land use units within the Sokhulumi wetland and its catchment area. (Date taken 3/1/2018). (a- wetland drainage (furrows); b- alien plants within a wetland; c- animal tramping on the wetland's upslope catchment; d- settlements around the catchment of the wetland). 49

Figure 4-10: Illustration of alien vegetation and furrows with the Sokhulumi wetland and settlements and agricultural practices around the wetland's upslope catchment. 50

Figure 4-11 a-d: Illustrates surrounding land use units within the Tweefontein wetland and its catchment area. (Date taken 4/1/2018). (a- a pipe illustrating water abstraction from the wetland); b- a road traversing a wetland; c – agricultural practices on the wetland's upslope catchment; d- a dam within the wetland's upslope catchment). 53

Figure 4-12: Illustration of built dams within the Tweefontein wetland and agricultural practices around the wetland's upslope catchment. 54

CHAPTER 1 INTRODUCTION

1.1 Background

A wetland assessment is generally “the gathering and analysis of information needed for wetland decision making” and for this a robust tool is needed. Wetlands are generally assessed for three important aspects namely 1) the Present Ecological State (WET-Health), 2) impact assessment and 3) for functions and values of a wetland (DWAF, 2004). According to Macfarlane *et al.* (2007), wetland health is as “a measure of the similarity of a wetland to a natural or reference condition”. The determination of the wetland health needs a tool that allows easy use and is scientifically reliable. Information generated will be invaluable for wetland management and conservation. Further to this, the tool will be valuable in educating pupils and interested community members about the ecological integrity and importance of South African wetlands, and in turn water resource managers will be alerted in cases were management action are needed.

Tools to assess the health of wetlands have been established in SA and are applicable to most regions in the country. These tools made head way in progressing wetland management in the country over the last decade and that includes the 1999-Resource Directed Measures (RDM) wetland Present Ecological State (PES) assessment method, Wet-Health and Wet-IHI methods (DWAF 1999, Macfarlane *et al.* 2007, Rountree *et al.* 2007). Currently, there is widespread use of these methods, however, they have shortcomings and need to be further fine-tuned for ease of use (Ollis & Malan, 2014; Ollis *et al.* 2013). The above methods require competent scientists with appropriate background, training and experience (Macfarlane *et al.* 2007) and therefore, a paradigm shift is needed whereby citizens can contribute meaningfully to the conservation of wetlands by becoming active in determining their integrity.

To date efforts have been made in order to monitor wetlands in the country by focusing on parameters such as hydrology, vegetation and evaluation of ecosystem goods and services. However, there’s currently no validated tool available in SA that is developed for citizen science to formally determine the ecological integrity of wetlands (Kotzé, 2015). In an attempt to overcome the above-mentioned shortcoming Kotzé (2015) developed a simple science tool for evaluation of the ecological condition of a wetland based on land-cover types. This method lends its approach from the WET-Health level 1 vegetation component. This study aims to compare results obtained from the citizen science land-cover based tool and the already assessed wetlands where the existing Wet-Health tool was used in order to establish whether similar results can be achieved. If so, citizen scientists will be afforded an opportunity to learn and participate meaningfully in knowledge generation that can assist in the protection and sustainable utilisation of wetlands in the country. According to Kotzé *et al.* (1995), Dini (2004) and

Gardner *et al.* (2015), wetlands are continuously being degraded at an alarming rate which stems from a range of human (or anthropogenic) activities. Examples of land use changes are cultivation of crops, forest plantations, canalisation, and artificial drainage systems. These activities have the potential to alter important ecological conditions of the wetland, *inter alia* species diversity, ecological patterns, natural processes and health that maintains that biodiversity (DWAF, 2001). Assessing the well-being of these systems on a regular basis, can contribute to their long-term management and sustainability.

In SA, about 50% of wetlands in some catchments in the country are either completely degraded and are non-existent (Kotzé and Breen, 1994; Lindley, 2003). Further to this, the remaining wetlands were identified as the most threatened of all South Africa's ecosystems (Driver *et al*. 2012). Wetland integrity research or fieldwork has always been carried-out by competent scientist and that tends to be costly and time consuming. There isn't any involvement of the citizens in providing valuable information on wetland's health in response to the how land is utilised in the proximity to these water resources Kotzé (2015). Furthermore, the existing methods provide an unsatisfactory degree of variability between the results generated by the different methods and by different assessors applying the methods to the same wetlands (Ollis & Malan, 2014). Currently, there is a need for regional or local scale assessments in order to feed into the national scale monitoring database and a citizen-based science tool might be the answer in achieving these objectives.

1.2 Problem Statement

The Wetland Health Rapid Assessment has to date required expert knowledge with a background in wetland science. The reliability, repeatability and comparability of results from assessments conducted by different assessors using the Wet-Health tool is questionable and leaves much to be desired (Ollis & Malan, 2014). There is a growing recognition to enhance community participation in wetland conservation and protection and failing which, wetland ecosystem values will remain unknown rendering them prone to degradation. Efforts have been made in trying to involve local people in wetland management, not only as data collectors, but for them to learn and acquire knowledge. This can aid in them in contributing meaningfully in protecting, managing and using wetlands sustainably. However, none of the interventions have touched on assessing the health of wetlands Kotzé (2015). Hence, the recent development of the citizen-science land-use based tool.

Land-use activities in SA, and elsewhere, have been shown to have detrimental impacts on wetland integrity over the years, leading to almost half the wetlands being lost or completely destroyed (Brinson & Malvarez, 2002), (Dini, 2004),(Kotzé *et al.* 1995). A first step in collating the state of health of wetland in the country can help prevent the continual degradation of these important ecosystems. Since

available methods are costly and time consuming, this tool can act as an early-detection tool for wetland degradation that needs serious interventions before they are completely destroyed.

This study sought to highlight how land-cover types transform wetland ecosystems and their catchment areas from a natural condition, and further investigated the correlation between the extent or intensity of the land-cover types and the ecological integrity of wetlands. Furthermore, a comparison of results obtained from the same wetlands where both the Wet-Health tool and the citizen-science tool are used, was carried out in order to test their congruence/divergence. Where similarities in the obtained results were conclusive or comparable, knowledge gained from this study would allow social learning, and in turn allow environmental managers to protect wetlands more effectively by knowing the present ecological state of wetlands at a local scale. Opportunities for the prevention of further degradation and rehabilitation of impacted wetlands will be achieved promptly using less or minimal financial resources.

1.3 Justification

From a scientific point of view, the study generated knowledge on how the use of land is related to the state of wetlands in SA. The study contributes as an interim tool that can be used by the public at large before the refinement and amalgamation of already existing wetland health assessment methods can be finalised and tested. Practically, knowledge acquired will assist in planning for sustainable utilisation and management of wetlands. Citizen science wet-health assessment can also assist in long-term monitoring, which will inform management decision-making in the protection, management and conservation, and restoration of wetlands. Furthermore, knowing the health of wetlands remaining in the country and striving for their protection can be informed by a tool such as this one. For this, an appropriate method, which generate reliable and comparable results, needs to be used for determining the health of the wetland.

1.4 Aim and Objectives

The aim of the project is to compare and determine the congruence or divergence of the results obtained by using the existing Wet-Health tool and the newly developed Citizen-Science Land-cover Based Wetland Assessment Methods for assessment of the wetland health.

The objectives of the research are:

- to determine the ecological condition or health of various wetlands by identifying the land-cover types present in wetlands, as well as in the upslope catchments by applying the land cover based wetland assessment tool.

- to identify the intensity and extent of these land-cover units and infer the magnitude of the impact on the ecological health of a wetland.
- to compare the results from the above assessments with those obtained from the independent Wet-Health assessments that have been carried out for the same wetlands.

1.5 Scope of the study

A rapid wet-health assessment based on land-cover type protocol which offers a broad assessment of the health of a wetland (Kotzé, 2015) is used to assess various wetlands in Gauteng and North West Province. The study focuses on land-cover changes and the extent, both in the wetland itself and its upslope catchment, and inference of their impacts. Site selection was based on accessibility to the wetlands, sites located in both natural areas (protected areas) and in areas mostly impacted by anthropogenic activities, *inter alia* urbanisation and agriculture. Detailed site descriptions are provided in Chapter 3 and co-ordinates and year of the initial assessments with the Wet-Health tool are provided in Table 1.

1.6. Report outline

The study is reported in six chapters. The first chapter has given an introduction to the study, the scientific problem, the justification and objectives. The second chapter consist of the literature review. Wetland characteristics, classification and legislation (globally and locally), ecosystem functions and impacts that land use practices have on wetland ecosystem health are highlighted. Already existing Wet-Health assessment tools in SA and internationally are also outlined. The third chapter gives an overview of the geographical location of the sampled wetlands, wetland description, the climate and vegetation in the Gauteng and North-West province. The chapter also discusses the method used in wetland health assessments based on land cover tool and the analytical framework. It also outlines the methods used in collection of data and data analysis used for the two main aspects of the study, namely; land cover changes in the wetland itself and in their upslope catchment. The fourth chapter discusses the findings of the study, possible explanations of the findings when compared with results from an independent study, and conclusions drawn from the findings. The fifth chapter discusses the findings of the study relative to the already the existing PES results. Insights gained from the data analysis is also discussed in more depth, thus providing a more in-depth analysis of the findings presented in chapter four. The sixth chapter gives the conclusions of the study from the specific objectives, limitations and recommendations given the outcome or findings. The last chapter provides the bibliography that were cited in this study

CHAPTER 2 LITERATURE REVIEW

2.1. Introduction

As this study focuses on the citizen science ecological health determination of wetlands, the literature review begins with an overview that covers aspects relating to wetlands. Aspects such as wetland definition, wetland classification, legislation and regulations pertaining to them, functions and value of wetlands, major threats especially resulting from land-cover types are included. The literature review then re-visits research on existing assessment tools for wetland PES, both internationally and locally and citizen science tools, benefits and challenges are also highlighted. The idea of using a citizen science tool in the determination of the PES in SA of wetlands is unique, therefore, its benefit is highlighted.

2.1.1. Wetland Definition

The term 'Wetland' has been defined differently worldwide for many years with an attempt to decide on a proper definition for its effective regulation and management (National Research Council, 1995). In the USA, the final definition of a wetland became operational from 1977 and it was that of The US Army Corps of Engineers (Corps) and the US Environmental Protection Agency who define a wetland as follows "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas ". This definition was later revised and newly defined during the development of the classification system by (Corwardin *et al.* 1979) and has been used as a basis for wetlands definitions by other countries including SA, in order to meet their regional and local needs. The United States Fish and Wild Life Services (USFWS) in 1979 defined wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or land is covered by shallow water" Corwardin *et al.* (1979). In 1998, National Water Act (Act 36 of 1998) adopted the (Cowardin *et al.* 1979) definition which defines wetlands as "Wetlands are 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 Ramsar Convention in 2010, (Managing wetlands) defined (Ramsar, 2010) wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed 6 m" and is currently universally accepted and used. The difference between the NWA and the Ramsar 2010's definitions is that rivers and estuaries are excluded in the NWA definition, however, the national

wetland inventory in SA made provisions for those ecosystems (Dini *et al.* 1998) and captures the "deep water habitat" definition by Cowardin *et al.* (1979). Therefore, given their transitional nature (wet area –dry-land), location in the landscape, wetlands tend to differ from one another in terms physical, chemical and biological attributes.

2.1.2. Wetland characteristics in SA

Wetlands are characterised by three concepts that are used as indicators in the landscape including hydrology, hydrophytic vegetation and hydric soils (Collins, 2005). Although hydrology is the primary indicator that drives wetland functions (Mitsch & Gosselink, 2007), it is difficult to assess due to seasonal variability, especially in arid and semi-arid countries like SA. As a result, both hydrophytic vegetation and hydric soil have become better indicators of indirectly assessing hydrology. According to Tiner (1999), a hydrophyte is defined as "a plant adapted for life in water or periodically flooded and /or saturated soils (hydric soils) and growing in wetlands and deep-water habitats; it may represent the entire population of a species or only a subset of individuals so adapted". Because hydrophytes respond easily to changes in hydrology and may be absent at times, the hydric soils remain a better criterion for wetland indication (Omar *et al.* 2014).

Hydric soils forms under prolonged water saturation and eventually develops anaerobic conditions due to oxygen depletion. For wetland identification and delineation in South Africa (DWAF, 2005), the three-class soil water regime (permanent, seasonal and temporary) system developed by (Kotzé *et al.* 1996) is being used as a soil indicator. This identifies the morphological "signature" in the soil profile that emanates from a prolonged and frequent saturation. The prolonged and frequent saturation conditions are commonly in Champagne, Katspruit, Willowbrook and Rensburg soil forms which are common to SA wetlands (Scotney & Wilby, 1983).

2.1.3. Wetland legislation in SA

Currently in South Africa (SA), there is no national policy on protection and rehabilitation of wetlands despite the fact that it was the 5th country in 1975 to become party to the international intergovernmental co-operation, the "Ramsar Convection". As part of the Convection, a commitment was made for the conservation and wise use of wetlands through national actions and international cooperation for sustainable development. The Ramsar Convention in 1971 aimed to protect the habitat of waterfowls, however, over the years the objectives of the convention have been broadened. It now includes the prevention of loss of wetlands to preserve their fundamental ecological functioning and their economic, cultural, scientific and educational values (Ramsar, 2012). In an effort to fulfil its obligation as contracting party, SA has developed a number of policies and legislative frameworks relating to the

protection of wetlands against their degradation. Further to this, fragmentation of the laws and/or legislations dealing either directly and indirectly to protection and management of wetlands amongst government departments at local, provincial and national levels also presents challenges to effectively manage wetlands (Dini & Everard, 2016). (Kotzé *et al.* 1995) is of the thinking that perhaps a continuous degradation of wetlands is due to weakness in the enforcement of these laws.

The first substantial legal instrument for the protection of wetlands was the promulgation of the Conservation of Agricultural Resources Act (Act 43 of 1983) ("CARA"). The purpose of the act is to control utilisation of the natural agricultural resources in of SA in order to promote 1) the conservation of the soils, water resources and vegetation and 2) to combat weeds and invader plants. As wetlands are part of the water resources, CARA helps to regulate the over- utilisation and rehabilitation of these water ecosystems through the prescription of control measures for land users. Utilisation and protection of vleis, marshes, water sponges and water courses were specifically provided for in Regulation 7 of the Act. As a result, authorisation must be obtained for a range of impacts associated with cultivation of wetland areas.

Section 24 of the 1996 Constitution of SA states that "everyone has the right to an environment that is not harmful to their health or wellbeing; and to have the environment protected, for the benefit of present and future generation, through reasonable legislative and other measures that prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development". This overarching legislative framework was the starting point for development and promulgation of national policies, strategies and implementation plans for the protection of water ecosystems. In the past century, many wetlands have been destroyed, changing South Africa's landscape mainly to make way for sectors of the economy including agriculture, mining, industries, residential and recreational development. In an effort to implement wise use and conservation of wetlands, the Environmental Conservation Act 73 of 1989 ("ECA") identified activities that may impact the environment and in such cases an authorisation or permit became a prerequisite before commencement of those activities. The Act was developed in line with the Integrated Environmental Management (IEM) concept. The concept introduced a procedure for assessing site-specific impacts resulting from development on the environment. According to (Lloyd and Sally, 1994), co-existence of environmental protection and economic development can only be achieved if environmental impacts are to be minimised/mitigated by all costs.

The National Environmental Management Act (Act 107 of 1998) (NEMA) ensures that urban and commercial developments do not alter the natural state of the wetlands. The growing recognition of the concept of IEM resulted in the development of the White Paper in Environmental Management Policy

for SA in 1998 that was followed by NEMA. NEMA presents a framework legislation that replaced some of ECA provisions Glazewski and Witbooi (2005); Wood (2003). It is through its principles that the environment is protected and conserved. Principle 4(a) on sustainable development advocates for "disturbances of ecosystems and loss of biological diversity to be avoided, or where it cannot be altogether avoided, are minimised and remedied" National Environmental Management Act (Act 107 of 1998). In 2006 new regulations were promulgated and certain types of activities were excluded by more detailed thresholds. In 2010 and 2014 more changes on the regulations of activities have taken place including the recent amendments in 2017 (NEMA: EIA Regulations and Listing Notices, 2017).

2.1.4. Types of wetland ecosystems

According to the Ramsar classification of wetland types, there are 42 types of wetlands grouped into 3 main categories that separates different types of wetlands. Included are the marine and coastal wetlands, inland wetlands and man-made wetlands (Ramsar, 1991). Different forms of wetlands in the landscape includes marshes, estuaries, mudflats, mires, ponds, fens, pocosins, swamps, deltas, coral reefs, billabongs, lagoons, shallow seas, bogs, lakes, and floodplains. Since it is the requirement of the NWA (Act 36 of 1998) to classify wetlands, the underlying geology has been used to distinguish between six different types of wetlands in SA. These include the seeps, depressions, wetland flats, flood-plain wetlands, channelled and unchannelled valley bottoms. Details of these six types were compiled by (Ollis *et al.* 2015) in the hydrogeomorphic classification system for easy identification as depicted in Figure 1. This paved a way towards the advancement of wetland management in the country since common features can be managed with common strategies.

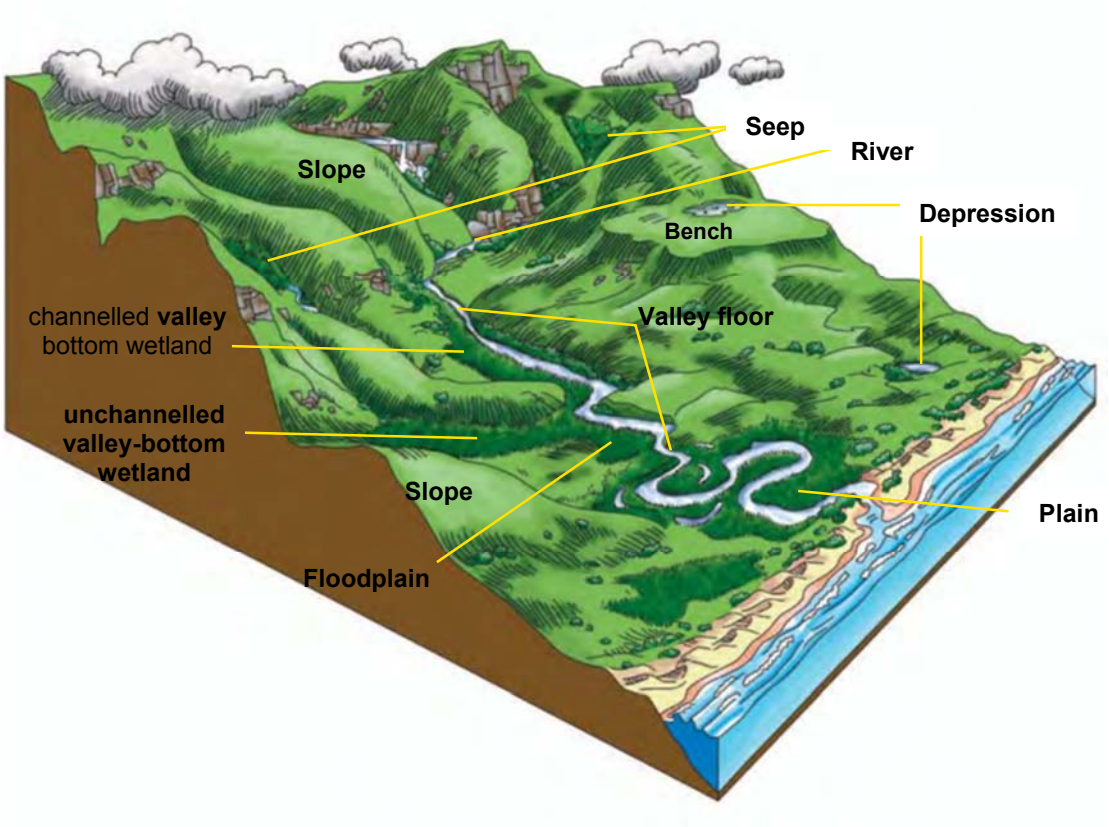


Figure 2-1: National Wetland Classification System of SA (source: (Ollis *et al.* 2013).

2.1.5. Importance of wetlands

Wetland ecosystems are performing a number of ecological functions and are now being appreciated in many countries around the world including SA. In recent years, scientists have recognised the environmental benefit that a wetland provides and their sustainable management and protection is now being accentuated Millenium (2005). Kotzé *et al.* (1995) refers to wetland benefits as “those functions, products, attributes and services provided by the ecosystem that have value to humans in terms of worth, merit, quality or importance”. These benefits may be derived from products that may arise from the functions or attributes occurring within the ecosystem that can be consumed directly or indirectly. Benefits such as water quality purification, flood attenuation, groundwater recharge and stream flow maintenance amongst others have been documented McCartney (2000), Kotzé *et al.* (2005), Postel & Carpenter, (1997) and Kotzé & Breen, (1994). Not all wetlands are able to provide these benefits equally. It all depends on the location of the wetland (geographic or within a catchment) and wetland size. Therefore, understanding the wetland function is important when it comes to its management, protection and conservation because its value to itself, surrounding ecosystem and the society will be known.

2.1.6. Wetland Classification

Wetlands are continuously under threat due to human activities. Knowledge about these valuable ecosystems including their extent, distribution, and functionality, physical and biotic characteristics can shed light on how these system can be better managed and conserved (Finlayson and Valk, 1995). The starting point is grouping similar types of wetland ecosystems with homogenous natural attributes into categories in order to develop a wetland inventory (Cowardin and Golet, 1995). This process was aided in South Africa (SA) by the development of the South African Inventory System that allowed easy development of national strategies in order to easily manage, implement, monitor wetlands at national, provincial and local level (Dini *et al.* 1998). The first proposed classification system was adapted from that of the USFWS by (Corwardin *et al.* 1979) which uses vegetation types to classify wetlands and it is still widely used in many parts of the world. The USA classification system was mainly considered for use in SA because of a number of reasons. This includes "its hierarchical structure; an open structure able to be adapted to South African conditions, simplicity and -clarity; consistency and comprehensiveness**"**. Consistencies are indicated by types in the same hierarchical level showing the same degree of detail and comprehensiveness covers all wetland types and habitats in the region after minor modification" (Corwardin *et al*. 1979). Therefore, six systems namely marine, estuarine, lacustrine, riverine, palustrine and endorheic were identified up to the class level. Subsequent to that, efforts were made in trying to classify wetlands in various regions in the country (Begg, 1986), (Jones and Day, 2003), (Dini and Cowan, 2000), (Dely, 1999), (Marneweck and Batchelor, 2002), however- the need for classification at a national scale was still imperative. As a result, Ewart-Smith *et al.* (2006) developed a classification system at a national level for use by wetland scientists and managers as baseline information for describing and classifying wetland units. Further to this, the broad definition of the 'Ramsar Convention' and HGM elements were considered in this classification. The HGM considers two important wetland attributes: geomorphology and the water regime of the wetland Ewart-Smith *et al.* (2006). The use of the HGM element was motivated by the fact that this approach provides for the classification system with the ability to give insight to the functional aspects of the wetland ecosystem (Dini and Cowan, 2000). A study by Kotzé *et al.* (1994) paved the way by introducing the HGM approach where the location of a wetland was identified on a terrain unit and soon after more studies were conducted with modifications of the Kotzé *et al.* (1994) approach. These included techniques developed for assessing ecological conditions of a wetland (Macfarlane *et al.* 2007), ecosystem services provided by wetlands (Kotzé *et al.* 2005) and for wetland rehabilitation planning Sieben *et al.* (2011). These techniques are widely used in SA to date for various purposes and are providing value in the management, protection and conservation of wetlands in the country.

2.2. Major threats to wetland ecosystems in SA

Wetlands are SA's most endangered ecosystems and currently make up 2.4 percent of the country's surface area. Up to 65% of these areas are at risk of destruction (Driver *et al.* 2012). Major threats include land uses such as grazing, drainage for commercial agricultural activities (cropping), drainage for construction of tourism facilities, rapid urban development, industrialisation and mining activities (DWAF, 2005). Agricultural practices have been recognised as the greatest cause of historical loss of wetlands globally (Tiner, 1984). This is mainly due to their ability to retain water in the catchment as a results of clay soils, even in drier conditions and slowly releases it to supplement base-flow, their location is therefore deemed favourable for crop production and overexploitation. However, slight changes in hydrological and water quality gradients that comes with crop cultivation, rendered wetlands vulnerable to degradation as sensitive ecosystems (Skaggs *et al.* (1994). More often than not, subsequent impacts of such activities can become far-reaching and irreversible resulting in the loss of important ecosystem functions of a wetland.

2.3. Effects of land cover types of the wetland and catchment.

Transformed environments such as fields, pastures, urbanisation and informal settlements, *inter alia,* are human modifications that are impacting greatly on wetlands. Impacts result in changes in the hydrology, soil, nutrient content and the biological composition of wetland systems. In SA, agriculture is on top of the list as a water resource user, and associated impacts on wetlands includes activities such as tillage, drainage, intercropping, rotational cultivation, grazing and extensive usage of pesticides and fertilizers. Furthermore, agricultural activities have the potential to alter the slope, resulting in the decrease or increase of surface run-off (Kotzé and Breen, 1994). Impoundments of large river systems have widespread impacts on the structure and function of wetlands (Chipps *et al.* 2006) altering the natural river flows impacting on the river-floodplain connectivity. Other land uses include urbanisation, industrialisation and mining activities. About 48% of South African ecosystems are threatened by land transformation leaving 21 ecosystems (5%) vulnerable (Driver *et al.* 2012). Wetlands as habitat for biodiversity in general, are impacted on by both direct and off-site impacts and include change in flow patterns, change in surface roughness and replacement of the natural vegetation (Kotzé and Breen, 1994). Indirect impacts are those that emanate from the catchment area of a wetland and therefore, surrounding activities have a great influence on wetland health and functionality Lee *et al*. (2006). Important to consider is how these surrounding activities can alter the quality of water entering the wetland from the point and non-point sources and the timing thereof. Ortega *et al.* (2004) is of the view that for wetland management to be successful, integration of indicators both at the wetland and catchment scale is paramount. Activities such as afforestation, water abstraction and damming have the potential to affect the hydroperiod of the wetland (Sinchembe and Ellery, 2010). On the other hand,

water quality is a burning issue as a result of run-off from land use activities such as mining, intensive animal production, sewage works, industries, crop production, poorly managed grazing land, human settlements and inadequate sanitation. Knowledge of the land use activities in a catchment including its catchment area, when it comes to assessing the present state of wetlands can pave away towards a better management of these resources. This is reiterated by Kotzé *et al.* (2012) by indicating that wetland integrity highlights the weakened health of a wetland.

2.4. Wetland assessment tools

2.4.1. International wetland assessment tools

There are a number of wetland assessment methods that have been developed worldwide. These methods have mainly adopted three broad approaches namely, the hydromorphic functional, biological or habitat assessment. All these methods consider the three main wetland features such as the hydrology, hydric soils and biotic communities. Furthermore, they are developed to be used at different spatial scales, differs in the amount and expertise required, and cannot be applied equally well to all wetland types.

In the rapid assessment methods in particular, data collection should be easy and should be conducted within a short period of time. Furthermore, less expert opinion is needed when collecting data compared to other wetlands assessment methods. In the review of all existing assessment methods developed for US in the rapid determination of the ecological wetland condition, (Fennessy *et al.* 2007) highlights four important criteria that needs to considered when developing or adopting rapid assessment methods. The method should be able to 1) measure the current condition of the wetland, 2) its use should require a site visit to complete the assessment, 3) be truly rapid and 4) the assumption that underlie the method can be verified. Only six methods out of 16 developed, met the criteria established for the rapid assessment of the wetland conditions. Some of these methods are discussed below.

2.4.1.1. International rapid assessment methods

Hydrogeomorphic (HGM) and Index of Biotic Integrity (IBI) method

The HGM and IBI methods are the widely used approaches for environmental assessment of wetlands in the USA (Brinson, 2009; Stevenson and Hauer, 2002). Both methods evaluate the wetlands by comparing wetlands to be assessed to wetlands in the reference conditions. A reference condition is the existing and relatively unaltered ecosystems that are used as the benchmarks for comparison. Both the wetlands and reference must, however, be located in the same region.

The HGM approach by (Brinson *et al.* 1995) is a rapid wetland assessment tool that has three components to functional assessment and that includes classification by geomorphic setting, articulation of functions, and the use of wetland sites to establish reference standards. Functions are mainly characterised by attributes or variables that can be measured to infer the degree to which each function respond and this information then forms part of the calibrated data set. In a calibrated data set, each wetland, and 0.0 to the lowest functioning. In essence, the HGM is mainly an application of logic models having algorithm arranged attributes. This method follows the use of the functional performance and the wetland is deemed to be in good condition if the functions it provides are not altered by anthropogenic activities.

The state of Ohio has well-developed biological criteria methods for streams. The Index of Biological integrity (IBI) and Invertebrate Community Index (ICI) approaches are well documented (Ohio, 1987a; Ohio, 1987b) and assesses the wetland based on plants and macro-invertebrates communities. Index of Biological Integrity is a quantitative measure that assesses attributes such as taxonomic richness of fish, and Invertebrate Community Index assesses taxonomic richness of macro-invertebrates that changes along the gradient of human disturbances. Over the years, efforts have been made in the development of IBI approach for wetlands using potential vascular plants attributes Fennessy (1998), Fennessy *et al.* (2002), Mack (2001). The latter led to the development of sampling methodologies that began with wetlands that are still in a natural condition. To date, the semi-quantitative disturbance or biological integrity scale method Ohio Rapid Assessment Method (ORAM) (version 5), is regarded as the one and only among a handful rapid assessment methods that effectively assess natural wetland conditions (Fennessy, 2004). The IBI approach has been developed since 1991 by US Environmental Protection Agency (Simon, 1991) and it can be adopted and re-developed using various assemblages in wetland bio-assessments. As with the HGM approach, the IBI approach also has 3 core elements or components. That includes 1) characterisation of different assemblages of organisms, 2) establishment of metric scores based on differences in assemblage attributes and 3) a multimeric index that summarises the multiple assessments of biotic condition. By comparing changes in the biological attributes among wetland types that have been exposed to a broad range of human disturbances, metrics are established. An IBI score for each biological assemblage is then established by summing up all selected individual metrics scores.

Landscape Development Index (LDI)

Brown and Vivas (2005) developed a quantitative method called the LDI that measures the gradient of anthropogenic activities. The index is derived from using land cover characteristics from aerial photographs of land within 100m buffer surrounding the wetland in flat terrains. Available Geographic Information System (GIS) land use/land cover data can also be used, and this is coupled with ground

truthing and verification of land uses in the area of influence. Each land use is then assigned an intensity factor after characterisation. Subsequent to that, a total area weighted development intensity is calculated for the area of influence or the extent of landscape that needs to be delineated. The delineation is mainly achieved by delineating a watershed or a drainage basin of the landscape unit. The percentage of each land use/land cover is then multiplied by intensity co-efficient that are scaled from 1-10. Measurements are based on the energy use per unit area per unit time. This method can be applied at river, stream catchment or smaller scale of individual isolated wetland catchment according to (Brown and Vivas, 2005). This is achieved through the estimated use of energy per unit area.

Delaware Rapid Assessment Procedure (DERAP)

DERAP is the method that was mainly developed for all non-tidal freshwater wetlands in the Outer Coastal Plain regions of Maryland and Delaware (Jacobs, 2010). The coastal plains of Delaware are classified into six wetland classes that includes the depression, flat, riverine, slope wetlands and associated subclasses. This method is designed to obtain two separate scores, namely wetland condition and wetland value. In this method the intensity of stressors such as habitat, hydrology and buffer features in relation to the wetland at a site are taken into consideration (Jacobs, 2010).

The presence of stressors are calibrated at a site with comprehensive wetland condition data using the related Delaware Comprehensive Assessment Procedure (DECAP) Index of Wetland Condition (IWC) to assign a condition score. DECAP is an HGM-based method that uses reference data to develop variables that are responsive to disturbance and are scaled from least disturbed to most disturbed. These variables are then combined into functions and an IWC. The IWC is a single composite score that represents the overall condition of the site.

Florida Wetland Rapid Assessment Procedure (WRAP)

WRAP is a rating index procedure that was developed in Florida by (Miller and Gunsalus, 1999) with the following objectives; 1) to establish a simple, accurate, consistent and timely regulatory tool, 2) to track trends over time, and 3) to offer guidance for the environmental site plan development. Numeric ranking for individual ecological and anthropogenic factors (variables) are established in this method. Variables considered includes wildlife utilisation, wetland overstory/shrub canopy, wetland vegetative ground cover, adjacent upland/wetland buffer, field indicators of wetland hydrology and water quality input and treatment systems. The current wetland condition is then evaluated using the numerical outputs derived from each variable, rating the wetland type according to its attributes and characteristics.

The method provides a single rating or score that gives an indication of the wetland condition on the continuum ranging from full ecological integrity (natural condition) to highly degraded or poor condition. Three major components are considered when conducting these methods and that includes the 1) Wetland impact, 2) Wetland stressors (buffer condition), 3) Wetland restorability. The summary of ratings and overall score is then obtained automatically when all data is captured.

The wetland impact assessment focuses on evaluating HGM, vegetation and water quality conditions. The wetland stressors (buffer condition) focuses on stressors that occur in adjacent areas surrounding the wetland. The wetland restorability is mainly designed to evaluate the capability of a wetland for restoration.

All wetland types are considered and the HGM must be 1). The riverine type, 2) must have the potential for woody vegetation and 3) must have a standing water component that can be evaluated for water quality. Wetlands are assessed further for their potential, capability and restorability. For site characterisation, fish, amphibians or aquatic reptile species, percentage of standing water, evidence of endangered species, emergent vegetation are evaluated.

Wetland impact evaluation

HGM condition

HGM condition is assessed using three categories including non-occurring or slight, indicating that less than 15%, of the concerned area is affected, moderate indicating that 15-60% of the concerned area is affected and severe indicating that 60% of the concerned area is affected. After scoring the hydrogeomorphic conditions, the hydromorphology condition index then considers the sum of the lowest scores divided by 20.
Four components of the hydromorphic attributes are then evaluated and that includes the riparian-wetland conditions, the stream balance with the water and sediment supplied by the watershed, riverine or floodplain characteristics and riverine stream bank with vegetation (having a deep binding rootmass). All these attributes are then scored with scores ranging from 0-8.

The Riverine index is then used to when a sum of all scores are divided by the potential scores (usually maximum scores). The riverine Index is then combined with the hydrogeomorphic condition Index to give the overall score.

Vegetation condition

For vegetation condition assessments, attributes such as bare ground, invasive and disturbance-caused undesirable plants, noxious weeds, woody species establishment, utilisation of trees and shrubs, percent of physical removal of tree/shrub layer or dead wood are evaluated with scores ranging from 0-10. If site only has herbaceous vegetation, all points are summed and divided by 30. If woody species are present, each score is divided by 10 and the actual score obtained is divided by the potential score. All scores are then summed up and divided by 6.

Water quality conditions

For the water condition attributes such as algae or duckweed, cattails, sediment and turbidity, surface oils and foams, toxics, salinity are considered. Then the Water Quality Index is used when the sum of the lowest two scores is divided by 20.

Wetland Stressor evaluation

Buffer condition/ Degree of stress

For a buffer condition a 100m buffer around the wetland is considered. Stressors in the buffer area that are likely to impact the wetland are evaluated in order to ascertain whether the stressors are the probable cause of wetland impacts. The buffer condition is then used as an input in calculating the overall score. The degree of stress assist in establishing whether there is a relationship between the stressors that are re-occurring in the buffer area and the wetland impact score. Stressors are scored ranging from none (no stressors) – to very apparent stressors and their distribution. Attributes considered include bare ground, noxious weeds, disturbance caused undesirable plants, grazing intensity, recreational activities, hayfields, row crops, clear-cuts, feedlot or concentrated livestock, residential development, human-constructed dams or dykes, human induced saline seeps, industrial or commercial activities, oil and gas development, stressors within 100-500 meters of wetland, 16-21 roads. The buffer condition or stressor index is then used when four lowest scores are calculated and divided by the total possible assessment area.

Automated Wetland Impacts and Overall Scores

Wetland impact score

The calculation of the wetland impact score does not take the buffer condition into account. Instead, it is compared to the buffer condition or stressor index to help determine if there are any cause and effect

relationships between the two. The following automated calculations illustrates how the overall wetland impact score is derived.

If surface water is present within a wetland, the HGM Condition Index is multiplied by 0.4, Vegetation Condition Index is multiplied by 0.4 and Water Quality Condition Index is multiplied by 0.2. All values are then entered into appropriated boxes in the scoring tool and calculated. The resulting value is captured in the wetland impact score box.

If there is no surface water present, the HGM Condition Index is multiplied by 0.5, Vegetation Condition Index is multiplied by 0.5. The two values are then entered into appropriated boxes in the scoring tool and calculated. The resulting value is captured in the wetland impact score box.

The Overall score

The Overall score is computed and is derived from the HGM Condition Index, Vegetation Condition Index, Water Quality Condition Index, and the Buffer Condition or Stressor Index. The Overall score is equally dependant on whether there is surface water on site or not and that influence the value used when calculating different indices.

If there is surface water present, the HGM Condition Index is multiplied by 0.3, the Vegetation Condition Index is multiplied by 0.3, the Water Quality Condition Index is multiplied by 0.2, and the Buffer Condition Index is multiplied by 02. All values are then entered into appropriated boxes in the scoring tool and calculated. The resulting value is captured in the overall score box.
If there is no surface water present, the HGM Condition Index is multiplied by 0.4, the Vegetation Condition Index is multiplied by 0.4, and the Buffer Condition Index is multiplied by 0.2. All values are then entered into appropriated boxes and calculated. The resulting value is captured in the overall score box. Lastly, stressors that are occurring near the wetland are then ranked in order to determine whether stressors are occurring in a watershed or a region.

Evaluating Wetland Restorability

Effort and the cost for restoring a wetland are evaluated together with the trend of the wetland condition (upward or downward trend). The ‘capability’ of a wetland for restoration is also assessed. If impacts are too severe, a wetland can only be restored to meet its capability.

With all these assessment methods developed, others were designed mainly for non-expert use Carletti *et al.* (2004). However, training is still essential in order to formulate quality judgement. In the review of

rapid assessment methods in North America, time and cost of an assessment were the main factor making rapid assessment method by non-expert a viable option for effective wetland management.

2.4.1.2. International rapid assessment methods for non-experts

Four rapid assessment methods were designed for non-experts including the Coastal Method (CM) (Cook *et al*. 1993), HGM, the Maine Citizen Tidal Marsh (MCTM) method and Stoney Creek Wetland Protection Plan (SCWPP) (Tilton *et al*. 1997). The MCTM is the method that appears to be widely used and the MCTM guide is utilised (Carletti *et al.* 2004).

The MCTM uses the numerical score called an Average Functional Index (AFI) score for evaluating the ecological integrity of wetlands, particularly tidal marshes. This is done based on answers to a series of "predictor questions" that are based on physical characteristics of wetlands that relates to the ecological and socio-economic functions that wetlands perform. Aerial photographs and national inventory maps as used as baseline data together, with on-site field investigation for assessing each function and value of a wetland. Functions and values assessed include the ecological integrity of the marsh system and of the zone of influence, wildlife, finfish and shellfish habitat, recreational potential, aesthetic quality, educational potential and noteworthiness. A high AFI indicates a high degree of ecological integrity and a low AFI indicates a marsh that has been heavily impacted by human activity.

2.4.2. Wetland assessment tools in SA

In SA, there are several tools that have been developed for the rapid assessment of wetland health and are applicable in most regions in the country. These tools have aided in advancing wetland science in the country over the years and that includes the 1999-RDM wetland PES assessment method for floodplains and palustrine wetlands (DWAF, 1999), Wet-IHI for floodplains and valley-bottom wetlands (Rountree *et al.* 2007) and Wet-Health assessment tool (Macfarlane *et al.* 2007). Currently, there is widespread use of WET- IHI and Wet-Health methods, however, they have shortcomings and need to be further fine-tuned for easy use (Ollis and Malan, 2014).

Wet-Index of Habitat Integrity (Wet–IHI)

Wet–IHI is a MS Excel-based model that was designed for floodplain and channeled valley bottom wetland types (Rountree *et al.* 2007). The wetland can be assessed using a both Level 1, which is a desktop assessment and Level 2 that involves field verification. The Level 2 method is rapid, requiring approximately 3 hours in the field. Aerial photos; maps and/or satellite imagery are also used to assist in the assessment. Three drivers are assessed and that includes hydrology, geomorphology and water quality. Vegetation as a responder to land use activities as modifiers on the wetland and its catchment

is also assessed. Each factor to be assessed is ranked and weighted against other factors, since not all would be important to the same degree. Ranking varies from the most important or influential with a score of (1) to the least important with a score of (0). The most important factor is ranked first and it gets a rank of (1), which translates into a weighting of 100% and the other factors are then ranked relative to that. The degree of impact or change of a factor is then rated from (0) (no change) to (5) (most extreme change). The approximate percentage of the real extent of the wetland system which has been impacted by a factor is then estimated. Then total extent percentages must always add up to 100%. Both the rating and the extent scores generates the impact score. Multiplying this score by the weighing score, in turn generates the weighted impact score to account for the differential influence of factors being evaluated.

Impacts scores are then assigned confidence scores where low confidence is given a score of (1) (i.e. the impact score was derived from very scares data) and 5 (i.e. the impact score was derived from data rich as well as ecological system knowledge).

Wet-Health assessment tool

The Wet-Health is a method that evaluates wetland impacts where the score is from 0 (unimpacted and close to natural) to 10 (wetland change is significant) Macfarlane *et al.* (2007). The method can be conducted in two levels: Level 1, which requires greater level of professional judgement and Level 2: which requires a general wetland experience and training. The wetland is first characterised into HGM units that are assessed individually. The impacts of human activities are then quantified, and the impact scores are then converted into a Present Ecological State scores.

This process starts with the evaluation of both the spatial extent of the impact of each activity in the affected area and the intensity of the impacts, separately. The extent is expressed as a percentage and is basically the proportion of the wetland and / or its catchment affected by a given activity. The intensity is the degree to which wetland characteristics have been altered for each of the four components (hydrology, geomorphology, water quality and vegetation) and is scored on a scale ranging between (0) – (10). Zero (0) represents no impacts and (10) represents complete wetland transformation when compared to the natural condition. Subsequent to that, the magnitude of the impact (the overall impact of a particular activity/activities of the component of the wetland health) is also expressed on a scale 0-10. The overall magnitude of impact is then achieved by multiplying the intensity score and the extent of the impact as follows:

Magnitude = Extent / 100 x Intensity.

Once magnitudes of impact of individual activities and/or indicators have been calculated, these are combined in a structured way to provide a measure of overall impact on a scale of zero (0) - ten (10), scaled into six categories. No impact is categorised between zero (0) – zero point nine (0.9), Small impact between one (1) – one point nine (1.9), moderate impacts between two (2) – three point nine (3.9), large impacts between four (4) – five point nine (5.9), serious impacts between six (6) – seven point nine (7.9) and critical impacts between eight (8) – ten (10). The above processes are undertaken for all four components including hydrology, geomorphology, water quality and vegetation integrity. For all four components, a Present Ecological State category is then produced. All scores can then be combined into a single score Present State score by using the below formula:

Health = ((Hydrology score) x3 + (Geomorphology score) x2 + (Vegetation score) x2) ÷ 7, which gives a score ranging from 0 (pristine) to 10 (critically impacted in all respects). Lastly the trajectory of change is assessed based on observed trends for management planning purpose to predict whether impacts will continue or improve in future. For this, change classes namely improvement, remain stable, slight deterioration and substantial deterioration, and their descriptions are used. Each class is then associated with a specific symbol to show the direction of change.

In reviewing the above-mentioned methods, (Ollis and Malan, 2014) is of the view that for the successful application of any of the available methods, training, a basic understanding of wetland ecological processes and a good background in assessing wetlands is required. The Wet-Health Level 1 method, in particular, has limitations that relates to its scoring sheet amongst others. The most significant is the fact that the method does not remove the element of human judgement, therefore, skilled scientists with background in wetland ecology and training in wetland assessment, coupled with experience in the field are required. The Wet-IHI was mainly developed for use in assessing wetland ecological integrity and to provide support to the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) for wetland monitoring purposes (Rountree *et al*. 2007). One of its limitations is that it was designed only for flood-plains and valley-bottom wetlands which is restrictive considering the types of wetlands identified in regions of SA. Shortcomings presented by the use of the available wetland methods to date in the absence of a better user-friendly method, will continue to present difficulties in assessing wetland health. Further to this, lack of knowledge about natural processes and what drives these ecosystems will render them forever vulnerable to possible degradation.

2.5. Citizen-Science tools in SA

Citizen science is defined as the involvement of the local communities in professional scientific research with no formal or limited training on the subject under investigation. In such cases, science tools are being utilised to collect the required data that can be used to inform water resource managers (Araya *et al.* 2009). Worldwide, participation of citizens or the public in data collection for ecological research purposes has been tried and tested before (Miller-Rushing *et al.* 2012). Although it's fairly new in developing countries, this is where it is mostly needed to assist in collecting data that would otherwise not be possible because the work is labour intensive, and often requires financial resources. According to Jordan *et al.* (2011) citizen-science is "partnerships initiated by scientists that involve non-scientists in data collection". However, according to Irwin (1995) there is more to citizen-science than the collection of data. He thinks that people can accumulate knowledge in citizen-science and that knowledge can be used to understand where the environmental impacts come from and respond accordingly. Further to this, the buy-in of water resource managers is needed in order to ensure that data collection is not in vain but can be used to inform important management decisions. Regardless of its rapid expansion, data generated from the citizen-based monitoring programs are still not used by natural resource managers due to their scepticism when it comes to the quality and comparability (Conrad and Hilchey, 2011). Therefore, there is a growing need for citizen science data to be validated in some way (Silvertown, 2009).

Locally, a number of citizen science initiatives have recently been developed for assessing ecological conditions of various water resources, such as rivers and streams, estuaries, springs including wetlands. The Zandvlei Trust Co-ordinated Annual count (Coordinated Water bird Counts) (CWAC, 2014) is the citizen science monitoring programme that has been initiated focusing on fauna and fauna sighting, distribution and census of all water bodies in SA. This assists scientist in studying the water bird movement and distribution throughout the Southern Africa wetlands, dams, vleis, estuaries, and rivers for all seasons. Other initiatives allow citizen scientist to develop a mobile application that can be used to observe plant communities associated with wetlands in order to delineate the wetland boundaries (Van Zyl, 2014). While the above-mentioned tool touches on wetland delineation, citizen-science tools that will assess both the integrity (health) and the level of ecosystem services of a wetland will go a long way in the advancement of the involving public participation in wetland management. Currently, the rapid assessment techniques have been developed but that is for competent scientists with appropriate background Macfarlane *et al.* (2007), Kotzé *et al.* (2005). An easy to use citizen science tool that will result in a robust learning outcome in as far as wetland health and their ecosystems functions are concerned, is therefore needed to add to and strengthen current initiatives.

2.5.1. Benefits of citizen-science tools

Currently, citizen scientists are participating in many water resource management research and monitoring interventions worldwide, including wetlands. These fields include, amongst others, climate change, invasive species, conservation biology, ecological restoration, water quality monitoring, population ecology etc. (Silvertown, 2009). One of the overarching benefits of citizen involvement in data collection is that it can be cost effective as long-term data can be generated over a large geographic scale. More so that the main challenge of water resource management in SA, is minimal capacity with adequate skills in three spheres of the government, resulting in data gaps that makes management of such ecosystems difficult without continuous long-term data. However, this can only be achieved through participation that in turn stimulates social learning. Water resource management issues can thus be achieved in a sustainable manner as experiences in data collection can result in motivated, scientific knowledgeable and interaction of similar minded people that cares about the environment Bonney *et al.* (2009); Jordan *et al.* (2012).

CHAPTER 3 MATERIALS AND METHOD

A one-day workshop was attended at Ixopo Golf course in Kwa-Zulu Natal (KZN) where the use of the wetland tool was demonstrated. An introduction and background information to wetlands was conducted. Before undertaking the field visit, the tool was thoroughly explained and maps of delineated wetlands where assessed and clarity was provided. The day concluded with the discussion of results and information sharing.

3.1. Approach and method used in the assessment

Assessments of the ecological health of wetlands were based on rapid assessment of one site visit to each wetland from the 03rd-05th January 2018 and assessments were conducted on 6 wetlands. The tool and scoresheet were used to assess the wetlands and quantitative scores were collected. Three wetlands located in the North-West and Gauteng provinces (SA), respectively as indicated in Table 3-1 were assessed.

Table 3-1: Wetlands already assessed with Wet-Health by Imperata Consulting (Imperata Consulting, 2013-2016).

Province	Prepared by	Project/Wetland Name	PES Assessment History	Wetland Location	
				X	Y
NW	Imperata Consulting	Rietfontein	2013	25° 50'12.50"S	27° 22'30.40"E
		Bokkraal	2014	25° 48'35.80"S	26° 28'18.80"E
		(Kgaswane Nature Reserve) Kgaswane Wetland Complex			
		Kgaswane Target Area 1	2014	25° 43'13.52"S	27° 11'38.33"E
		Kgaswane Target Area 2	2014	25° 43'08.70"S	27° 11'17.61"E
		Kgaswane Headwater Triburtary 1	2014	25° 42'52.83"S	27° 10'45.36"E
Gauteng		Sokhulumi (Vlakfontein)	2013	25° 35'39.63"S	28° 52'02.50"E
		Farm Doornrandjie Wetland - Pretoria Rural	2009 & 2014	25° 53’ 25.53” S	27° 59'05.53"E
		Tweefontein wetland	2016	25° 33’ 56.95’’S	28° 29’35.05’’E

These wetlands were previously assessed using the WET-Health tool in the study conducted by Imperata Consulting in 2013-2016 (Imperata Consulting, 2013, 2014a-c and 2016). Aurecon appointed Imperata Consulting to undertake an ecological wetland assessment for the purpose of rehabilitation

through the Working for Wetlands Programme. This study includes the determination of the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) and ecosystem service assessments for selected wetlands in Gauteng and North-West province. These wetland assessment reports generated forms part of the environmental authorisation phase and rehabilitation plan for the Working for Wetlands programme. These assessments are intended to determine baseline conditions of targeted wetland areas, identify wetland problems suitable for rehabilitation, and indicate how the proposed rehabilitation interventions will benefit the targeted systems.

3.2. Study sites

3.2.1. North-West province

3.2.1.1. Rietfontein

Catchment description

Rietfontein wetland is located in the Sterkstroom River catchment area, which forms part of the Crocodile West and Marico Water Management Area (WMA). The Sterkstroom River forms a confluence with the Crocodile River at the north-eastern border of quaternary catchment A21K. The wetland is approximately 8.8 ha covering >3% of its catchment and the catchment is approximately 327 ha in size (Figure 3-1). The local climate is characterised by a low mean annual precipitation (MAP) of 651 mm, and a high mean annual evapotranspiration (MAE) of 1744 mm (Middleton and Bailey, 2008). The wetland is located on the Gold Reef Mountain Bushveld vegetation unit, described by Mucina and Rutherford, (2006) and the Gold Reef Mountain Bushveld has a least threatened conservation status. Land use within the catchment include agriculture (irrigated and dryland cultivation), dams, siviculture practices and urban development.

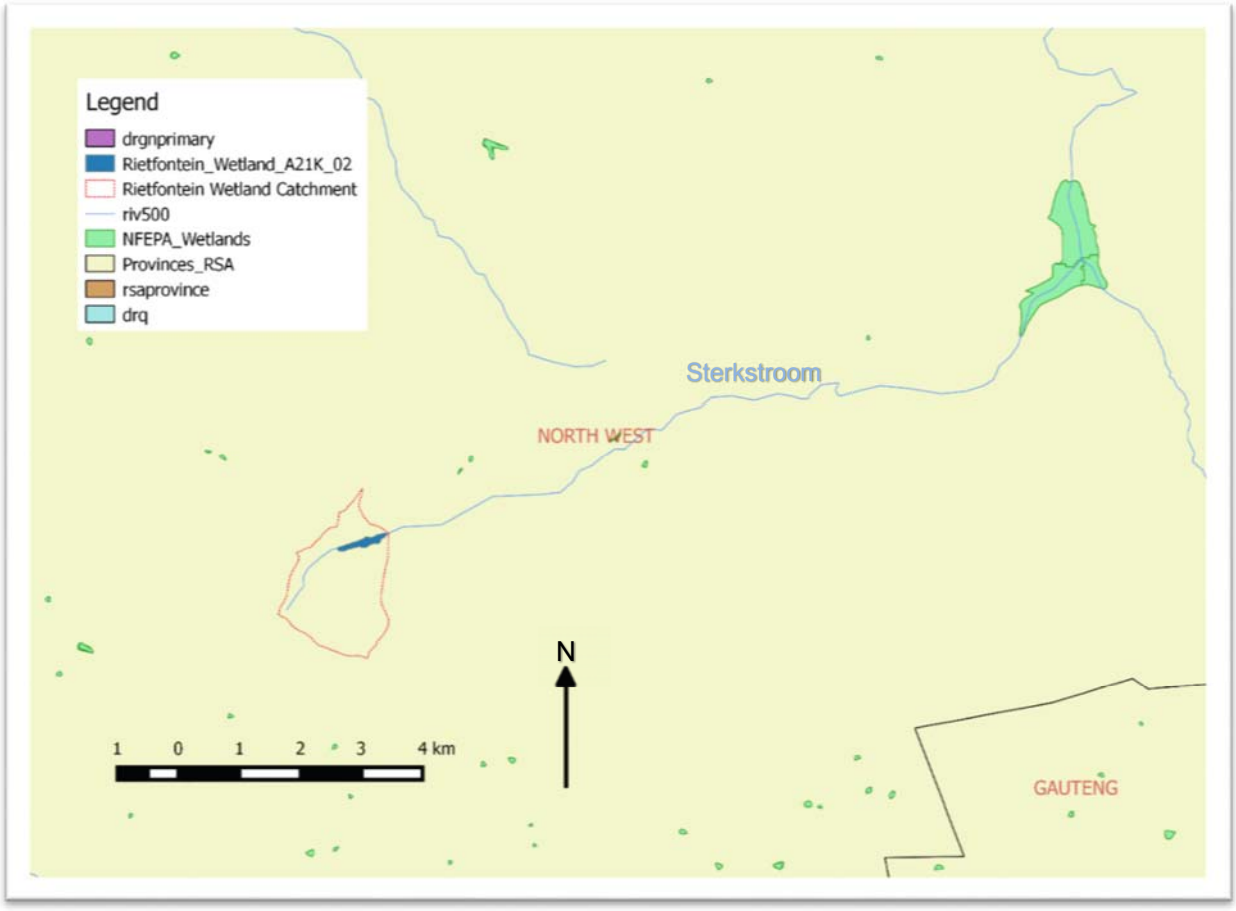


Figure 3-1: Illustration of Rietfontein wetland in relation to its catchment.

3.2.1.2. Bokkraal

Catchment description

The wetland catchment forms part of the Crocodile (West) Marico WMA, quaternary catchment A31A, and drains into the Marico River approximately 11.7 km north of the wetland. The wetland target area is approximately 5.48 ha with a catchment of approximately 4017 ha (Figure 3-2). Quaternary Catchment A31A has a MAP of approximately 602 mm and a potential evapotranspiration of ±1849 mm. Three bands of regional vegetation units occur within the wetland catchment. They include Carletonville Dolomitic Grassland in the upper (headwater) reaches of the catchment; the vegetation unit has a vulnerable conservation status and is poorly protected on a national scale (Mucina and Rutherford, 2006). The lower reaches of the catchment is covered by the Dwarsberg-Swartruggens Mountain Bushveld also having a low vulnerable conservation status. The general terrain and gradient

of the catchment changes from gently undulating plains in its headwaters, while slopes become steeper towards the target area and lower catchment boundary.

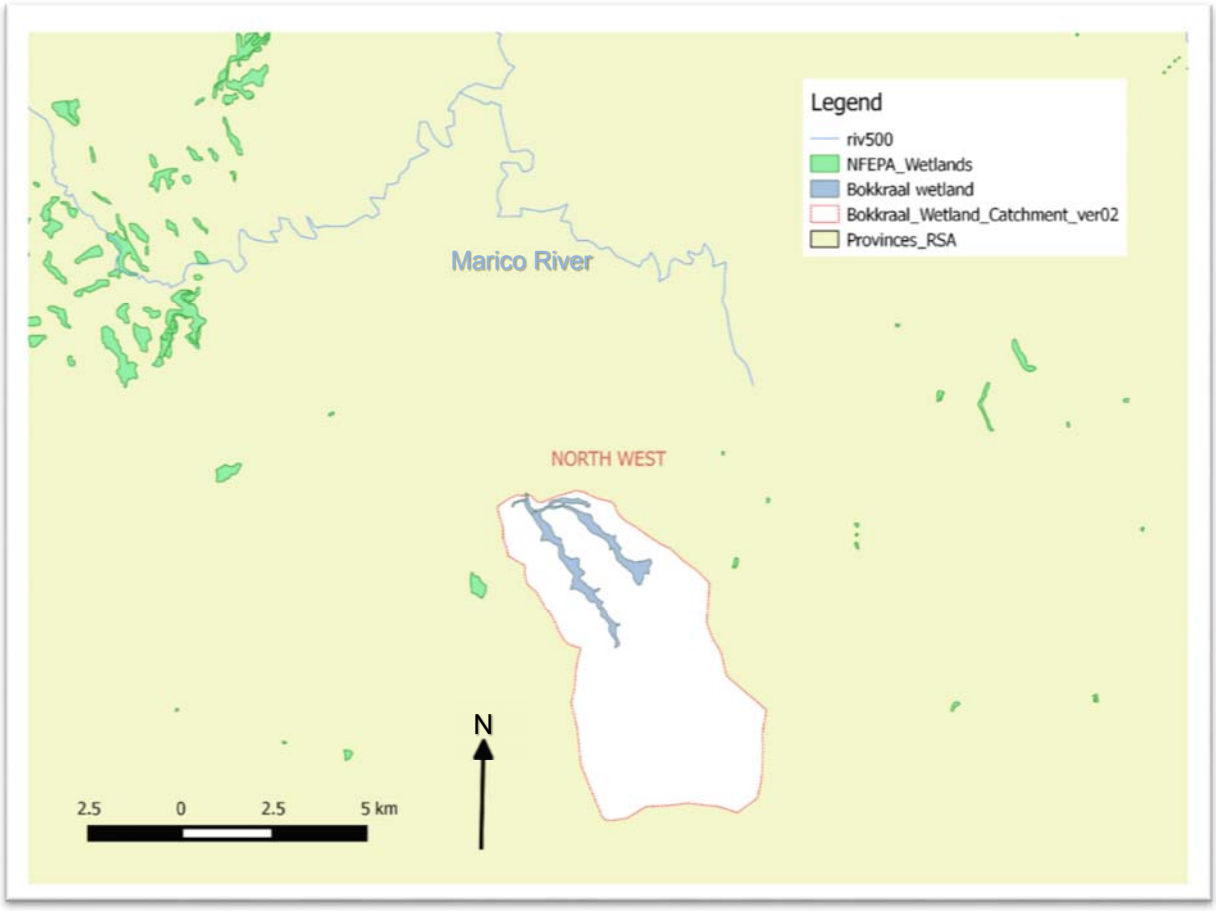


Figure 3-2: Illustration of Bokkraal wetland in relation to its catchment.

3.2.1.3. Kgaswane Nature Reserve Wetland complex

Catchment description

The Kgaswane wetland catchment forms part of the Crocodile (West) Marico WMA and drains into the Hex River approximately 7.5 km east of the wetland in Quaternary Catchment A22H. The catchment has a size of approximately 1655 ha and is entirely located within the Kgaswane Mountain Reserve (4260 ha), which is characterised by an untransformed landscape that only contains restricted development, such as access roads and a few tourist-related facilities. The wetland catchment is

located in a mountainous area with steep slopes and waterfalls located downstream. The wetland is approximately 162.12 ha with the catchment of Kgaswane wetland complex being approximately 1656 ha (Figure 3-3) (Imperata Consulting, 2014c).

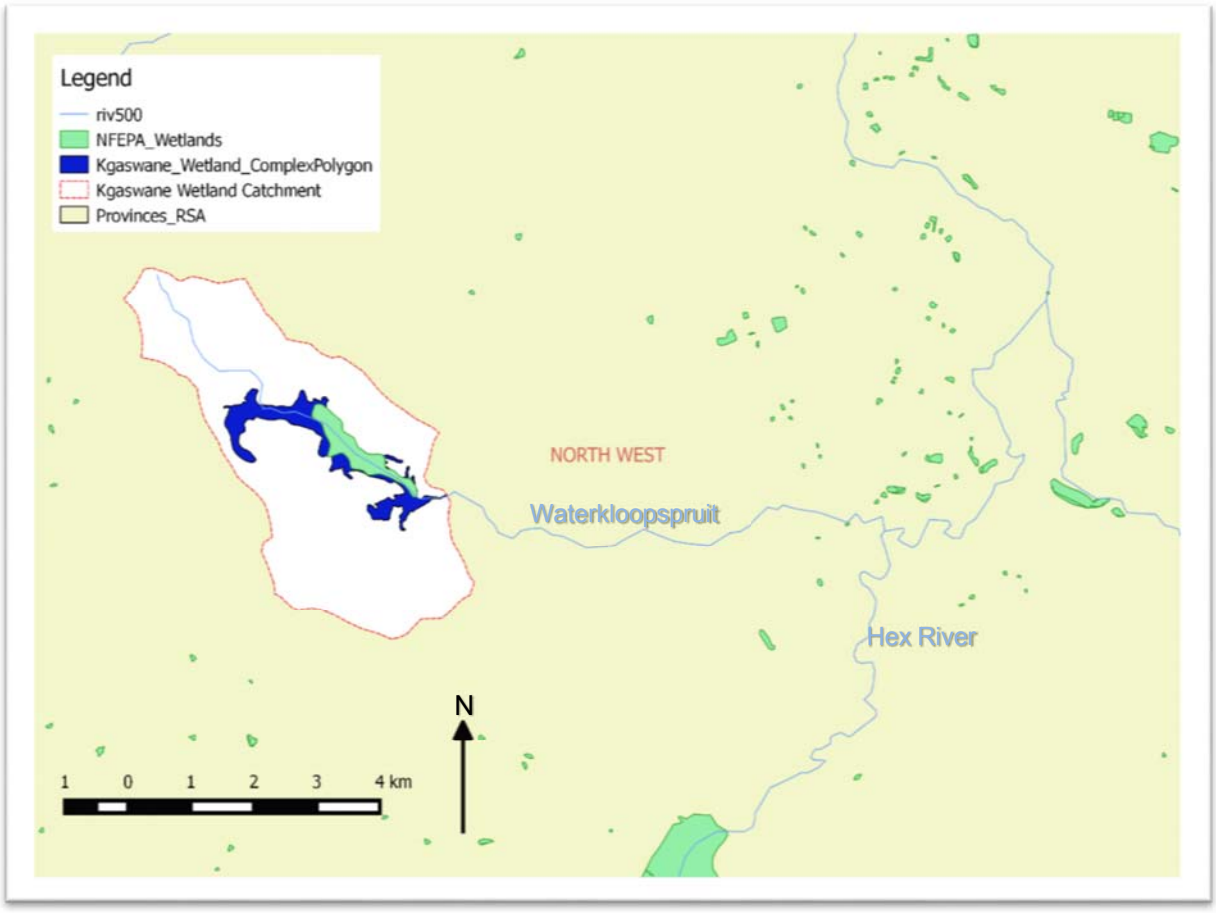


Figure 3-3: Illustration of Kgaswane Nature Reserve wetland in relation to its catchment.

3.2.2. Gauteng province

3.2.2.1. Doornrandjie Wetland: Pretoria Rural

Catchment description

The wetland catchment (Figure 3-4) forms part of the Crocodile (West) and Marico WMA within the quaternary catchment A21C. The assessed wetland section is located approximately 6 km northeast of Lanseria Airport, 4.1 km northwest of Diepsloot Informal Settlement, and ±10 km south-southeast of

Pelindaba. The MAP of 682 mm and a MAE is approximately 1700 mm (Middleton and Bailey, 2008). The wetland and its entire catchment is located within the Egoli Granite Grassland vegetation unit as described by (Mucina and Rutherford, 2006) and has an endangered conservation status. Currently, land use within the wetland and its catchment is grazing. However, historic cultivation practices are evident throughout the wetland.

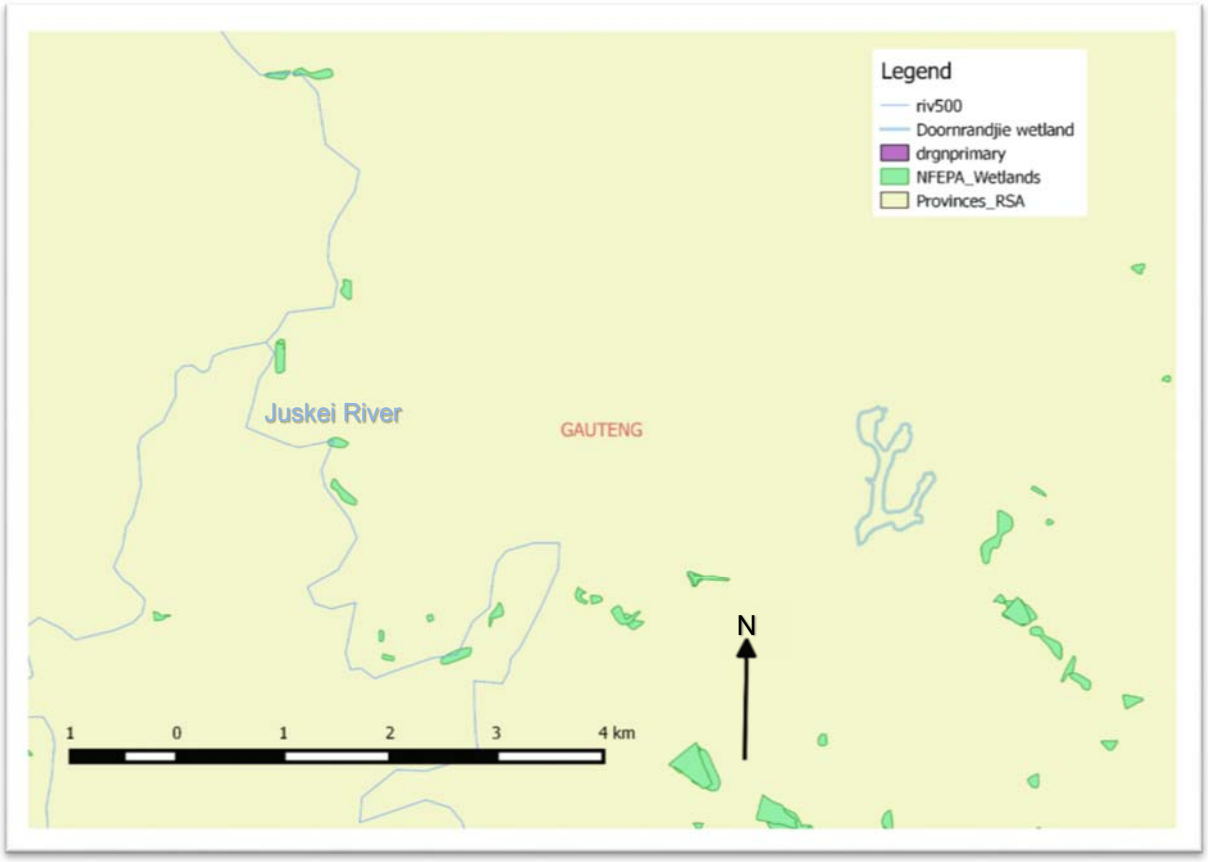


Figure 3-4a: Illustration of Doornranjie wetland in close proximity to the Juskei River.

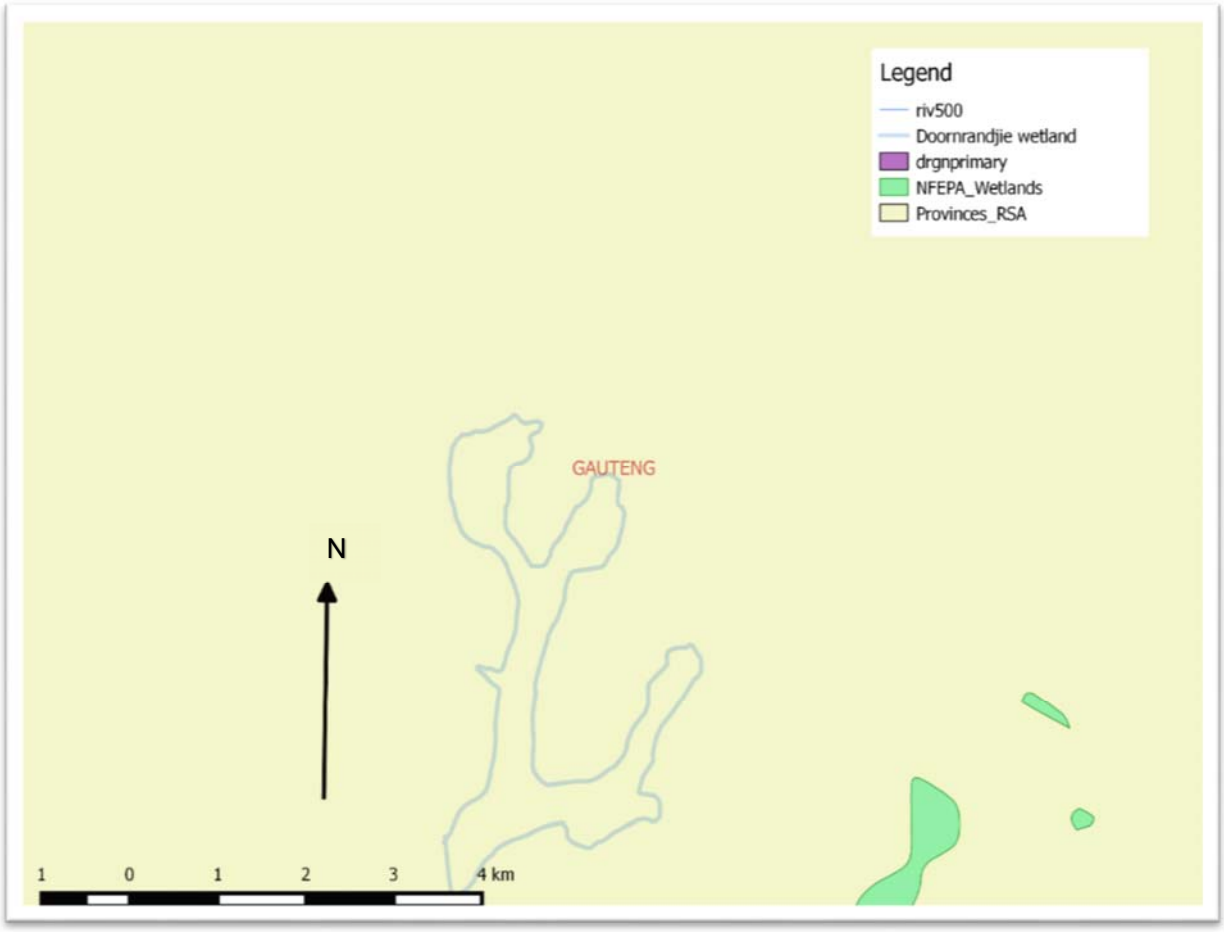


Figure 3-5b: Illustration of Doornranjie wetland zoomed in.

3.2.2.2. Sokhulumi

Catchment description

The wetland catchment forms part of the Wilge River Catchment area and is located with the Olifants WMA in quaternary catchment B20H and drains a portion of north-eastern Gauteng and western Mpumalanga. The wetland is mainly located within Gauteng Province, but a portion of its western side overlaps with the Mpumalanga Province. The catchment is 1835 ha in extent with the extent of the wetland being approximately 194 ha in size. The local climate is characterised by a MAP of 672 mm and a high MAE of 1764 mm (Middleton and Bailey, 2008). The wetland is located on the transitional area between the Rand Highveld Grassland in the south, and the Central Sandy Bushveld to the north (Mucina and Rutherford, 2006). Land use within the wetland include grazing, dams, current and historic

cultivation, while clumps of alien trees, specifically *Populus* x *canescens* and *Eucalyptus* cf. *camaldulensis* are also present.

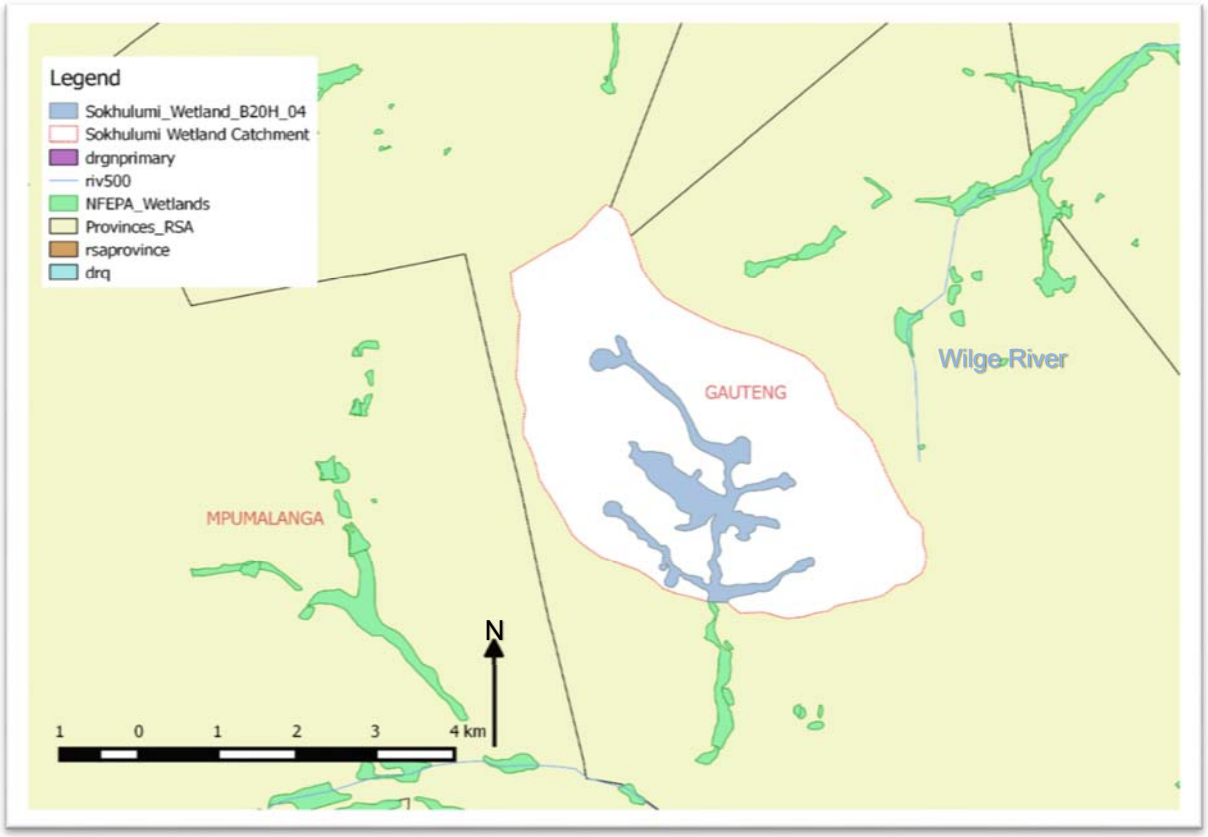


Figure 3-6: Illustration of Sokhulumi wetland in relation to its catchment.

3.2.2.3. Tweefontein

The Tweefontein Wetland is located approximately 25 km northeast of Pretoria, 12 km northeast of Roodeplaat Dam and 9 km north of Premier Dam. Surrounding areas include Refilwe and Cullinan to the south, with the R573 Road to the west and north.

Catchment description

Tweefontein wetland is approximately 71.40 ha in size with the catchment size 1856.62 ha. Three target areas were assessed on the delineated wetland. The entire Tweefontein Wetland and all four of its target areas are located outside of the Gauteng Urban Edge (Imperata Consulting, 2016) and form part of the Central Sandy Bushveld vegetation unit (Mucina and Rutherford, 2006). The MAP over the area

varies between 600-700 mm (Le-Maitre and Christine, 2008) and a high potential MAE of about 1 800 mm prevails (Middleton and Bailey, 2008). The catchment land use is dominated by cultivated commercial lands, woodlands, open bush, grassland and thicket or dense bush.

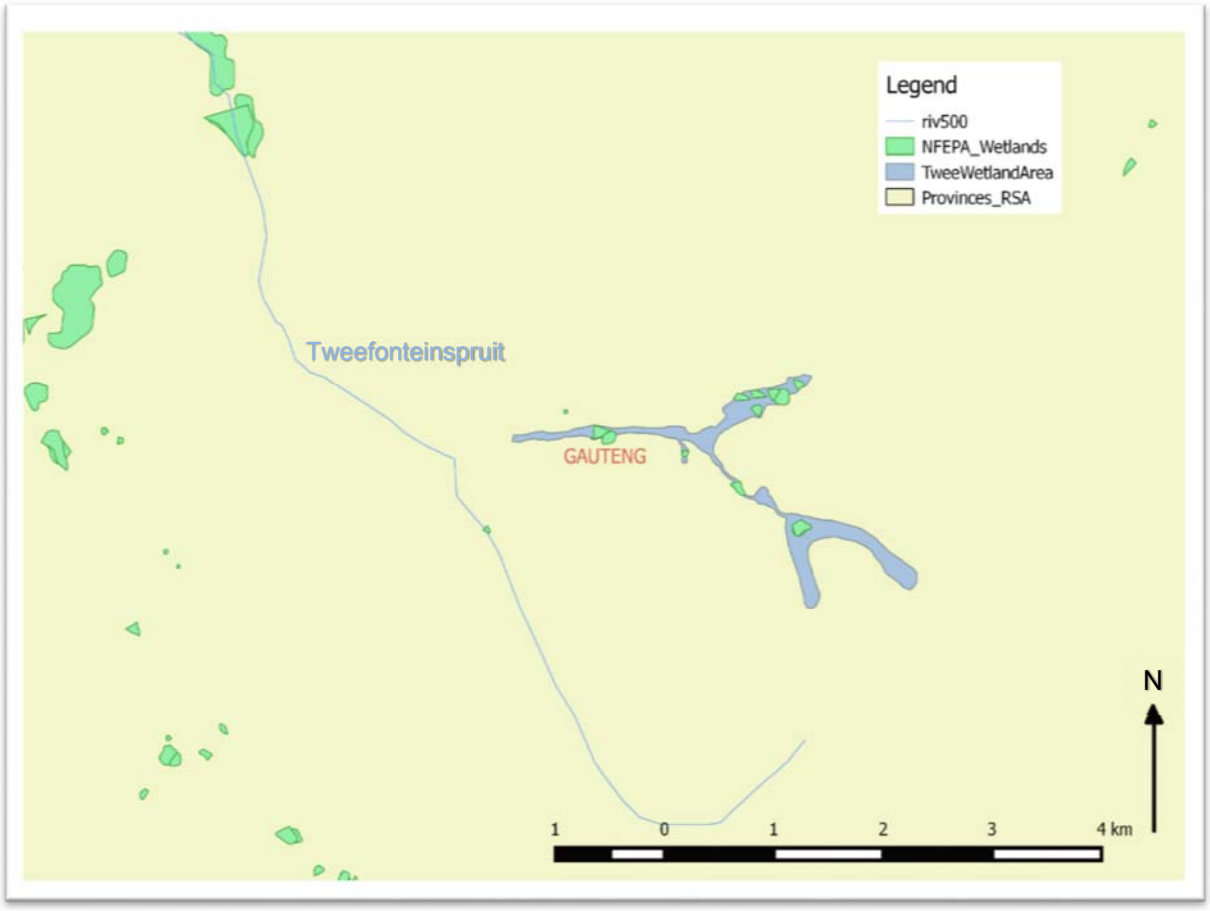


Figure 3-7: Illustration of Tweefontein Wetland in close proximity to the Tweefonteinspruit.

3.3. Wetland assessment method using the Citizen Science tool

3.3.1. Wetland delineation

In terms of wetland delineation and mapping, shape files of delineated wetlands and their catchment areas were obtained from Imperata Consulting as this study only focuses on testing the newly developed tool. The delineation of the boundary of the wetland in the field, which in itself would require several days to undertake, will only be necessary if wetland to be assessed has not previously been

delineated. The detailed map-option protocol was used as outlined by Kotzé (2015), however, the wetland delineation step was already carried out during the assessments of wetlands with Wet-Health tool. It is generally used to determine the overall ecological condition or health score of wetlands assessed. Basic steps followed in the assessment using the newly developed tool are outlined below:

3.3.2. Step 1: Mapped/delineated wetlands

Wetlands and their upslope catchment was done using a number of data sets that were useful in capturing and updating the wetland boundaries, and that includes vector data below (Table 3-2) (Imperata Consulting, 2013-2016). Selected wetlands mapped by Imperata Consulting were used ground-truthed and assessed using the Citizen Science tool.

Table 3-2: Ancillary data utilised to capture wetland boundaries.

Data set name	Data type:	Scale	Source	Description
Catchment boundaries	Polygons		DWA/DWS, 2012	Primary, secondary, tertiary and quaternary catchment data.
Large dams and rivers	Polygons and lines	1:500 000	DWA/DWS	Large dams and rivers mapped at 1:500 000 scale.
Land cover 2014	1:50 000	DEA		Land cover categories https://www.environment.gov.za/mapsgraphics#national_landcover
Political boundaries (provincial, district, local and ward boundaries)*	Polygons	vary	MDB	Political boundaries to use for orientation purposes.
Sub-quaternary catchments	Polygons	NFEPA		ATLAS of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources Atlas and data (DVD) can be obtained from the WRC or data can be downloaded from SANBI's BGIS website.
Topographical data from topographical maps*	Various (polygons, lines and points)	1:50 000	DRDLR	River lines, river areas, water bodies (small dams), railway lines, railway stations, roads.

3.3.3. Step 2: Desktop assessment

The aerial imagery (Google Earth Pro) information source was considered for the desktop assessment in order to note land use units surrounding the wetland and its catchment before undertaking field visits. The function that tracks changes over time was also utilised to assess land cover changes.

3.3.4. Step 3: Fieldwork

Observations of wetlands and associated catchments from a nearby vantage points and a walk through the wetlands were conducted in the field. Photographs at the site were taken to provide a snap shot of land uses on the wetlands and their up-slope catchments. All land use units were recorded and units from google-earth, confirmed. Additional land uses that were not visible through aerial imagery were also noted. An example of the latter are pipes located in the wetland for water abstraction.

3.3.5. Step 4: Recording of the data sheets (Citizen Science tool)

A list of land-cover or disturbance types commonly occurring in wetlands and the upslope catchments, to which typical impact scores have been pre-assigned in a table format was used to aid the process. Land types surrounding the wetland and its catchment were recorded on two separate rapid assessment data sheets. The extent of the land type was also recorded as either small, moderate or extensive. All scores were captured on spreadsheets (wetland on-site and the upslope catchment assessment sheet) in Microsoft (MS) excel, to which default impact scores have been assigned based on existing research and expert judgment (Appendix A - Table 1 & 2). Both data sheets were then reviewed to check which factors are having the greatest impacts on the wetland's ecological processes. The higher the intensity, and the more extensive the land cover, the greater the magnitude of impact on the wetland.

This involves firstly assessing the spatial extent of individual land-uses (expressed as a proportion of the wetland or its catchment) (Table A-1 and 2). The intensity of impact of each individual land-use on each of the four components (hydrology, geomorphology, water quality and vegetation) on a scale ranging from 0 (no impact or deviation from natural) to 10 (critical impact or complete transformation from natural) were separately identified.

The magnitude of impact for each land-cover present is then determined by multiplying the relative extent of that impact, by the pre-assigned intensity of impact score provided by the relevant table of the method. All impact magnitude scores for the individual land-covers present are then calculated to derive an overall ecological impact score for land-cover in the wetland, and its wetland's upslope catchment.

For the wetland upslope catchment, the total score determined of impacts on a wetland from land uses in the wetland's upslope catchment was automatically adjusted by calculating the extent of the natural vegetation buffer zone. The extent of the buffer zone around the wetland was also indicated by using guidelines as illustrated in Figure 3-7. The adjustment is based on following multiplier: Low to moderately low extent of buffer zone = 1 (i.e. the impact score remains the same); Intermediate = 0.9; moderately high to High = 0.7.

The overall scores for land-cover, both in the wetland itself and in the wetland's upslope catchment, were then finally combined in such a way that the higher score has the dominant effect but is adjusted by the lower score by using a 2:1 weighting ratio. This ratio is based on the assumption that a land-cover (e.g. commercial crops) in the wetland itself impacts more directly on the ecological condition of the wetland than if it is located in the wetland's upslope catchment.

A combined overall impact score is derived from the scores for hydrology, geomorphology, water quality and vegetation, weighted as 3:2:2:2, as recommended by Macfarlane *et al.* (2007). The overall score ranges from 0 to 10, and six PES categories (A to F) are identified as follows: 0-0.9 = A; 1-1.9 = B; 2-3.9 = C; 4-5.9 = D; 6-7.9 = E; and 8-10 = F (Table 3-3), where a category A means the wetland is in a totally natural state, and a category F means the wetland is highly degraded with virtually no wetland functioning remaining. These are the same categories used by (DWAF *et al.* 2007) and (Macfarlane *et al.* 2007).

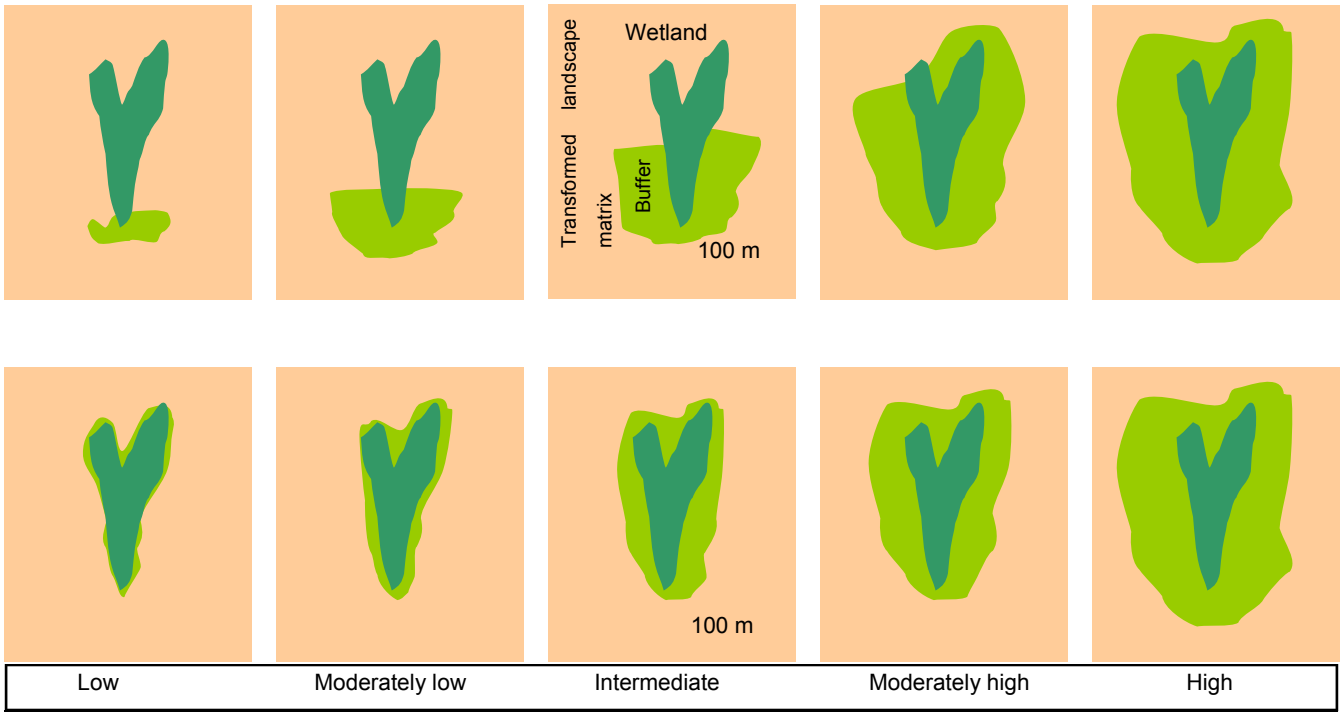


Figure 3-8: A guideline for scoring the extent of a buffer zone of natural vegetation around a wetland (source: Kotzé 2015).

Table 3-3: Overall impact score categories and corresponding Present Ecological State (PES) categories (modified from MacFarlane *et al*. 2007).

Overall impact score range	Impact category	Description	PES category
0-0.9	None	No discernible modification or the modification is such that it has no impact on wetland integrity.	A
1-1.9	Small	Although identifiable, the impact of this modification on wetland integrity is small.	B
2-3.9	Moderate	The impact of this modification on wetland integrity is clearly identifiable, but limited.	C
4-5.9	Large	The modification has a clearly detrimental impact on wetland integrity. Approximately 50% of wetland integrity has been lost.	D
6-7.9	Serious	The modification has a clearly adverse effect on this component of habitat integrity. Well in excess of 50% of the wetland integrity has been lost.	E
8.0-10	Critical	The modification is present in such a way that the ecosystem processes of this component of wetland health are totally / almost totally destroyed.	F

3.4. Wetland and upslope-catchment condition assessment

Wetlands in SA with its high evapo-transpiration rates (which are usually nearly double the regional rainfall) (Water Research Commision, 2011), depend on catchments to provide runoff and groundwater flows. Catchments of wetlands can be defined as the action of collecting water in an area, from the highest to the lowest collection point (and in the case of the wetland found on site, a valley bottom wetland and isolated hill slope seepage system) (Ollis *et al.* 2013). The condition of the wetland's catchment thus has a profound impact on the nature of the flow entering the aquatic ecosystem. Therefore, the extent of the catchment is determined, and its condition assessed by identifying possible impacts and source pollution. The aquatic systems of the study site forms part of a larger hydrogeomorphic drainage network and thus share a larger catchment. (Table 3-4) shows an example of catchment use descriptions and proportional percentages.

Table 3-4: Example of the percentile land use of the catchment of the study area

Catchment land use	Percentile (%)
Agriculture	-
Housing	10
Industrial	60
Roads	10
Natural (disturbed)	20
Natural (reference)	-
Total	100

CHAPTER 4 RESULTS

Six wetlands were assessed in the study using the newly developed wetland health citizen-science assessment tool based on land-cover. (Macfarlane *et al.* 2007) expresses wetland health as a measure that indicates the manner in which the state of the wetland has changed compared to its natural or reference condition. The citizen science tool examines the extent of land cover types present within the wetland and its catchment area and infers its PES state. The resultant overall magnitude of impact scores calculated from the tool are translated into PES categories. The overall magnitude of impact scores combines both the land cover type impacts on wetlands and their catchments. The PES results derived by the use of the citizen science tool is compared to results obtained from the Wet-Health tool and further analysed (Table 4-1).

Table 4-1: Overall magnitude of impact scores and PES scores derived from the current study compared to the scores derived by the dependent assessor from Imperata Consulting (Imperata Consulting, 2013, 2014a-c & 2016).

Regional (Provincial) Location of wetlands	Wetlands assessed	Overall magnitude of impact scores in the current study	PES category obtained in this study using CS methodology	Overall magnitude of impact scores from the independent assessor	PES category by independent assessor from Imperata Consulting (Wet-Health) was used
North-West	Rietfontein	3.1	C	4.2	D
	Bokkraal	2.2	C	3.6	C
	Kgaswane	0.4	A	0.4	A
Gauteng	Doornrandjie	2.8	C	3.6	C
	Sokhulumi	3.9	C	3.1	C
	Tweefontein	2.4	C	1.7	B

4.1. Wetlands assessed in North-West province

Rietfontein, Bokkraal and Kgaswane Nature Reserve wetlands and associated upslope catchments were assessed (Figure 4-1 - 4-6). Both Rietfontein and Bokkraal wetlands were found to have a PES

of C category and, Kgaswane wetland was found to have a PES of an A category (Table 4-1). A wetland with a PES of C is in a moderately modified state. This means that loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A wetland in a PES of A category means that the wetland is still natural or unmodified.

4.1.1. Rietfontein wetland

The Rietfontein wetland (Figure 4-1) was found to be moderately modified with a PES of C in this study (Table 4-2). When looking at the Google Earth image the area is largely a conservation area. However, field assessment revealed other land uses such as flagstone mining (Figure 4-1- catchment (b) and a house on the upslope catchment). The presence of the dirt road that crosses through the wetland was also observed together with some eroded areas in the wetland. The independent assessor found the wetland to be in a D category. In addition to the impacts noted in the current study, the steep slope and shallow soil nature of the catchment was taken into consideration, and that contributed to the impact directly on the wetland itself by causing erosion. Hence, a wetland that is largely impacted was recorded. The overall magnitude of impact score from this study was found to be 3.1 and that from the independent assessor was found to be 4.21, yielding different PES categories for the Rietfontein wetland (Table 4-2 & Table B-1.1).

Wetland



a



b

Catchment



Figure 4-1 a-d: Illustrates surrounding land use units within the Rietfontein wetland and its catchment area (Date taken 29/12/2017). (a- represent a wetland that is still pristine with a gravel road traversing it; b- represent wetland excavation; c- represents flagstone mining upslope of the catchment; d- catchment that is still natural except for flagstone mining).

Table 4-2: PES results – Rietfontein wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:		2.4
Total magnitude of impact from impacts in the wetland's upstream catchment:		0.9
Combined overall magnitude of impacts:		**3.1**
Present Ecological State Category (see next table)		**C**
Any impacts on the wetland which you consider to have been omitted or important influencing factors which have not been accounted for:		
None		
TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:		
Large improvement	□	**Supporting motivation:** If flagstone mining is stopped, impacts on the wetland upslope catchment will stabilise.
Slight improvement	■	
Remain the same	□	
Slight decline	□	
Large decline	□	

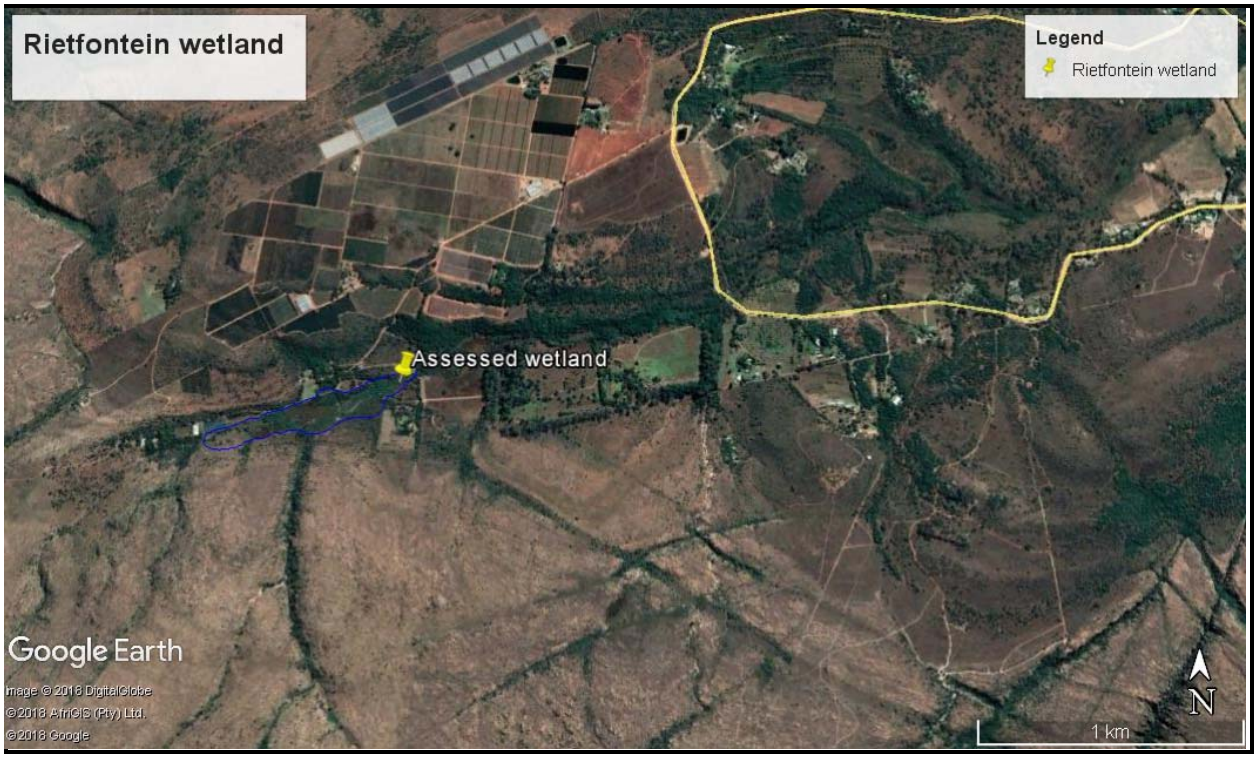


Figure 4-2: Illustrates the natural area surrounding the Rietfontein wetland as well as agricultural activities on the upslope catchment of the wetland.

4.1.2. Bokkraal wetland

The Bokkraal wetland (Figure 4-3) was found to be largely natural with a PES of C (Table 4-3). This is attributed to furrows that are identified on the wetland upslope catchment (middle reaches of the wetland) and minor cultivation practices within the wetland (Figure 4-4). There is a pond that is being fed water from the spring and the water is stored in a large reservoir for irrigation of orchards. The results from the independent assessor found the Bokkraal wetland was also determined the PES to be in a C category. Furrows were also identified as the main impact that contributes to transformation on water inputs and were considered to be large in this instance.

Wetland



a



b

Catchment



c

Figure 4-3 a-c: Illustrates surrounding land use units within the Bokkraal wetland and its catchment area. (Date taken 29/12/2017). (a- represent water abstraction for irrigation purposes; b- wetland that is still pristine and water flowing from the headwater; c- catchment that is still natural).

Table 4-3: PES results – Bokkraal wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:		1.7
Total magnitude of impact from impacts in the wetland's upstream catchment:		0.6
Combined overall magnitude of impacts:		**2.2**
Present Ecological State Category (see next table)		**C**
Any impacts on the wetland which you consider having been omitted or important influencing factors which have not been accounted for:		
None		
TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:		
Large improvement	☐	**Supporting motivation:**
Slight improvement	☐	The wetland will slightly improve if minor impacts such as cultivation and water abstraction can be reduced.
Remain the same	☐	
Slight decline	☒	
Large decline	☐	

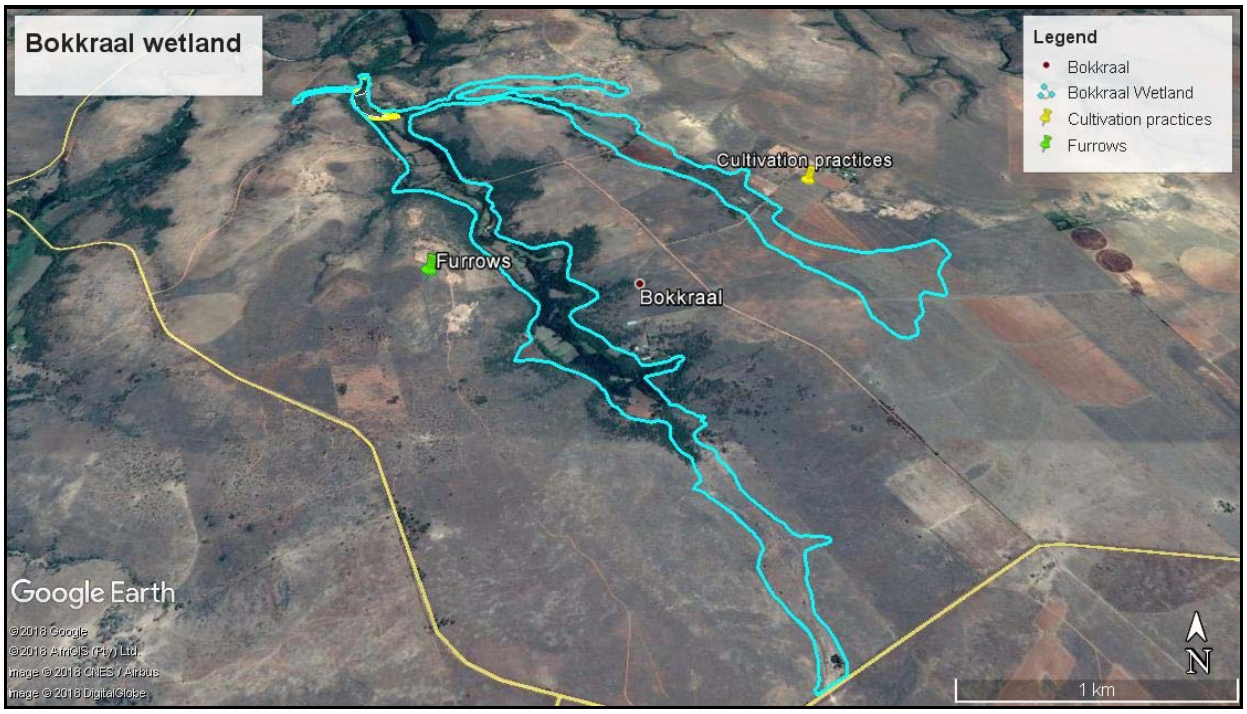
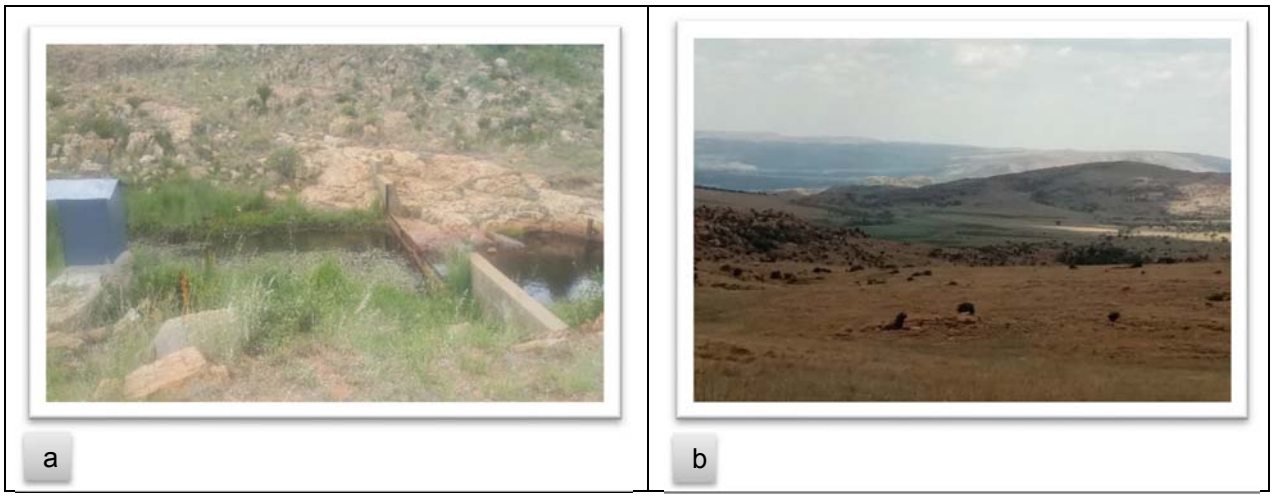


Figure 4-4: Land-use units (cultivation practices and furrows) on the upslope catchment area of the Bokkraal wetland.

4.1.3. Kgaswane Nature Reserve

Both the results from this study and that of the independent assessor found the PES of the Kgaswane Nature Reserve (Figure 4-5) to be an A category (Table 4-4 & Table B-3.1). A PES of an A category is expected in Kgaswane Nature Reserve due to its protected status.

Wetland



Catchment



Figure 4-5 a-d: Illustrates surrounding land use units within the Kgaswane Nature Reserve wetland and its catchment area. (Date taken 05/1/2018). (a- weir erected to slow down the velocity of water; b- represent a wetland that is still pristine; c and d - catchment that is still natural).

Table 4-4: PES results – Kgaswane Nature Reserve wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:	0.4
Total magnitude of impact from impacts in the wetland's upstream catchment:	0.0
Combined overall magnitude of impacts:	**0.4**
Present Ecological State Category (see next table)	**A**

Any impacts on the wetland which you consider having been omitted or important influencing factors which have not been accounted for:

None

TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:

Large improvement	☐	**Supporting motivation:**
Slight improvement	☐	Wetland condition is still natural with impacts that are insignificant
Remain the same	☒	
Slight decline	☐	
Large decline	☐	

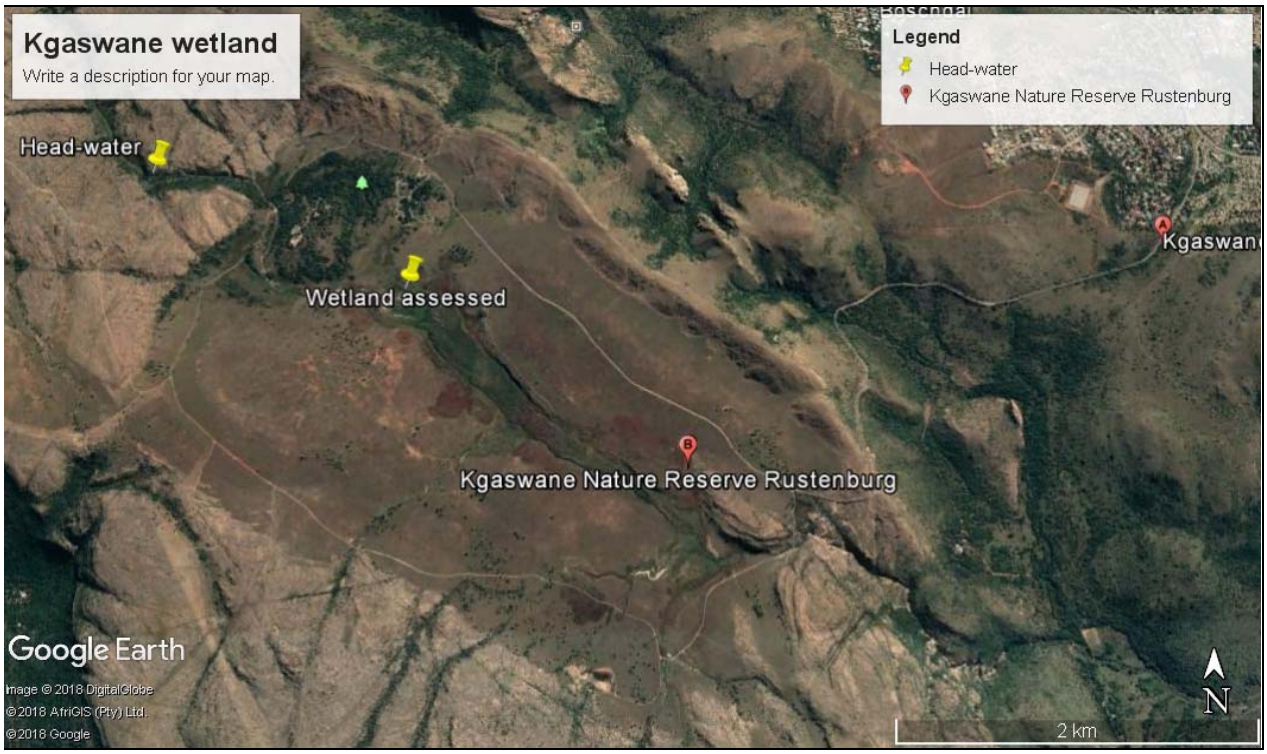


Figure 4-6: Illustration of Kgaswane wetland and its upslope catchment that is still in a natural condition.

4.2. Wetlands assessed in Gauteng province

Doornrandjie, Sokhulumi and Tweefontein wetlands and the upslope catchments were assessed. All wetlands were found to have a PES of C (Table 4-1). PES of C is moderately modified, i.e. “Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged”. Similar results were obtained by the independent assessor on all three wetlands.

4.2.1. Doornrandjie wetland

The PES of the Doornrandjie wetland (Figure 4-7) was found to be PES of C (Table 4-5). That is attributed to a small dam, livestock trampling, dirt roads crossing through a wetland and furrows identified on the upslope catchment of the wetland (Figure 4-8). Results from the independent assessor also found the PES of the Doornrandjie wetland to be category C. This was attributed to gully erosion and furrows that continue to cause a desiccation impact and the establishment and encroachment of invasive alien plant species into the target area.

Wetland



a



b

Catchment



c

Figure 4-7 a-c: Illustrates surrounding land use units within the Doornrandjie wetland and its catchment area. (Date taken 06/1/2018). (a- represents animal trampling within a wetland; b- represent foot-paths within a wetland; c- catchment that is still natural with minor development).

Table 4-5: PES results – Doornrandjie wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:	2.0
Total magnitude of impact from impacts in the wetland's upstream catchment:	0.9
Combined overall magnitude of impacts:	**2.8**
Present Ecological State Category (see next table)	**C**

Any impacts on the wetland which you consider having been omitted or important influencing factors which have not been accounted for:		
Livestock trampling causing erosion in the wetland		
TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:		
Large improvement	□	**Supporting motivation:** Artificial drainage can be reduced and rehabilitated to restore wetland functions
Slight improvement	□	
Remain the same	□	
Slight decline	■	
Large decline	□	

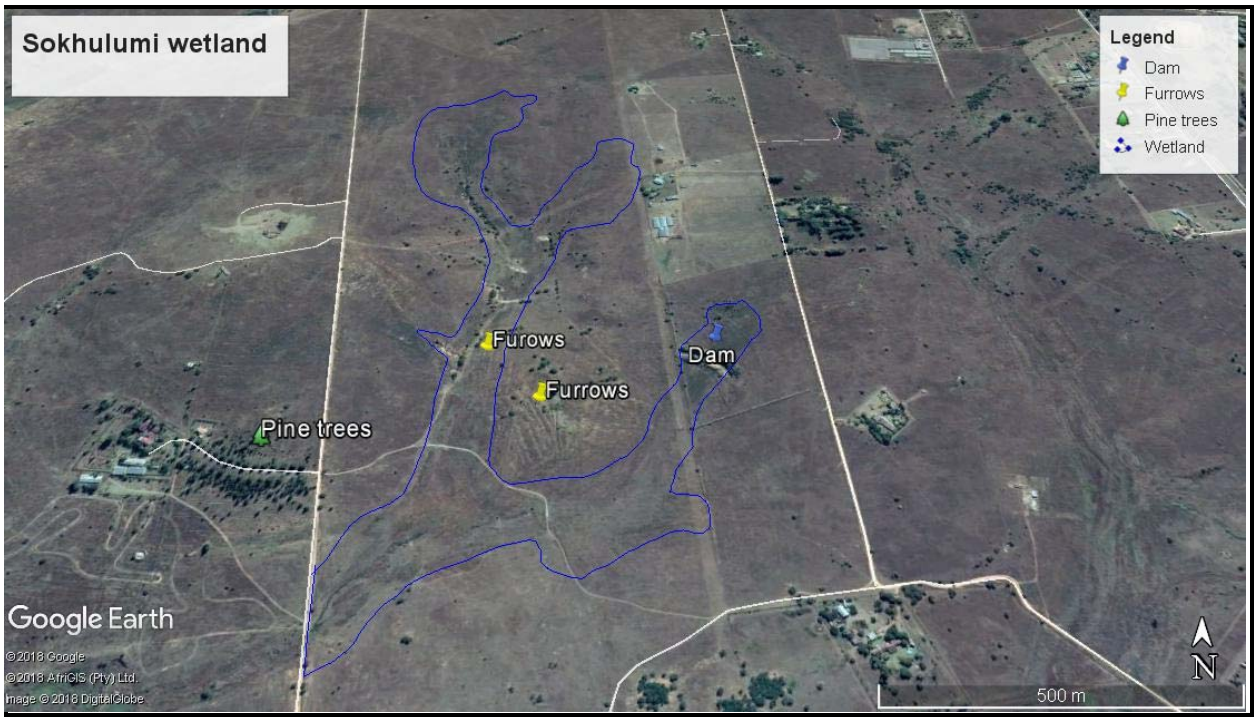


Figure 4-8: Illustration of furrows (wetland drainage) on the upslope catchment of the Doornrandjie wetland, wetland impoundment and alien vegetation in close proximity to the wetland.

4.2.2. Sokhulumi wetland

The PES of the Sokhulumi wetland (Figure 4-9) was found to be PES of C (Table 4-6). That is attributed to alien vegetation both in a wetland area (*Populus x canescens*) and in the upslope catchment (*Eucalyptus cf. camaldulensis*). Small dams, furrows (in draining towards the wetland and in the upslope catchment), livestock trampling, and dense settlement identified on the upslope catchment of the wetland (Figure 4-10). Results from the independent assessor also found the PES of the Sokhulumi wetland to be category C. This was largely attributed to impacts related to grazing, cultivation and hardened surfaces (villages) to catchment hydrology. Historical drainage has however caused notable changes to the three components of wetland health assessed.

Wetland



Catchment



Figure 4-9 a-d: Illustrates surrounding land use units within the Sokhulumi wetland and its catchment area. (Date taken 3/1/2018). (a- wetland drainage (furrows); b- alien plants within a wetland; c- animal tramping on the wetland's upslope catchment; d- settlements around the catchment of the wetland).

Table 4-6: PES results – Sokhulumi wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:	3.0
Total magnitude of impact from impacts in the wetland's upstream catchment:	1.3
Combined overall magnitude of impacts:	**3.9**
Present Ecological State Category (see next table)	**C**

Any impacts on the wetland which you consider having been omitted or important influencing factors which have not been accounted for:
Instream Dam and a dam on the upstream catchment **Alien vegetation- *Eucalyptus sp*. and Poplar trees**

TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:		
Large improvement	☐	**Supporting motivation:** Alien invasive plants are impacting on the hydrology of the wetland and hydrology is a main driver. Improvement can only be seen if there can be eradication of alien invasive plants and rehabilitation of the area with furrows.
Slight improvement	☐	
Remain the same	☐	
Slight decline	☐	
Large decline	☐	

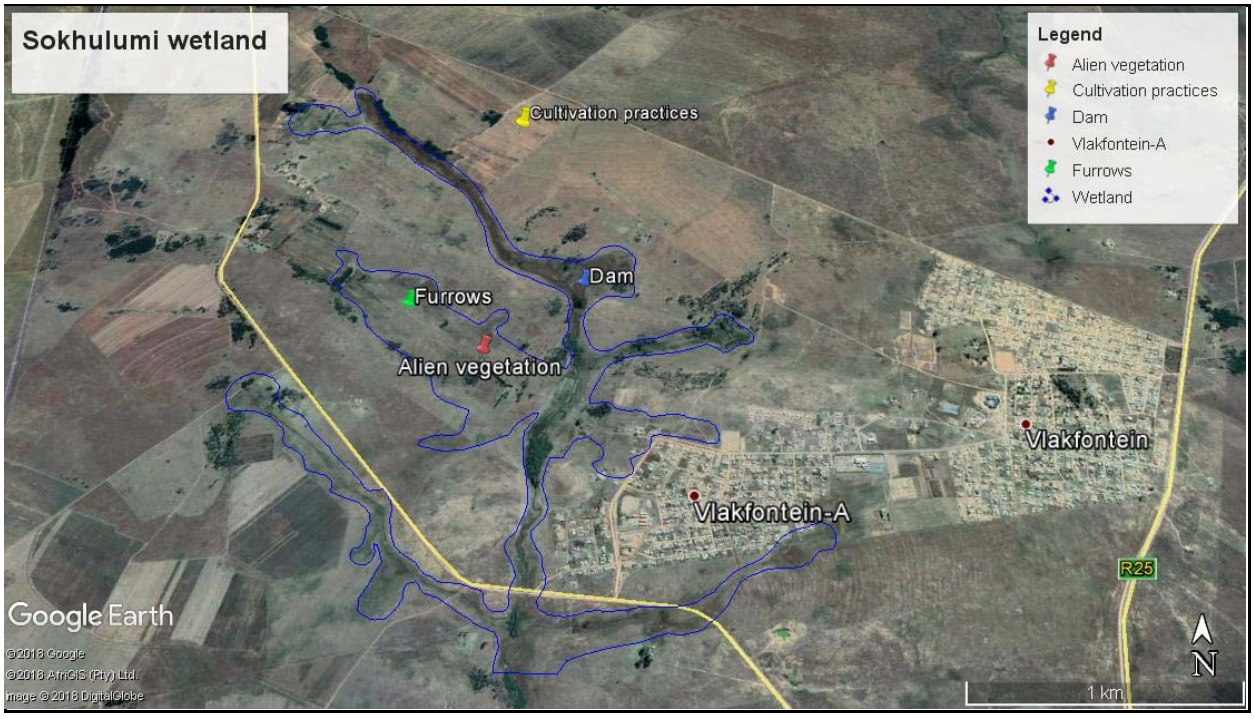


Figure 4-10: Illustration of alien vegetation and furrows with the Sokhulumi wetland and settlements and agricultural practices around the wetland's upslope catchment.

4.2.3. Tweefontein wetland

The PES of the Tweefontein wetland (Figure 4-11) was found to be PES of C (Table 4-7). That is attributed to a small dam, dirt roads crossing through a wetland, and cultivation practices identified on the upslope catchment of the wetland (Figure 4-12). Results from the independent assessor also found the PES of the Tweefontein wetland to be category B. This was attributed to a vehicle track transects through the upper reach of the seep wetland, two shallow furrows, and an enclosed spring that is used to supply drinking water to the nearby farmhouse. In addition to this, the presence of dense stands of the Category 2 alien and invasive species (Turpie *et al.* 2008) *Acacia dealbata*, along with a few smaller clumps of the Category 1b Alien Invasive Species (AIS) tree *Eucalyptus* cf. *camaldulensis* were also relevant.. Stands of *Acacia mearnsii* were also present in between stands of *A. dealbata,* presence of a furrow that is connected to the breached dam wall, but also intercepts runoff from the southern approach bordering the target area, and old cultivated lands border the wetland and encroached into the target area in the past. The difference in the PES category is derived from the different overall scores. The overall scores for the current study was found to be 2.4 and that from the independent assessor was found to be 1.7.

Wetland



a



b

Catchment



c



d

Figure 4-11 a-d: Illustrates surrounding land use units within the Tweefontein wetland and its catchment area. (Date taken 4/1/2018). (a- a pipe illustrating water abstraction from the wetland); b- a road traversing a wetland; c – agricultural practices on the wetland's upslope catchment; d- a dam within the wetland's upslope catchment).

Table 4-7: PES results – Tweefontein wetland and its upslope catchment assessment results.

Total magnitude of impact from impacts within the wetland:	1.7
Total magnitude of impact from impacts in the wetland's upstream catchment:	1.0
Combined overall magnitude of impacts:	**2.4**
Present Ecological State Category (see next table)	**C**

Any impacts on the wetland which you consider having been omitted or important influencing factors which have not been accounted for:
Dams within a wetland, furrows supplying water to the farmhouse

TRAJECTORY OF ANTICIPATED CHANGE OVER THE NEXT 5 YEARS:		
Large improvement	☐	**Supporting motivation:**
Slight improvement	☐	The system can only improve if furrows are closed and rehabilitated
Remain the same	■	
Slight decline	☐	
Large decline	☐	

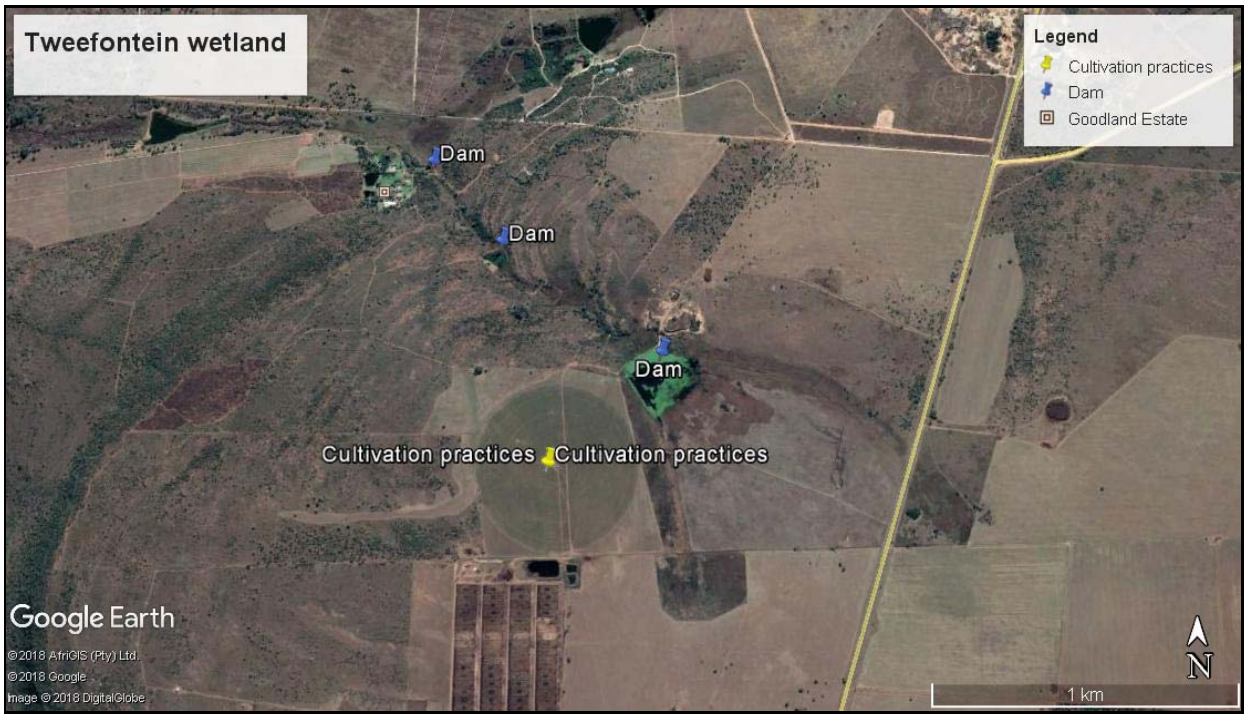


Figure 4-12: Illustration of built dams within the Tweefontein wetland and agricultural practices around the wetland's upslope catchment.

CHAPTER 5 DISCUSSION

The outcomes that resulted from of this study indicates that the newly developed method is an effective tool for assessing wetland health based on land-cover. This is the first study to compare the PES results derived by the use of two different methodologies to assess similar wetlands to determine how comparable these methods are to each other. A comparison of the new developed and the Wet-Health Level 1 methods revealed indications that the newly developed method can be invaluable to the wetland community in SA. One advantage of using the new developed land–cover based method as it builds from the Level-1 of the Wet-Health method is that, HGM units are not assessed individually like in the Wet-Health method. As a result, assessment of wetlands with the newly developed method can be the most time effective, considering that the field visit and PES calculations can be achieved within a day of conducting the survey. This is achieved by capturing all land use units in the scoring sheet during the field survey and noting comments for the land use that is not reflecting on the list of landcover/disturbance types provided. Once all these are captured on the spreadsheet, then a PES score is immediately derived unlike the Wet-Health method that needs interrogation of the intensity scores for each HGM unit. Therefore, aassessing individual HGM and then summing up all scores to achieve the overall health of the whole wetland as employed in Wet-Health assessment, can be time consuming particularly where several wetlands needs to be assessed to achieve a synopsis of the state of health of wetlands at a catchment scale. The overall magnitude of impacts for hydrology, geomorphology and vegetation for the wetland as a whole are calculated based on the area weighted average of the HGM units in the wetlands.

The success of the citizen-science tool in obtaining similar results when compared to that of the independent operator makes this method to be appealing although it also presents room for improvements. What stands out is that, firstly the method is designed to be used by multiple user group including citizen scientists. Whereas Wet-Health tool can only be used by operators with a basic tertiary education in agriculture and /or environmental sciences. The use of the new tool by citizen scientist can contribute in wetland education and awareness to the broader society and can ignite a greater understanding of wetland protection. What is imperative is achieving a change in attitude towards wetland protection from the grass-root level. Using a tool like this can achieve that. Using this tool can enable users to understand how human activities impacts on wetlands and their catchment, and that can assist in the sustainable use of these resources.

Furthermore, it has pre-assigned impact intensity scores that eliminates biased or subjective scoring in the field. Only minimal training is required for the tool to be used successfully. On the contrary, the Wet-Health's scoring function relies solely on best professional judgement. The Wet-Health presents a score for individual components assessed (hydrology, vegetation and geomorphology). The assessor has an

opportunity to assess impact scores derived from the three components against his/her own understanding. Should the scores and its associated description not match with the understanding of altered hydrology, geomorphology or vegetation, the scores can be adjusted. This approach encourages variability and different people are likely to get different results, making the result of the tool not to be repeatable. Hence the need for the refinement and updated of the Wet-Health tool (Kotzé *et al.* 2018; Ollis and Malan, 2014).

5.1. North-West Wetlands

Results obtained for wetlands in North-West were different for Rietfontein wetland when compared to the results from the independent assessor except for Kgaswane Nature Reserve and Bokkraal wetlands that produced similar PES results. Both tools produced a moderate A overall impact score of 0.4 for Kgaswane Nature Reserve wetland. Bokkraal wetland was found to be in a PES category of C and the independent assessor also obtained a C category. However, a noticeable difference was only observed in the overall impact score ranges. The Citizen Science (CS) tool produced a score of 2.2 indicating a low C and the independent assessor obtained a score of 3.6 indicating a high C using a Wet-Health tool.

The Rietfontein wetland results indicated a PES of a wetland to be in a C category and that of the independent assessor was found to be in a PES of a D category. A moderate C overall impact score of 3.1 was obtained compared to a low D score of 4.2 from the independent assessor. Variations are due to fact that more impacts by the independent assessor study were obtained, as compared to when using satellite imagery (Google Earth). Citizen-science tool is only used to obtain baseline information in the absence of in-depth studies. Once in-depth studies are conducted with field investigations thoroughly assessing wetland impacts, wetland information can be thus updated and possible management strategies can be investigated.

5.2. Gauteng Wetlands

The results of all wetlands in Gauteng Province indicated that the PES of wetlands to be in a C category, i.e. that modification of wetland integrity is clearly identifiable but limited for the Sokhulumi and Doornrandjie wetlands. Similar results were also obtained from the independent study where the Wet-Health tool was used, even though the citizen-science tool was tested for the first time in Gauteng. For Sokhulumi wetland, a high C score (3.9) was obtained when the CS tool was used compared to a moderate C score from the Wet-Health tool rendering the difference to be negligible. The same was also observed with the Doornrandjie wetland scores where a moderate C (2.8) was obtained using the

CS tool and a high C (3.6) obtained using the Wet-Health tool. The PES result obtained for Tweefontein wetland was different to that obtained by the independent assessor. A C category was obtained by using CS tool and a PES category of a B was obtained using the Wet-Health tool. Given that Gauteng Province is highly urbanised and is regarded as the economic hub of SA, more degraded wetlands are to be expected. However, in this case all Gauteng wetlands are situated in rural settings of the province, hence limited modification. The dependency of expert judgment in using the Wet-Health assessment tool has been highlighted amongst hindrances in wetland conservation (Ollis and Malan, 2014), making it difficult to be used in a country with wetlands that are continually being degraded. A more robust method, which can build on the strengths of both already existing methods that can be used on a broad-scale assessments (with field verification) was deemed to be the answer to already existing challenges in wetland management (Kotzé, 2015; Ollis and Malan, 2014).

This represents an alternative option for combatting challenges associated with wetland protection. Dumakude and Graham (2017) also demonstrated that this tool can be used by citizen-scientist for environmental education, and for environmental monitoring and management. In this study citizens from different educational background tested the tool for the first time, subsequent to being trained and results were positive when compared to that of experts in the wetland field. This tool presents a breakthrough in wetland protection and management in that local communities can actively participate in acquiring knowledge regarding wetland management and move beyond just awareness, to encouraging locals to take ownership regarding the protection of wetlands.

The study shows the need for further testing of this method on different types of wetlands located at various regions. A rapid, easily used and defensible tool should have a wide application. The method needs to be tested for its ability to distinguish between wetlands along a range of varying conditions, i.e. from natural (A) – highly degraded (F).

Thus far in SA, government initiatives encouraged public participation in wetland restoration processes. Successes with programmes like Working for Wetlands, Mondi Wetlands Projects and SA crane work have been documented (Barnes, 1998; Turpie *et al.* 2008). There is a need for a paradigm shift in natural resource management that will look at transferring knowledge and responsibility more to the citizens depending on these ecosystems (McKinley *et al.* 2017), (Aceves-Bueno *et al.* 2015). This newly developed citizen-science tool has the potential to achieve that especially in enhancing an understanding of the impacts that each land cover has in a wetland and its catchment. Furthermore, it can also support wetland monitoring that is still a challenge in SA (Goffredo *et al.* 2010).

5.3. Land use activities as a challenge

Land-use cover / or anthropogenic activities on the wetland and its upslope catchment have been highlighted as the driving forces of wetland degradation (Bond, 2002). It is imperative that the catchment of the wetland be well understood in order to determine its physical, chemical and biological characteristics and activities in it (Davies and Day, 1998). All wetlands having a PES of a C category (Doornrandjie, Sokhulumi and Tweefontein) in Gauteng, modification has been attributed to furrows, small dams and a dirt road transecting the wetland and formal and informal settlements in the case of Sokhulumi. All these impacts have the potential to intercept flow destined for the wetland, i.e. hydrology is mainly impacted as a result of altered flow or runoff regime. Tillage or effects of climate change have the potential to reduce water in permanently wet areas, therefore drying up wetlands. This in turn, can affect aquatic habitat and aquatic biota and infestation by alien vegetation can occur replacing indigenous plants, particularly in disturbed areas Grenfell *et al.* (2005). This was the case with the Sokhulumi wetland were more *Eucalyptus* species (*sp*.) were identified around the area that was having numerous historical furrows in the upslope catchment. The presence of *Eucalyptus sp.* also contributes to the drying up of the wetland as their water consumption is high. Since ecological processes occurring in a wetland are driven by hydrology, aquatic biota in the wetland's upslope catchment can say a lot about catchment's land-use.

Rivers and wetlands reflect the health and ill-health of the catchment, it is therefore of key to monitor them. According to (Dickens *et al.* 2003) "monitoring involves regularly collecting information overtime so as to measure the extent of variation from a predetermined standard or position, specified in the management objective/s". Therefore, development of citizen-based monitoring program can be a good start in wetland data generation that can aid in identifying gaps and help set priorities and allocate resources (Dickens *et al.* 2003). Therefore, a paradigm shift in natural resource management from a costly central control towards approaches in which citizens scientist play a much more meaningful role needs to be strengthened.

5.4. Assumptions

The researcher assumes that knowledge of the land-cover types and activities surrounding a wetland and its associated catchment can assist in gaining an insight relating to the ecological health of the wetland. Furthermore, it is assumed that if local communities participates in full routine monitoring of wetland attributes that can enhance their understanding of wetland ecological processes. This understanding will in turn inform them on how land cover impacts these processes in the short or long term.

5.5. Limitations of the research

This study forms part of the testing stages of this newly developed citizen science land-based wetland assessment tool. The outcome of this study forms a baseline for further testing and comparative studies with already assessed wetlands on a wider scale. Lessons learnt can aid in advancing wetland assessment practices in the SA, particularly by the citizens of the country.

Wetland and catchment delineation were not undertaken, which is a requirement when applying this method. Delineation requires a high level of experience, especially in the interpretation of the appearance of the soil in the field and in the identification of wetland plant species. It is advised that one should seek assistance from someone who is experienced with delineation or assessment of wetland that are already delineated.

Only six wetlands were assessed in this study due to limitations of time and budget. It is acknowledged that for consistent and conclusive outcome of the comparative study, more wetlands from different spatial and regional scale should be assessed.

Even though the whole wetland is assessed on satellite imagery, the on-site walk through were only done at specific positions informed by land cover units mapped at a desktop level. For example, other impacts such as abstraction through a pipe might be missed especially if the wetland assessed is too vast and such impact cannot be identified through Google Earth either.
One of the shortcomings is on hydrogemorphic (HGM) units not being accounted for in relation to activities around wetlands, although identification of wetland's HGM type allows an improved assessment of ecological condition.

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion with respect to the study objectives

The aim of the project as mentioned in Chapter 1 was to compare and determine the congruence or divergence of the results obtained by using the existing Wet-Health tool and the newly developed Citizen-Science Land-cover Based Wetland Assessment Methods for assessment of the wetland health. Specifically, the objectives of the study were:

- to determine the ecological condition or health of various wetlands by identifying the land-cover types present in wetlands, as well as in the upslope catchments by applying the land cover based wetland assessment tool.
- to identify the intensity and extent of these land-cover units and infer the magnitude of the impact on the ecological health of a wetland.
- to compare the results from the above assessments with those obtained from the independent Wet-Health assessments that have been carried out for the same wetlands.

According to the citizen science land-based assessment tool, selected Gauteng wetlands attained a score reflecting PES category of a C (i.e. moderately modified) except for Tweefontein wetland with a PES of a B category. North-West wetlands attained a PES score of an A category for Kgaswane Nature Reserve wetland and C category for both Bokkraal wetland and Rietfontein wetlands. This means that Kgaswane Nature Reserve wetland is still in a natural state. Bokkraal and Rietfontein wetlands are moderately modified when compared to the natural condition. Similar PES categories were obtained using both tools. This data suggests this tool can be used by locals to infer wetland condition by using land use activities. However, one limitation of this study is that only wetlands that are still in a good condition were tested (PES of A-C). Further testing of the tool would have to be conducted on a variety of wetlands surrounded by intense land-cover types and distribution.

The tool was able to infer the magnitude of the impacts since the intensity of impact score was pre-assigned, making it easy to apply the methods for both the wetland and its upslope catchment. The objectives of this study have been achieved and the assumptions has been reasonably confirmed. It can therefore be concluded that civil society can be integrated into wetlands routine monitoring applying the land-cover based method. Environmental awareness can therefore go beyond just learning about wetland benefits and uses, to taking full responsibility in managing these resources for future generations.

Four (4) out of six wetlands assessed, indicated the same PES score as those obtained from the independent assessor using the Wet-Health tool. That includes Bokraaal, Kgaswane, Sokhulumi and Doornranjie wetlands. However, out of the four (4) that were similar, the overall impact score ranges were fairly consistent for Kgaswane, Sokhulumi and Doornranjie wetlands. For Bokkraal wetland, a noticeable difference was observed on the overall impact score obtained using both tools. The Citizen Science (CS) tool produced a score of 2.2 indicating a low C and the independent assessor obtained a score of 3.6 indicating a high C using a Wet-Health tool. For Kgaswane wetland, an overall impact score of 0.4 was obtained using both methods. For Sokhulumi wetland, a high C score (3.9) was obtained when the CS tool was used compared to a moderate C score from the Wet-Health tool rendering the difference to be negligible. The same was also observed with the Doornrandjie wetland scores where a moderate C (2.8) was obtained using the CS tool and a high C (3.6) obtained using the Wet-Health tool. The study is therefore, promising in elucidating the wetland present state based on land cover impacts. This represents an improvement in wetland science knowledge in SA, especially regarding environmental education of the public. This will help people understand activities that have a detrimental impact on wetland health, and therefore people will be able to monitor these activities within wetlands in their communities. This, together with an open-mindedness in the academic community, government, Non-Governmental Organisations (NGO's) and other stakeholders dealing with wetland management in SA, is the new dawn for successful wetland conservation and management since its everyone's responsibility to take care of wetlands.

It is important, however, to understand limitations of the newly developed method. It can be invaluable in that it provides an affordable method that can be routinely and rapidly used. As to whether it can be consistently applied in various regions, will have to be further tested, including its repeatability and precision. Consideration of the wetland type or HGM unit will have to be factored in when the method is refined as impacts emanates from the modification of the main driver of the system e.g. Hydrology. Each wetland type/ HGM unit either receives water from upstream or from the catchment. Furthermore, wetland types like pans can rely on ground water discharge for their survival. Therefore, accounting for wetland types in the methods can become an improvement to the method.

Its repeatability and precision, will prove its value as an educational tool or data generating tool that can be validated and will be defensible in rigorous screening. However, it is a reliable and valuable tool for the scoping level purposes only. The method does not intend to replace intensive Wet-Health Level 2 assessments and it does not provide detailed information on the health of a specific wetland.

6.2. Recommendations

- There is an urgent need for the potential of citizen science tool in wetlands to be further tested in different regions and the method validated. Further testing across multiple regions can aid in assessing the robustness and reliability and accuracy of results.
- Participants from different educational backgrounds and school leaners should be encouraged to use this tool. However, adequate training on the chain of cause-and-effect between activities in the catchment which impact the wetland's hydrology, geomorphology and water quality should be conducted prior to testing.
- Repeatability of results need to be tested where different users from different backgrounds assesses one and the same wetland and results compared. Should results be repeatable, they can be compared with outputs from the independent assessor to conclusively assess their congruency.
- Recommendation outlined above addresses possible refinements of the tool that can contribute to wetland management in SA. However, these recommendations are not exhaustive, further testing can reveal more lessons to be learnt.
- The urgent need to preserve wetlands in the country has been documented by SANBI, Department of Water and Sanitation (DWS) and DEA (Driver *et al.* 2012). Reality is that government are faced with a challenge of being under staffed and wetland monitoring is yet to be implemented nationally (WRC, 2016). However, incorporating citizen science tool in the National Wetland Monitoring Programme (NWMP) to be collaborative with such community-based initiatives can benefit the country in the long run. Piloting needs to take place on a local scale and broadened, depending on the positive outcomes until such time all parties involved in wetland conservation and management can begin to trust citizen science as a collaborative approach.

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PUBLISHED AMENDMENTS TO THE NEMA: EIA REGULATIONS AND LISTING NOTICES

GNR 326 EIA Regulations (7 April 2017)
GNR 327 Listing Notice 1 (7 April 2017)
GNR 325 Listing Notice 2 (7 April 2017)
GNR 324 Listing Notice 3 (7 April 2017)

1. APPENDIX A

Completed scoring sheets for wetlands assessed using the newly developed citizen-science tool.

A-1. Rietfontein Wetland

Table A-1.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	
	Plantations of pine, wattle or poplar trees	5.7	
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	10
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	5
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	

frequently burnt			
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	85
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	

Table A-1.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	20
Built up dense settlements, roads railway lines and airfields	6.0	5
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	
Natural vegetation	0.0	75
Eroded areas	5.0	
Dams	4.5	

A-2. Bokkraal Wetland

Table A-2.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	5
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
	Plantations of pine, wattle or poplar trees	5.7	
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	10
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very frequently burnt	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	85
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	

Table A-2.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	5
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	10
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	
Built up dense settlements, roads railway lines and airfields	6.0	5
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	
Natural vegetation	0.0	85
Eroded areas	5.0	
Dams	4.5	

A-3. Kgaswane Wetland

Table A-3.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
	Plantations of pine, wattle or poplar trees	5.7	
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	5
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very frequently burnt	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	95

Table A-3.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	5
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	10
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	
Built up dense settlements, roads railway lines and airfields	6.0	5
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	
Natural vegetation	0.0	100
Eroded areas	5.0	
Dams	4.5	

A-4. Sokhulumi/ Vlakfontein Wetland

Table A-4.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	5
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	15
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
	Plantations of pine, wattle or poplar trees	5.7	
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very frequently burnt	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	85
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	

Table A-4.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	
Built up dense settlements, roads railway lines and airfields	6.0	30
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	20
Natural vegetation	0.0	50
Eroded areas	5.0	
Dams	4.5	

A-5. Doornrandjie Wetland

Table A-5.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	5
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	15
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
	Plantations of pine, wattle or poplar trees	5.7	
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	5
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very frequently burnt	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	90
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	

Table A-5.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	10
Built up dense settlements, roads railway lines and airfields	6.0	
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	
Natural vegetation	0.0	90
Eroded areas	5.0	
Dams	4.5	

A-6. Tweefontein Wetland

Table A-6.1: Overall impact intensity scores, ranging from 0 (no impact) to 10 (critical impact), for different land-cover types potentially occurring **within a wetland**.

Land-cover/disturbance types[1]		**Overall intensity of impact[2]**	**Extent (% of wetland)**
Annual crops, commercial, irrigated[2]	Conventional tillage, with severe artificial drainage[3]	7.5	
	Conventional tillage, with moderate artificial drainage[3]	6.1	
	Conventional tillage, with negligible artificial drainage[3]	4.9	
	Minimum tillage, with severe artificial drainage[3]	6.5	
	Minimum tillage, with moderate artificial drainage[3]	4.9	
	Minimum tillage, with negligible artificial drainage[3]	3.9	
Annual crops, commercial, not irrigated[4]	Conventional tillage, with severe artificial drainage[3]	7.1	
	Conventional tillage, with moderate artificial drainage[3]	5.6	
	Conventional tillage, with negligible artificial drainage[3]	4.5	
	Minimum tillage, with severe artificial drainage[3]	6.3	
	Minimum tillage, with moderate artificial drainage[3]	4.8	
	Minimum tillage, with negligible artificial drainage[3]	3.8	
Annual crops, subsistence[5]	With severe artificial drainage[3]	6.4	
	With moderate artificial drainage[3]	4.7	
	With negligible artificial drainage[3]	3.8	
Sugarcane[6]	With severe artificial drainage[3]	7.1	
	With moderate artificial drainage[3]	5.4	
	With negligible artificial drainage[3]	4.4	
Vineyards[6]	With severe artificial drainage[3]	6.2	
	With moderate artificial drainage[3]	4.5	
	With negligible artificial drainage[3]	3.7	
Orchards[6]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	5.0	
	With negligible artificial drainage[3]	4.2	
Planted pastures, annual[6,7]	With severe artificial drainage[3]	6.6	
	With moderate artificial drainage[3]	4.8	
	With negligible artificial drainage[3]	4.1	
Planted pastures, perennial[6,7]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	4.1	
	With negligible artificial drainage[3]	3.2	
Unmaintained perennial pastures	With severe artificial drainage[3]	5.4	
	With moderate artificial drainage[3]	3.7	
	With negligible artificial drainage[3]	2.6	
Recently abandoned lands[8]	With severe artificial drainage[3]	5.8	
	With moderate artificial drainage[3]	3.9	
	With negligible artificial drainage[3]	2.9	
Old abandoned lands[8]/ semi-natural areas[9]	With severe artificial drainage[3]	5.5	
	With moderate artificial drainage[3]	3.2	
	With negligible artificial drainage[3]	1.8	
Tree plantations	Plantations of eucalypt trees	6.4	
	Plantations of pine, wattle or poplar trees	5.7	

Land-cover/disturbance types[1]		Overall intensity of impact[2]	Extent (% of wetland)
Dense invasive alien plant infestation	Eucalypt trees	6.2	
	Pine, wattle or poplar trees	5.4	
	American brambles or other herbaceous invasive alien plants	4.0	
Erosion gullies	Erosion gully with negligible vegetation colonization	7.7	
	Erosion gully colonized with vegetation (mainly alien species)	6.2	
	Erosion gully colonized with vegetation (mainly indigenous species)	5.6	
Infrastructure (Urban and roads)	Formal residential	8.0	
	Informal residential	7.8	
	Commercial/industrial	8.8	
	Roads	8.2	5
Infilling without infrastructure	Natural sediment/soil used as infill	8.1	
	Foreign material/ solid waste (e.g. concrete rubble, plastic) used as infill	8.3	
	Mine dumps (spoil from the mining of underlying rock)	9.7	
Mines and quarries	Mining of clay or sand	8.8	
	Mining of underlying rock	10.0	
Sports fields or gardens[11]	Sports fields or gardens on the original wetland ground surface	4.2	
	Sports fields or gardens on wetland which has been infilled	7.4	
Recent sediment deposits	Recent sediment deposition (deep, resulting in loss of wetland conditions).	7.2	
	Recent sediment deposition (shallow, with wetland conditions persisting, although diminished).	3.4	
Dams, ponds and areas where were water supply has been artificially sustained	Deep flooding by dams/ artificial ponds or upstream of embankments, not used for aquaculture	6.0	
	Deep flooding by dams/ artificial ponds or upstream of embankments, used for aquaculture	6.7	
	Shallow flooding by dams/ artificial ponds or upstream of embankments in the unit[8]	3.1	
	Paddy fields	5.1	
	Seepage downslope of dams or embankments or areas where water supply has become more sustained (e.g. from irrigation return flows)[12]	2.8	
Natural, drained[12]	Natural vegetation with severe artificial drainage[3]	4.1	
	Natural vegetation with moderate artificial drainage[3]	2.1	
Natural, with wastewater flows[13]	Natural area of wetland into which the point-source release of untreated or poorly treated wastewater flows (see Figure 2 and 3).	5.1	
	Natural area of wetland into which the point-source release of treated wastewater flows (see Figure 2 and 3)	3.6	
Natural areas, very frequently burnt	Natural area of wetland which are burnt every year (e.g. as part of a firebreak)	2.2	
Natural areas with small on-site impacts	Natural area of wetland affected by scattered invasive alien plants or other minor impacts	1.2	95
Natural	Natural vegetation with negligible/no artificial drainage[3]	0.0	

[1]Intensive livestock grazing is not listed as a land-cover as such, but is assumed to be associated with planted pastures. If it occurs in any of the other land-cover types listed in the table (e.g. old lands) then it is suggested that the impact intensity score be increased by 2 points. Intensive livestock grazing is taken as a stocking rate of higher than 2 ha per large stock unit.

Direct pumping of water out of the wetland is also not covered because of the difficulty of assessing the extent and intensity of the effect on wetland hydrology (see Macfarlane et al. 2009). However, if information is available for assessing this impact then note this under additional notes and include the impact as artificial drainage, because it has a potentially similar effect to artificial drainage in lowering the water level in the wetland.

[2]Intensity of impact has been scored on a scale of 0 (nil/negligible) to 10 (critical) and Overall Intensity was calculated in Part 2 Table 3 as the average of the Hydrology, Geomorphology, Water quality and Vegetation scores, weighted as 3:2:2:2, as recommended by Macfarlane et al. (2009).

[3]Artificial drainage generally comprises open artificial drainage furrows (canals) which are visible on the ground surface, as well as including the draining effect of erosion gullies and incised stream channels. However, it may also comprise buried perforated pipes that are not visible on the ground surface. Severity of artificial drainage depends on spacing, depth and orientation of drainage furrows/pipes in relation to flows (including sub-surface) and tends to be most severe where drainage furrows/pipes are deep, dense and/or oriented to effectively intercept flows through the wetland. For all cultivation types where the level of artificial drainage is not known, it should be assumed to be moderate, given that most wetland cultivation is associated with at least some level of drainage.

[4]For annual crops, commercial, if it is unknown whether there is irrigation or not then it should be assumed that there is irrigation because annual crops are usually irrigated. If it is unknown whether tillage is conventional or minimum tillage then conventional tillage should be assumed because this is more widespread than minimum tillage.

[5]It is assumed that for subsistence agriculture, tillage is by hand and that limited supplementary irrigation takes place.

[6]It is assumed that annual planted pastures (usually ryegrass), vineyards and orchards are irrigated but perennial pastures and sugarcane are not irrigated.

[7]For planted pastures, it is assumed that fertilizer is applied periodically and the pasture intensively grazed. If it is unknown whether the planted pasture is annual or perennial then it should be assumed that it is annual, because in wetlands these are much more widespread than perennial pastures.

[8]Recently abandoned lands are taken as those that have been abandoned within the last year or two (following a period of being under cultivation, timber plantations or subject to some other form of physical disturbance which removed all of the natural vegetation, e.g. with a bulldozer) and are still strongly dominated by annual weedy (ruderal) plants. Old abandoned cultivated lands are those that have been abandoned for long enough for perennial indigenous species to become well represented. If it is unknown when, approximately, the lands were abandoned, then assume that they are old abandoned cultivated lands (i.e. lands abandoned more than three years ago) unless it can be seen that the area is still dominated by annual weeds. Old abandoned lands are likely to be more widespread than recently abandoned lands.

[9]Semi-natural vegetation refers to vegetation where the species composition has been significantly altered, but characteristic indigenous species are still reasonably well represented, although weedy and/or alien species are also generally well represented. If artificial drainage of the semi-natural areas is not known then it should be assumed to be negligible.

[10]The impact of a road is scored up to the edge of the road embankment. This impact does not include the damming effect of a road which is dealt with under “Dams and ponds”

[11]For sports fields and gardens, if it is unknown whether the area is infilled, then assume that it has been infilled because this is probably the most widespread option.

[12]Drained natural areas often support dense stands of common reed (*Phragmites australis*) or bulrush (*Typha capensis*), which outcompete most of the indigenous plant species.

[13]In order to determine whether point-source discharge of water is flowing through an area of wetland will generally require fairly close observation on the ground

If some areas in the wetland could potentially be placed in more than one land-cover class given in Table 3 then select that class which has the highest impact intensity score. For example if an area of wetland is subject to the point-source release of untreated wastewater into the wetland (Intensity score 5.1) as well as having scattered invasive alien plants (Intensity score 1.3) then the impact intensity score for this area is taken as 5.1.

Table A-6.2: Impact intensity scores for a range of different land-cover types potentially occurring in a wetland's upslope catchment.

Land-cover types	**Overall intensity of impact on the downstream wetland[1]**	**Extent in the wetland's upslope catchment**
Tree plantations, eucalypt	5.5	
Tree plantations, pine, wattle or poplar	4.5	
Orchards	5.5	
Vineyards	4.0	
Annual commercial (row) crops, irrigated	5.5	20
Annual commercial (row) crops, not irrigated	4.5	
Annual subsistence crops	4.0	
Sugarcane	4.0	
Mines and quarries	8.0	
Built up dense settlements, roads railway lines and airfields	6.0	
Golf courses, sports fields & low density settlements	3.0	
Old lands/ semi-natural vegetation	0.5	
Natural vegetation	0.0	78
Eroded areas	5.0	
Dams	4.5	2

[1]Intensity of impact is scored on a scale of 0 (nil/negligible) to 10 (critical). The impact intensity is based on considering impacts on Water quantity and pattern and on Water quality, as shown in Table 3 below and the rationale following the table.

Table A-7: level of confidence in the use of land-cover to infer wetland ecological condition according to the four respective components of condition (Kotzé, 2015).

Components of ecological condition	**Level of confidence**	**Rationale**
Hydrology	Intermediate	The strong link between land-cover and hydrology has been well demonstrated, but is potentially influenced by several site-specific factors, e.g. the inherent infiltration potential of the soil in the wetland's upslope catchment. For further information on these factors see Macfarlane et al. (2007).
Geomorphology	Intermediate	Land-cover relates directly to geomorphology in as far as eroded areas are identified as a specific land-cover type. However, land-cover can also have several indirect effects, but, as is the case with hydrology, these effects may potentially be influenced by several site-specific factors, e.g. the longitudinal slope of the wetland, which affects surface water flow velocity (and therefore the potential to erode). For further information on these factors see Ellery et al. (2009) and Macfarlane et al. (2007).
Vegetation	Moderately high	Vegetation itself is a prominent feature of land-cover and therefore the link between land-cover and vegetation is very direct. Nonetheless, this link is still subject to the influence of site-specific factors. For example, the land-cover type "old cultivated lands" may represent varying levels of recovery of the native vegetation, subject to the influence of site-specific factors such as soil type or varying levels of competition from invasive alien species. For further information on these factors see Macfarlane et al. (2007) and Corry (2012).
Water quality	Intermediate/ Moderately low	While the link between land-cover and water quality has been very well demonstrated, it is probably the least direct and clear of all of the components, and therefore potentially most influenced by several site-specific factors. For further information on these factors see Malan and Day (2012).

2. APPENDIX B

PES results for wetlands assessed using the Wet-Health tool by the independent assessor.

B-1. Rietfontein Wetland

Table B-1.1: Summary of present wetland health based on the Wet-Health assessment for Rietfontein wetland.

HGM Unit	Ha	Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
1	9	100	6.5	1	3.1	1	1.9	1
PES Category			**E**	↑	**C**	↑	**B**	↑
Wetland Impact Score			**4.21**					
Wetland PES			**D**					

B-2. Bokkraal Wetland

Table B-2.1: Summary of present wetland health based on the Wet-Health assessment for Bokkraal wetland.

Wetland Name	Ha	Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
Bokkraal	5.48	100	5.1	-1	2.3	-1	2.5	-1
PES Categories			**D**	↓	**C**	↓	**C**	↓
Wetland Impact Score			**3.57**					
Wetland PES			**C**					

B-3. Kgaswane Wetland

Table B-3.1: Summary of present wetland health based on the Wet-Health assessment for Kgaswane wetland.

Wetland Name	Ha	Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
Kgaswane	62	100	0.0	-1	1.4	-1	0.2	-1
PES Categories			**A**	↓	**B**	↓	**A**	↓
Wetland Impact Score			**0.43**					
Wetland PES			**A**					

B-4. Doornrandjie Wetland

Table B-4.1: Summary of present wetland health based on the Wet-Health assessment for Doornrandjie wetland.

Wetland name	Ha	Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
Doornrandjie	17	100	5	-1	1.4	-1	3.7	-1
PES Categories			**D**	↓	**B**	↓	**C**	↓
Wetland Impact Score			**3.60**					
Wetland PES			**C**					

B-5. Sokhulmi Wetland

Table B-5.1: Summary of present wetland health based on the Wet-Health assessment for Sokhulumi wetland.

HGM Unit	Ha	Extent (%)	Hydrology		Geomorphology		Vegetation	
			Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
1	195	100	5.0	1	2.0	1	1.2	1
PES Category (See Table 5.29)			**D**	↑	**C**	↑	**B**	↑
Wetland Impact Score			**3.08**					
Wetland PES			**C**					

B-6. Tweefontein Wetland

Table B-6.1: Summary of present wetland health based on the Wet-Health assessment for Tweefontein wetland.

Tweefontein wetland		**Status Quo**
Size of Wetland (Target Area)		1.1 ha
Impact Scores	Hydrology	1.0
	Geomorphology	1.8
	Vegetation	0.9
	Overall	1.7
Ecological Category (combination of all three ecological integrity components)		**B**