BIODIVERSITY OF KRUGERSDORP GAME RESERVE

July 2015

Specialist report

Biodiversity of Krugersdorp Game Reserve

SPECIALIST REPORT

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to the authors (listed above) by Mogale City Local Municipality, desktop data and information extracted from existing reports and public datasets, information generated by field surveys during the project and consultation with stakeholders. Whilst the authors have exercised all due care and diligence in reviewing the supplied information and preparing the contents of this Report the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data and information. The authors do not accept responsibility for any errors or omissions in the supplied information and do not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of the investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which the authors had no prior knowledge nor had the opportunity to evaluate.

EXECUTIVE SUMMARY

INTRODUCTION

The Krugersdorp Game Reserve (KGR) is a 1 300 ha municipal game reserve, established in the 1960s, outside the town of Krugersdorp in Mogale City Local Municipality. The MCLM is applying for nature reserve status for the KGR under the National Environmental Management: Protected Areas Act (Act 57 of 2003). As part of this process, a baseline biodiversity assessment of the KGR was requested.

The scope of the assessment was to

- Define the vegetation communities and habitat types of the reserve
- Map the wetlands and describe wetland characteristics
- Describe the health of the aquatic ecosystems of the Tweelopiesspruit
- Describe the avian, mammal and herpetofauna of the reserve in terms of suitability of habitats for different species assemblages
- Describe the potential for threatened species to occur on the reserve and record any observations of threatened species
- Map the soils of the reserve
- Define the veld condition and grazing capacity of the reserve
- Provide recommendations for improved management of the biodiversity of the reserve.

SITE DESCRIPTION

Topographically and geologically, the reserve is divided into two main portions: a southern plateau underlain by arenite of the Black Reef Formation with outcroppings of Malmani subgroup dolomite, and a northern, lower-lying and steeper portion underlain by dolomite. These two portions are separated by an escarpment of Black Reef and Government Reef quartzites.

The Tweelopiesspruit, once a non-perennial stream, bisects the reserve from north to south. The river has flowed continuously since mine water decant began discharging acid mine drainage (AMD) into the stream in 2003. Several seeps, non-perennial drainage lines and springs are scattered around the reserve. At least one spring does not show contamination by AMD.

SOILS

The soils of the reserve are largely shallow Huttons and Mispahs (less than 25 cm deep) overlying bedrock. In footslopes and drainage lines, patches of deeper soils, in particular Oakleaf, Milkwood, Tukulu and Bainsvlei are found. A deeper patch of Hutton soil in the South-Eastern portion of the reserve, east of the main access road, may have been ploughed in the distant past. The soils are erodible and there is severe gully erosion on the banks of the Tweelopiesspruit. Managing runoff from roads, maintenance of dirt roads, and management of 4x4 routes is essential to prevent further erosion.

There is a possibility of heavy metal contamination of the soil through dust from nearby mine dumps, and through subsurface movement of Acid Mine Drainage. Specific laboratory tests would be required to determine whether this is the case.

VEGETATION

A vegetation survey across the reserve identified three broad vegetation groups (grassland, woodland and wetland) divided into 10 communities. Several of these communities were identified from only one survey site.

Group	Name	Description
Grassland		
1	Rocky grassland	Selectively grazed, deeper soils. Covers most of the area of the reserve. Includes patches of transformed and degraded grassland.
1.1	Cynodon grassland	Heavily grazed, Shallow soils, Grazing lawns. Invaded by *Richardia braziliensis* Subset of group 1
1.2	Kikuyu grassland	Kikuyu lawns and invaded areas. Dominated by exotic grasses and forbs. Drainage lines include poplar
1.3	Eragrostis grassland	Grassland on rocky ridge. Possibly old lands (>100 years)
Woodland		
2.1	Riverine shrubland	Riverine shrubland
2.2	Sparse Dolomite woodland	Shallow soils, Infrequent fire. Dolomitic grassland with scattered bushclumps
2.3.1	Open dolomite woodland	Steep, rocky, wooded slope. Herbaceous layer entirely dominated by *Seteria lindenbergiana*. Transitional to Celtis woodland
2.3.2	Celtis woodland	Tall riverine woodland
2.3.3	Unclassified riverine woodland	Tall closed woodland
Wetland		
3	Wetland vegetation association	Riverine grassland, seeps and drainage lines form a heterogenous wetland association.

The dominant vegetation community was the short, dense, tufted grasslands covering most of the reserve. These grasslands were dominated by Increaser 2 and 3 grasses (signifying heavy grazing and selective grazing), with moderate forb diversity at the time of the survey (December 2014). Some areas of grassland had a small but potentially significant woody component in the form of clumps of *Diospyros* and *Acacia*, which may encroach into the grasslands and substantially alter the vegetation structure.

There were two important sub-groups within the grassland community: kikuyu grasslands (grasslands either planted to or invaded by *Pennisetum clandestinum*), and Cynodon grasslands (very heavily grazed areas dominated by the perennial creeping grass *Cynodon dactylon*). Both of these communities had low forb diversity and were invaded by exotic forbs, in particular the mat-forming *Richardia braziliensis*.

The woody areas showed more complexity in composition, with several sub-communities, mostly described by only one survey site. Along the northern, steeper portion of the Tweelopiesspruit, a tall, mature riparian forest dominated by *Celtis africana* occurred. This woodland type was contiguous with other woodland communities with decreasing proportions of *Celtis* and increasing proportions of *Diospyros* and microphyllous trees, particularly *Acacia karroo*. Towards the margins of the woodlands, more grassland components became apparent. The woody communities mainly occurred in drainage lines, rocky areas and riverine areas in the north of the KGR. The north-west of the reserve, inside and around the lion enclosure, was particularly characterized as an open savanna with dense woodlands in drainage lines. This may be as a result of lower fire frequencies and lower herbivore numbers inside and around the lion enclosure. Patches of short, even-aged cohorts of *Acacia karroo* could be seen emerging on the margins of dense woody clumps.

The veld condition was calculated to be average to good, apart from the *Cynodon* grasslands which were in poor condition.

A number of invasive alien plant species were observed on the reserve. Existing alien plant control programmes will need to be continued, and expanded to include species currently not controlled. Kikuyu (*Pennisetum clandestinum*) is a major threat where it invades drainage lines and bottomlands. A monitoring and management strategy for alien plants is recommended.

The reserve is severely overstocked at more than double its carrying capacity. The total grazing capacity of the reserve was estimated to be 216 animal units (AU), which is substantially less than the estimated stocking density of 419 AU (grazers) and 529 AU (total, including browsers) in April 2015.

A proposal to reduce stock numbers was examined. The proposal would reduce the stocking density of grazers to 115 AU, which would (a) allow the veld to rest from the current heavy grazing; and (b) allow management more flexibility in determining the future management strategy, until stock numbers recover to recommended levels. The proposal would reduce the ratio of selective grazers to bulk grazers to 1:3, which is still greater than recommended. A ratio of 1:1 or more of bulk to selective grazers is recommended for highveld grasslands.

Category	Total AU	Grazing AU	Proposed Grazing AU
Bulk grazer	48	48	37
Selective grazer	260	260	51
Mixed feeder	207	110	24
Browser	14	1	1
Grand Total	529	419	115

WETLANDS

The wetlands associated with the Tweelopiesspruit and its tributaries are the most important wetland features of the KGR. The section of the Tweelopiesspruit associated with the KGR can be classified into a northern riparian and southern wetland area. The wetland area is driven by an artificial input of highly polluted water in a landscape with gentle slopes. Low energy water flows consequently allow for saturated soil conditions and the persistence of hydrophytic vegetation. The steep slopes of the northern section of the reserve lead to high energy water flows and riparian conditions.

Hydro-geomorphic types	Description
Riparian habitat	The watercourse in the northern section of the reserve.
Valley bottom with a channel	In the southern section of the reserve, the watercourse is characterised by a depositional environment. Stands of *Phragmites australis, Typha capensis*, and various sedge and grass species are characteristic of this system. Species recorded here include *Cyperus denudatus, Paspalum dilatatum, Fuirena pubescens, Kyllinga erecta, Pycreus macranthus, Fuerena pubescens and Schoenoplectus corymbosus*
Seepage Wetlands	A seepage component is evident along the channelled valley bottom wetland recorded in the southern section of the KGR. Stands of the grass *Imperata cylindrica* are characteristic of this area, together with some evidence of lateral water movement in the soil including orange mottling within 50cm of the soil surface and oxidation along the root sheaths of plants that grow in this area.
Drainage lines	In the KGR several drainage lines occur on steep slopes, draining into the Tweelopiesspruit in the northern section of the site.

The Present Ecological State of the wetland is calculated as E (The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.). The wetland is in a highly altered state from its original reference condition. However, particularly the reed beds are highly functional in terms of their effect on improving water quality.

The EIS score is slightly higher than expected (C - Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale) since the wetland falls within a Nature Reserve. Furthermore, the degree of data available on particularly water quality, creates the ideal opportunity for future research.

AQUATIC BIOMONITORING

Aquatic biomonitoring using the SASS5 system has been conducted previously in the KGR since AMD began decanting into the Tweelopiesspruit. Two additional surveys (winter and summer) were conducted for this study.

All sites along the Tweelopiesspruit showed poor to critical SASS5 scores, which improved slightly to a “fair” score at the downstream end of the Tweelopiesspruit as it exited the reserve. The pH of the Tweelopiesspruit

was slightly below neutral during the dry season survey, but dropped to acidic (pH 3.2 – 3.9) in the wet season, probably as a result of non-treatment of acid decant from the adjacent mine. The pH of the tributary of the Tweelopiesspruit, which was unaffected by the AMD, remained unchanged between the dry and wet season surveys. Dissolved oxygen was low for all sampling sites, but increased further downstream (from ~86% to ~95%). The dissolved oxygen of the tributary was lower, at ~76%.

The overall river health of the Tweelopiesspruit and tributary was classified as E- (seriously modified) during the dry season, with the downstream portions of the Tweelopiesspruit improving to D (poor) during the wet season.

FAUNA

An assessment of habitat suitability of the reserve for birds, mammals, reptiles and amphibians was conducted, combined with a review of literature and data sources on faunal distribution, threatened species and habitat preferences.

The KGR provides a diversity of different habitat types (terrestrial, arboreal, wetland and rupicolous [rocky] habitats). Of these, the terrestrial component is the largest and has the potential to host the most diversity of species. The wetland habitats, especially the riparian areas along the Tweelopiesspruit, are in poor condition and the poor aquatic biomonitoring results indicate very low likelihood of finding aquatic animals.

The reserve is at an important crossroads of bird distribution, as it is located at the transition of the savanna and grassland biomes (north and south) and at the boundary of moist and arid grasslands (east and west). As rainfall varies from year to year, bird species characteristic of wetter or dryer environments are likely to temporarily shift into and out of the reserve. The reserve is currently well connected with adjacent grasslands and provides an important refuge for birds from a substantial surrounding area.

Sixty-six species of mammals are still likely to be part of the present-day mammal species assemblage, nine of which are red listed species; the occurrence of 27 species was confirmed.

Out of the maximum of 384 bird species expected for the site during 1987-1991, and including the 342 species so far reported since 2009 for the 12 pentads on and around the site (SABAP2), 311 bird species have a **high** (132 species, 103 confirmed), **medium** (103 species, 16 confirmed) or **low probability** (76 species, 5 confirmed) to occur on site, based on the habitats available. Site visits and online records confirmed 124 species. However, a number of species dependent on wetland or riparian systems (for example, waterfowl, fish eagle, storks, herons) are likely to have lower than expected probabilities of occurrence due to the poor condition of the Tweelopiesspruit.

Fifty-nine reptile species (3 confirmed) and 15 amphibian species (3 confirmed) are likely to occur on site). The poor condition of the Tweelopiesspruit is likely to restrict populations; however, there are several artificial and natural water points scattered around the reserve which are unaffected by the Acid Mine Drainage which provide habitat for amphibians. Populations of Giant Bullfrog have been recorded in grasslands adjacent to the reserve, but there has been no record of the species on the reserve for 17 years.

The connectivity of the reserve to adjacent grasslands is good, with the exception of the N14 highway on the northern boundary and the major road on the southern boundary. However, the Tweelopiesspruit provides a corridor of migration to the north.

There is a dearth of raptors, which is of concern. Improved management of the grasslands (following fire and stocking recommendations laid out in this report) would help to improve the diversity and abundance of small prey animals.

CONCLUSIONS AND RECOMMENDATIONS

A vision and mission needs to be developed for KGR before detailed recommendations can be proposed. Currently, several different, and often contradictory, plans for the reserve are being informally discussed by the reserve management.

The National Environmental Management: Protected Areas Act opens with the statement

> *To provide for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes…*

and therefore biodiversity and ecosystem integrity should be key to the vision of the KGR.

The biggest single influence on every aspect of the functioning of the KGR is undoubtedly acid mine drainage. The water quality and ecological integrity of the Tweelopiesspruit has been severely degraded, affecting the entire aquatic food chain. There are potentially serious health effects on animals and humans that drink the water. Subsoil movement of harmful elements from the Tweelopiesspruit outwards has been detected. There is a high risk of sinkhole formation in the dolomite compartments underneath the KGR and adjacent urban areas.

Continued monitoring of the water quality of the Tweelopiesspruit and other springs is essential. Movement of AMD from the mine void to adjacent aquifers is possible which would result in contamination of aquifers used for drinking water.

Remediation measures must be implemented in partnership with government and the private sector.

Other key recommendations in the reserve include:

- Soil erosion, as a result of low clay content, steep slopes and dispersive soils. All roads and runoffs need to be designed to prevent soil erosion. Several existing tracks urgently require rehabilitation or closure. Several active erosion gullies on the Tweelopiesspruit must be rehabilitated
- Stocking density. The metabolic mass (animal units) on the reserve needs to be reduced substantially from the April 2015 game count, to below 216 AU grazers. The proportion of bulk grazers (e.g. zebra, buffalo, cattle) needs to be increased and the proportion of selective grazers (small and medium antelope) decreased.
- A fire management plan with five blocks, burned rotationally in the dormant season, was proposed. Point-source ignitions (igniting block burns from a single point or several points rather than all along the boundary) were recommended to encourage patch burning for biodiversity
- Alien plant control measures must continue, and additional measures for other species like kikuyu should be implemented.
- A zoning plan for future developments in the reserve is required to avoid impacts on wetlands and riparian areas.

LIST OF ACRONYMS

AMD	Acid Mine Drainage
ASPT	Average score per taxon
AU	Animal Unit (equivalent to a 450 kg steer)
DEA	Department of Environmental Affairs
DEAT	(former) Department of Environmental Affairs and Tourism
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	(former) Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity (wetlands)
FRAI	Fish Response Assessment Index
FSA	Fish Support Area
GDARD	Gauteng Department of Agriculture, Environment and Rural Development
GPS	Global Positioning System
GSM	Gravel, Sand and Mud
Ha/AU	Hectares per animal unit
IHAS	Integrated Habitat Assessment System
KGR	Krugersdorp Game Reserve
mamsl	Metres above mean sea level
MBCP	Mpumalanga Biodiversity Conservation Plan
MCLM	Mogale City Local Municipality
NEMA	National Environmental Management Act (Act 107 of 1998, as amended)
NEMA	National Environmental Management Act 107 of 1998
NEMBA	National Environmental Management: Biodiversity Act (Act 10 of 2004)
NEMPA	National Environmental Management: Protected Areas Act (Act 57 of 2003)
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act 36 of 1998
PES/C	Present Ecological State/Category
RHP	River Health Programme
RIVCON	River Condition
RWQO	Receiving Water Quality Objective
SASS5	South African Scoring System version 5
SAWQG	South African Water Quality Guideline
TDS	Total Dissolved Salts
TWQR	Target Water Quality Range
VEGRAI	Riparian Vegetation Response Assessment Index

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Part 1: Overview

1 INTRODUCTION

1.1 Overview

Krugersdorp Game Reserve (KGR) is a municipal nature reserve within Mogale Municipality. The Municipality plans to have the KGR gazette as a Nature Reserve under the National Environmental Management: Protected Areas Act (NEMPA) (Act 57 of 2003). As part of this process, a detailed environmental management plan is required, which in turn requires a baseline assessment of the current biodiversity and ecosystem status of the reserve.

The specialist studies were combined into one integrated assessment rather than multiple individual assessments. The aim was to provide a common spatial framework for all to work from (the landscape units, see below) and to combine the expertise of different specialists in one multi-disciplinary study. This was achieved through two workshops: a planning workshop where the field sampling approach was determined, and an analysis workshop where the results of the surveys were collated and discussed to determine the best approach for managing the biodiversity of the reserve.

1.2 Objective

To provide a baseline assessment of the current status of the KGR's biodiversity, in particular habitat types, vegetation communities, aquatic health and threatened or protected species, in order to inform recommendations for the environmental management plan.

1.3 Scope of work

- Description of vegetation communities and potential habitats for threatened plants
- Description of veld condition
- Soil map
- Description of wetland health
- Description of habitat suitability for small animals (small mammals, reptiles, amphibians, birds)
- Description of health of aquatic ecosystems
- Recommendations for conservation of biodiversity

1.4 Background and resumes of consultants

Aspect investigated	Specialist	Qualifications and SACNASP registration number	Dates of field surveys
Technical project management; veld and landscape functioning, report editing, mapping	Alan Short	MSc (Grassland Science) (University of KwaZulu-Natal) SACNASP 400098/14	Dec 2014
Overall project administration; wetlands	Antoinette Bootsma	BSc(Hons) SACNASP 400222/09	Dec 2014
Soils	Mariné Pienaar	MSc (Agric) (University of Pretoria) SACNASP 400274/10	Dec 2014
Vegetation and botanical diversity	Antoinette Eyssell-Knox	MSc.(University of Pretoria) SACNASP 400019/11	Dec 2014
Water quality in aquatic systems	Lorainmari van den Boogert	MSc. Plant Sciences (University of Pretoria) SACNASP SASS5 accredited	Sep 2014; Jan 2015
Avifauna	Alan Kemp	PhD (Rhodes University) SACNASP 400059/09	Dec 2014
Mammals	Ignatius (Naas) Rautenbach	PhD (University of Natal) SACNASP 400300/05	Dec 2014
Herpetofauna	Jaco van Wyk	MSc (University of the Free State) SACNASP 400062/09	Dec 2014

Alan Short is a rangeland ecologist with 15 years' experience in South Africa and Mozambique. He has published several papers and numerous reports on veld management for livestock production and biodiversity management, and has collaborated on multi-disciplinary research projects investigating fire, grazing, soils, biodiversity and other ecosystem characteristics. He has practiced as an independent consultant since October 2013. His scientific career includes 5 peer-reviewed papers, numerous conference papers, unpublished technical reports to land-users, and several popular articles. He is an associate editor of the *African Journal of Range and Forage Science*.

Antoinette Bootsma is a wetland specialist who has conducted numerous wetland surveys for Environmental Impact Assessments and wetland delineations. She is the founder and director of Limosella Consulting and has worked across South Africa on multiple projects.

Antoinette Eyssell-Knox is a botanist and horticulturalist with experience at the South African National Biodiversity Institute and as an independent consultant. She has conducted multiple botanical surveys across South Africa.

Mariné Pienaar is the founder and director of Terra Africa, which conducts soil assessments and soil mapping for agriculture, mining, industry and Environmental Impact Studies across Africa.

Dr Ignatius (Naas) Rautenbach is a former director of the Transvaal Museum and author of numerous papers and books on mammals of southern Africa, including 85 scientific publications in peer reviewed subject journals, 18 popular articles, 10 books, and >400 contractual EIA research reports. He has extensive field work and laboratory experience in Africa, Europe, USA, Alaska, Brazil and Mexico.

Dr Alan Kemp is a distinguished ornithologist and former manager of the Transvaal Museum of Natural History. His publishing career includes 53 scientific papers or notes in refereed journals; 48 papers at national and international congresses; 6 scientific (unpublished) reports on environment and natural resources; 74 popular scientific papers and 18 contributions in books. He remains active in an editorial role for Bird Conservation International, and has been an independent consultant since 2005.

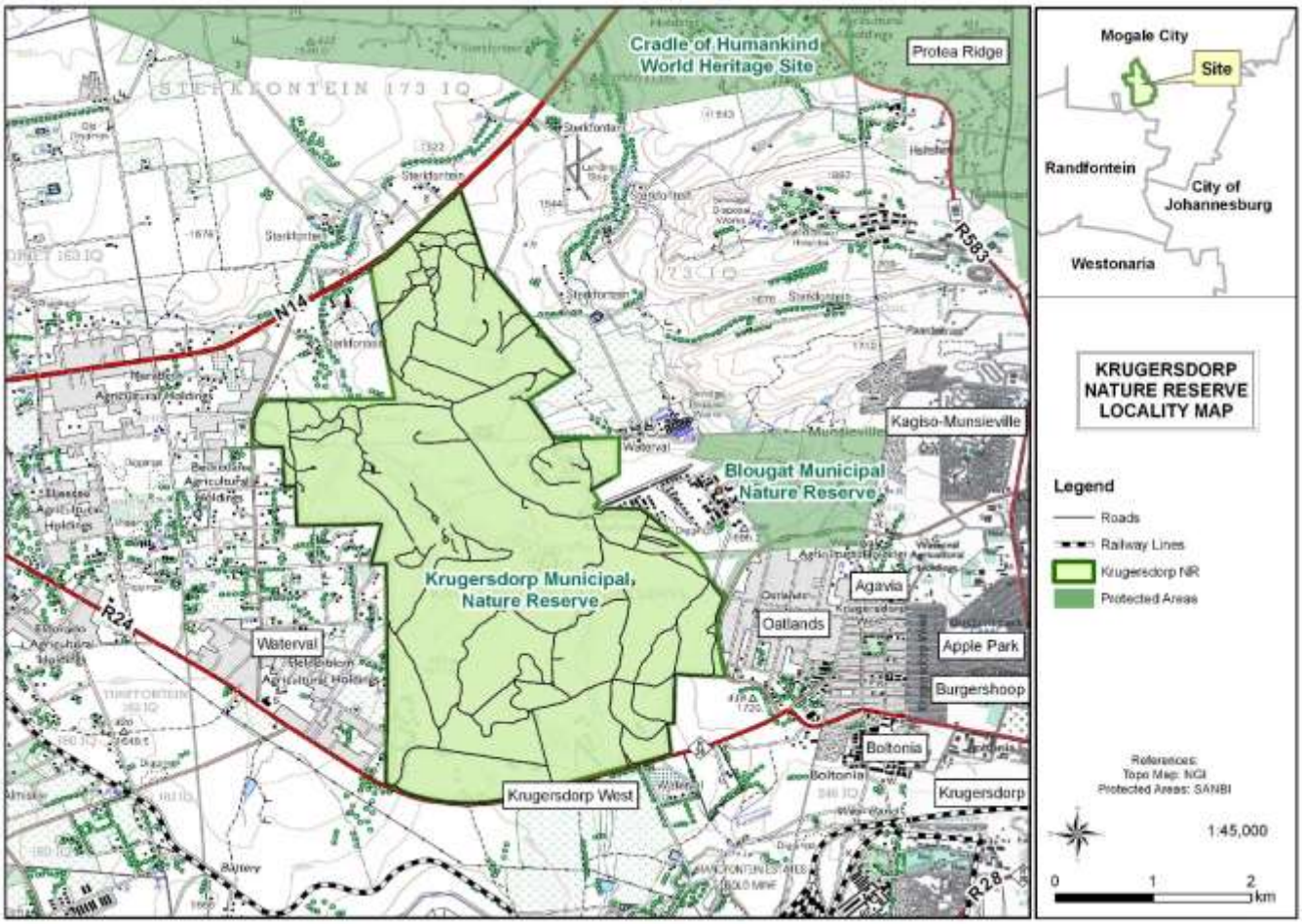
Jaco van Wyk is a herpetologist with experience across South Africa and the Prince Edward Islands. He has contributed to Author and co-author of 52 scientific publications in peer-reviewed and popular subject journals, and >150 contractual EIA research reports. He has extensive field work and laboratory experience in Africa.

1.5 Site description

1.5.1 Location

The 1 346 ha Krugersdorp Game Reserve is situated outside the town of Krugersdorp in Mogale Municipality, Gauteng province (Map 1). It is bounded in the north by the N14 highway and by the R24 in the south. Built up suburbs lie on the western boundary, with some light industry on the eastern boundary. To the north and east relatively undeveloped grassland occurs. The small Blougat Municipal Reserve to the East is separated from the KGR by development, but linked by an arc of undeveloped land to the north of the Blougat NR.

The reserve was established in 1960s with a donation of land to the Krugersdorp Municipality by Harmony Gold Mines, on condition that it be kept in perpetuity as a nature reserve (S. du Toit, Mogale Municipality, pers. comm).



Map 1: Location of Krugersdorp Game Reserve in Relation to the town of Krugersdorp and the Cradle of Humankind World Heritage Site

1.5.2 Climate

The mean annual rainfall for Krugersdorp is 736 mm (Stevens et al. 2014), falling mostly in the summer months between November and March. The temperature is moderate with frosts in winter and warm days in summer, with a mean maximum of 25°C. Most of the rain falls in the form of thunderstorms in summer.

The cool, moist climate is characteristic of an environment with relatively low annual variation in rainfall; the ecology of the system is relatively stable and is more likely to be influenced by management actions such as fire regime and stocking rate, than by extreme variations in climate such as droughts (Illius and O'Connor 1999, Buis et al. 2009).

1.5.3 Geology and topography

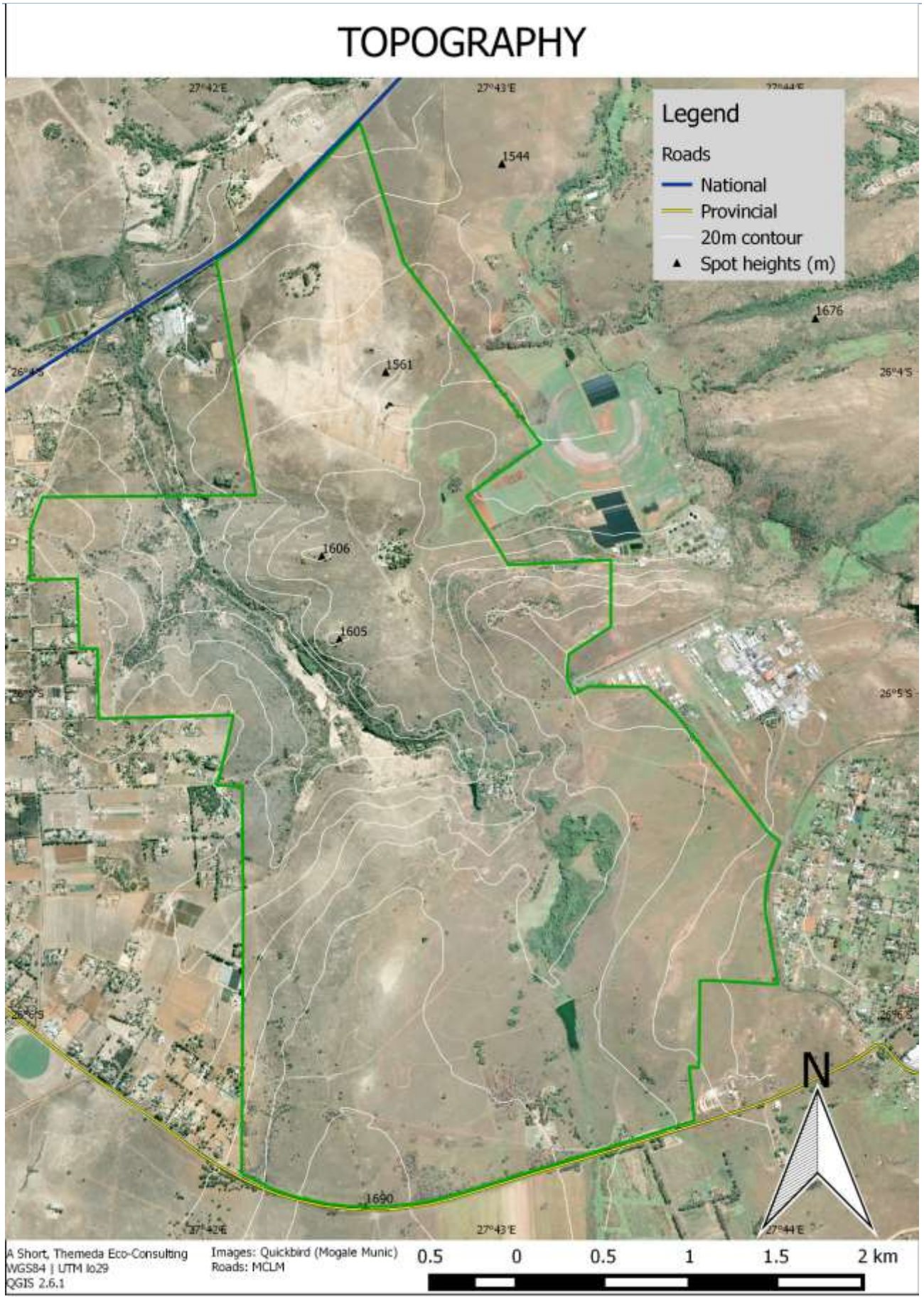
The KGR consists of rolling hills, with a plateau of between 1640 and 1680 m in the south of the reserve, dropping to about 1500 m on the northern boundary of the park (Map 2). The park is bisected by the Tweelopiesspruit flowing north to join the Rietspruit River outside the northern boundary of the park (Map 3).

From east to west, a shallow escarpment drops down to the dolomite plateau of the northern portion of the park. The Tweelopiesspruit drops over a small waterfall where it meets the escarpment. These two natural features (the river and the escarpment) effectively divide the reserve into four unequal portions. The river meanders more gently across the upper plateau, but after dropping down the escarpment it is confined by steep, wooded banks and flows more swiftly. The escarpment and the steep sloping valleys of the northern portion of the park provide a topographic contrast to the gentle slopes of the southern portion of the park and the dolomite plains around the kikuyu plains.

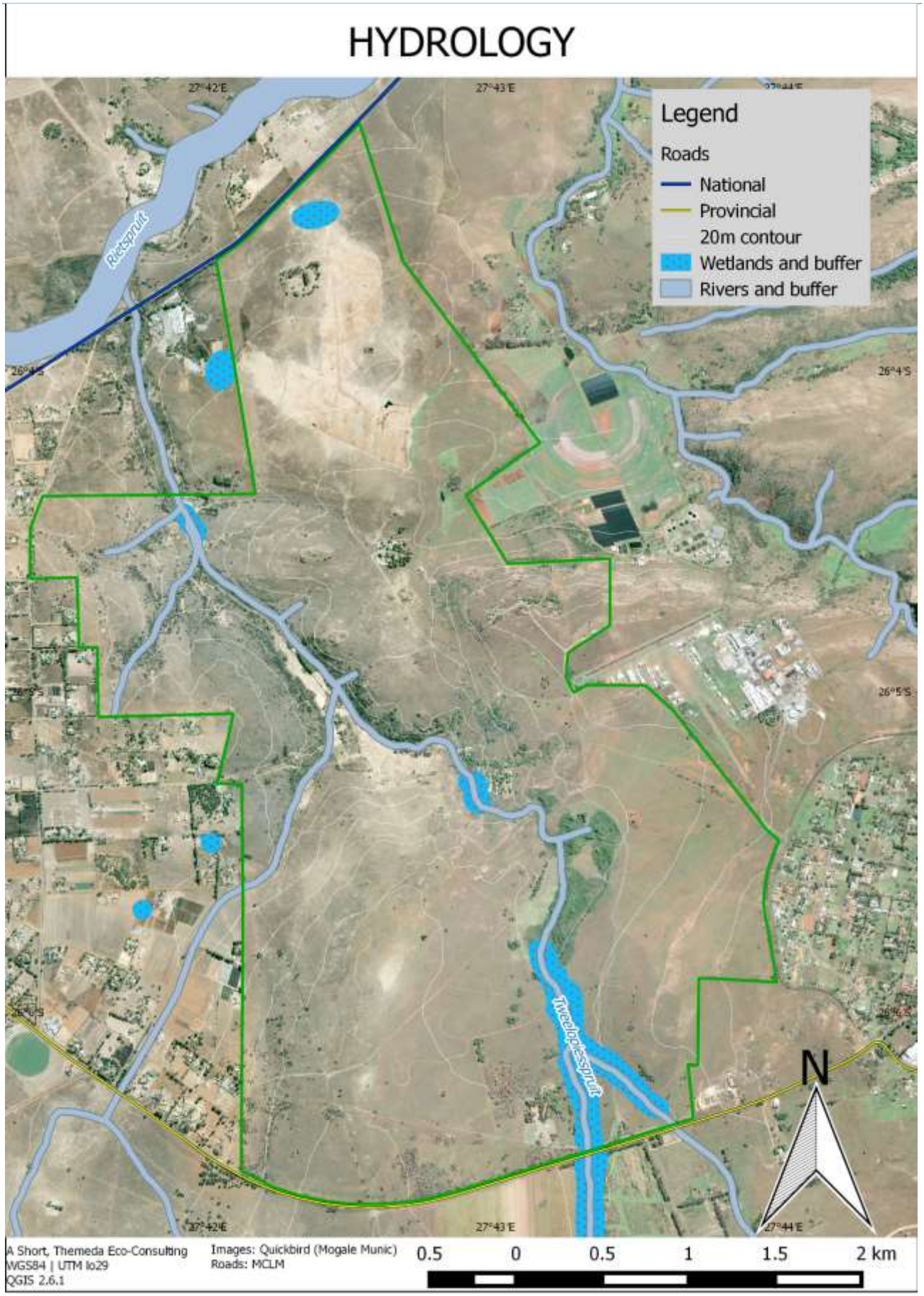
The northern half of the reserve, below the escarpment, is dominated by dolomite, while the southern plateau is dominated by quartzites overlying dolomite, with some significant areas of dolomite at the surface (Map 4). The dolomite has a profound influence on the hydrochemistry of the reserve; acid mine drainage from upstream mines is of major concern as it influences the quality of the water in the Tweelopiesspruit and may accelerate the formation of sinkholes in dolomitic strata (Winde and Stoch 2010).

The effects of the mine water decant on surface water quality and impacts on the aquatic ecosystem and potential effects on the reserve and downstream have been reported elsewhere (du Toit 2006, Hobbs and Cobbing 2007, McCarthy et al. 2010) but the possible subsurface movement of contaminants are poorly understood (Coetzee et al. 2009).

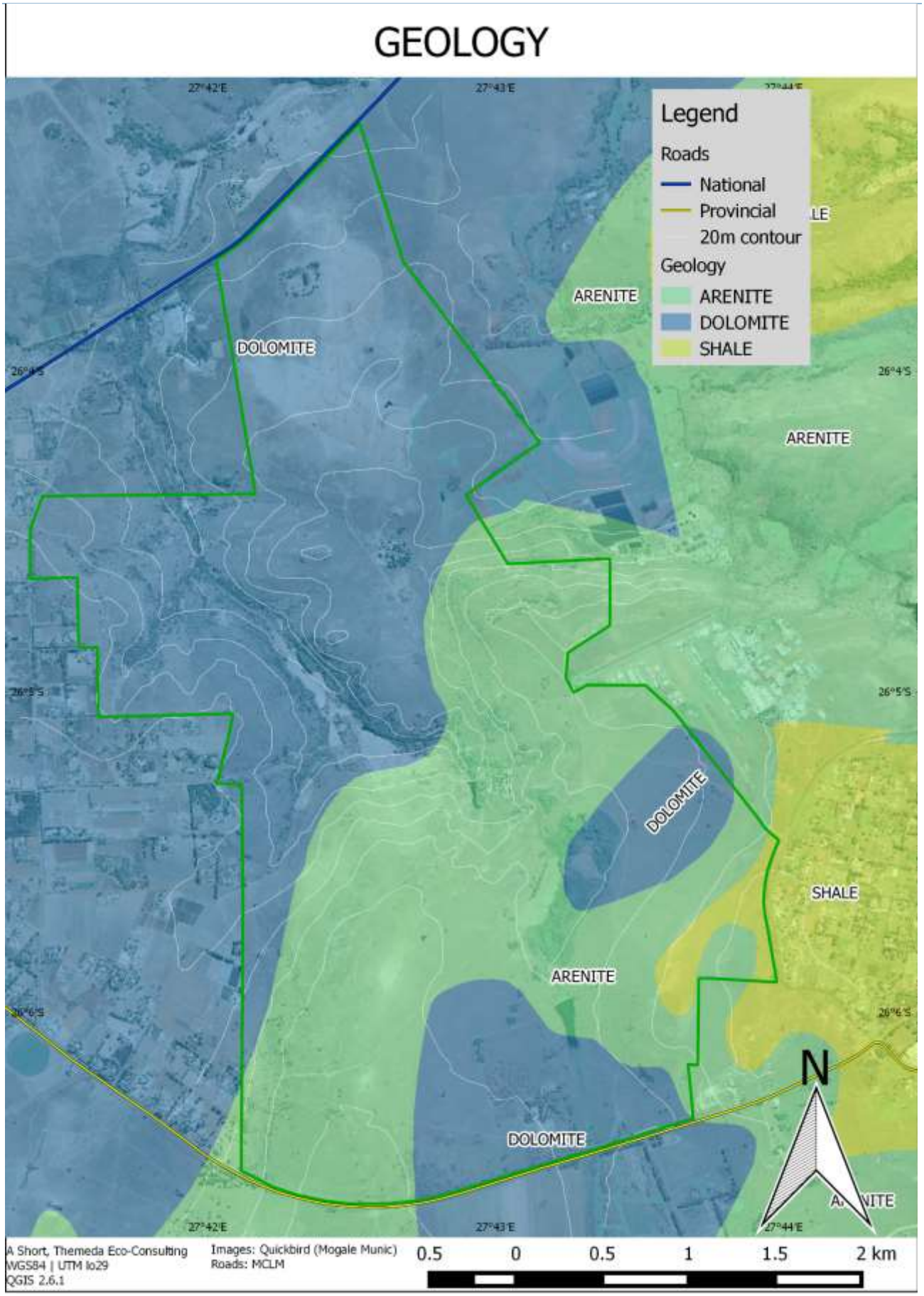
The geology is important to the movement of water through subterranean aquifers, according to Coetzee et al. (2009). They describe area as underlain by rocks of the Witwatersrand Supergroup, with the Black Reef formation of the Transvaal Supergroup occurring as a “thin surface layer over the underlying Witwatersrand rocks”. The dolomite layers occur as outliers, separated from the karst formations to the north by a structure of Black Reef and West Rand Group Quartzites. This structure separates the contaminated water of the West Rand Goldfield mine void from the important karst aquifer to the north (Coetzee et al. 2009). The flooded mine void extends into the southern portion of the KGR, and the dolomitic Zwartkrans compartment and its aquifers lie to the north of the reserve. Coetzee et al. (2009) identified a large fault bisecting the antiform structure in the KGR which could allow polluted groundwater to move from the mining area to the aquifers.



Map 2: Topography of Krugersdorp Game Reserve



Map 3: Hydrology of Krugersdorp Game Reserve, showing major rivers and buffer zones



Map 4: Geology of the Krugersdorp Game Reserve

1.5.4 Vegetation

The vegetation of Krugersdorp Game Reserve is split approximately in two along the geological boundaries. In the north, the vegetation type is Carletonville Dolomite Grassland, and Soweto Highveld Grassland on the southern plateau (Mucina and Rutherford 2006) (Map 5).

Both grassland types are under threat from transformation, and the Krugersdorp Game Reserve is therefore an important conservation area for these two vegetation types (Table 1). The percentage of area protected for each of these two vegetation types includes the KGR.

These grassland types are short, dense swards dominated by tufted grasses such as *Themeda triandra*, *Schizachyrium sanguineum*, *Tristachya rehmannii*, and many others. Botanical species richness is high and there are several rare and threatened plant species occurring in these vegetation types (described in more detail in the Vegetation section below).

The veld was described by Acocks (1988) as Bankenveld. It is extremely sour (that is, losing significant nutritional value to grazers in the winter). The annual yield is approximately 1700 kg/ha/year in this veld type (Grunow et al. 1970). Fire is an important component of the ecosystem, and the flora of the grasslands are well-adapted to regular burning. Indeed, exclusion of fire causes dramatic shifts in species composition and vegetation structure, with an increase in the cover of woody species and a large change in the composition of herbaceous species (Short 2001, Bond et al. 2003, Uys et al. 2004).

Table 1: Description of conservation status of the vegetation types in Krugersdorp Game Reserve, and the national status and targets of the vegetation types

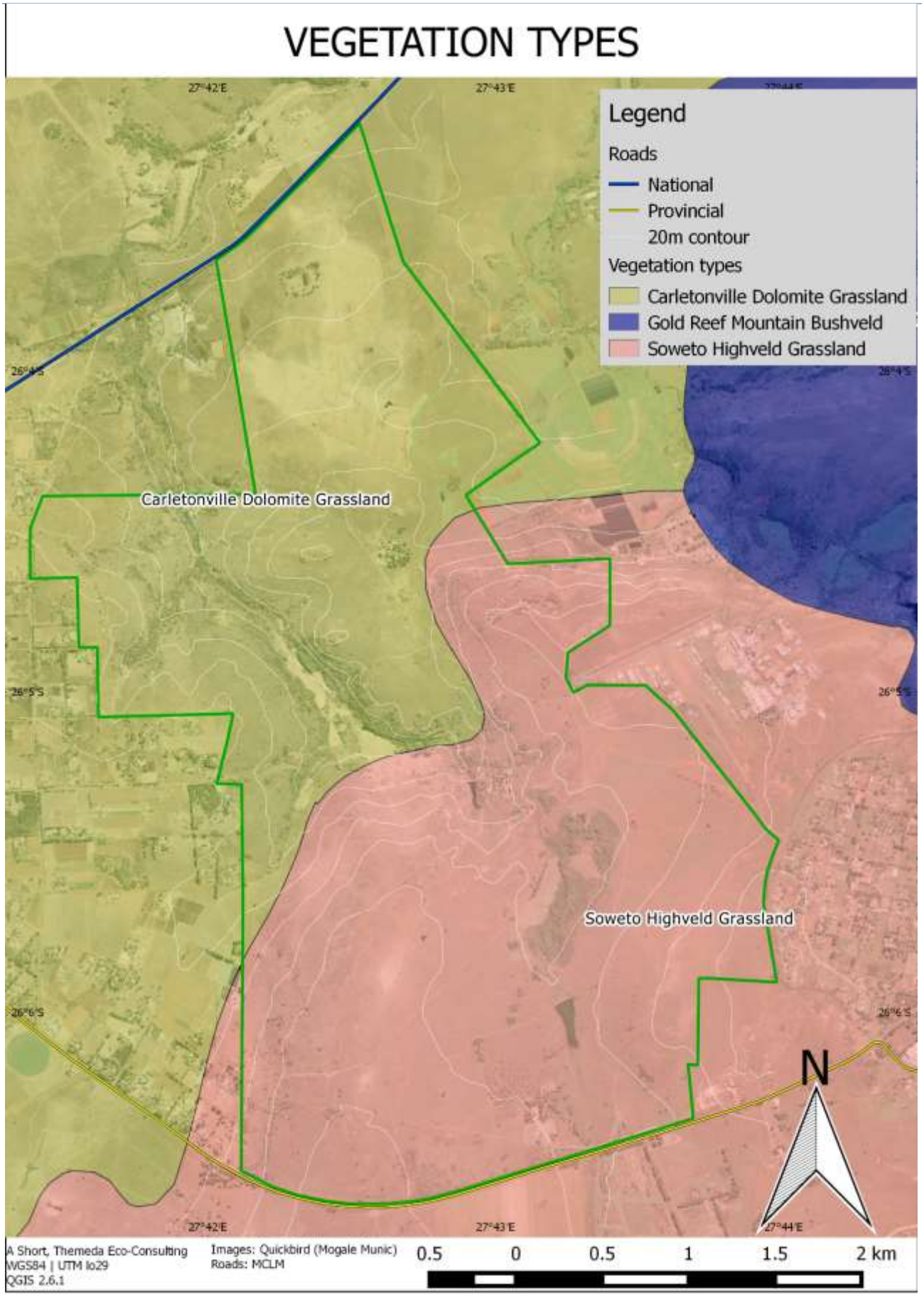
Vegetation type	Proportion of entire vegetation type protected	Conservation status	Target protection for entire vegetation type	Proportion of entire vegetation type transformed (2006)
Gh 15 Carletonville Dolomite Grassland	1.8% (+1.2% in private conservation areas)	Vulnerable	24%	23.9%
Gm 8 Soweto Highveld Grassland	0.2%	Endangered	24%	47.3%

1.5.5 Landscape Units

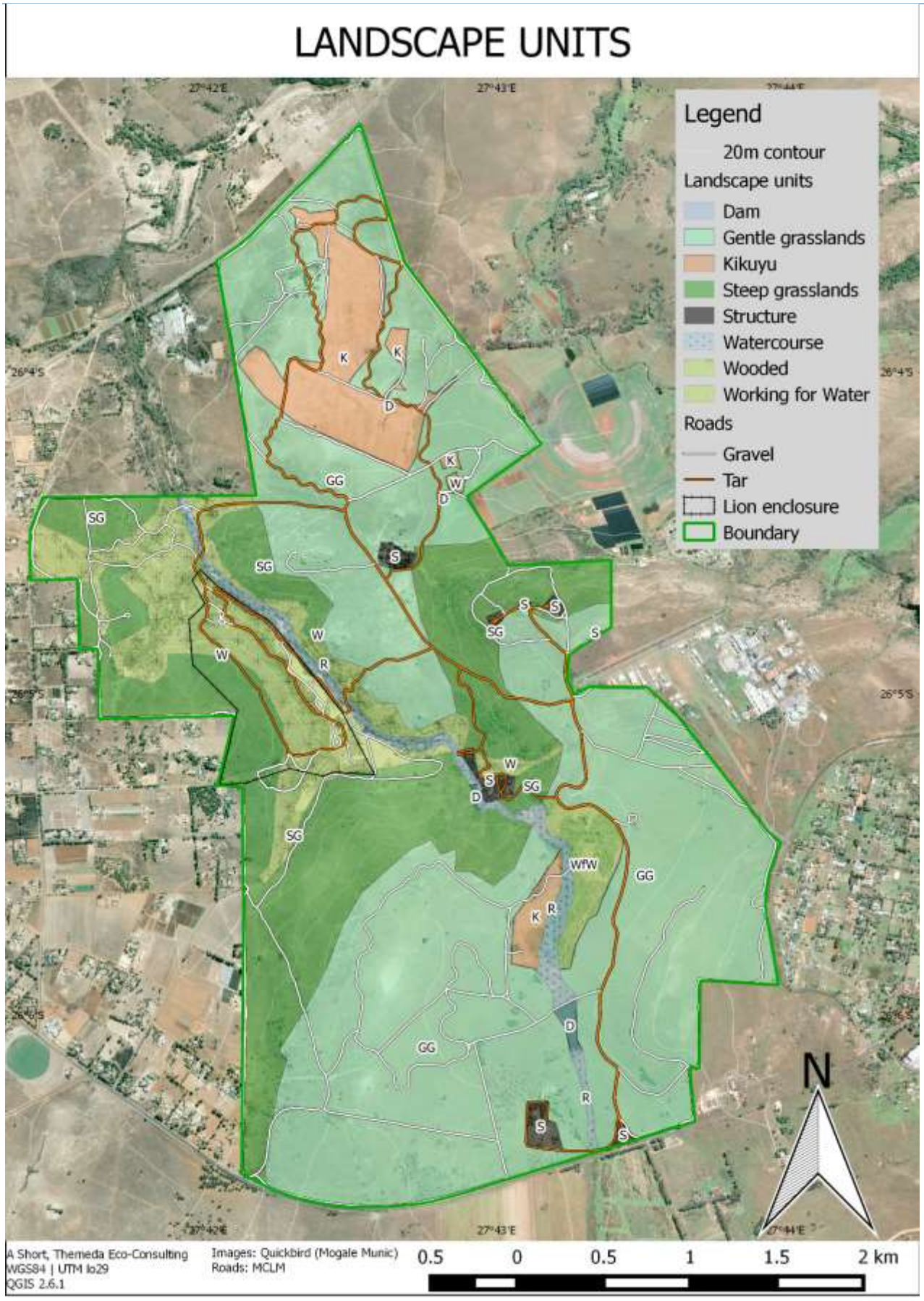
The reserve was divided into a number of landscape units according to topography and vegetation structure (Map 6). These landscape units were used to guide the field surveys, by distributing sampling effort among the landscape units in an attempt to ensure that the complete landscape diversity of Krugersdorp Game Reserve was sampled.

Seven landscape units were initially identified through interpretation of aerial photography. These were: steep grasslands (those grassland areas on steep hillslopes); gentle grasslands; kikuyu (areas of pastures planted to kikuyu for grazing); watercourses (the narrow band of riparian vegetation on either side of the Tweelopiesspruit); wooded (areas dominated by woody species, outside the immediate riparian area, mostly savannas); and Working for Water (areas of alien plants that had been cleared by the Working for Water alien plant control programme). Patches of trees (largely aliens) planted around structures were included in the "structures" category, which encompassed all major infrastructure features such as the lodge and camping areas. Dams were the final category.

These categories were not intended to be definitive and were merely used as the first phase in planning the field work. The different landscapes of the KGR were refined and corrected by field work and subsequent analysis. Nonetheless, the terminology chosen for the landscape units dominates much of the discussion in the specialist reports below.



Map 5: Vegetation types of Krugersdorp Game Reserve and environs (Mucina and Rutherford 2006)



Map 6: Landscape units of Krugersdorp Game Reserve, determined by mapping topography and vegetation structure.

1.5.6 Vertebrate habitats

The topography and vegetation structure combined to form several unique landscape-scale habitats for vertebrates. Vertebrate distributions are not only or very dependent on the minutiae of plant associations (described by the vegetation types under section 1.5.4, or by the more detailed vegetation communities outlined in this report). Mammal assemblages can at best be correlated with botanically defined biomes, while birds are more correlated with biomes defined by vegetation structure (Rautenbach 1978, 1982, Harrison et al. 1997).

The four main habitat types are **terrestrial**, **arboreal** (tree-dwelling), **rupicolous** (rock-dwelling) and **wetland**.

1.5.6.1 TERRESTRIAL HABITAT

The terrestrial habitat type prevails spatially. It consists of grasslands on both the gentle and steeper slopes of the rolling landscapes, being mesic highveld grassland on slightly deeper red soils in the south, and shallow, gravelly soils in the north. Although the grass cover throughout is generally <50 cm in height, it provides in most areas adequate refuge and nourishment for smaller terrestrial animals (Photo 1). A rotational burning regime is implemented on the KGR, as a consequence of which the most recently burnt areas in the northeast and southwest sectors were in the process of re-sprouting during the site visits. In places, the unburnt grasslands have been grazed very short, which is conducive to species preferring short grass or exposed areas. There are several areas where kikuyu was either planted (northern part) or has invaded (valley floors and drainage lines). The geological substrate is unlikely to affect the distribution of terrestrial species. The same suite of birds can be expected to be found on the kikuyu pastures as the adjacent natural grassland.

Photo 1: A view east across the southwest and southeast sectors of terrestrial mesic Soweto Highveld Grassland habit, looking across the shallow valley of the Tweelopiesspruit to the walled residential areas of Krugersdorp West and illustrating the density and height of the grass cover over most of this terrain

1.5.6.2 ARBOREAL HABITAT

Patches of alien trees (eucalypts, oaks, wattles, poplars) occur either in clumps around sites of human habitation (entrance gate, staff houses, camp site) or scattered as individual trees across the area. Some of the larger exotic trees provide resting, roosting and nesting sites to vertebrates, besides foliage, nectar or seeds as nutrition. Rocky outcrops within the grasslands, and along some of the steeper gradients and watercourses sloping down to the river course are wooded (Photo 2) mostly by indigenous shrubs and small trees with only a few alien invasive species. Other small indigenous shrubs and trees, especially *Vachellia (Acacia) karroo* and *Diospyros lycoides*, are scattered throughout the grassland in fire-protected locations or around infrastructure. The riparian zone of the river only has a few alien oaks and wattles along its southern levees, but below the falls supports tall *Celtis africana* (white stinkwood) woodland. The 64 ha lion enclosure within the northwest sector, being in effect an exclusion camp to most herbivores and only rarely and partially burnt in the last decade, provides an interesting control study relative to the remaining 1 300 ha of the KGR, exhibiting notably higher density and diversity of ground and woody cover from the valley floor to the western hill crest.

Photo 2: View northeast from rupicolous habitat on the quartzite ridge, west of the lodge in the wooded Tweelopiesspruit below, with the southeast quartzite ridge on the far side. Note the dolomite quarry on the north bank below, with the patch of tall trees around the camp site on the saddle above

1.5.6.3 RUPICOLOUS HABITAT

Generally, the rupicolous habitat is fragmented (Photo 2), occurring along ridges and crests of steeper slopes. The largest natural rock faces occur alongside the northern dolomitic stretches of the Tweelopiesspruit from below the falls at the lodge, but a small quarry in the dolomite adjacent to the Ou Kraal Lapa, and the honeycomb of small old mine shafts and old sewage lines along the south-eastern quartzite ridge, especially southeast of the camp site, provide good habitat for rock- and cave-loving species. In addition, sinkholes of various sizes, several with rocky walls and cavities, occur in the flatter northern dolomitic areas, most filled with woody plants but fenced or filled with razor wire that prevent access.

1.5.6.4 WETLAND HABITAT

The wetland habitat and water quality is described in more detail elsewhere in Section 4. Main features are the Tweelopiesspruit bisecting the reserve from South to North, with several dams along its length. Open water is available mainly from the Tweelopiesspruit, but a few artificial pools, notably a small dam and tank in the northeast and ponds around the lodge are otherwise available.

The banks of the watercourse are covered with dense stands of reeds, especially around the dams, but the rank semi-aquatic vegetation preferred by moisture-reliant animals is also present below the dam walls, mainly sedges (Photo 3). The contamination of the Tweelopiesspruit by Acid Mine Drainage has deposited thick layers of precipitate on streambeds and aquatic vegetation but appears to have had little effect on the riparian vegetation. Artificial dams remain uncontaminated, as do tributaries of the Tweelopiesspruit. Other, scattered seeps and springs occur in the reserve.

1.5.7 Infrastructure

The KGR is well serviced by a network of gravel and tar roads (Map 1), covering nearly 300 km (Table 2). However, many of the gravel roads marked on the map are only accessible by four-wheel-drive vehicle, and many are closed to tourists. Some of the mapped roads barely exist at all, particularly in the south-western portion of the reserve.

Table 2: Road network of Krugersdorp Game Reserve

Road type	Length (km)
Gravel	130
Tar	149
Grand Total	**279**

There are a number of complexes, buildings, and ruins scattered around the reserve, as well as graveyards. These structures are primarily tourist infrastructure (e.g. the lodge and campsite) and associated management (staff housing and gate). The reserve is fenced with a sturdy game fence along its entire perimeter, blocking movement of larger animals. The 64 ha lion enclosure is sturdily fenced, with very little grazing occurring inside the enclosure. Several other exclosures occur (e.g. where sinkholes in the dolomite have been fenced, and around graveyards). The lion enclosure fence is old and deteriorating, and requires maintenance. Management of the KGR is considering the possibility of moving the enclosure, pending approval on a reduced size from GDARD.

The KGR allows a mixture of self-drive, game-drive, cycling and horse-riding to explore the reserve, and suitable facilities for these activities are incorporated into the infrastructure.

Several dams are built along the Tweelopiesspruit, as well as artificial water-bodies elsewhere in the reserve. Several ruined buildings, some old mine workings, and an abandoned aviary complete the most obvious infrastructure.

Photo 3: Top: View southwest across the largest and southernmost hippo dam on the Tweelopiesspruit, showing the dense stand of reeds along the banks. Bottom: with the yellow-orange sediment deposited all along the river bed

Part 2: Baseline Ecological Surveys

2 SOILS

MARINÉ PIENAAR

2.1 Methods

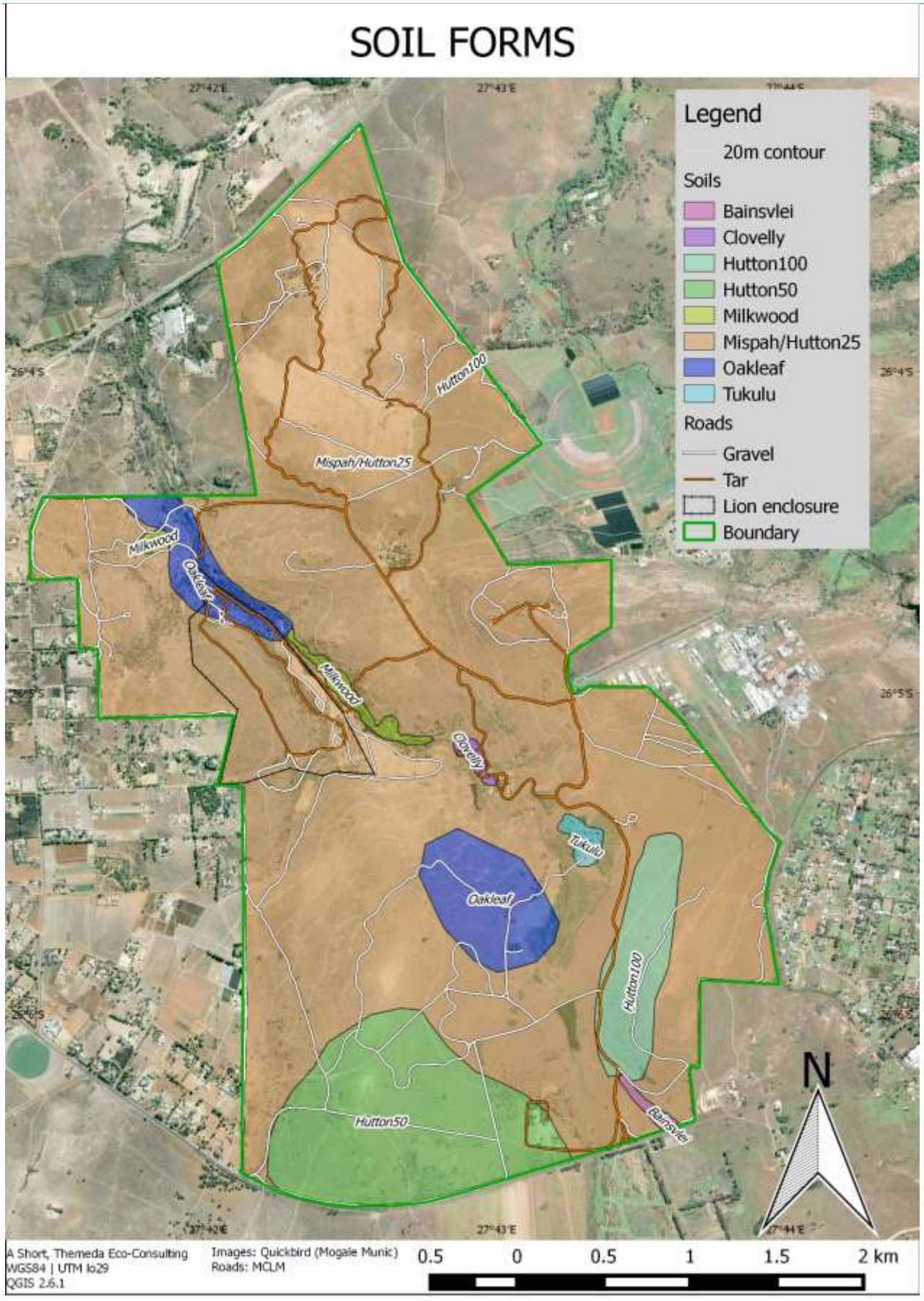
A stratified random sampling approach was used to distribute soil and vegetation sampling points among the landscape units, with a sampling density of 1 point per 100 ha (minimum one point per polygon). This was used to guide the survey; additional points were surveyed at unique points in the landscape and not all of the planned sample points could be accessed. Nonetheless, the strategy allowed a largely unbiased distribution of sample points.

The soil profile was examined to a maximum of 1.5m using an auger. Representative soil samples were collected of top- and subsoil horizons for each soil form encountered. Observations were made regarding soil texture, structure, colour and soil depth at each survey point. A cold 10% hydrochloric acid solution was used on site to test for the presence of carbonates in the soil. The soils are described using the S.A. Soil Classification Taxonomic System (Soil Classification Working Group 1991). For soil mapping, the soils were grouped into classes with relatively similar soil characteristics.

Eleven representative soil samples were collected of top- and subsoil horizons for each soil form encountered. Only topsoil samples were collected from very shallow soil profiles underlain by hard rock. Samples were sent to Nvirotek Laboratories and were analysed for pH (KCl and H_2O), phosphorus (Bray1), exchangeable cations (calcium, magnesium, potassium, sodium), organic carbon (Walkley-Black) and texture classes (relative fractions of sand, silt and clay).

2.2 Results

Nine different soil units were identified for the Krugersdorp Game Reserve. Eight different soil forms are present but differentiation was made between deep and medium-deep Hutton soils to fit into the management plans for the Reserve as since deeper soils provide a more stable growth habitat. The Krugersdorp Game Reserve is dominated by a combination of Mispah and shallow Hutton soils (these two soil forms were combined into one soil unit as a result of the similarity in soil properties and management measures required). The soil chemistry of the samples analysed illustrates the influence of the underlying geology on the soil properties well. The soils overlying dolomite (the largest portion of the Reserve) has very high calcium, magnesium and sodium content while the soils underlain by arenite and shale are low in exchangeable cations with acidic pH levels. The organic carbon levels in the topsoil range from fairly low (1.25%) to high (6.11%) for South African veld conditions.



Map 7: Soil map of Krugersdorp Game Reserve, showing survey sites. The number included with the Hutton soils refers to the average soil depth in cm

2.2.1 Mispah/Hutton25

The Mispah form consists of a shallow orthic A horizon (5 to 15 cm) underlain by hard rock, coarse gravel or parent material and with large areas rock outcrops visible on the surface (Photo 4). The shallow Hutton form consists of an orthic A horizon (with an average depth of 5 cm) overlying a red apedal horizon (depths of this horizon ranging between 10 and 25cm) that is restricted in depth by hard rock or unspecified weathering material. Both the Mispah and Hutton forms have reddish-brown orthic horizons that are darkened by the accumulation of organic material (organic carbon ranges between 3.09 and 3.70%). The texture of the topsoil and subsoil is sandy clay-loam.

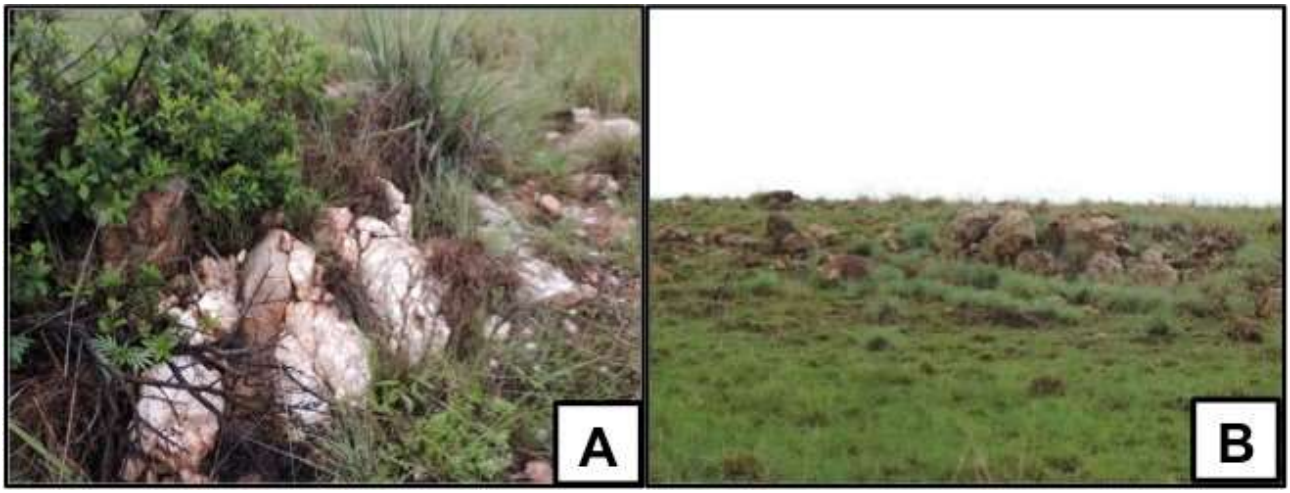


Photo 4: Photographic examples of rock outcrops within the Mispah/Hutton25 soil unit (A and B)

2.2.2 Hutton (Hutton50 and Hutton100)

Hutton soil forms ranging between 50 cm and 100 cm were identified in three areas. These profiles have similar horizon organisation as described for the shallow Hutton profiles above except that the red apedal B1-horizon is much deeper and ranges between 40 cm to deeper than 100 cm. The medium deep Hutton soils occur on the southern border of the Krugersdorp Game Reserve while the deep Hutton profiles occur in two isolated portions. The clay content ranges between 26 and 28% and there are no abrupt structure or texture changes between the A and B1 horizons. The pH levels of this soil form range between very strongly acid in the topsoil and strongly acid in the subsoil (as represented by KG11 and KG12 – see Appendix 2)

2.2.3 Oakleaf

Two areas with Oakleaf soils were identified on site. The largest portion is present in the northern portion of the Reserve in the riparian area of the Tweelopiesspruit. The profiles here consist of an orthic A horizon (25 cm), overlying a neocutanic B horizon (120 cm) on unspecified material. The neocutanic horizons observed have non-uniform colouring and cutans and channel infillings are visible. Evidence of earlier anthropic activities in this soil unit is evident by the presence of building materials (Photo 5A). The second portion is in the middle of the site just west of the Tweelopiesspruit. The profiles here are much shallower (not deeper than 50 cm). Both Oakleaf soil units have very high organic carbon content in the topsoil (5.76 to 6.11%) as well as high exchangeable calcium and magnesium levels (represented by KG06, KG07 and KG10 – see Appendix 2).

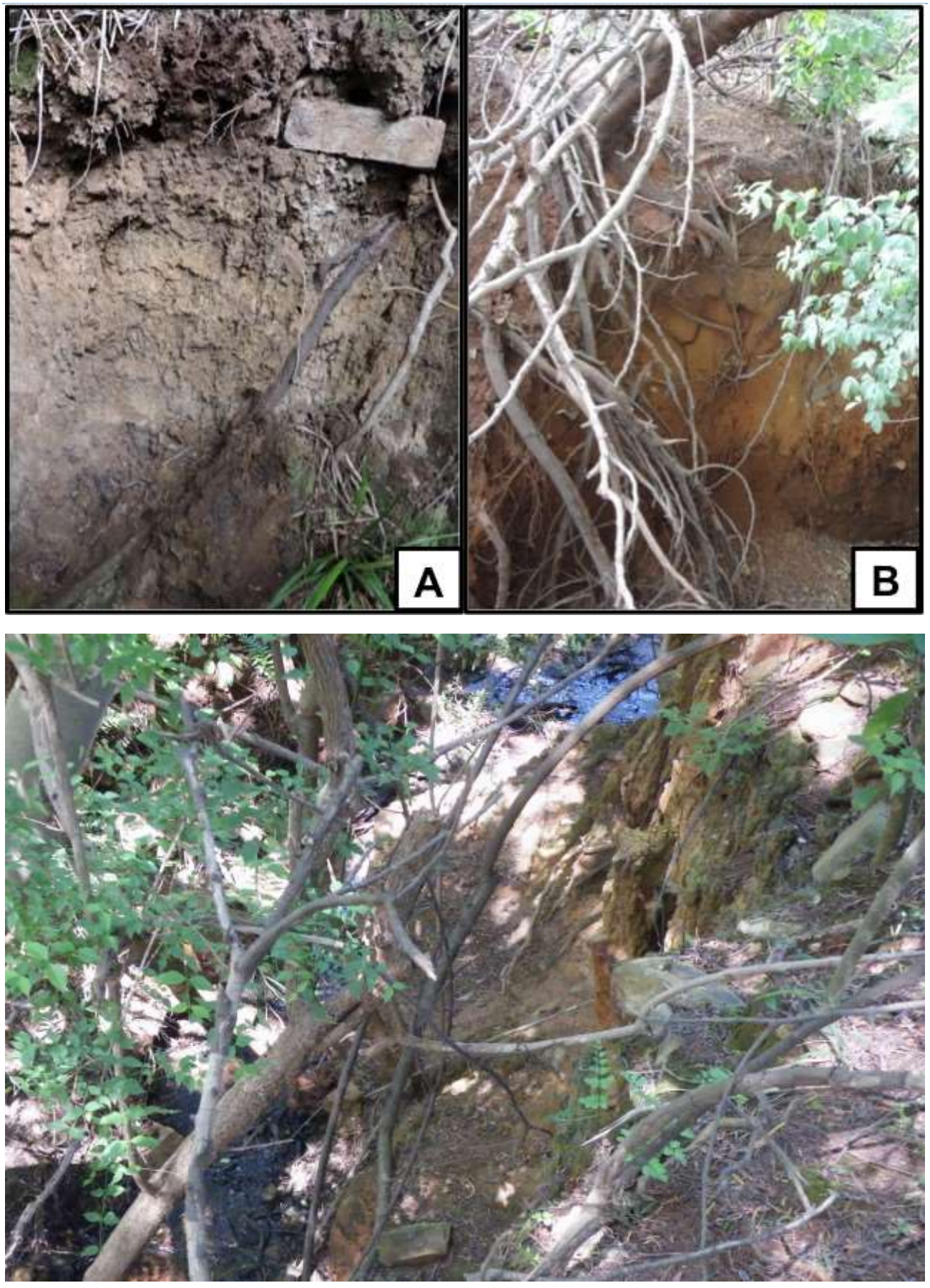


Photo 5: Top: Photographic examples of (A) the Oakleaf soil form; note the bricks near the top of the profile, and (B) the Clovelly soil form. Bottom. A view of an erosion gully from the top of the bank. Note the depth of the gully and active erosion.

2.2.4 Clovelly

Soils of the Clovelly form are present in one isolated area within the Reserve. There is currently a large erosion gully within this soil unit that will increase in extent in the absence of future rehabilitation of this gully and proper storm water management (Photo 5B). The Clovelly soil forms consist of a sandy loam orthic A horizon on a well-drained yellow-brown apedal B horizon overlying unspecified material where limited pedogenesis has taken place. Soil depths of the Clovelly profiles observed on site within the erosion gully are deeper than 150 cm (Photo 5 Bottom).

2.2.5 Bainsvlei

A small portion of Bainsvlei soil occurs just north of the Krugersdorp Game Reserve entrance. This form consists of an orthic A horizon overlying a red apedal B horizon that is underlain by a soft plinthic B horizon. The predominant feature of this soil unit is the soft plinthic B horizon that shows the accumulation of iron and manganese oxides and hydroxides in the form of high-chroma mottles and concretions (Photo 6). This soft plinthic horizon is evidence of a fluctuating subsurface water table and intermittent periods of wetness especially during the rainy season. The Bainsvlei profiles surveyed on site are deeper than 100 cm.

2.2.6 Milkwood

The Milkwood form occurs in two different areas, a tiny portion in the northern part of the Reserve as well as a small narrow section alongside the Tweelopiesspruit (Map 7). The Milkwood soils consist of a melanic A horizon with dark colours overlying hard rock (dolomite) (Photo 6B). The melanic A horizon has a clay-loam texture and 3.75% organic carbon. It has 6.22 cmol(+) exchangeable cations per kilogram clay for every one percent of organic present. The pH of the soil is slightly acidic to neutral (see KG05, Appendix 2). The profiles observed are not deeper than 25 cm.

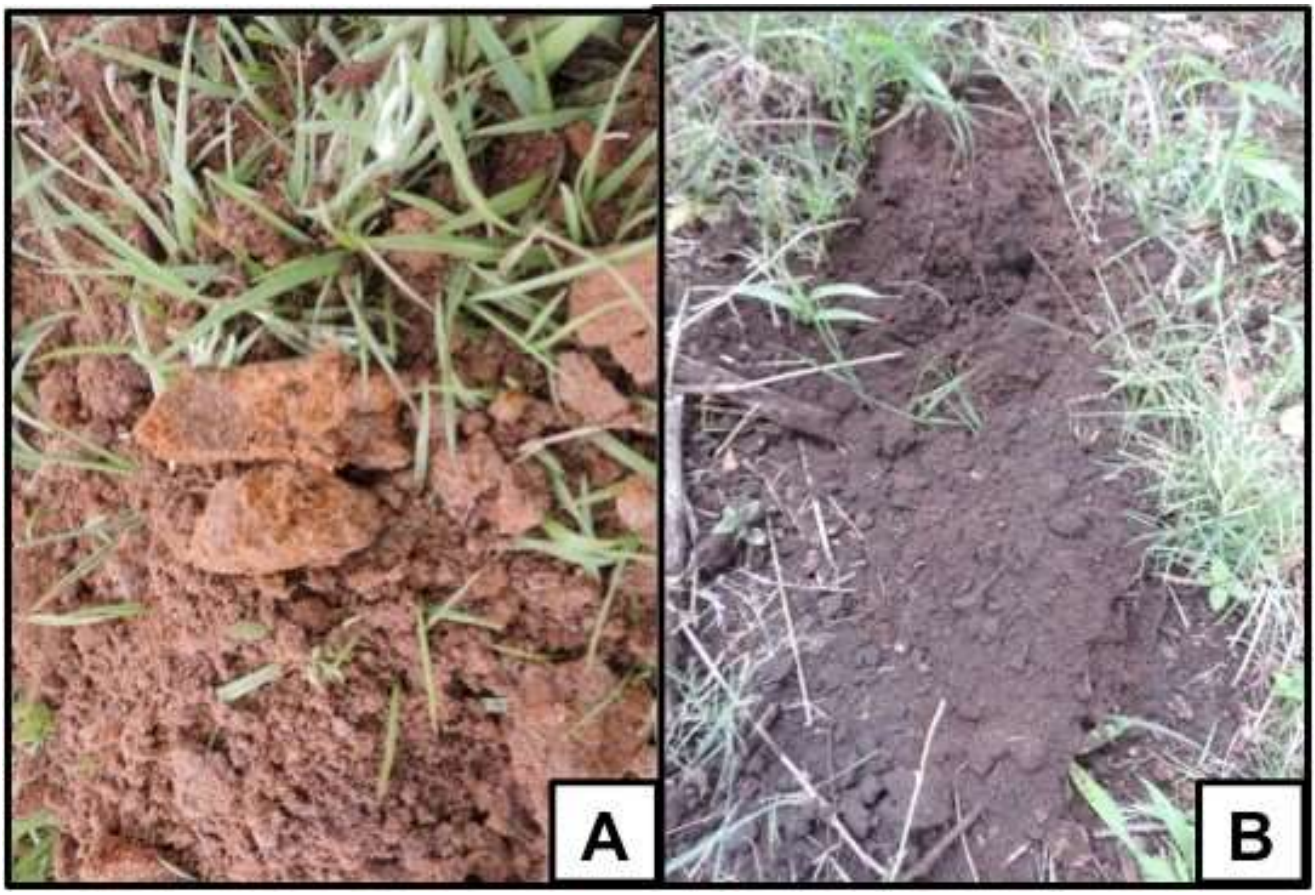


Photo 6: Photographic examples of (A) soft plinthic B2-horizon of the Bainsvlei form and (B) humic A horizon of the Milkwood form

2.2.7 Tukulu

A small section of Tukulu soils are present just east of the Tweelopiesspruit. The Tukulu soil forms in the Reserve consists of a sandy-loam shallow orthic A horizon on a neocutanic B horizon overlying unspecified material with signs of wetness. The pH of the Tukulu profiles is moderately acidic and exchangeable cation levels (calcium, magnesium, potassium) much lower than that of the soil profiles underlain by dolomite (KG08 and KG09, Appendix 2).

2.3 Conclusion

Soils within the Krugersdorp Game Reserve are rather homogeneous in properties and only a few differentiations occur as a result of the underlying geology, pedogenic processes as a result of the landscape (fluctuating water table) and micro climatic conditions (cool, moist environments in the riparian zones).

Photo 7: Acid mine drainage in the Tweelopiesspruit

The soil chemistry was normal, apart from one anomaly near the kikuyu plains where P was over 200mg/kg. Possible origins include wastewater irrigation of the kikuyu from the 1960s to 2011. However, only one site showed this spike in P.

The lowest organic matter (OM) value in the topsoil was 1.6%. The remainder of samples were 5-6% OM, which is high. Subsoil OM was insignificant.

The two biggest areas of concern with regards to soil management within the Krugersdorp Game Reserve are the following:

- Evidence of soil erosion gullies and ongoing soil erosion is present in the Reserve. The soil has naturally a high erodibility index as a result of the physical and chemical properties that is further aggravated by the natural slopes of the landscape. Animal activities, especially overgrazing of certain areas, as well as storm water run-off from surfaced roads may increase erosion.
- The constant creation of new roads for use by off-road vehicles is a danger to soil stability. These vehicles disturb the vegetation that protects the soil surface from erosion and the compaction caused by these vehicles moving over the surface, reduces the water infiltration rate of the soil and therefore increase the erosion risk.
- The presence of soil pollution as a result from surrounding mining and industrial activities is of major concern. Even though it was outside the scope of this study, evidence of acid mine drainage in the Tweelopiesspruit was observed (Photo 7; Section 5: Aquatic Biomonitoring). Apart from the obvious effects of acid mine drainage, water running through mining properties very often contain toxic levels of metals such as lead and arsenic. Dust blowing from the surrounding gold mine tailings storage facilities (TSF's) may settle on land within the Reserve boundaries and this may lead to increased metal levels in topsoil and uptake of these metals by the field grass roots. High levels of several heavy metals were found in the KGR by Nadasan et al. (2014), with evidence of migration through the soil from the Tweelopiesspruit outwards.

2.4 Recommendations

The following are recommended with regards to the successful management of soils of the Krugersdorp Game Reserve:

- All areas already affected by erosion should be identified, mapped and the extent of the erosion be determined. Once this has been established, a sound erosion rehabilitation plan should be developed that will prevent further erosion and recover the areas that have been affected.
- The creation of new 4x4 routes should be avoided as far as possible. In areas where informal roads have already been created, the situation should be evaluated and land stabilisation measures be implemented.
- Existing surfaced roads should be evaluated and where necessary, storm water drainage should be installed to avoid erosion gullies developing next to the road, especially after high intensity rainfall episodes.
- Any alien vegetation removal programme or revegetation programme should be conducted during the winter months when the chance of rain is very low and therefore uncovered soil surfaces will not be exposed to erosion risk.
- Previous studies have indicated high levels of soil pollutants (Nadasan et al. 2014). Should metal levels exceed the current threshold levels stipulated in the Framework for the Management of Contaminated Land (DEA 2010), a strategic site decontamination plan should be devised as part of the management strategy.
- It is further recommended that air quality monitoring be implemented to detect the levels and content of dust settling on the soil surface of the Reserve.

3 VEGETATION

ANTOINETTE EYSSELL-KNOX AND ALAN SHORT

3.1 Methods

3.1.1 Vegetation communities

The soil sampling points were used to guide the vegetation survey. Not all points could be accessed and additional points were surveyed to describe the heterogeneity of the landscape where necessary.

The cover-abundance of all plants in a 10x10 m plot was described, as well as litter cover and bare soil. Where necessary, woody plant presence was listed in a nested 50x50m plot to capture low density woody species. A photograph was taken of most sites; it is hoped that these will form the foundation of future fixed-point photographic monitoring of the veld.

Several rapid assessments were conducted of a handful of sites, where the presence of dominant and charismatic species was recorded. These sites were not included in the formal analysis, but were used to fill in gaps in the vegetation map by assigning them to existing groups.

The cover abundances of each site were transformed to proportional abundance. An agglomerative hierarchical classification using Bray-Curtis dissimilarities was conducted using the PC-ORD software package (McCune and Mefford 2006). Agglomerative techniques have been shown to give better community classification results than the commonly used TWINSPAN (Two-Way Indicator Species Analysis) method (Belbin and McDonald 1993), although all methods have their strengths and weaknesses (Anderson and Clements 2000). The resulting groups were then examined and in some cases, sites were reassigned to groups based on ecological and management criteria. Additional plots surveyed during the soil, wetland and aquatic biomonitoring surveys were added to appropriate groups based on dominant vegetation.

The initial group classification based on the multivariate procedure was refined and some groups were assigned as sub-groups of main vegetation types.

GDARD provided the list of threatened plant species for quarter degree square 2627BA.

3.1.2 Veld condition and landscape functioning

The grass, forb, bare ground and litter estimates, as well as grass height and woody density, from the vegetation survey were used to describe the veld condition of the site and estimate carrying capacity.

A score-card method was used retrospectively, to assign veld condition scores to each site based on the species composition and site description obtained during the field survey. The most appropriate score-card method was judged to be that of Fourie & Roberts (1977), which was adapted by E. van Zyl (KZN Department of Agriculture and Environmental Affairs, pers. comm). The technique was developed for the Highveld and Karoo, and relies on assigning scores out of 10, to five variables (species composition, plant cover, vigour, soil surface condition, insect and rodent damage). Bush encroachment is dealt with separately.

Once veld condition scores are determined, a table of veld condition scores against rainfall is used to estimate carrying capacity in ha/AU[1].

3.1.3 Increasers and Decreasers

Plants, especially grasses, are commonly categorized in veld management terminology into "Increasers" and "Decreasers", according to the way the population of a species typically responds to fire and grazing (Table 3).

Table 3: Descriptions of ecological categories

Category	Description	Examples
Increaser 1	Grasses which increase when the veld is rested from grazing and is not burned for many years. **Burn and graze the veld for animals; burn but graze lightly or no grazing for biodiversity**	*Trachypogon spicatus* *Tristachya rehmannii* *Hyparrhenia hirta* is sometimes placed in this category
Decreaser	Grasses that decrease when the veld is over- or undergrazed. These grasses, together with certain increaser 1s, are usually the best indicators of good veld condition and are often highly palatable **Graze the veld; burn only if necessary**	*Themeda triandra* *Andropogon appendiculatus*
Increaser 2	These grasses increase with heavy grazing, often combined with frequent fire. Many of the grasses have moderate grazing value and can form the backbone of grazing in moderate condition veld **No burning, reduce stocking**	*Eragrostis* species *Heteropogon contortus* *Hyparrhenia* spp. are placed in this category in this report, but also thrives in old lands and appears to be invading open veld.
Increaser 3	These grasses increase with selective grazing, especially by sheep. They tend to be unpalatable, wiry grasses that are avoided by animals and thrive when surrounding grasses are grazed. **Burn and graze veld early, remove animals to rest palatable grasses**	*Elionurus muticus*

3.2 Results: Vegetation communities

The formal classification procedure identified several vegetation communities in the reserve (Figure 1). These were grouped by structure into grassland, woodland and wetland communities. Several of the sites were represented only by a single site, which complicated mapping of vegetation communities.

In addition to the sites used in the formal classification procedure, several other sites surveyed during the wetland and soil surveys, where dominant species were noted, were added into the existing classification by comparing species composition of these sites with the species composition of the classified communities (Table 4). This process was necessarily subjective.

[1] One animal unit (AU) is equivalent to a 450kg steer, requiring 10kg of forage (dry matter) per day. A simple formula to convert animals to AU is to take the average weight of a species, multiply by 2, add 100 and divide by 1000: (mass x 2+100)/1000 (Smith 2006)

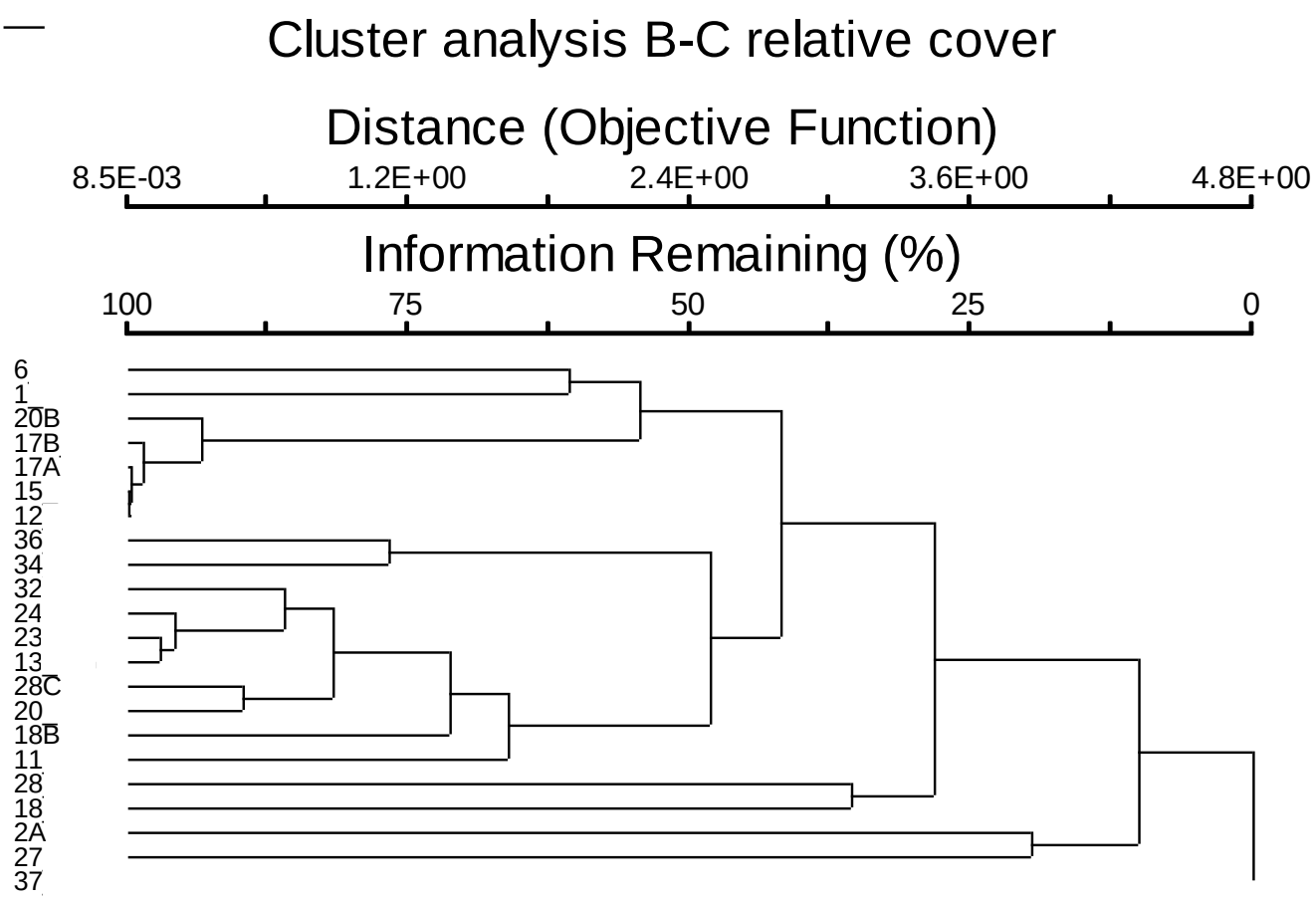


Figure 1: Cluster analysis of 22 sites, showing the classification of sites into groups. The groups are described in Table 4.

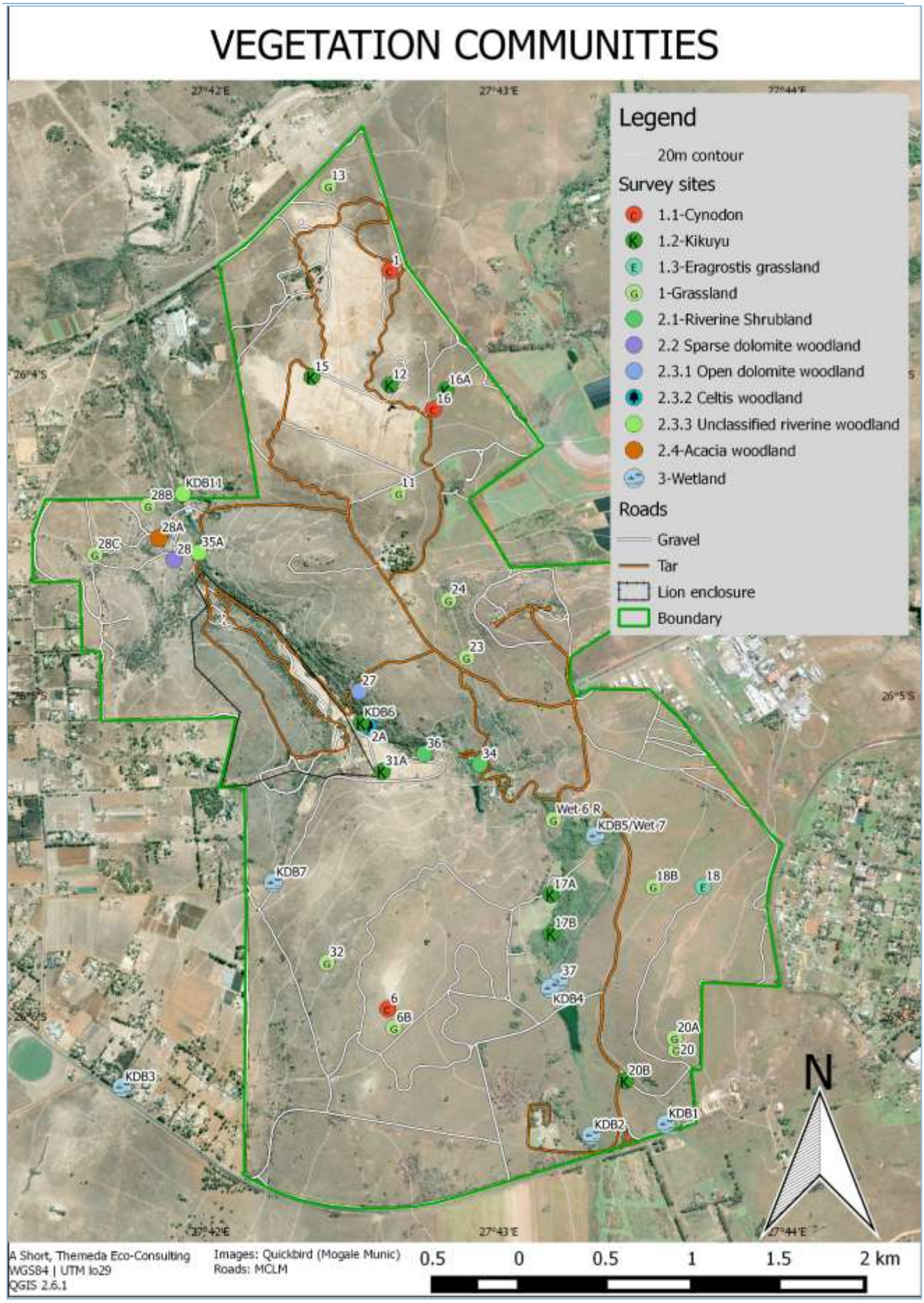
Table 4: Description of groups identified in the cluster analysis from field surveys

Group	Name	Sites	Description	Dominant Species
Grassland				
1	Rocky grassland	11 13 18B 20 20A 23 24 28C 32	Selectively grazed, deeper soils. Covers most of the area of the reserve. Includes patches of transformed and degraded grassland.	Grasses: *Eragrostis* spp.; *Alloteropsis semialata*; *Loudetia simplex*; Sedges: *Cyperus esculentus*; *Cyperus rupestris*; Shrubs and trees: *Seersia lancea; Seersia pyroides*; *Seersia magalismontana*; *Acacia karroo; Serephium plumosum.*
1.1	Cynodon grassland	1 16 6	Heavily grazed, Shallow soils, Grazing lawns. Invaded by *Richardia braziliensis* Subset of group 1	Grasses: *Cynodon dactylon*; *Eragrostis* spp.; Sedges: *Cypersus esculentus*; Forbs; *Richardia braziliensis*; *Parinari capensis*
1.2	Kikuyu grassland	12 15 16A 17A 17B 20B	Kikuyu lawns and invaded areas. Dominated by exotic grasses and forbs. Drainage lines include poplar	Grasses: *Pennisetum clandestinum*; *Paspalum dilatatum*; *Paspalum notatum*; *Cynodon dactylon*; Sedges: *Cyperus esculentus*; Forbs: *Richardia braziliensis*; *Helichrysum* spp.; *Physalis viscosa*; *Solanum sisymbrifolium*; *Commelina subulata*; Shrubs and trees: *Populus* sp.; *Diospyros lycoides*
1.3	Eragrostis grassland	18	Grassland on rocky ridge. Possibly old lands (>100 years)	Grasses: *Eragrostis lehmanniana*; *Eragrostis chloromelas*; *Tristachya rehmannii*; *Cynodon dactylon*; *Elionurus muticus*; Forbs: *Solanum*

Group	Name	Sites	Description	Dominant Species
				elaeagnifolium; *Selago densiflora*; *Commelina africana*; *Chaetacanthus setiger*
Woodland				
2.1	Riverine shrubland	34; 36	Riverine shrubland	Grasses: *Panicum coloratum; Setaria nigrirostris; Panicum maximum; Eragrostis curvula*; Sedges: *Cyperus esculentus*; Forbs: *Xerophyta retinervis*; *Commelina benghalensis*; *Hypoxis rigidula*; Shrubs and trees: *Asparagus cooperi*; *Gymnosporia polyacantha*; *Diospyros lycioides*; *Seersia pyroides*; *Ziziphus mucronata*; *Cussonia paniculata*; *Leucosidea sericea*; *Acacia mearnsii*;
2.2	Sparse Dolomite woodland	28	Shallow soils, Infrequent fire. Dolomitic grassland with scattered bushclumps	Grasses: *Setaria sphacelata*; *Eragrostis lehmanniana*; *Themeda triandra*; *Andropogon appendiculatus*; *Heteropogon contortus*; *Arundinella nepalensis*; Forbs: *Scabiosa columbaria; Albuca sp.*; *Senecio venosus*; *Hermannia transvaalensis*; *Polygala amatymbica*; Shrubs and trees: *Acacia karroo*; *Seersia pyroides*; *Olea europaea* subsp *africana*; *Asparagus laricinus*; *Diospyros lycioides*; *Ziziphus mucronata*
2.3.1	Open dolomite woodland	27	Steep, rocky, wooded slope. Herbaceous layer entirely dominated by *Seteria lindenbergiana*. Transitional to Celtis woodland	Grasses: *Setaria lindenbergiana*; Trees: *Acacia caffra*; *Acacia karroo*: *Cussonia paniculata*; *Seersia pyroides*; *Euclea crispa*; *Gymnosporia buxifolia*; *Buddleja saligna*; *Ehretia rigida*; *Ziziphus mucronata*; *Celtis africana*
2.3.2	Celtis woodland	2A	Tall riverine woodland	Grasses: *Stipa dregeana*; Trees: *Celtis africana*; *Acacia karroo*; *Gymnosporia buxifolia*; *Euclea crispa*; *Seersia pyroides*
2.3.3	Unclassified riverine woodland	35A	Tall closed woodland	Soil sample site; no species assessment conducted. However, the structure and composition differs from the Celtis woodlands
Wetland				
3	Wetland vegetation association	37	Riverine grassland, seeps and drainage lines form a heterogenous wetland association.	Grasses: *Imperata cylindrica*; *Andropogon* eucomis; *Paspalum dilatatum*; *Phragmites australis*; *Dactyloctenium aegyptium*; Sedges: *Cyperus denudatus*; *Kyllinga erecta*; *Fuirena pubescens*; *Pycreus macranthus*; *Schoenoplectus corymbosus*; Bullrushes: *Typha capensis*; Forbs: *Nidorella anomala*; *Verbena brasiliensis*; *Limosella* sp.

The northern portion of the KNR is situated within the Carletonville Dolomite Grassland, while the southern portion of the site is situated within the Soweto Highveld Grassland (Mucina and Rutherford 2006). It must be noted that the National Vegetation Map is a broad scale assessment based on amongst others, geology, soil and climate and variation on a finer-scale can be expected. It is thus likely that the vegetation on the KNR is transitional between these two vegetation types, including characteristic species of both vegetation types.

Although the site is situated in the grassland biome, patches of woodland and shrubland occur, mainly within the northern portion of the site and along the river.



Map 8: Location and vegetation classifications of sites.

The **northern portion** of the reserve falls within the Carletonville Dolomite Grassland, part of the original Bankenveld veld type described by Acocks (1988) which is a transitional veld type between the grasslands of the high interior plateau (south) and the bushveld of the low interior plateau (north). The Magaliesberg roughly forms the division between these veld types (van Wyk and Malan 1998). Being transitional, the Bankenveld includes a number of woody plants that mostly grow in rocky places, especially on hillsides and sheltered ravines. Warmer northern slopes could also include bushveld elements. This could explain the occurrence of the woody vegetation in the northern portion of the KGR. The shrubland on outcrops or koppies forms a distinct structural vegetation type within the grassland matrix (Mucina and Rutherford 2006). However, these shrublands are restricted to the rocky slopes where surface rockiness is high.

The **southern portion** of the reserve is situated in the Soweto Highveld Grassland (Mucina and Rutherford 2006). This vegetation was previously classified as the veld type *Themeda*-veld by Acocks (1988). *Themeda* veld comprises a dense grassland dominated by the grass the climax grass *Themeda triandra* (red grass). Other dominant grasses include *Elionurus muticus, Eragrostis racemosa, Heteropogon contortus* and *Tristachya leucothrix*. This veld type is known to occur in association with black turf soils and frost in winter and the occurrence of trees are limited. This could explain the limited woody plant cover on the southern portion of the KGR. Although a dominant grassland vegetation, shrubland can occur on rocky outcrops where they are protected from fire and grazing (Mucina and Rutherford 2006). In general, the higher the rock cover, the higher the relative cover of woody species to herbaceous species.

Hills and ridges in the study area are often covered by a mosaic of open woodland on the warmer and drier north-facing slopes, closed woodland in more sheltered sites or along rivers and streams. Cooler south-facing slopes may have *Protea caffra* woodland communities, while the more exposed and higher altitude areas comprise grassland (Grobler et al. 2000).

3.2.1 Group 1: Rocky grasslands

3.2.1.1 DESCRIPTION:

The Rocky grassland community is the dominant vegetation within the KGR (Photo 8, Photo 9) and although not in a climax state due to various factors (e.g. grazing or lack of fire), this vegetation group closely represents the reference state. The community occurs across both the dolomite and quartzite geology and encompasses both the vegetation types of the reserve, indicating substantial overlap in species composition.

The grassland is dominated by Increaser 2 *Eragrostis* species (*E. chloromelas* and *E. curvula*) as well as *Alloteropsis semialata* (black-seed grass). Climax and Decreaser grasses such as *Themeda triandra* (red grass) and *Brachiaria serrata* are low in cover abundance, while increaser 2 and 3 grasses such as *Eragrostis plana, Setaria sphacelata, Aristida junciformis, Eragrostis racemosa, Heteropogon contortus, Loudetia simplex* and *Aristida congesta* subsp. *congesta* are more abundant. This veld condition is indicative of overgrazing or selective grazing by smaller animals (especially *Alloteropsis semialata*) (Kirkman 2002, Short 2010). As this grassland comprises much of the KGR, there are subtle botanical differences between steep and gentle slopes, dolomite and quartzite, as well as in areas with deeper soil. Two main sub communities are distinguished: Group 1.1 Cynodon grassland, and Group 1.3: Eragrostis grassland.

A variety of herbaceous species were recorded. The species occurrence varied depending on the soil substrate. The most common forbs are: *Commelina africana, Felicia filifolia, Chamaecrista comosa* var. *capricornia*, an *Albuca* species (not in flower at the time of this assessment), *Senecio venosus*, *Hypoxis obtusa*, *Asparagus cooperi, Kohautia amatymbica* and *Cyanotis speciosa*. Areas with high rocky cover include *Xerophyta retinervis, Bulbostylis burchellii*, the ferns *Pellaea calomelanos* and *Cheilanthus viridis* var. *viridus*, *Senecio oxyriifolius* and *Rotheca hirsuta*. Areas where overgrazing is evident also include the shrub *Seriphium plumosum* (bankruptbush), which is known to increase in destabilised grassland.

The steeper rocky areas included small shrubs and trees such as *Searsia pyroides, S. lancea, S. zeyheri* (on dolomite areas) and *Protea welwitchii*.

Photo 8: A typical view of Group 3: Rocky Grassland. Note the tufts of *Alloteropsis semialata*, a sign of selective grazing.

Photo 9: Recently burnt grassland

3.2.1.2 THREATENED SPECIES:

The Declining *Boophone disticha* grows within the rocky grassland. In addition, suitable habitat for the following species occur, therefore there is a likelihood of these species occurring within KGR (Table 5).

Table 5: Threatened species that potentially occur within the rocky grassland community

Species	Conservation status	Habitat
Bowiea volubilis subsp. *volubilis*	Vulnerable	Open woodland, rocky hills, often in shaded areas.
Brachycorythis conica subsp. *transvaalensis*	Vulnerable	Short grasslands, hillsides, on sandy gravel overlying dolomite, sometimes also on quartzites; occasionally open woodland; 1000 – 1705 m.
Callilepis leptophylla	Declining	Grassland or open woodland, often on rocky outcrops or rocky hillslopes.
Cleome conrathii	Near Threatened	Stony quartzite slopes, usually in red sandy soil, grassland or open to closed deciduous woodland, all aspects.
Delosperma gautengense	Vulnerable	Amongst rocks on hillslopes of the Magaliesberg and associated ridge systems, on south facing slopes.
Delosperma leendertziae	Near Threatened	Rocky ridges; on rather steep south facing slopes of quartzite in mountain grassveld.
Drimia sanguinea	Near Threatened	Open veld and scrubby woodland in a variety of soil types.
Gladiolus robertsoniae	Near Threatened	Moist highveld grasslands, found in rocky sites, mostly dolerite outcrops. Corms are wedged in rock crevices. Restricted to seeps and stream banks where moisture is available at the end of the dry season.
Habenaria mossii	Endangered	Six scattered populations known. Open grassland on dolomite or sandy soil
Holothrix randii	Near Threatened	Grassy slopes and rock ledges, usually southern aspects.
Hypoxis hemerocallidea	Declining	Occurs in a wide range of habitats, from sandy hills on the margins of dune forests to open rocky grassland; also grows on dry, stony, grassy slopes, mountain slopes and plateaux; appears to be drought and fire tolerant.
Ilex mitis var. *mitis*	Declining	Along rivers and streams in forest and thickets, sometimes in the open
Khadia beswickii	Vulnerable	Open areas on shallow surfaces over rocks in grassland.
Lithops lesliei subsp. *lesliei*	Near Threatened	Grasslands, rocky areas. Growing under the protection of forbs and grasses
Melolobium subspicatum	Vulnerable	Grassland
Pearsonia bracteata	Near Threatened	Grassland

3.2.1.3 ECOLOGICAL FUNCTION

This grassland is species rich and under optimum management practices, it is likely to support an even higher species diversity than what was noted at the time of this assessment. This grassland provides habitat to the Declining geophyte *Boophone disticha*. It could potentially support a number of protected plant species.

3.2.1.4 MANAGEMENT CONSIDERATIONS

The veld is overstocked with game, and selectively grazed. More detailed veld management recommendations will be given below. A fire and stocking management plan, with stocking limits, needs to be developed for the reserve.

Red data species identified will require special consideration. Many species are threatened by harvesting for the medicinal plant or horticultural trade and visitors should not be allowed access to populations of threatened plants where practical.

Bush encroachment into the grassland is a serious potential threat (Ward 2005, O'Connor et al. 2014), as can be seen from the cohorts of *Acacia karroo* that have established in certain areas in the grasslands as well as the numerous young Acacias in the woodlands. The management should aim to keep the bulk of the reserve as an open grassland using fire and, if necessary, active bush control, to prevent rapid encroachment of woody species.

3.2.2 Sub Group 1.1: *Cynodon dactylon* grassland

3.2.2.1 DESCRIPTION

Cynodon dactylon (couch grass) is an Increaser 2 grass that grows abundantly in overgrazed veld. This grass dominate this vegetation community is driven by grazing, forming a lawn-like grassland, transformed from the reference grassland state (Photo 10). The *Cynodon dactylon* grassland is embedded in Group 1 Rocky Grassland and mainly occurs on flat crests. The reference grassland forms a complex mosaic dominated by many species. Instead of a variety of highveld grasses, *Cynodon dactylon* was dominant along with the ruderal weeds *Richardia brasiliensis, Solanum sisymbriifolium* (dense-thorned bitter apple/wild tomato), *Physalis viscosa* (sticky gooseberry) and the invasive *Cyperus esculentus* (yellow-nut sedge). This grassland has a low species richness, with many species being pioneer or weedy, and a moderate basal cover.

The southern extent of this vegetation group were less transformed than the northern extent and typical rocky grassland species such as *Parinari capensis* and *Rotheca hirsute* persisted here, with a lower invasion of weedy species.

The following grass species occurred in low abundances *Eragrostis gummiflua, Eragrostis curvula, Aristida congesta* subsp. *barbicollis* and *Brachiaria serrata*

Herbaceous species remnant from the reference state include *Selago densiflora, Parinari capensis, Indigofera melanadenia* and *Rotheca hirsuta*.

3.2.2.2 THREATENED SPECIES

None recorded and none are expected to occur

3.2.2.3 ECOLOGICAL FUNCTION

Provides grazing, while the mat forming *Cynodon dactylon* (couch grass) protect the soils from erosion.

3.2.2.4 MANAGEMENT CONSIDERATIONS:

The grazing lawn is stable and protects the soil surface. It is likely that the system has shifted to a new stable state (sensu Westoby et al. 1989). Management interventions would include: reducing the stocking pressure (discussed below), or protecting the site from grazing with fences and excluding

fire. However, it would be difficult to justify the expense of the second option. The prevalence of *Richardia brasiliensis*, an invasive ground-cover herb, is of concern as the weed thrives in short grass conditions (Short et al. no date). The site could be used to conduct small experiments in management using small exclosure plots to exclude grazers, and controlled use of fire.

Richardia brasiliensis can be controlled by cultivation and is generally susceptible to herbicides (Bromilow 2010).

Solanum sisymbriifolium is difficult to control, other than by foliar application of triclopyr (Bromilow 2010).

Cyperus esculentus is difficult to control, also gives off a toxin that suppress the growth of other plants (allelopathy) and can forms dominant stands (Bromilow 2010).

Photo 10: The southern portion of the *Cynodon dactylon* grasslands, on the ridge crest near site 6

3.2.3 Group 1.2: Kikuyu grassland

3.2.3.1 DESCRIPTION:

This vegetation group is characterised by the dominance of the exotic and invasive *Pennisetum clandestinum* (kikuyu grass). This vegetation was subdivided into two groups, based on its position in the landscape, as well as its origin.

3.2.3.2 KIKUYU LAWNS

On the northern portion of the site, a large area was historically planted as fodder for rhinoceros and are referred to here as kikuyu lawns. Consequently, this area is dominated entirely by kikuyu grass (*Pennisetum clandestinum*) (Photo 11). Weedy species such as *Cyperus esculentus*, *Physalis viscosa, Richardia brasiliensis* and *Solanum sisymbrifolium* are prominent. Some indigenous grass species that occurred in low abundances include *Eragrostis plana* and *Cynodon dactylon*. Around the edges of this kikuyu lawn, the indigenous grasses *Eragrostis chloromelas, Eragrostis lehmanniana* and *Eragrostis plana* occur with some indigenous herbaceous plants such as *Cyanotis speciosa* and *Hermannia depressa*. It is deduced that the kikuyu lawn is spreading into the surrounding *Cynodon dactylon* grassland, which is itself a sign of degradation and heavy grazing around the kukuyu pastures. The lawns are favoured by many of the animal species occurring within the KGR.

Photo 11: Kikuyu lawns, site 15. Weedy species (Solanum) can be seen in the foreground with herds of wildlife in the background

3.2.3.3 INVADED DRAINAGE LINES

The sample plots 17A, 17B and 20B are situated within drainage lines and are also dominated by *Pennisetum clandestinum* with a high occurrence of the sedge *Cyperus esculentus*. However, the species composition included a higher grass and forb count and included the exotic grass *Paspalum dilatatum*, indigenous increaser II grasses *Cynodon dactylon, Eragrostis curvula* and *Paspalum notatum* and the indigenous increaser III grass *Aristida junciformis*. The herbaceous layer included weedy species with an affinity for moist areas such as *Solanum elaeagnifolium*, *Verbena brasiliensis* and indigenous forbs *Commelina subulata* and a *Helichrysum* species. The invasive *Populus canescens* also occurred in this subgroup.

Although both sub communities were dominated by *Pennisetum clandestinum*, their position in the landscape and origin differs. The *Pennisetum* lawns were planted, whereas the invasive *Pennisetum clandestinum* spread into moist and low lying areas and invaded drainage lines, where it outcompetes indigenous species.

Photo 12: Kikuyu invaded drainage line (site 16GG on Map 7)

3.2.3.4 THREATENED SPECIES

None recorded and none are expected to occur in the *Pennisetum* lawns. However, the drainage lines could provide suitable habitat for the Declining geophytes *Crinum bulbipsermum*, *C. macowanii* as well as *Eucomis autumnalis*.

3.2.3.5 ECOLOGICAL FUNCTION

The *Pennisetum* lawns provide grazing, while its creeping growth form and high productivity protect the soils from erosion. However, this benefit does not compensate for the loss of typical grassland species diversity due to invasion by this exotic grass.

3.2.3.6 MANAGEMENT CONSIDERATIONS:

The extent of the *Pennisetum* lawns must be demarcated by pegging the area in the veld. The area must be monitored annually and any spread in growth beyond the demarcated area must be removed (manually or by a foliar herbicide sprayed under the correct conditions (e.g. no wind) to prevent die back of indigenous vegetation.

Within drainage and low lying areas, *P. clandestinum* must be manually removed, ensuring that no plant parts remain from where it could spread again. This should form part of the KNR alien invasive plant management plan, as well as the removal of the *Populus* species from the drainage lines.

3.2.4 Sub Group 1.3: Eragrostis grassland

3.2.4.1 DESCRIPTION

Sub group 1.3 Eragrostis grassland occurred on one site, 18, at the foot of a gentle, rocky slope (Map 5). The site occurred on the only patch of deep Hutton soils on the KGR (Map 7), and it is possible that this grassland community is a secondary grassland resulting from cultivation, probably more than a century ago and perhaps in the more distant past. This observation is speculative but is based on the dominance of *Eragrostis* spp. (typical of old, disturbed lands) and the unique species composition of the site compared to the surrounding grassland

The grassland was almost entirely dominated by *Eragrostis* species, with a low forb species richness, including *Commelina africana*, *Selago densiflora, Cyanotis speciose, Tagetes minuta* (khakibos), and *Diospyros lycioides*

3.2.4.2 MANAGEMENT CONSIDERATIONS

There is little reason to manage this site differently from most of the rest of the reserve. The deep soils and gentle gradient provide good productivity and there is minimal risk of soil erosion. The grass cover is good, and the site can be included in adjacent burning blocks.

3.2.5 Group 2.1: Riverine shrubland

3.2.5.1 DESCRIPTION:

Riverine shrubland grows on the steeper slopes around the river, with more rocky cover on the eastern side of the river than on the western side. The vegetation structure was classified as low closed woodland (Edwards 1983), which forms a distinct vegetation group within the surrounding grassland. This area represents a small ravine after the waterfall that separates the plateau wetland area from the riverine habitat. The woody canopy cover was dominated by the shrub *Diospyros lycioides* (blue bush). Other woody species include *Searsia pyroides, Ziziphus mucronata* (buffalo-thorn) and *Leucosidea sericea* (ouhout). The grass layer was dominated by *Panicum coloratum* and *Setaria nigrirostris* (large seed setaria). The tall growing grass *Panicum maximum* (Guinea grass) is more common in denser vegetated areas, while the exotic grass *Bromus catharticus* (rescue grass) is more prevalent closer to the river. Some notable differences, especially in the herbaceous layer, exist between the eastern and western portion of the river. The western portion is shadier and include the geophyte *Scadoxus puniceus* (paintbrush) and the invasive tree *Acacia mearnsii* (black wattle) along the riparian edge. The denser vegetation included *Gymnosporia polyacantha* (kraal spike thorn) in the shrub layer and the medicinal *Artemissia affra* (wilde als), whereas the eastern side includes a higher rocky cover, less dense vegetation and numerous herbaceous species such as *Asparagus cooperi, Commelina benghalensis* and *Hypoxis rigidula*. This vegetation is closely related to the rocky grassland, with the difference of the high woody cover. The fern *Cheilanthus viridus* subsp. *viridis* grows on both sides of the river.

Although the tree *Celtis africana* (white stinkwood) was not recorded in sample plots, its presence outside of the plots, especially closer to the river, was noted.

This vegetation type is likely a transitional form between the grassland and riparian Celtis woodlands.

Photo 13: Riverine shrubland. Top: Western side of Tweelopiesspruit. Bottom: Eastern Side of Tweelopiesspruit below lodge

3.2.5.2 THREATENED SPECIES

This vegetation type appears to be transitional between grassland and riparian woodland, and therefore is likely to have some elements of both. Suitable habitat for the following species occur, therefore there is a likelihood of these species occurring within KGR (Table 5).

Table 6: Threatened species that potentially occur within the riverine shrubland community

Species	Conservation status	Habitat
Ilex mitis var. *mitis*	Declining	Riverbanks, streambeds, evergreen forests.
Dicliptera magaliesbergensis	Vulnerable	Forest, savanna (Riverine forest and bush).

3.2.5.3 ECOLOGICAL FUNCTION

The riverine shrubland plays a role in buffering the riparian area from potential adverse impacts such as stormwater and effluent. The vegetation is imperative to maintain the health and functioning of the hydrology of the area. In addition, this vegetation type is structurally important as arboreal habitat for fauna.

3.2.5.4 MANAGEMENT CONSIDERATIONS:

It may serve as a nucleus for bush thickening and management should monitor the edges of the woodlands to measure whether woody vegetation is expanding out into the grassland.

There are signs of severe erosion gullies at various points along the river and these need to be rehabilitated. Prevention of further erosion is critical (see section 2: Soils).

3.2.6 Group 2.2: Sparse dolomite woodland

3.2.6.1 DESCRIPTION

This vegetation group is typical of Bankenveld where woody plant assemblages occur on rocky hillsides and warmer northern slopes include bushveld elements. Although open patches of grassland is present, the vegetation structure is classified as low, sparse woodland (Edwards 1983), becoming denser in drainage lines. The dominant tree species include *Searsia zeyheri, Diospyros lycioides, Celtis africana, Acacia karroo* and *Ziziphus mucronata*. These tree species are also common within the riparian vegetation. Open grassy areas are dominated by the grass *Setaria sphacelata* (golden setaria), *Themeda triandra* (red grass) and *Heteropogon contortus* (spear grass). The exposed dolomite, as well as limited grazing in this vegetation supports a high number of herbaceous species such as *Crabbea acaulis, Aloe greatheadii, Ipomoea crassipes, Ocimum obovatum* subsp. *obovatum, Hermannia transvaalensis, Asparagus cooperi, Jamesbrittenia aurantiaca* as well as the geophyte *Ornithoglossum vulgare* (Cape poison onion) (Photo 14). Disturbances in the grass-tree layer dynamic could result in bush densification in this vegetation unit, as *Acacia karroo* (sweet thorn trees) is already encroaching into this vegetation group.

3.2.6.2 THREATENED SPECIES:

Similar to the rocky grassland vegetation community, this sparse woodland could provide habitat to a number of threatened species such as the following (Table 7):

Table 7: Threatened species that potentially occur within the rocky sparse dolomite woodland community

Species	Conservation status	Habitat
Brachycorythis conica subsp. *transvaalensis*	Vulnerable	Short grasslands, hillsides, on sandy gravel overlying dolomite, sometimes also on quartzites; occasionally open woodland; 1000 - 1705m.
Callilepis leptophylla	Declining	Grassland or open woodland, often on rocky outcrops or rocky hillslopes.
Drimia sanguinea	Near Threatened	Open veld and scrubby woodland in a variety of soil types.
Hypoxis hemerocallidea	Declining	Occurs in a wide range of habitats, from sandy hills on the margins of dune forests to open rocky grassland; also grows on dry, stony, grassy slopes, mountain slopes and plateaux; appears to be drought and fire tolerant.
Khadia beswickii	Vulnerable	Open areas on shallow surfaces over rocks in grassland.

Photo 14: Left: Sparse dolomite woodland at site 28. Right: *Ornithoglossum vulgare* on dolomite

3.2.6.3 ECOLOGICAL FUNCTION

This grassland is species rich and under optimum management practices, it is likely to support an even higher species diversity than what was noted at the time of this assessment and could potentially support a number of protected plant species.

3.2.6.4 MANAGEMENT CONSIDERATIONS

Bush encroachment and bush densification is the major concern in this vegetation community. The community can support a number of browsers, which may be desirable to park management. However, the large numbers of young *Acacia karroo* saplings indicate a major bush densification episode is already occurring.

Increased fuel loads and hotter fires are recommended to reduce the bush densification before it becomes a problem. The objective should be to keep the scattered woody component, with denser woody clumps in drainage lines, while suppressing recruitment of large numbers of young saplings.

3.2.7 Group 2.3.1: Open dolomite woodland

3.2.7.1 DESCRIPTION:

This vegetation group is situated on steep west facing slopes and forms the divide between the grassland on the plateau and the lower lying *Celtis* woodland. The tree layer is dominated by the microphyllous *Acacia caffra* (common hook thorn) and *Acacia karroo* (sweet thorn). Broad leafed trees and shrubs include *Searsia zeyheri, S. pyroides, Gymnosporia buxifolia, Euclea crispa* and *Cussonia paniculata* (Highveld cabbage tree). The grass layer was completely dominated by *Setaria lindenbergiana* (mountain bristle grass). The geophyte *Chlorophytum bowkeri* grew on and wedged between rocks under trees. Other herbaceous species include an unidentified *Gladiolus* species (not in flower at the time of the assessment).

Photo 15: Open dolomite woodland. The herbaceous layer is dominated by *Setaria lindenbergiana* (90% cover).

3.2.7.2 THREATENED SPECIES:

None was recorded at the time of the site visit. However, the open dolomite woodland could provide habitat to a number of threatened species such as the following (Table 8)

Table 8: Threatened species that potentially occur within the open dolomite woodland community

Species	Conservation status	Habitat
Adromischus umbraticola subsp. *umbraticola*	Near Threatened	Rock crevices on rocky ridges, usually south-facing, or in shallow gravel on top of rocks, but often in shade of other vegetation.
Bowiea volubilis subsp. *volubilis*	Vulnerable	Shady places, steep rocky slopes and in open woodland, under large boulders in bush or low forest.
Ceropegia decidua subsp. *pretoriensis*	Vulnerable	Direct sunshine or shaded situations, rocky outcrops of the quartzitic Magaliesberg mountain series, in pockets of soil among rocks, in shade of shrubs and low trees, can be seen twining around grass spikes.
Cineraria austrotransvaalensis	Near Threatened	Amongst rocks on steep slopes of hills and ridges, as well as at the edge of thick bush or under trees; on all aspects and on a range of rock types: quartzite, dolomite and shale; 1400 – 1700 m.

3.2.7.3 ECOLOGICAL FUNCTION

The rocky slopes, thick grass cover and woody structure likely form an important faunal habitat. Like the Riverine shrubland, it forms an ecotone between the grassland and riparian area and can significantly reduce the velocity of stormwater from the slopes. It therefore plays an important role in the health and functioning of the hydrology of the area

3.2.7.4 MANAGEMENT CONSIDERATIONS

There is potential for *Acacia* species to encroach into the neighbouring grasslands. Fire should be administered sparingly, but fires will be needed to keep the relatively open woody canopy.

3.2.8 Group 2.3.2: *Celtis africana* woodland

3.2.8.1 DESCRIPTION

The *Celtis* woodland comprises most of the riparian vegetation, north of the waterfall. This vegetation grows on gentle, rocky slopes along the river and is dominated by the tall growing *Celtis africana* (white stinkwood) trees. Smaller trees or tall shrubs such as *Gymnosporia polyacantha, Euclea crispa* (blue guarri), *Buddleja saligna* (false olive) and *Searsia pyroides* (common wild currant) grow in the understory (Photo 16). The grass layer is dominated by *Stipa dregeana* var. *elongata*. The herbaceous layer was sparse and comprised unidentified groundcovers as well as a *Gladiolus* species. None of these species were in flower at the time of the site assessment and species identification is therefore tentative.

3.2.8.2 THREATENED SPECIES

None was recorded at the time of the site visit. However, the Celtis woodland could provide habitat to a number of threatened species such as the following (Table 9)

Table 9: Threatened species that potentially occur within the *Celtis* woodland community

Species	Conservation status	Habitat
Crinum bulbispermum	Declining	Along rivers and streams or in damp depressions in black clay or sandy soil.
Dicliptera magaliesbergensis	Vulnerable	Forest, savanna (Riverine forest and bush).
Ilex mitis var. *mitis*	Declining	Riverbanks, streambeds, evergreen forests.
Prunus africana	Vulnerable	Forests, bushveld.

3.2.8.3 ECOLOGICAL FUNCTION

This area is the only area of mature riverine forest. It is a highly functional and fertile part of the landscape, providing fauna habitat and soil protection. The species composition is relatively low.

3.2.8.4 MANAGEMENT CONSIDERATIONS

Fire should be excluded. There is a small risk of invasion of kikuyu from the adjacent kikuyu lawns, although they are separated by the river. However, this does not preclude vegetative material being brought across the small stream by animals. In addition, the area should be monitored for the emergence of the declared invader *Acacia mearnsii* (black wattle) that has already invaded the upper reaches of the riparian area.

Photo 16: Celtis africana woodland. Two views from the same site (2A), in different directions. Note the tall *Celtis* tree in the background of the top photo.

3.2.9 Group 9: Wetland complex

3.2.9.1 DESCRIPTION

Only one site was formally surveyed which fell into this category (site 37). The wetlands are dealt with in more detail in the Wetland and Aquatic Biomonitoring sections.

The riparian wetlands of the Tweelopiesspruit are a complex of small, nearly monospecific stands of various wetland-associated species. The plot on which the survey was conducted was dominated by *Imperata cylindrica*; however, within a few meters of the plot were patches dominated by *Typhus capensis*, *Limosella* sp., poplar, *Phragmites australis* and others (Figure 2).

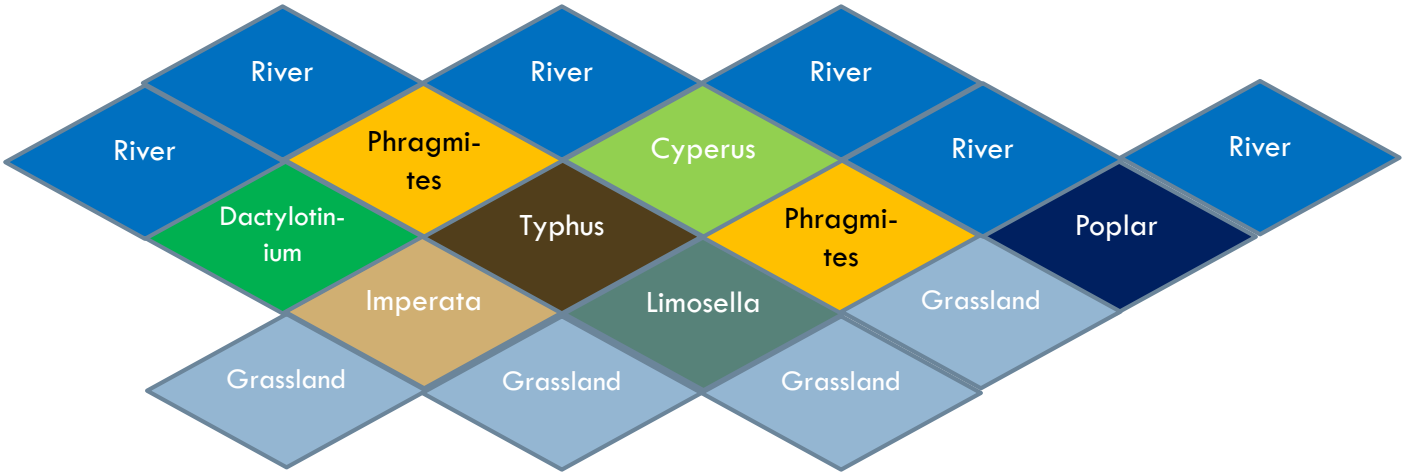


Figure 2: Idealized layout of patches along the Tweelopiesspruit near site 37 (below Hippo dam). The river flows from left to right. Site 37 was located on the Imperata patch. The patches are each a few meters in extent (from 3-10m).

Site 37 was characteristic of the flat, slow-flowing upper reaches of the Tweelopiesspruit. Other wetlands on the reserve (drainage lines and seeps) showed a mixture of grassland and wetland species, with a substantial cover of exotic species (poplar, wattle, kikuyu, *Cyperus esculentus*, *Paspalum* spp., etc.).

3.2.9.2 THREATENED SPECIES

Suitable habitat for the following species occur with the wetland complex (Table 5).

Table 10: Threatened species that potentially occur within the wetland complex

Species	Conservation status	Habitat
Crinum bulbispermum	Declining	Along rivers and streams or in damp depressions in black clay or sandy soil.
Gladiolus robertsoniae	Near Threatened	Moist highveld grasslands, found in rocky sites, mostly dolerite outcrops. Corms are wedged in rock crevices. Restricted to seeps and stream banks where moisture is available at the end of the dry season.
Ilex mitis var. mitis	Declining	Along rivers and streams in forest and thickets, sometimes in the open

3.2.9.3 ECOLOGICAL FUNCTION AND MANAGEMENT

These are dealt with in more detail in section 4: Wetlands.

3.2.10 Summary of distribution of threatened species

Threatened species have been recorded in and around the reserve. The threatened species and their habitats that may occur on the reserve are shown in Table 11

Table 11: Threatened species that were confirmed to occur or could occur in the Krugersdorp Nature Reserve, as well as the vegetation group in which they are likely to occur

Species	Conservation status	Habitat	Flowering period	Vegetation group that the plant could occur in / suitable habitat					
				Rocky grassland	Sparse woodland on dolomite	Low open woodland, steep	Riverine shrubland	Celtis woodland	Wetland / moist grassland
Confirmed to occur in the reserve									
Boophone disticha	D	Dry grassland and rocky areas.	Oct-Jan	X					
Historically recorded in the reserve, high likelihood of occurring									
Lithops lesliei subsp. *lesliei*	NT	Occurs in rocky places, growing under the protection of surrounding forbs and grasses. This plant is well camouflaged in brown shale on hilltops and difficult to spot when not in flower.	Mar-Jun	X					
Historically recorded within 5km of the reserve with a likelihood of occurring in the reserve									
Delosperma leendertziae	NT	Rocky ridges, on rather steep south facing slopes of quartzite in mountain grassveld.	Oct-Apr	X					
Historically recorded within the QDS that the reserve is situated in – some likelihood of occurring if suitable habitat is present									
Bowiea volubilis subsp. *volubilis*	VU	Shady places, steep rocky slopes and in open woodland, under large boulders in bush or low forest.	Sep-Apr			X			
Callilepis leptophylla	D	Grassland or open woodland, often on rocky outcrops or rocky hillslopes.	Aug-Jan & May	X					
Habenaria mossii	Endangered	Occurs in grassland on dolomite. In black or sandy soil	Mar-Apr		X				
Holothrix randii	NT	Grassy slopes and rock ledges, usually southern aspects.	Sep-Oct	X					
Ilex mitis var. *mitis*	D	Riverbanks, streambeds, evergreen forests.	Oct-Dec				X	X	

Species	Conservation status	Habitat	Flowering period	Vegetation group that the plant could occur in / suitable habitat					
				Rocky grassland	Sparse woodland on dolomite	Low open woodland, steep	Riverine shrubland	*Celtis* woodland	Wetland / moist grassland
Khadia beswickii	VU	Open areas on shallow surfaces over rocks in grassland.	Jul-Apr	X	X	X			
Melolobiun subspicatum	VU	Grassland. Very small pockets of suitable habitat remain within the Gauteng province but are threatened by development and the resulting altered fire regime	Sep-May	X	X				
Pearsonia bracteata	NT	Plants in Gauteng and North West occur in gently sloping Highveld grassland, while those in the Wolkberg were collected from steep wooded slopes and cliffs in river valleys.	Dec-Apr	X	X	X			
Other species for which suitable habitat is present, but with no historical records of occurring in the area									
Brachycorythis conica subsp. *transvaalensis*	VU	Short grasslands, hillsides, on sandy gravel overlying dolomite, sometimes also on quartzites, occasionally open woodland; 1000 – 1705 m.	Jan-Mar	X					
Drimia sanguinea	NT	Open veld and scrubby woodland in a variety of soil types.	Aug-Dec	X					
Gladiolus robertsoniae	NT	Moist highveld grasslands, found in rocky sites, mostly dolerite outcrops. Corms are wedged in rock crevices. Restricted to seeps and stream banks where moisture is available at the end of the dry season.	Oct-Dec	X					X
Hypoxis hemerocallidea	D	Occurs in a wide range of habitats, from sandy hills on the margins of dune forests to open rocky grassland; also grows on dry, stony, grassy slopes, mountain slopes and plateaux; appears to be drought and fire tolerant.	Sep-Mar	X					

Species	Conservation status	Habitat	Flowering period	Vegetation group that the plant could occur in / suitable habitat					
				Rocky grassland	Sparse woodland on dolomite	Low open woodland, steep	Riverine shrubland	*Celtis* woodland	Wetland / moist grassland
Cineraria austrotransvaalensis	NT	Amongst rocks on steep slopes of hills and ridges, as well as at the edge of thick bush or under trees; on all aspects and on a range of rock types: quartzite, dolomite and shale; 1400 – 1700 m.	Mar-Jun		X	X			
Adromischus umbraticola subsp. *umbraticola*	NT	Rock crevices on rocky ridges, usually south-facing, or in shallow gravel on top of rocks, but often in shade of other vegetation.	Sep-Jan	X		X			
Crinum bulbispermum	D	Along rivers and streams or in damp depressions in black clay or sandy soil.	Sep-Nov						X
Crinum macowanii	D	Grassland, along rivers, in gravelly soil or on sandy flats.	Oct-Jan						X
Dicliptera magaliesbergensis	VU	Forest, savanna (Riverine forest and bush).	Feb-Apr				X	X	

3.3 Veld condition

The overall veld condition of the KGR is poor to average. Mostly, the reasons for the low veld condition scores are a high abundance of invasive plants (especially kikuyu in many sites), a high abundance of grasses that indicate signs of overgrazing, like Eragrostis species, and in some cases, low plant cover and signs of erosion.

Soil loss was not a serious problem in most of the sites. In general, there was good litter cover and plant cover, with little to no sheet erosion. The steeper grasslands and the woodlands generally had lower soil condition scores, largely due to the slopes. The highest soil condition scores were on the gentle slopes and the kikuyu sites (Figure 3).

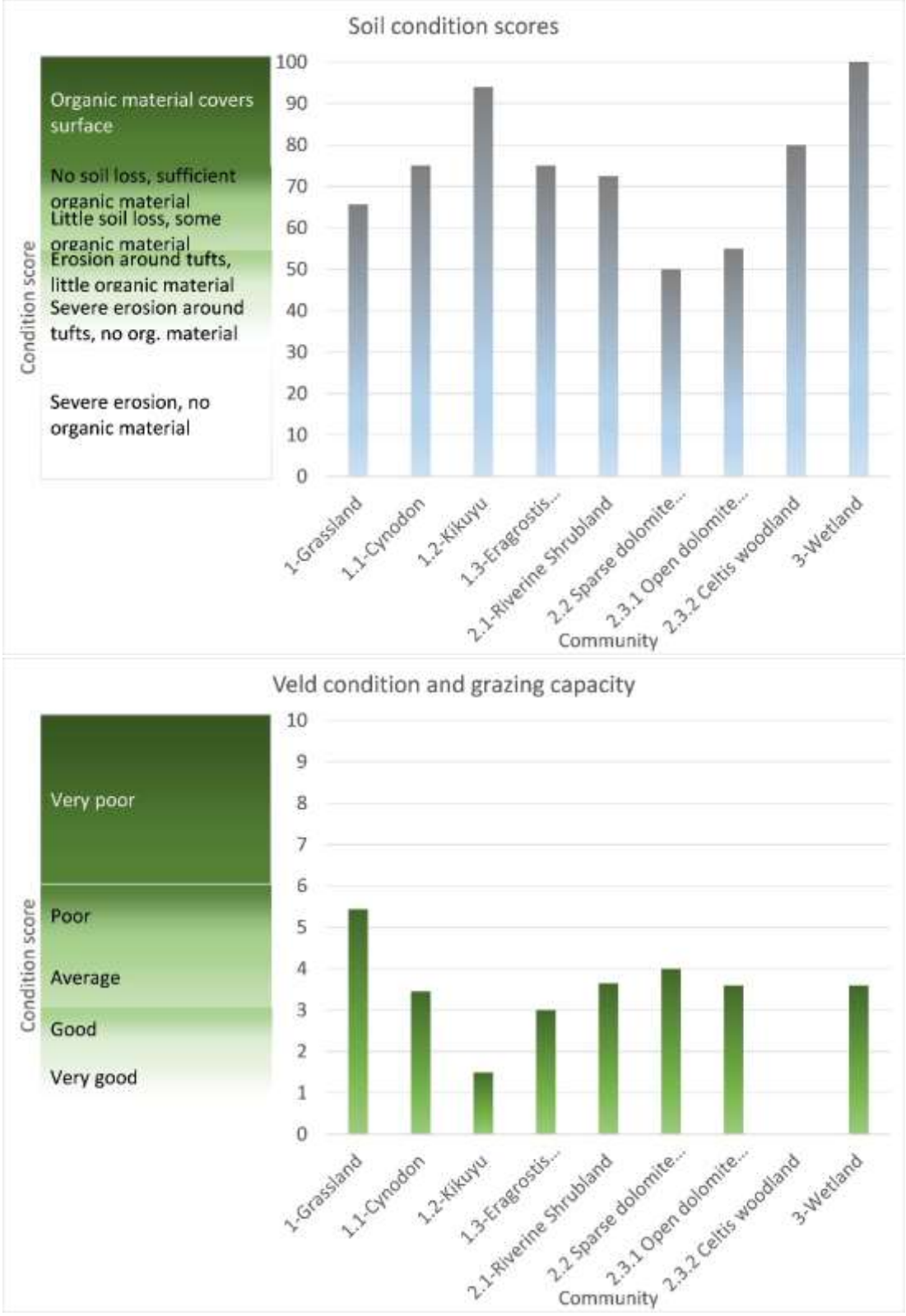


Figure 3: (Top) Average soil condition for each of the vegetation communities in Krugersdorp Game Reserve. (Bottom): veld condition score (text) and grazing capacity (ha/AU) for each of the communities. The grazing capacity scores are based on agricultural norms; conservation norms should be set at about 70% of the agricultural norms (Camp and McCulloch 2008)

3.4 Conclusion

The vegetation of the reserve is in moderate condition in most areas, with some areas invaded by exotic species, particularly along watercourses and drainage lines. Although the reserve is dominated by grasslands, there are small but important patches of other vegetation communities, in particular along the steep and rocky slopes alongside the Northern portion of the Tweelopiesspruit, and in the dolomite grasslands in the north-west of the reserve.

There is a real threat of bush encroachment and bush thickening in the reserve, as can be seen from the numerous small sized stands of *Acacia karroo* in various locations around the reserve.

The diversity of vegetation structure provides important habitat heterogeneity and is likely to increase the potential for biodiversity. However, the woody element of the vegetation must be carefully managed to ensure that large areas of open savanna and grassland do not transform into impenetrable thickets.

The effect of AMD on riparian vegetation is difficult to determine. The main effect of the decant appears to be: transforming the Tweelopiesspruit into a perennial stream, and turning the Hippo Dam into a permanent water body, which would affect vegetation dynamics on the very edge of the river and dam.

The invasion of exotics, especially kikuyu, wattle and poplar, is the biggest threat to the vegetation of the reserve, followed by overgrazing and selective grazing by large numbers of game.

3.5 Recommendations

A detailed veld management plan will be outlined below. The basic principles of managing for conservation will be:

- Set thresholds for woody plant density and manage fire and game numbers to keep woody density below those thresholds (especially young, recruiting plants)
- Reduce stock numbers and develop a veld management plan involving fire rotation
- Develop a fire management plan for regular burning of the grasslands and open woodlands. Vary the fire routine to ensure a diversity of burn ages
- Manage alien vegetation. Set targets for woody aliens, as well as for kikuyu, and ensure that aliens do not encroach further into natural vegetation
- Set areas aside for low, medium and high impacts. Should any threatened plant populations be found, mark them, and isolate them from major tourism activities. Report any populations of threatened plants to GDARD

4 WETLANDS

ANTOINETTE BOOTSMA

4.1 Introduction

4.1.1 Scope of Work

Wetland and riparian delineations and functional assessments were conducted to:

- Provide input into the identification of sensitive ecological areas within which future activities such as creation of watercourse crossings, roads etc. are governed by national and regional legislation and policies;
- Highlight management recommendations aimed at protecting the watercourse from further degradation; and
- Explore ecohydrological opportunities provided by the wetlands on the KGR to contribute to conservation in this reserve.

4.1.2 Wetland assessment

Knowledge of the hydrological processes and dynamics gives an understanding of how a wetland or riparian system functions in a particular landscape setting. Wetlands are sensitive interfaces where terrestrial and hydrological components of the landscape interact, forming specialized habitat and producing unique chemical environments.

The wetlands associated with the Tweelopiesspruit, which flows through the KGR, are an integral component of the biodiversity of the Park. Furthermore, they provide a critical function by positively influencing water quality.

Water that enters the park is characterised by low pH and heavy metal pollution associated with Acid Mine Drainage (AMD). Several wetland features enable them to positively affect AMD, these include adsorption and ion exchange, bioaccumulation, bacterial and abiotic oxidation, sedimentation, neutralization, reduction, and dissolution of carbonate minerals (Perry and Kleinmann 1991). For example, literature reports mechanisms whereby the anoxic zone in wetland sediments provide conditions which favour microbial and chemical reducing processes, enabling the transforming iron and sulfates to insoluble forms (Fennessy and Mitsch 1989). Settling of suspended solids that occurs from water velocity control of the wetland then removes contaminants from the aquatic environment.

4.2 Site description

4.2.1 Drainage

The Tweelopiesspruit receives acid mine drainage (AMD) from raw and neutralised mine water. Historically, the source of water was precipitation and runoff as well as some decanting from five springs that are located adjacent to the southern section of the current watercourse (Map 9). The volume of water artificially directed into this watercourse has altered its natural characteristics, changing a dry non-perennial stream with unchannelled valley bottom wetland components into a perennial river and channelled valley bottom wetland.

4.2.1.1 WETLAND IMPORTANCE

Wetlands are protected by the National Water Act because of their importance and their vulnerability to damaging impacts (Ferrar and Lötter 2007). Wetlands are important because they:

- Provide hydrological control which helps prevent soil erosion (attenuate floods, store and release water slowly);

- Recharge groundwater sources;
- Purify water by trapping many pollutants, including sediment, heavy metals and disease causing organisms;
- Are very productive since they supply nutrients and water in a stable environment for rapid plant growth and thus can be used as grazing areas if done on a sustainable basis; and
- Are one of the most biodiverse ecosystems, providing life support for a wide variety of species, some totally reliant on wetlands for their survival (Davies and Day 1986, DWAF 2005).

Wetlands are among some of the most threatened habitats in the world. In some catchments in South Africa, studies have revealed that over 50% of the wetlands have already been destroyed. Altering the water flow and quality may destroy or damage wetlands, and continued wetland destruction will result in less pure water, less reliable water supplies, increased severe flooding, lower agricultural productivity, and more endangered species (DWAF 2005). Mining activities, agriculture, and other sources of contamination are among the causes of impacts on this habitat.

The National Water Act, 1998 (Act No. 36 of 1998) [NWA] provides for Constitutional water demands including pollution prevention, ecological and resource conservation and sustainable utilisation. In terms of this Act, all water resources, including springs, aquifers, watercourses, and surface water are the property of the State and are regulated by the Department of Water and Sanitation (DWS).

The NWA defines a wetland as "land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil." In addition to water at or near the surface, other distinguishing indicators of wetlands include hydromorphic soils and vegetation adapted to or tolerant of saturated soils (DWAF 2005).

Riparian habitat often perform important ecological and hydrological functions, some similar to those performed by wetlands (DWAF 2005). Riparian habitat is also the accepted indicator used to delineate the extent of a river's footprint (DWAF 2005). It is defined by the NWA as follows: "Riparian habitat includes the physical structure and associated vegetation of the areas associated with a watercourse, which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas".

Water uses for which authorisation must be obtained from DWS are indicated in Section 21 of the NWA. Section 21 (c) and (i) is applicable to any activity related to a wetland:

- Section 21(c):Impeding or diverting the flow of water in a watercourse; and
- Section 21(i):Altering the bed, banks, course or characteristics of a watercourse.

Authorisations related to wetlands are regulated by Government Notices R.1198 and R.1199 of 18 December 2009. GN 1198 and 1199 of 2009 grants General Authorisation (GA) for the above water uses on certain conditions:

- GN R.1198: Any activity in a wetland for the rehabilitation of a wetland for conservation purposes.
- GN R.1199: Any activity more than 500 m from the boundary of a wetland.

These regulations also stipulate that these water uses must the registered with the responsible authority. Any activity that is not related to the rehabilitation of a wetland and which takes place within 500 m of a wetland are excluded from a GA under either of these regulations. Wetlands situated within 500 m of proposed activities should be regarded as sensitive features potentially

affected by the proposed development (GN 1199). Such an activity requires a Water Use Licence (WUL) from the relevant authority.

In addition to the above, the proponent must also comply with the provisions of the following relevant national legislation, conventions and regulations applicable to wetlands and riparian zones:

- Convention on Wetlands of International Importance - the Ramsar Convention and the South African Wetlands Conservation Programme (SAWCP)
- National Environmental Management Act, 1998 (Act No. 107 of 1998) [NEMA]
- National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)
- National Environment Management Protected Areas Act, 2003 (Act No. 57 of 2003)
- Regulations GN R.982, R.983, R. 984 and R.985 of 2014, promulgated under NEMA
- Conservation of Agriculture Resources Act, 1983 (Act 43 of 1983)
- Regulations and Guidelines on Water Use under the NWA
- South African Water Quality Guidelines under the NWA
- Mineral and Petroleum Resources Development Act, 2002 (Act No. 287 of 2002).

4.3 Methodology

The delineation method documented by the Department of Water affairs and Forestry in their document "Updated manual for identification and delineation of wetlands and riparian areas" (DWAF 2008), and the Minimum Requirements for Biodiversity Assessments (GDARD 2012) as well as the Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems (Ollis et al. 2013) was followed throughout the field survey. These guidelines describe the use of indicators to determine the outer edge of the wetland and riparian areas such as soil and vegetation forms as well as the terrain unit indicator.

A hand-held Garmin Montana 650 was used to capture GPS co-ordinates in the field. 1:50 000 cadastral maps and available GIS data were used as reference material for the mapping of the preliminary watercourse boundaries. These were converted to digital image backdrops and delineation lines and boundaries were imposed accordingly after the field survey.

4.3.1 Wetland and riparian delineation

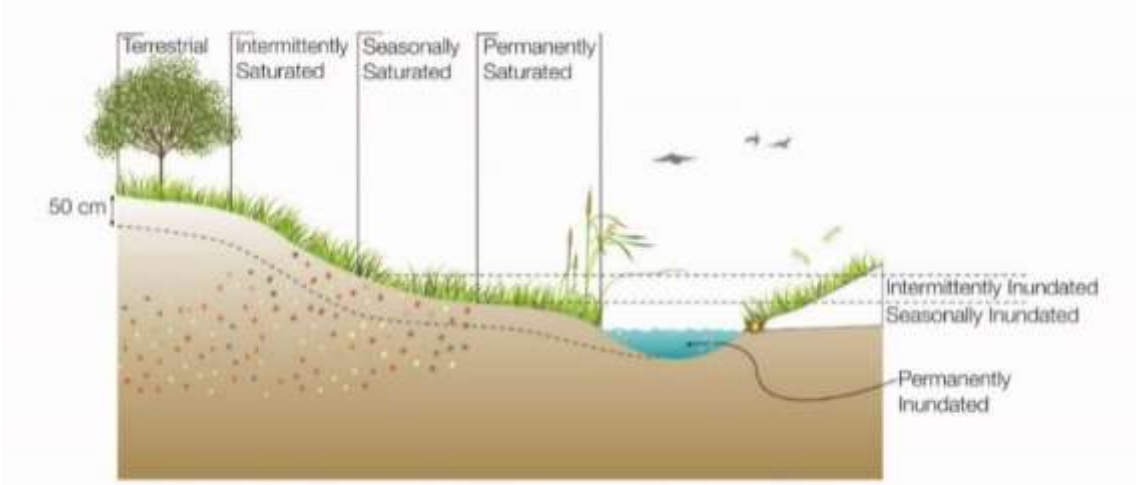


Figure 4: Typical cross section of a wetland (from Ollis et al. 2013)

Wetlands are identified based on the following characteristic attributes (DWAF 2005) (Figure 4):

- The presence of plants adapted to or tolerant of saturated soils (hydrophytes);
- Wetland (hydromorphic) soils that display characteristics resulting from prolonged saturation; and

- A high water table that results in saturation at or near the surface, leading to anaerobic conditions developing within 50 cm of the soil surface.

4.3.1.1.1 The Terrain Unit Indicator

The terrain unit indicator (Figure 5) is an important guide for identifying the parts of the landscape where wetlands might possibly occur. Some wetlands occur on slopes higher up in the catchment where groundwater discharge is taking place through seeps. An area with soil wetness and/or vegetation indicators, but not displaying any of the topographical indicators should therefore not be excluded from being classified as a wetland. The type of wetland which occurs on a specific topographical area in the landscape is described using the Hydrogeomorphic classification which separates wetlands into 'HGM' units. The classification of Ollis, *et al*. (2013) is used, where wetlands are classified on Level 4 as either Rivers, Floodplain wetlands, Valley-bottom wetlands, Depressions, Seeps, or Flats (Figure 6).

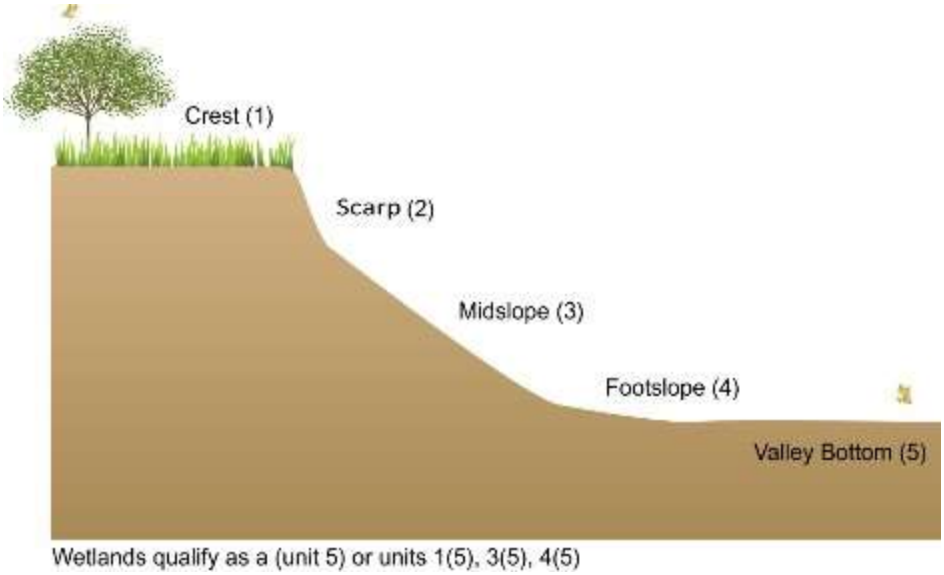


Figure 5. Terrain units (DWAF, 2005)

4.3.1.1.2 Riparian Indicators

Riparian habitat is classified primarily by identifying riparian vegetation along the edge of the macro stream channel. The macro stream channel is defined as the outer bank of a compound channel and should not be confused with the active river bank. The macro channel bank often represents a dramatic change in the energy with which water passes through the system. Rich alluvial soils deposit nutrients making the riparian area a highly productive zone. This causes a very distinct change in vegetation structure and composition along the edges of the riparian area (DWAF 2008). The marginal zone includes the area from the water level at low flow, to those features that are hydrologically activated for the greater part of the year (Kleynhans et al. 2007). The non-marginal zone is the combination of the upper and lower zones (Figure 7).

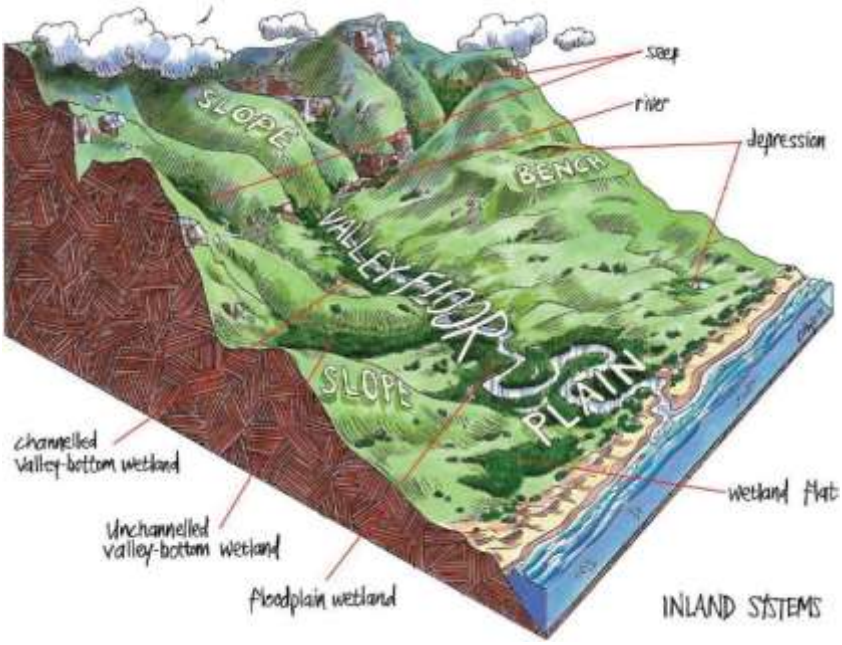


Figure 6: Wetland Units based on hydrogeomorphic types (Ollis *et al.* 2013)

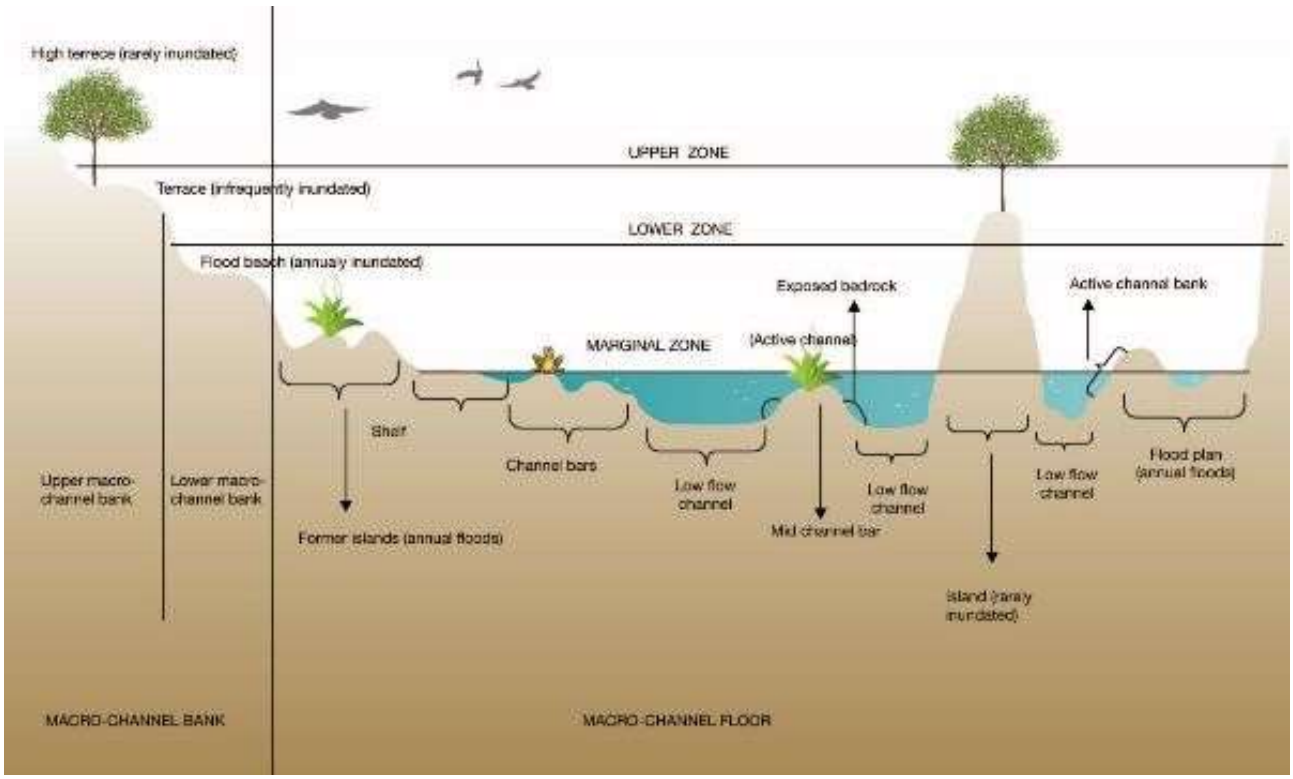


Figure 7: Schematic diagram illustrating an example of where the 3 zones would be placed relative to geomorphic diversity (Kleynhans *et al*, 2007)

The vegetation of riparian areas is divided into three zones, the marginal zone, lower non-marginal zone and the upper non-marginal zone (Table 12). The different zones have different vegetation growth.

Table 12: Description of riparian vegetation zones (Kleynhans *et al*, 2007).

Vegetation zone	Alternative descriptions	Extends from	Extends to	Characterized by
Marginal	Active features; Wet bank	Water level at low flow	Geomorphic features/substrates that are hydrologically activated (inundated or moistened) for the greater part of the year.	See above; Moist substrates next to water's edge; water loving- species usually vigorous due to near permanent access to soil moisture
(Non-marginal) Lower	Seasonal features Wet bank	Marginal zone	Usually a marked increase in lateral elevation.	Geomorphic features that are hydrologically activated (inundated or moistened) on a Seasonal basis. May have different species than marginal zone
(Non-marginal) Upper	Ephemeral features; Dry bank	Lower zone	Usually a marked decrease in lateral elevation	Geomorphic features that are hydrological activated (inundated or moistened) on an Ephemeral basis. Presence of riparian and terrestrial species Terrestrial species with increased stature

4.3.1.1.3 Riparian Area

A riparian area can be defined as a linear fluvial, eroded landform which carries channelized flow on a permanent, seasonal or ephemeral/episodic basis. The river channel flows within a confined valley (gorge) or within an incised macro-channel. The "river" includes both the active channel (the portion which carries the water) as well as the riparian zone (Kotze 1999).

Riparian areas can be grouped into different categories based on their inundation period per year. Perennial rivers are rivers with continuous surface water flow, intermittent rivers are rivers where surface flow disappears but some surface flow remains, temporary rivers are rivers where surface flow disappears for most of the channel (Figure 8). Two types of temporary rivers are recognized, namely "ephemeral" rivers that flow for less time than they are dry and support a series of pools in parts of the channel, and "episodic" rivers that only flow in response to extreme rainfall events, usually high in their catchments (Seaman et al. 2010). The riparian areas recorded on site are thus classified as episodic streams due to the high elevation of these streams.

Figure 8: The four categories associated with rivers and the hydrological continuum. Dashed lines indicate that boundaries are not fixed (Seaman *et al*, 2010).

4.4 Wetland functionality, status and sensitivity

The Aquatic Biomonitoring chapter discusses the functional assessment of the riparian component of the watercourse. This chapter will therefore focus on the wetland component of the watercourse through analysis of the Wet-Health and Ecological Importance and Sensitivity Score.

Wetland functionality is defined as a measure of the deviation of wetland structure and function from its natural reference condition. The natural reference condition is based on a theoretical undisturbed state extrapolated from an understanding of undisturbed regional vegetation and hydrological conditions. In the current assessment the hydrological, geomorphological and vegetation integrity was assessed for the wetland unit associated with the study site, to provide a Present Ecological Status (PES) score (Macfarlane et al. 2008) and an Environmental Importance and Sensitivity category (EIS) (DWAF 1999). The impacts observed for the affected wetlands on the study site are based on evidence observed during the field survey and land-use changes visible on aerial imagery.

The allocations of scores in the functional and integrity assessment are subjective and are thus vulnerable to the interpretation of the specialist. Collection of empirical data is precluded at this level of investigation due to project constraints including time and budget. Water quality values, species richness and abundance indices, surface and groundwater volumes, amongst others, should ideally be used rather than a subjective scoring system such as is presented here.

The functional assessment methodologies presented below take into consideration subjective recorded impacts to determine the scores attributed to each functional Hydrogeomorphic (HGM) wetland unit. The aspect of wetland functionality and integrity that are predominantly addressed include hydrological and geomorphological function (subjective observations) and the integrity of the biodiversity component (mainly based on the theoretical intactness of natural vegetation) as directed by the assessment methodology.

In the current study the wetland was assessed using, WET-Health (Macfarlane et al. 2008) and EIS (DWAF 1999).

4.4.1 Present Ecological Status (PES) – WET-Health

A summary of the three components of the WET-Health namely Hydrological, Geomorphological and Vegetation Health assessment for the wetlands found on site is described in Table 13. A Level 1 assessment was used in this report. Level 1 assessment is used in situations where limited time and/or resources are available.

Table 13: Health categories used by WET-Health for describing the integrity of wetlands (Macfarlane et al. 2008)

Description	Impact Score Range	PES Score	Summary
Unmodified, natural.	0-0.9	A	Very High
Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	1-1.9	B	High
Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact.	2-3.9	C	Moderate
Largely modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.	4-5.9	D	Moderate
The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9	E	Low
Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8.10	F	Very Low

The change class, description and symbols used to evaluate wetland health are summarised in Table 14.

Table 14: Trajectory class, change scores and symbols used to evaluate Trajectory of Change to wetland health (Macfarlane *et al.* 2008)

Change Class	Description	Symbol
Improve	Condition is likely to improve over the over the next 5 years	(↑)
Remain stable	Condition is likely to remain stable over the next 5 years	(→)
Slowly deteriorate	Condition is likely to deteriorate slightly over the next 5 years	(↓)
Rapidly deteriorate	Substantial deterioration of condition is expected over the next 5 years	(↓↓)

4.4.2 Ecological Importance and Sensitivity (EIS)

Ecological importance is an expression of a wetland's importance to the maintenance of ecological diversity and functioning on local and wider spatial scales. Ecological sensitivity refers to the system's ability to tolerate disturbance and its capacity to recover from disturbance once it has occurred (DWAF 1999). This classification of water resources allows for an appropriate management class to be allocated to the water resource and includes the following:

- Ecological Importance in terms of ecosystems and biodiversity such as species diversity and abundance.
- Ecological functions including groundwater recharge, provision of specialised habitat and dispersal corridors.
- Basic human needs including subsistence farming and water use.

The Ecological Importance and Sensitivity of each of the wetlands is represented are described in the results section. Explanations of the scores are given in Table 15.

Table 15: Environmental Importance and Sensitivity rating scale used for the estimation of EIS scores (DWAF 1999)

Ecological Importance and Sensitivity Categories		Rating	Recommended Ecological Management Class
Very High	Wetlands that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these wetlands is usually very sensitive to flow and habitat modifications. They play a major role in moderating the quantity and quality of water in major rivers	>3 and <=4	A
High	Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these wetlands may be sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water of major rivers	>2 and <=3	B
Moderate	Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water in major rivers	>1 and <=2	C
Low/Marginal	Wetlands that are not ecologically important and sensitive at any scale. The biodiversity of these wetlands is ubiquitous and not sensitive to flow and habitat modifications. They play an insignificant role in moderating the quantity and quality of water in major rivers	>0 and <=1	D

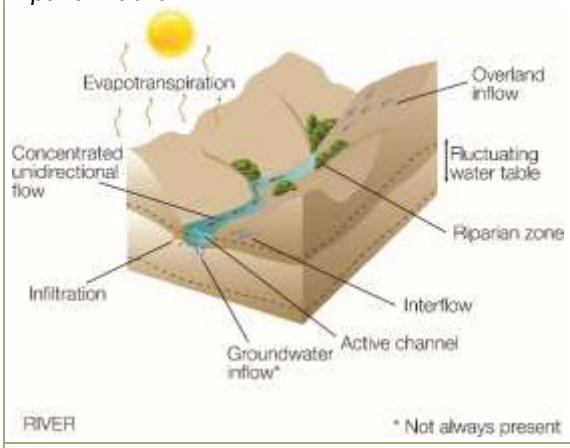
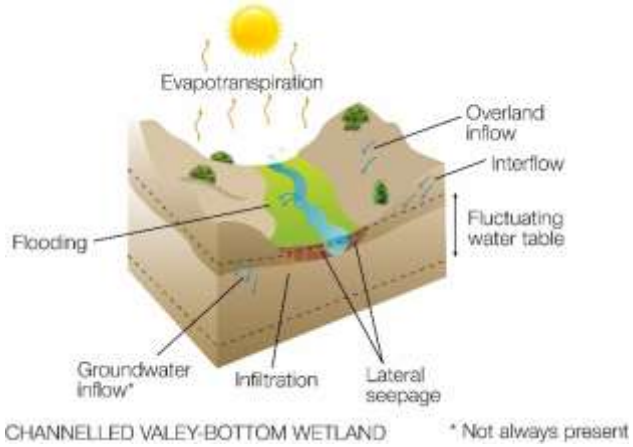
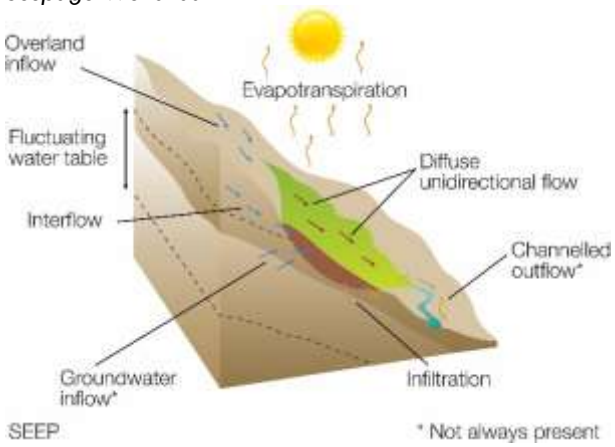
4.5 Results

4.5.1 Classification and delineation

The classification system developed for the National Wetlands Inventory is based on the principles of the hydro-geomorphic (HGM) approach to wetland classification (SANBI 2009). The current wetland study follows the same approach by classifying wetlands in terms of a functional unit in line with a level three category recognised in the classification system proposed by SANBI (2009).

Current characteristics of watercourses within the KGR boundaries are closely linked with underlying geology and topography (see section 1.5.3: Geology and Topography). Slopes are gentle forming undulating plains. The watercourse in this section of the Reserve is wide and characterised by low energy flows and saturated conditions. Seepage and springs are found adjacent to the watercourse. These conditions follow the definition of wetlands rather than rivers (Photo 17). The classification of the watercourse is presented as per the highlighted sections in Table 16 below (adapted from Brinson 1993, Kotze 1999, Marneweck and Batchelor 2002, DWAF 2005).

Table 16: Wetland types

Hydro-geomorphic types	Description
Riparian habitat 	Linear fluvial, eroded landforms which carry channelized flow on a permanent, seasonal or ephemeral/episodic basis. The river channel flows within a confined valley (gorge) or within an incised macro-channel. The "river" includes both the active channel (the portion which carries the water) as well as the riparian zone. **These characteristics clearly describe the watercourse in the northern section of the reserve.**
Valley bottom with a channel 	Linear fluvial, net depositional valley bottom surfaces which have a straight channel with flow on a permanent or seasonal basis. Episodic flow is thought to be unlikely in this wetland setting. The straight channel tends to flow parallel with the direction of the valley (i.e. there is no meandering), and no ox-bows or cut-off meanders are present in these wetland systems. The valley floor is, however, a depositional environment such that the channel flows through fluvially-deposited sediment. These systems tend to be found in the upper catchment areas. **In the southern section of the reserve, the watercourse is characterised by the depositional environment described above. Stands of *Phragmites australis, Typha capensis*, and various sedge and grass species are characteristic of this system. Species recorded here include *Cyperus denudatus, Paspalum dilatatum, Fuirena pubescens, Kyllinga erecta, Pycreus macranthus, Fuerena pubescens and Schoenoplectus corymbosus***
Seepage Wetlands 	Seepage wetlands are the most common type of wetland (in number), but probably also the most overlooked. These wetlands can be located on the mid- and footslopes of hillsides; either as isolated systems or connected to downslope valley bottom wetlands. They may also occur fringing depressional pans. Seepages occur where springs are decanting into the soil profile near the surface, causing hydric conditions to develop; or where through flow in the soil profile is forced close to the surface due to impervious layers (such as plinthite layers; or where large outcrops of impervious rock force subsurface water to the surface). **A seepage component is evident along the channelled valley bottom wetland recorded in the southern section of the KGR. Stands of the grass *Imperata cylindrica* are characteristic of this area, together with some evidence of lateral water movement in the soil including orange mottling within 50cm of the soil surface and oxidation along the root sheaths of plants that grow in this area.**

Hydro-geomorphic types	Description
Drainage lines 	These areas do not reflect hydromorphic soil or plants adapted to wet conditions. Neither is water evident throughout most of the year. However, important hydrological processes still occur, mainly high energy surface water runoff in response to rainfall events. Drainage lines may also be referred to as Episodic Streams for which the definition is rivers that only flow in response to extreme rainfall events, usually high in their catchments (Seaman et al, 2010). The functional assessment methodologies are not designed to assess the integrity of these drainage lines, however, they are protected under the National Water Act and as such should be considered as sensitive landscape elements that should be protected from degradation. **In the KGR several drainage lines occur on steep slopes, draining into the Tweelopiesspruit in the northern section of the site.**

The northern section of the reserve underlain by dolomite has steep slopes. Water flows here are characterised by high energy flows, little saturation of soils and no lateral seepage. This section of the watercourse is classified as a river with adjacent riparian habitat (**Error! Reference source not found.**B).

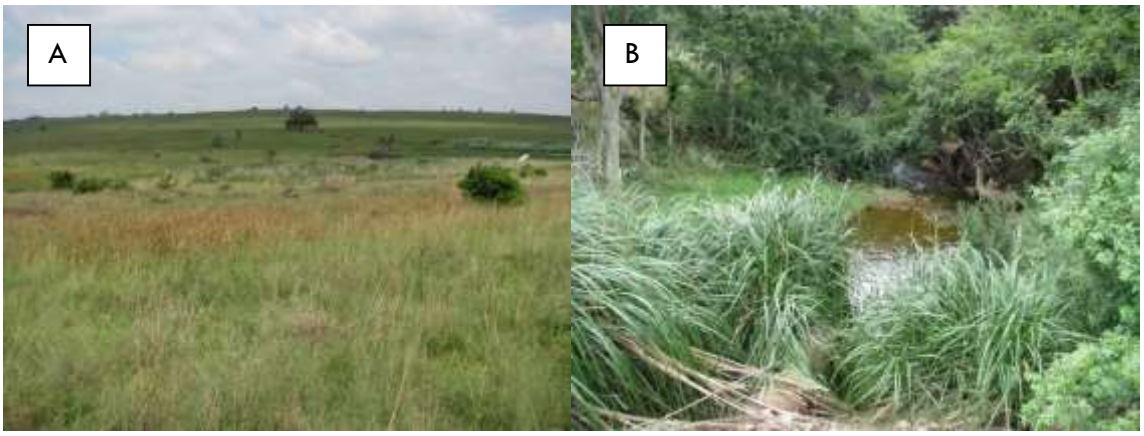


Photo 17: A: Gentle slopes and wide, low energy wetland system in the southern section of the site, B: Steep slopes and high energy narrow, riparian areas in the northern section of the site

The vegetation and soil characteristics of the watercourse are described in detail in dedicated chapters in this report and as such will not be duplicated here. However, interesting features noted included an absence of hydromorphic soils. In many cases deep red soils were recorded where vegetation reflected temporary wetland conditions. This reflects the artificial nature of particularly the wetland section of the watercourse. The release of mine waste water into the Tweelopiesspruit changed the system from a relatively dry non-perennial or unchannelled valley bottom system with seepage input to a channelled valley bottom wetland system, fed primarily from artificial water input. Lateral water input remains evident in the five springs located adjacent to the wetland. The wetland and riparian delineation is presented in Map 9.

Springs form part of the hydrology of the site although they are not necessarily associated with wetland characteristics. Springs form where water is discharged at the soil/rock interface. They are the result of water that has infiltrated into the substrate and has become subject to a high pressure so that, where a fissure in the rocks or suitable soil profile is located, water is released to form a spring. The location of springs in the KGR are presented in Map 9.

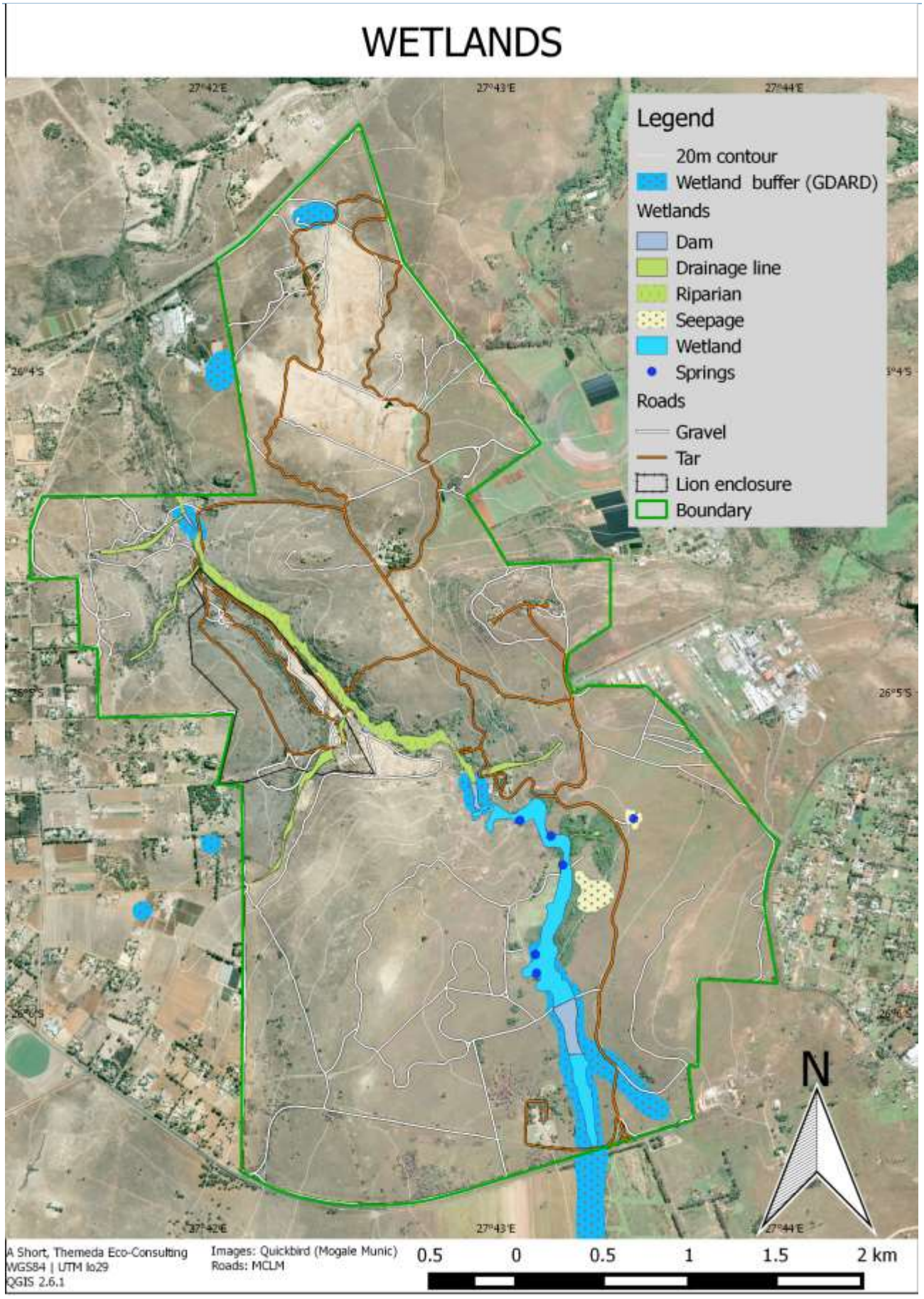
4.5.2 Wetland functionality, status and sensitivity

Functionality and sensitivity of the river and associated riparian habitat has been described in detail in the aquatic biomonitoring chapter of the report. The following section therefore focuses on the section of the Tweelopiesspruit that has been classified as a wetland area.

4.5.2.1 ECOLOGICAL IMPORTANCE AND SENSITIVITY (EIS)

The EIS scores for the wetlands studied during the study site visit are summarised below (Table 17). The wetland scored a C (Moderate) - Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water in major rivers (DWAF 1999).

Despite the wetland being in a nature reserve, the compromised state of the water quality negatively influenced the EIS score. Hydro-functional importance scored highest since this wetland (as part of the larger watercourse of which it forms part) is ideally suitable for research since long term data is available, particularly on water quality. Furthermore, many processes enable the wetland to improve the quality of water entering the system.



Map 9: Wetlands of Krugersdorp Game Reserve

Table 17: Combined EIS scores obtained for the wetlands on the study site (DWAF 1999).

Wetland	WETLAND IMPORTANCE AND SENSITIVITY	Importance	Confidence
Channelled Valley Bottom	Ecological importance & sensitivity	1.5	4.2
	Hydro-functional importance	2.8	4.0
	Direct human benefits	1.5	3.5
	Overall EIS score		**1.9 C**

4.5.2.2 PRESENT ECOLOGICAL STATUS (PES)

Apart from the fact that the wetland is driven by an artificial and highly polluted source of water, several impacts are relevant to the functionality of the wetland. Flow patterns are highly canalised. Input from springs and seepage areas adjacent to the main wetland body are in some instances also canalised. Although stands of *Populus X canescens* (poplar trees) have been removed, wetland plant species are in some areas characterised by suboptimal vegetation cover in terms of roughness, or the resistance they provide to water flow, enabling the wetland to attenuate high energy flows. This may be due to the recent removal of the Poplar trees and may improve with time.

In summary the PES score reflects the fact that the wetland is in a highly altered state from its original reference condition. However, the fact that, particularly the reed beds are highly functional in terms of their effect on improving water quality, should also be noted. The combined PES scores for the wetland is E. The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable (Macfarlane et al. 2008). The scores are summarised in Table 18 below.

Table 18: Summary of hydrology, geomorphology and vegetation health assessment for the wetlands located in the KGR (Macfarlane et al. 2008).

Wetland Unit	Extent (%)	Hydrology		Geomorphology		Vegetation		Overall Health Score	
		Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score	Impact Score	Change Score
Channelled Valley Bottom	100	3.5	0	3.6	-1	7.2	-1	4.59	-1
PES Category and Projected Trajectory		**C**	→	**C**	↓	**E**	↓	**D**	↓

4.6 Conclusion

The section of the Tweelopiesspruit associated with the KGR can be classified into a northern riparian and southern wetland area. The wetland area is driven by an artificial input of highly polluted water in a landscape with gentle slopes. Low energy water flows consequently allow for saturated soil conditions and the persistence of hydrophytic vegetation. The steep slopes of the northern section of the reserve lead to high energy water flows and riparian conditions.

The PES of the wetland is calculated as E. The wetland is in a highly altered state from its original reference condition. However, particularly the reed beds are highly functional in terms of their effect on improving water quality.

The EIS score is slightly higher than expected since the wetland falls within a Nature Reserve. Furthermore, the degree of data available on particularly water quality, creates the ideal opportunity for future research.

4.7 Recommendations

Wetlands provide a tourism opportunity for bird viewing and photography. Rehabilitation of the wetland to an increased functional state (or higher PES class) will see the improvement of the wetlands as habitat to insects, birds and fauna. Kikuyu grass in the reserve should be managed so as to not encroach onto wetland areas (including the protective 50m buffer zone) since this will have a highly detrimental effect on biodiversity and wetland function (See Section 4: Vegetation).

The use of wetlands to improve water quality, particularly AMD should be investigated. The possibility exists to expand reed beds, regularly remove sediments and harvest reeds in the late summer to remove toxicants that have settled out and assimilated into these elements. This also provides an ideal research opportunity since a body of data (although unpublished) is available for this section of the Tweelopiesspruit.

An alternative to managing the mine waste water in the Tweelopiesspruit is to divert this water into another watercourse in which it can be treated as part of an existing treatment facility. This allows the Tweelopiesspruit to revert to its original hydrological drivers. This option will necessarily require in-depth studies and rehabilitation since extensive long term pollution of sediments have occurred.

Future development including bridges and roads crossing the wetland or riparian area should take cognisance of the delineated watercourse. A 50m buffer zone should be considered as a sensitive environment in which development should not occur, or within which strict mitigation and rehabilitation measures should be implemented.

Broad impacts of construction and maintenance associated with potential future development activities includes the following:

Changing the physical structure within a water resource by destruction of wetland habitat. This impact is unavoidable given the nature of the proposed activities. The dispersive quality of soils, slopes and volume and energy of water flows should form part of the design of appropriate structures that will prevent damage to downstream areas resulting from the development.

Clearing/removal of natural vegetation. The plants that grow in wetlands and rivers are vital for preventing erosion, they play a role in the purification of water, reducing the severity of floods and regulating water, especially during droughts. The moment the vegetation is destroyed, these valuable functions disappear. In addition, vegetation around watercourses, especially upslope, holds soil in place and slows down water runoff during rainy events. The vegetation thus promotes groundwater recharge, while protecting soils from eroding, subsequently causing sedimentation in watercourses. The plant species characteristic of the system under discussion are pioneers and colonize easily on disturbed areas or sediment deposits and are therefore easy to rehabilitate given that alien vegetation is monitored and controlled.

Mobilization of sediments. Soil erosion could lead to increased sedimentation and turbidity in downstream of the activity, which in turn reduce the water storage capacity thereof, smother vegetation, and decrease oxygen concentration. If sedimentation is allowed to continue, wetlands will lose their function and likely become invaded by alien invasive plant species.

Compaction of wetland soils. Construction activities may compact soils from heavy equipment access which could inhibit seed germination, reduce water infiltration, inhibit root establishment, and result in bare soil exposure. In particular, soil compaction can lead to an increase in runoff during rainy events. This impact is largely unavoidable since the proposed activities need to occur in the watercourse. It is therefore necessary that the smallest possible footprint be identified, especially in terms of vehicle access and support crew. As far as possible work should occur in the dry season when soil compaction is less critical.

Changing or impeding the flow of water. This impact is unavoidable given the nature of the proposed activities. The dispersive quality of soils, slopes and volume and energy of water flows should form part of the design of appropriate structures that will prevent damage to downstream areas resulting from the development. During construction through a wetland, the majority of the flow of the wetland must be allowed to pass down the stream channel (i.e. damming must not be allowed to take place). In-stream diversions should be used rather than the construction of new channels

Exposure to erosion. Removal of stream bank vegetation, vegetation against slopes and compaction of soils, expose the resulting bare soils to erosion during rainfall events. Erosion removes the top soil layer, thereby preventing the successful establishment of indigenous vegetation on eroded soils. Eroded areas are likely to be colonised by alien invasive and pioneer plants, or in severe cases, no vegetation will establish causing high velocity runoff during rainfall events and continuous erosion. The occurrence of erosion resulting from the proposed activities should be closely monitored and addressed effectively.

Mobilisation of pollutants: Accidental pollution or illegal disposal and dumping of construction material such as cement or oil, as well as disposal or discharge of human (including partially treated and untreated sewage) into water resources will influence the water quality of watercourses, thereby influencing its functionality and the persistence of vegetation. Water is expected to seep into any area of digging that goes through a wetland area. It is likely that water could be contaminated within these trenches. Furthermore, the surrounding areas are already exposed to pollution which during high rainfall events could be washed into the wetlands – especially if vegetation cover is not sufficient to slow down water and filter pollutants.

Invasion by alien invasive vegetation: During construction, vegetation may be removed and soil disturbed. The seeds of alien invasive species that occur on and in the vicinity of the construction area could spread into the disturbed or stockpiled soils. In addition, the construction vehicles and equipment were likely used on various other sites and could introduce alien invasive plant seeds to the construction sites. From these construction sites, alien invasive plant species can easily spread downstream, likely resulting in offsite impacts.

Detailed mitigation and rehabilitation measures should be compiled to inform potential future developments. Mitigation measures should be based on the following principles:

- Limit the footprint of construction, thereby reducing compaction and destruction of natural vegetation.
- Limit the impact on the hydrology and morphology of the wetland and river.
- Prevention of pollution.
- Prevent/limit sedimentation.
- Preventing spread of alien invasive plants and control of existing populations of aliens.

5 AQUATIC BIOMONITORING

LORAINMARI DEN BOOGERT

5.1 Introduction

The National Water Act 36 of 1998 ("NWA") requires the management of water resources in South Africa, including the ecological integrity of water resources. Because biological communities integrate the effects of physical and chemical changes to the environment in the long-term, indices of aquatic integrity can be used as good indicators of changes in habitat quality, water quantity and quality as well as general environmental conditions (Ferreira and Graca 2008)

Ecostatus is defined by Kleynhans and Louw (2007) as: "The totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services." Ecostatus is therefore a reflection of the abiotic environment including hydrology, geomorphology and physic-chemical elements in an aquatic ecosystem upon the aquatic biota including fish, macroinvertebrates and riparian vegetation.

Macroinvertebrates assemblages and communities offer a good reflection of the prevailing flow regime and water quality in a river, and form an essential component in the river ecosystem. They are important processors of transported organic matter in rivers and serve a vital function in purifying the water in a river while simultaneously providing a valuable food source for larger aquatic and terrestrial animals (Thirion 2007).

5.1.1 Aquatic biomonitoring

Aquatic Biomonitoring was conducted in order to:

- Provide a literature review of the principles, methods, guidelines and criteria that are applicable to biomonitoring at Krugersdorp Game Reserve;
- Determine the current river health in the Krugersdorp Game Reserve; by using SASS5, VEGRAI, IHAS and FRAI biomonitoring methods (described below), as well as by measuring certain in situ water quality parameters, at identified sampling points;
- Report on the findings of the 2014 dry season biomonitoring survey conducted on the 1st and 2nd of September 2014 and the wet season biomonitoring survey conducted on the 19th of January 2015at these sampling points.

5.1.2 Aquatic ecosystems and their importance

Aquatic ecosystems are defined as "*the abiotic (physical and chemical) and biotic components, habitats and ecological processes contained within rivers and their riparian zones, reservoirs, lakes and wetlands and their fringing vegetation*" (DWAF 1996). Terrestrial biota, other than humans, dependent on aquatic ecosystems for survival are included in this definition. Despite being South Africa's most important ecosystems, aquatic ecosystems are the most impacted (Ferrar and Lötter 2007).

Humankind depends on many "services" provided by healthy aquatic ecosystems, including:

- Maintaining the assimilative capacity of water bodies for certain wastes through self-purification;
- Providing an aesthetically pleasing environment;
- Serving as a resource used for recreation;
- Providing a livelihood to communities dependent on water bodies for food;
- Maintaining biodiversity and providing habitats to that biota dependent on aquatic ecosystems; and

- Domestic and industrial uses.

Aquatic ecosystems, as a resource base, must be effectively protected and managed to ensure that South Africa's water resources remain fit for agricultural, domestic, recreational and industrial uses on a sustained basis (DWAF 1996).

5.1.3 Ecoregions and ecological importance

Ecoregions are regions that share similar ecological characteristics and according to Ferrar and Lötter (2007) this characterisation is *"based on the understanding that ecosystems and their biota display regional patterns that mirror causal factors such as climate, soils, geology, physical land surface and vegetation."*

The River Health Programme ("RHP") places the Krugersdorp Game Reserve falls within the *Western Bankenveld Ecoregion*. The *Western Bankenveld Ecoregion* has a complex topography that varies from lowlands, hills and mountains to closed hills and mountains with the relief varying from moderate to high. Although various bushveld and grassland types occur, mixed bushveld is the most definitive vegetation type of the region (River Health Programme 2005).

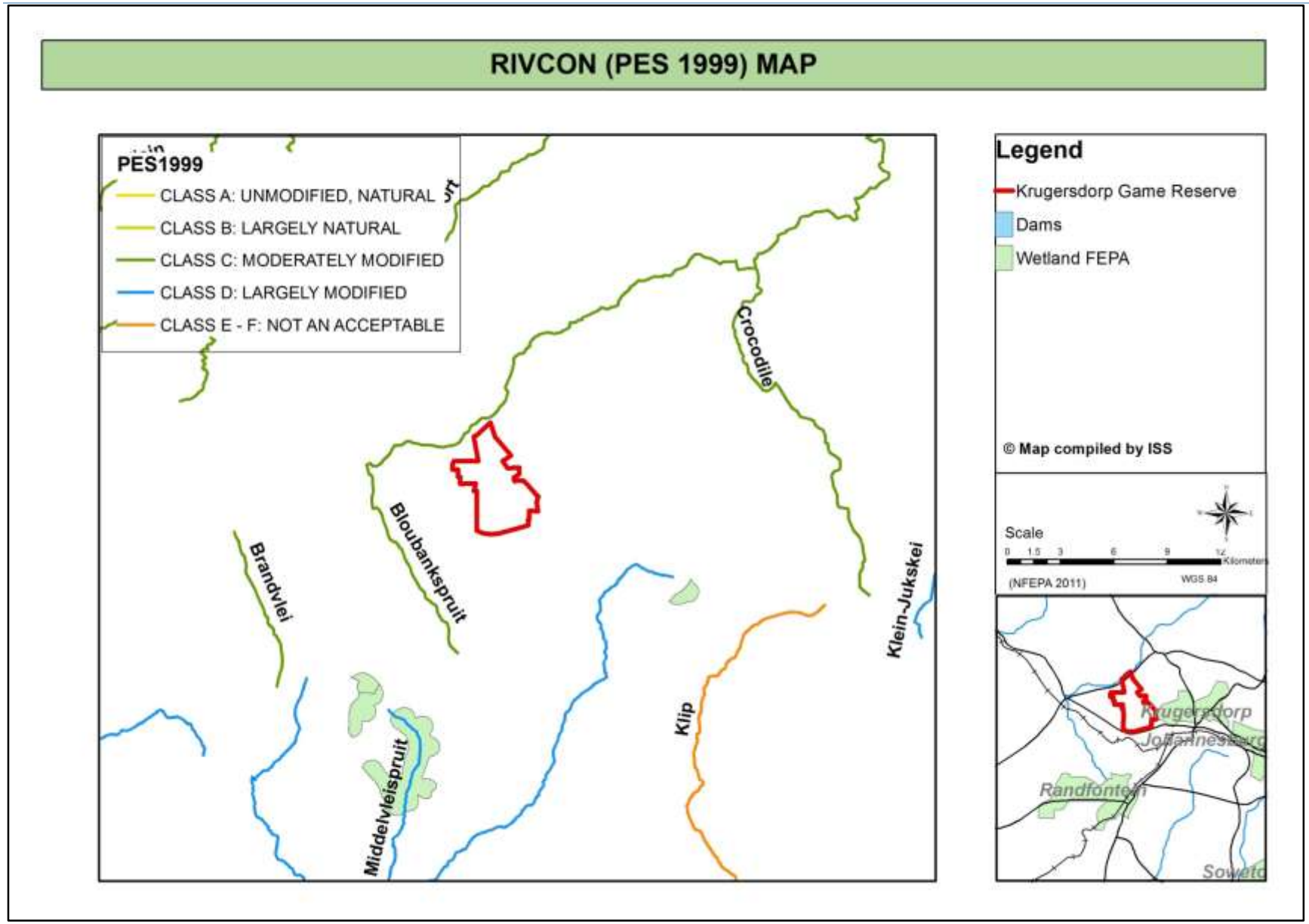
According to the delineation provided by Dallas (2005), the Level 1 Ecoregion of the area, is *Western Bankenveld* (7). The Level 2 Ecoregion is *Western Bankenveld* (7.06). The Krugersdorp Game reserve lies within the Crocodile (West) Marico Water Management Area, the Upper Crocodile sub-management area and between the Crocodile Highveld study unit. The overall Ecostatus for the Crocodile Highveld study unit is poor. Instream habitat-, macro invertebrate- and fish assemblage integrity is poor (River Health Programme 2005).

5.1.4 National Freshwater Ecosystem Priority Areas

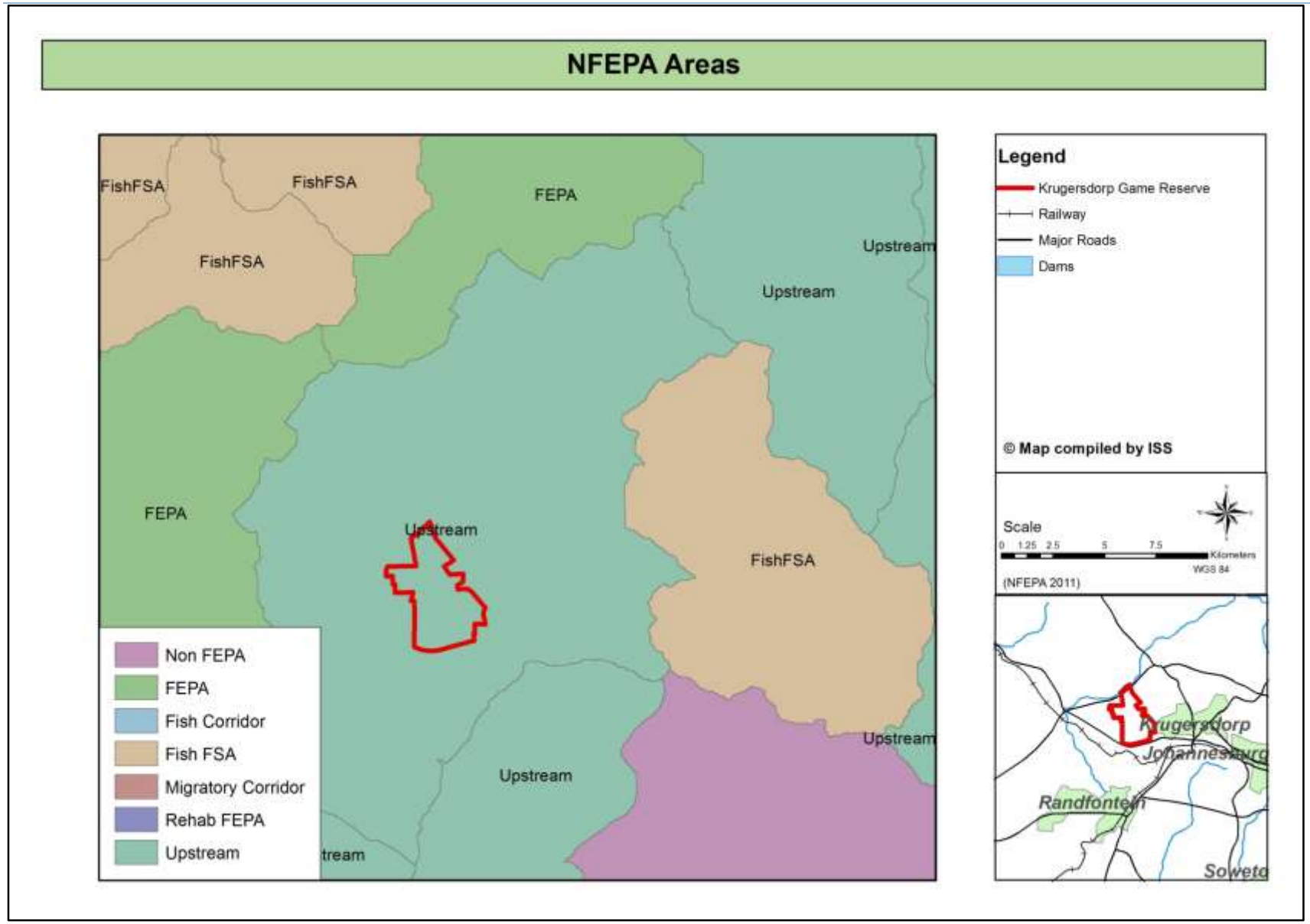
The **National Freshwater Ecosystem Priority Areas** ("NFEPA") project responds to the reported degradation of freshwater ecosystem condition and associated biodiversity, both globally and in South Africa. It uses systematic conservation planning to provide strategic spatial priorities for conserving South Africa's freshwater biodiversity, within the context of equitable social and economic development.

River Condition ("RIVCON") is a classification used by the NFEPA programme. *RIVCON A* and *B* are considered intact rivers that are able to contribute towards river ecosystem targets. According to NFEPA data, the major rivers in close proximity to Krugersdorp Game Reserve are classified as **RIVCON C, D** and **E/F** which indicates that the major rivers are moderately, largely, seriously or critically modified respectively.

There are a few **Wetland** NFEPA located to the south west as indicated in Map 10. However, the area falls into an **upstream**-FEPA and is an area earmarked for conservation of NFEPA's downstream of the Krugersdorp Game Reserve and further deterioration of water quality should be avoided (Map 11).



Map 10: RIVCON (PES 1999) Map for Krugersdorp Game Reserve



Map 11: NFEPA Map for Krugersdorp Game Reserve and surrounding area. Krugersdorp Game Reserve falls within an Upstream FEPA.

5.2 Methods

The following evaluation methods are used to determine overall river health:

- Physico-chemical evaluation, making use of the Integrated Habitat Assessment System (IHAS) and measuring relevant *in-situ* water quality parameters;
- Riparian Vegetation evaluation, making use of the Riparian Vegetation Response Assessment Index (VEGRAI);
- Aquatic Invertebrate evaluation, making use of the South African Scoring System, version 5 (SASS5); and
- Fish evaluation, making use of the Fish Response Assessment Index (FRAI).

These methods are standardised, quantitative, and replicable, and are discussed in more detail below.

5.2.1 Aquatic habitats and the IHAS method

The quality of the instream and riparian habitat has a direct influence on the aquatic community. Evaluating the structure and functioning of an aquatic ecosystem must therefore take into account the physical habitat to assess the ecological integrity. The IHAS (version 2) sampling protocol was used (McMillan 1998; Table 19) for use in conjunction with the SASS5 protocol to determine which habitats are present for aquatic macro-invertebrates.

In the IHAS method, the extent of each of the instream habitats is determined together with the physical parameter of the stream. This sampling protocol assists with the interpretation of the SASS5 data.

Table 19: IHAS Score Interpretation Guide

IHAS SCORE	INTERPRETATION
<65%	Insufficient for supporting a diverse aquatic macro invertebrate community
65%-75%	Acceptable for supporting a diverse aquatic macro-invertebrate community
75%	Highly suited for supporting a diverse aquatic macro-invertebrate community

5.2.2 In situ water quality

Water quality has a direct influence on in stream biota, and can fluctuate, depending on site-specific conditions. The biological monitoring of especially macroinvertebrates and fish thus need to be augmented with the *in situ* measurement of basic water quality indicator parameters (DWAF 1996), namely:

- **Temperature**, which plays an important role in water by affecting the rates of chemical reactions and therefore the metabolic rates of organisms. Temperature is one of the major factors controlling the distribution of aquatic organisms. Natural variations in water temperature occur in response to seasonal and diel cycles and organisms use these changes as cues for activities such as migration, emergence and spawning. Artificially-induced changes in water temperature can thus impact on individual organisms and on entire aquatic communities.
- **pH**. For natural surface water systems, pH values typically range between 4 and 11, and depend on the availability of carbonate and bicarbonate, which influences the buffer capacity of the water, and which are determined by geological and atmospheric circumstances.
- **Electrical Conductivity (EC)** is the measurement of the ease with which water conducts electricity and can also be used to estimate the total dissolved salts (TDS). TDS depends on the characteristics of the geological formations which the water has been in contact with, and

on physical processes such as rainfall and evaporation. Changes in EC can affect microbial and ecological processes such as rates of metabolism and nutrient cycling. The effect on aquatic organisms depend more on the rate of change than absolute changes in concentrations of salts.

- **Dissolved Oxygen (DO)** is the measurement of the percentage saturation of water with gaseous oxygen, which is generated by aquatic plants during photosynthesis, or which dissolved into the water from the atmosphere, and is naturally affected by the climatic, physical and chemical characteristics of the environment. The maintenance of adequate DO saturation levels in water is critical for the survival and functioning of aquatic biota. Therefore, the DO saturation levels provides a useful measure of the health of an aquatic ecosystem (DWAF 1996). Unpolluted water typically shows a DO of 100%, with lower values indicating depletion and higher values eutrophication. Typical oxygen saturation concentrations at sea level, and at TDS values below 3,000 mg/ℓ, are at around 13 mg/ℓ (5 °C); 10 mg/ℓ (15 °C); and 9 mg/ℓ (20 °C). There is a natural diurnal (24 hour cycle) variation in DO; concentrations to a minimum near dawn, then rise to a maximum by mid-afternoon. Seasonal variations arise from changes in temperature and biological productivity.
- It should be noted that the *in situ* measurement of these four water quality parameters does not represent the general water quality at the sampling locations or the streams. It is not a laboratory analysis of water quality, and does not measure macro anions and cations, metals or organic contaminants, nutrients or pesticides. The *in situ* measurements of these four parameters provide a snapshot of the water quality at the sampling point **at the time the biological samples were taken**, and thus can provide valuable insight into the characteristics at a sampling point that could have an influence on the aquatic biota at that point, and at the time of conducting the sampling for biomonitoring.

In situ measurements of Temperature, pH, EC and DO were taken in the main flow of the river or stream sampled, both prior to conducting the sampling for biomonitoring as well as after the completion of conducting the sampling for biomonitoring, by means of the following calibrated hand-held instruments:

- Hanna - HI 991300 – Temperature in °C, pH, and EC (in µS/cm);
- Hanna - HI 9146-04N – DO as % saturation.

The EC measurements in µ S/cm were converted to mS/m (10 µ S/cm = 1 mS/m) by dividing by 10.

Receiving water quality objectives (RWQOs) based on the water quality requirements for different users, are contained in a set of documents first published by DWAF in 1993, and revised in 1996.[2]

Certain quality ranges are required to protect and maintain aquatic ecosystem health. For each constituent, guideline ranges are specified, including the No Effect Range (Target Water Quality Range or TWQR), Minimum Allowable Values, Acceptable Range, and, for some parameters, Intolerable levels. The SAWQGs for aquatic ecosystems that are applicable to the in situ measurements of the water quality, are summarised in Table 20 below (DWAF 1996):

Table 20:SAWQGs for Aquatic Ecosystems applicable to in situ Water Quality measurements

Parameter	Unit	Target Water Quality Range	Minimum Allowable Values
Temperature	°C	should not vary from the background average daily water temperature considered to be normal for that specific site and time of day, by > 2 °C, or by > 10 %, whichever estimate is the more conservative	
EC	mS/m	Should not be changed by > 15 % from the normal cycles of the water body	
pH	pH units	Variation from background pH limited to <0.5 of a pH unit, or < 5%, whichever is the more conservative estimate	

[2] DWAF, 1996: South African Water Quality Guidelines, Volume 1 to 7

Parameter	Unit	Target Water Quality Range	Minimum Allowable Values
DO	% saturation	80 – 120	> 60 (sub lethal) > 40 (lethal)

5.2.3 Vegetation and the VEGRAI method

VEGRAI is a spreadsheet model developed by the DWA (Kleynhans et al. 2007) for the qualitative assessment of the response of riparian vegetation to impacts in such a way that qualitative ratings translate into quantitatively defensible results. In other words, it is a model which determines the response of vegetation to impacts in a way which can be defended by sound scientific methods (Figure 9).

Figure 9: VEGRAI Level 3 Analysis Diagram. The metrics in the VEGRAI model can be used to compare a location with a reference location to give a measure of vegetative response to impacts.

The VEGRAI spreadsheet model is composed of a series of metric groups (non-woody vs. woody) and metrics (abundance, cover requirement, species composition and population structure) each of which is rated in the field.

The vegetative *Ecological Category* is determined by examining the marginal, lower and upper zones of riparian vegetation and evaluating the metrics for the following metric groups in each zone:

- Non-woody vegetation in terms of cover, abundance and species composition; and
- Woody vegetation in terms of cover, abundance, species composition and population structure.

In a VEGRAI level 3 analysis, the riparian zone is divided into only marginal and non-marginal zones. The marginal zone includes vegetation of the area from the water level at low or basal flow, if present to those features that are hydrologically activated for the greater part of the year. The non-marginal zone is subdivided into the lower and upper zones.

The lower zone consist of geomorphic features that are hydrologically activated on a seasonal basis either yearly during high flow periods or every two to three years. The lower zone extends from the marginal zone and ends where a marked a marked increase in lateral elevation occurs. The upper zone extends from the lower zone to the end of the riparian corridor.

The upper zone consists of geomorphic features that are hydrologically activated on an ephemeral basis, less than every 3 years. The vegetative composition of the upper zone comprises of both terrestrial and riparian species (Kleynhans *et al*. 2007).

The VEGRAI method is a score-sheet method using a set of visual assessments of the physical environment, vegetation structure and species composition, including estimating the cover of dominant species. If two sides of a river bank are markedly different in respect of these aspects, each river bank should be treated as a separate site. The results are used to determine the VEGRAI Ecological Category.

5.2.4 Aquatic invertebrates and the SASS5 method

SASS5 is a rapid bio-assessment method used to identify changes in species composition of aquatic invertebrates to indicate relative water quality (Dickens and Graham 2002). Macroinvertebrate assemblages are good indicators of localized conditions in rivers. The SASS5 score will be high at a particular site if the taxa are pollution sensitive and low if they are mostly pollution tolerant.

The SASS5 Score, the number of taxa observed, and the average score per taxon (ASPT) are calculated for all of the biotopes combined. Dallas (2007) used available SASS5 Score and ASPT values for each eco-region in South Africa to generate biological bands on standardised graphs that are used as a guideline for interpreting any data obtained during the study. The meaning of each SASS5 Ecological Category is explained in Table 21 (Dallas 2007).

Table 21:Biological Bands and Ecological Category

EC	ECOLOGICAL CATEGORY	DESCRIPTION
A	Natural	Unmodified natural
B	Good	Largely natural with few modifications
C	Fair	Moderately modified
D	Poor	Largely modified
E	Seriously modified	Seriously modified
F	Critically modified	Critically or extremely modified

5.2.5 Fish and the FRAI method

Fish are good indicators of long-term (several years) effects and broad habitat conditions, and changes in the available habitat conditions. **FRAI** is a model recently developed by DWA (Kleynhans 2007) and is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers. The method is used to determine the **Present Ecological Category** (PEC) of the fish assemblage (Figure 10).

The purpose of FRAI is to provide a habitat-based and cause-effect evaluation to interpret the deviation of the assemblage to the reference condition.

Fish are sampled using a 10 mm-mesh scoop-net connected to a SAMUS 725MP electro shocking device. All fish species are identified and anomalies and general age structure will be recorded. Sampling should be kept to about 60 minutes. The results are used to establish the *FRAI Ecological Category*. Fish habitat is evaluated against the following parameters:

- velocity depth classes,
- cover,
- flow modifications,
- physico-chemical conditions,
- constraints on migration upstream.

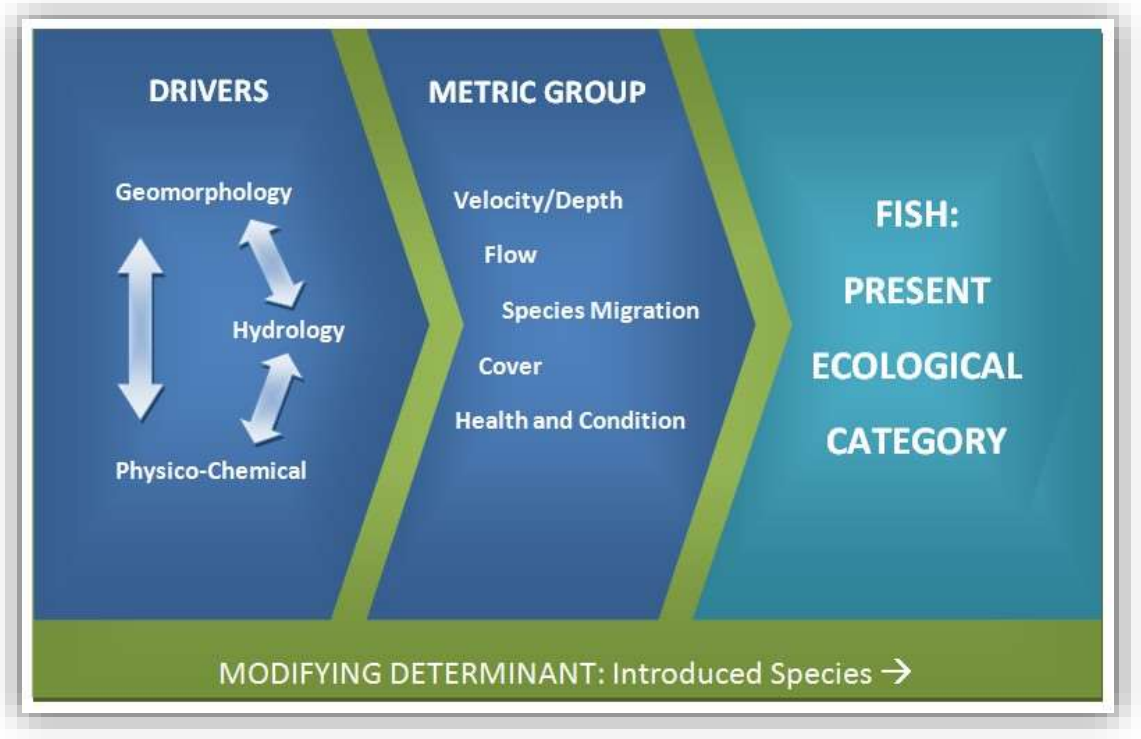


Figure 10: Fish Present Ecological Category Diagram. Fish Present Ecological Category is determined by an interaction of the ecological drivers and metric groups with the major determining factor being species not native to the system.

5.2.6 Overall data interpretation

For each sampling point, the VEGRAI Ecological Category (VEGRAI EC), SASS5 Ecological Category (SASS5 EC, as read from the ASPT-plot), and the FRAI Ecological Category (FRAI EC) determine the Overall River Ecological Category (Overall EC). The Overall Ecological Category is then compared against a baseline established in 1999 by NFEPA RIVCON (Map 10). Possible reasons for any measured changes since 1999 are then investigated by evaluating the *in situ* water quality measurements to determine if such deterioration can be ascribed to the mining activities.

5.2.7 Considerations for selecting sampling points for biomonitoring

Sampling points for biomonitoring can only be placed on rivers, due to the fact that SASS5, FRAI and VEGRAI are methods that were designed to assess river health. These methods are not suitable for wetlands systems. Two types of sampling points are required to effectively determine the status of the aquatic environment in a river system, namely a biomonitoring point and a reference point for comparison. Ideally, a reference point should be 2 km upstream from the biomonitoring points. If no feasible upstream reference point can be identified, a downstream reference point can be selected.

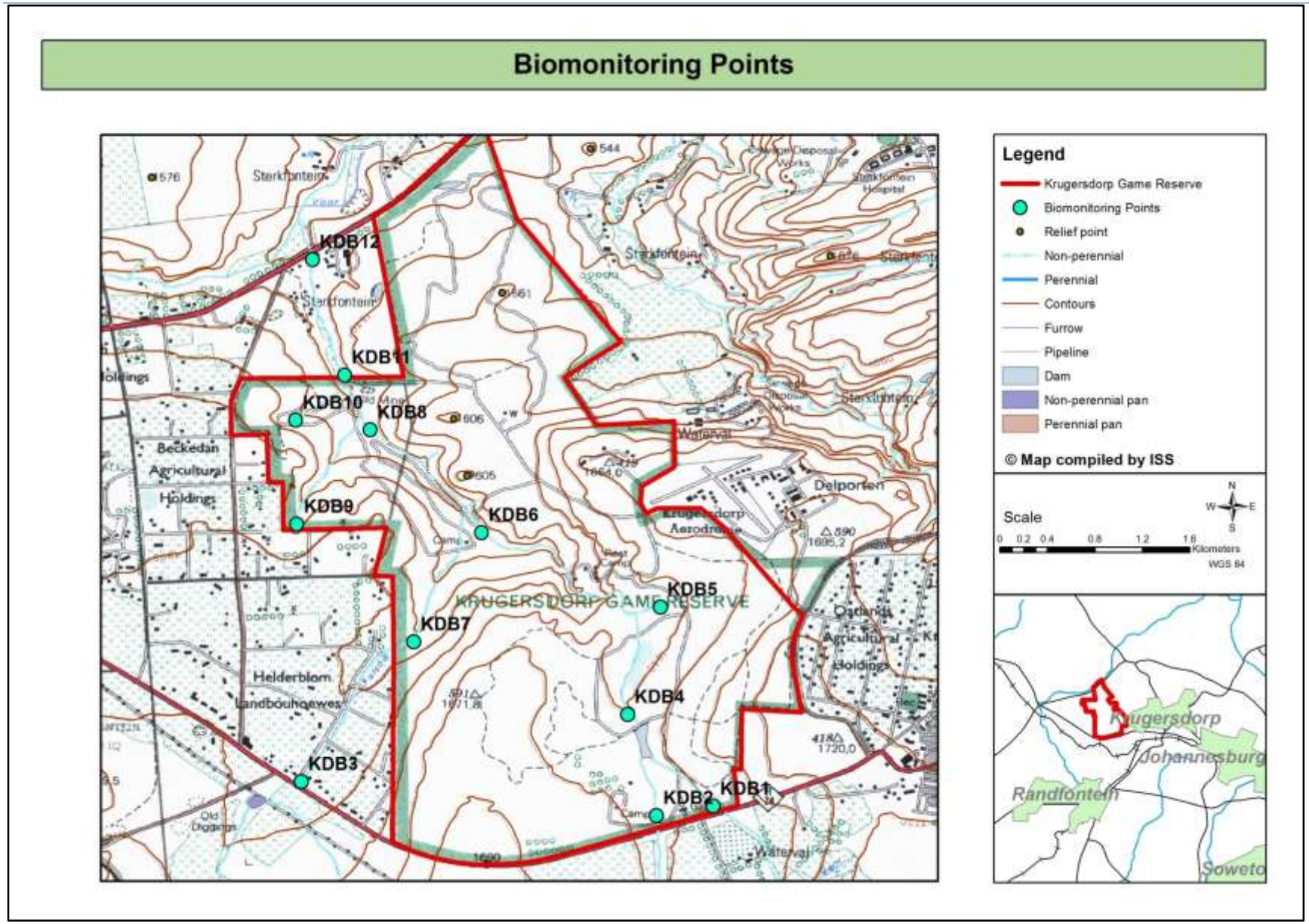
5.2.8 Sampling points for aquatic biomonitoring at Krugersdorp Game Reserve

To determine river health for the Krugersdorp Game Reserve a total of 12 sampling points were selected prior to the site visit (Map 12). For the 2014 dry season and 2015 wet season aquatic biomonitoring at Krugersdorp Game reserve, sampling points KDB1, KDB2, KDB3, KDB4, KDB6, KDB7, KDB11 and KDB12 were visited on the 1st and 2nd of September 2014 and again on the 19th of January 2015. KDB8, KDB9 and KDB10 are situated inside the lion enclosure and hence were not assessed.

5.3 Results

All relevant sampling points (KDB1, KDB2, KDB3, KDB4, KDB6, KDB7, KDB11 and KDB12) were visited on the 1st and 2nd of September 2014 and again on the 19th of January 2015.

After completion of the dry season site visit it was possible to determine *Overall Ecological Category* and River Health at KDB2, KDB4, KDB5, KDB6, KDB11 and KDB12. KDB1 and KDB3 are present in wetland systems and no surface water was present during time of the site visit. After completion of the wet season site visit the *Overall Ecological Category* and River Health could be determined at KDB2, KDB4, KDB6, KDB11 and KDB12. KDB5 had flow of less than 5cm during the wet season site visit and active flow channel was significantly less than in the dry season site visit.



Map 12: Sampling Points for Biomonitoring at Krugersdorp Game Reserve. GPS coordinates are shown in Table 22

Table 22:Suitability and Impacts Evaluation

Sampling point	Latitude	Longitude	SUITABILITY EVALUATION		Site Description	Habitat Description	Observations
 **KDB1**	-26.105578	27.726325	Site Visited Site Sampled Suitable for Future Sampling	Yes No-wetland system No	Biomonitoring point On unnamed tributary of the Tweelopiesspruit. Indicates water quality as received from upstream mines	Marginal vegetation wetland and grassland species; Non-marginal mostly grassland species; In valley bottom; No channel present; No surface water observed during 2014 dry or 2015 wet season site visits.	Grazing evident; Wattles were eradicated in dry season 2014; Mining upstream; R24 crossing upstream;
 **KDB2**	-26.106161	27.722031	SITE VISITED SITE SAMPLED SUITABLE FOR FUTURE SAMPLING	Yes Yes dry and wet season. Yes	Biomonitoring point On the Tweelopiesspruit. Indicates water quality as received from upstream mines	Strong flow; Marginal vegetation wetland and grassland species. Non-marginal mostly grassland species. Vegetation biotope limited.	Orange yellow precipitate present on vegetation as well as river bed – most likely a result of acid rock drainage; Clearing of some of the Phragmites spp., at the sampling point. R24 crossing upstream; Grazing evident; Invasive plant species present.
 **KDB3**	-26.103669	27.694889	Site Visited Site Sampled Suitable for Future Sampling	Yes No –wetland system No	Reference point Upstream reference point for KDB7 On unnamed tributary of the Tweelopiesspruit.	Alien invasive species; Marginal and non-marginal vegetation containing grassland and wetland species.	Woody and herbaceous alien and invasive species; Mines upstream; Impoundment present upstream; Littering.

Sampling point	Latitude	Longitude	SUITABILITY EVALUATION		Site Description	Habitat Description	Observations
 **KDB4**	-26.098527	27.719646	Site Visited	Yes	Biomonitoring point on Tweelopiesspruit Downstream of Hippo Dam.	Strong flow; Channelled flow from Hippo dam; Flow becomes diffuse not long after Hippo Dam; Marginal zone containing grassland and wetland species; Non-marginal zone containing mainly grassland species.	Orange yellow precipitate present on vegetation as well as river bed – most likely a result of acid mine drainage; Precipitate covers plans and riverbed extensively and leads to a loss in habitat for macro invertebrates; Mining present upstream; Hippo Dam located directly upstream; Alien invasive *Acacia spp*. present.
			Site Sampled	Yes dry and wet season.			
			Suitable for Future Sampling	Yes			
 **KDB5**	-26.090628	27.722243	Site Visited	Yes	Biomonitoring point On an unnamed tributary of the Tweelopiesspruit.	Spring origin approximately 20m upstream; Marginal and non-marginal vegetation fairly homogenous. Substrate, mainly GSM. Alien invasive plant species was present.	Working for water programme – removal of alien invasive trees evident; Alien invasive plants present; Reserve roads upstream of sampling point.
			Site Sampled	Yes dry season no wet season.			
			Suitable for Future Sampling	Yes			
 **KDB6**	-26.084751	27.708728	Site Visited	Yes	Biomonitoring point on Tweelopiesspruit. Below the lodge within the Krugersdorp Game Reserve.	Below dam; Strong flow; Channel prominent just after leaving dam – then get more dispersed flow; Large boulders, stones and GSM present. Marginal vegetation grassland and wetland species; Non-marginal vegetation contains indigenous woody species.	Dirt road present downstream; Orange yellow precipitate present on vegetation as well as river bed – most likely a result of acid mine drainage; High grazing pressure observed during dry season site visit; Impoundment upstream.
			Site Sampled	Yes			
			Suitable for Future Sampling	Yes			

Sampling point	Latitude	Longitude	SUITABILITY EVALUATION		Site Description	Habitat Description	Observations
 **KDB7**	-26.093047	27.703630	Site Visited	Yes	Biomonitoring point on an unnamed tributary of the Tweelopiesspruit.	Typical un-channelled wetland system. Grassland and wetland species present.	Culverts present downstream – not In channel but just lying on top of ground surface. Alien invasive *Acacia spp.* present; Grazing evident.
			Site Sampled	No –wetland			
			Suitable for Future Sampling	No			
KDB8	-26.076905	27.700263	Site Visited	No – within lion enclosure	Biomonitoring point on Tweelopiesspruit.		
			Site Sampled	No			
			Suitable for Future Sampling	Only if armed ranger is available			
KDB9	-26.084276	27.694589	Site Visited	No – within lion enclosure	Biomonitoring point on an unnamed tributary of the Tweelopiesspruit.		
			Site Sampled	No			
			Suitable for Future Sampling	Only if armed ranger is available			
KDB10	-26.084159	27.694647	Site Visited	No – within lion enclosure	Biomonitoring point on an unnamed tributary of the Tweelopiesspruit.		
			Site Sampled	No			
			Suitable for Future Sampling	Only if armed ranger is available			

Sampling point	Latitude	Longitude	SUITABILITY EVALUATION		Site Description	Habitat Description	Observations
 **KDB11**	-26.072849	27.698396	Site Visited Site Sampled Suitable for Future Sampling	Yes Yes Yes	Biomonitoring point on Tweelopiesspruit. Last point within the Krugersdorp Nature Reserve boundaries.	Strong flow; Marginal vegetation contained grassland and wetland species. Non-marginal mainly woody species.	Impoundment present upstream; Culverts present in active channel which were likely washed down the system during a flood event; Orange yellow precipitate present on vegetation as well as river bed – most likely a result of acid mine drainage; Over grazing evident; Alien and invasive species present; Bank erosion present.
 **KDB12**	-26.064043	27.695985	Site Visited Site Sampled Suitable for Future Sampling	Yes Yes Yes	Reference point Downstream for KDB4, KDB6, KDB8, KDB11. On Tweelopiesspruit	Marginal vegetation contained grassland and wetland species. Non-marginal mainly grassland species. In-stream vegetation present.	Maize fields present; Orange yellow precipitate present on vegetation as well as river bed – most likely a result of acid mine drainage; Bridge and road crossing present upstream.

5.3.1 Physico-chemical evaluation, with IHAS and *in situ* water quality

The IHAS results for KDB2 (upper Tweelopiesspruit) in both wet and dry seasons were insufficient for supporting a diverse aquatic macro invertebrate community. During the 2014 dry season KDB5 (tributary) had an insufficient habitat for supporting a diverse macro-invertebrate community. A high SASS5 score is therefore not expected for either of these sampling points. KDB4, KDB6, KDB11 and KDB12 (all along the Tweelopiesspruit) all had IHAS scores which are acceptable for supporting a diverse macro invertebrate community (Table 23; Table 24).

DO levels at biomonitoring point KDB5 (the tributary) was below the 80% TWQR saturation limit for aquatic ecosystems, but well above the 60% sub lethal saturation limit for both the dry and wet season. During the 2015 wet season DO levels of KDB4 were also below the 80% TWQR saturation limit for aquatic ecosystems, but well above the 60% sub lethal saturation limit (Table 23; Table 24)

There was a significant reduction in the pH levels for KDB2, KDB4, KDB6, KDB11 and KDB12 from the 2014 dry season to the 2015 wet season. pH recorded during the 2015 wet season sampling is below the TWQR limit for aquatic ecosystems. Conditions at sampling points KDB2, KDB4, KDB6, KDB11 and KDB12 during the 2015 wet season indicate acidic saline conditions (Table 23; Table 24).

Table 23:Physico-chemical evaluation for Sampling Points recorded during dry season 2014

Sampling point	kdb2		kdb4		kdb5		kdb6		kdb11		kdb12	
IHAS Score (%)	62		67		61		74		65		66	
IHAS Class description	Insufficient		Acceptable		Insufficient		Acceptable		Acceptable		Acceptable	
Visual appearance of water prior to sampling	Clear		Clear		Clear		Clear		Clear		Clear	
Date	2014/09/01		2014/09/02		2014/09/01		2014/09/01		2014/09/01		2014/09/02	
Time (hh:mm)	15:53	16:12	09:55	10:32	13:34	14.38	11.53	12:46	10:10	11:15	08:17	09:02
Temperature (°C)	20.8	19.6	14.7	15.5	19	19.9	12.2	12.6	10.9	11.6	11	11.2
pH	6.92	6.93	6.62	6.66	6.15	6.23	6.57	6.62	6.84	6.66	6.76	6.88
EC (mS/m)	371.3	379.2	359.5	355.1	10.9	116	303.5	307.7	309.7	296	301.2	**301.4**
DO (% saturation)	86.7	88.6	85.9	85.9	79.4	77.4	90	91	92.4	89.7	95	94

Table 24:Physico-chemical evaluation for Sampling Points recorded during wet season 2015

Sampling point	kdb2		kdb4		KDB5	kdb6		kdb11		kdb12	
IHAS Score (%)	60		69		NA	74		68		71	
IHAS Class description	Insufficient		Acceptable		NA	Acceptable		Acceptable		Acceptable	
Visual appearance of water prior to sampling	Yellow Brown		Clear		Clear	Clear		Clear		Clear	
Date	2015/01/19		2015/01/19		2015/01/19	2015/01/19		2015/01/19		2015/01/19	
Time (hh:mm)	12:30	12:47	11:46	12:07	11:40	09:12	09:42	10:28	10:59	07:48	08:11
Temperature (°C)	26.0	27.0	24.3	24.2	23.0	20.8	21.1	21.8	22.6	20.3	20.3
pH	3.55	3.57	3.46	3.47	6.27	3.59	3.60	3.91	3.90	3.95	**3.94**
EC (mS/m)	327.2	323.7	313.3	315.0	9.8	284.5	283.1	262.8	260.4	269.0	**269.5**
DO (% saturation)	85.1	86.4	71.2	74.8	73.7	86.5	86.3	89.5	87.1	88.0	89.1

The results of the vegetation assessment are presented in Table 25.

5.3.2 Aquatic invertebrates

Aquatic invertebrates that were found during SASS5 sampling are summarised in Table 26 for the 2014 dry season and Table 27 for the 2015 wet season. During the 2014 dry season no aquatic invertebrates were found at KDB2 and KDB4 these two sampling points therefore fall into the E-F SASS5 Ecological Category according to Dallas 2007. During the 2015 wet season aquatic invertebrates were found at KDB4 and the water level at KDB5 was too low for sampling.

The 2014 dry season the indicated that KDB5, KDB6, KDB11 and KDB12 all had a SASS5 *Ecological Category* of **E-F** (Figure 11).

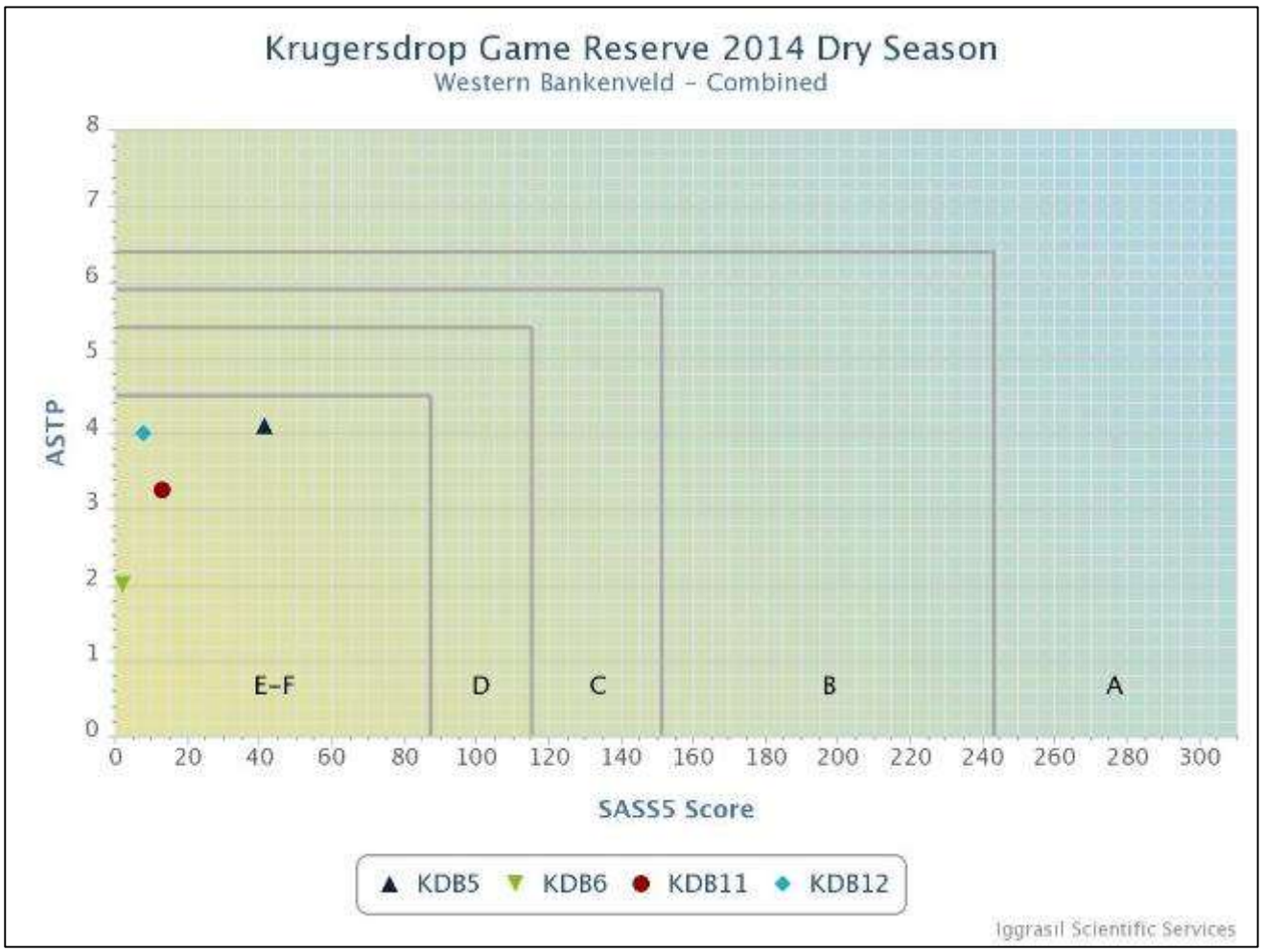


Figure 11: The SASS5 Score and ASPT for the sites sampled around Krugersdorp Nature Reserve in comparison to the biological bands for the Western Bankenveld **(Dallas 2007). See Table 21 for explanation of biological bands**

Table 25: Summary of VEGRAI results for the 2014 dry season and the 2015 wet season

Sampling point	Short description of surrounding vegetation	Dry Season Photo	Dry Season Level 3 VEGRAI Score (%)	Dry Season VEGRAI EC	Wet Season Photo	Wet Season Level 3 VEGRAI Score (%)	Wet Season VEGRAI EC
KDB2	High grazing pressure visible in dry season; Alien invasive *Acacia* and *Eucalyptus spp*. present; Instream vegetation limited; Vegetation recovered after summer rains. Bank erosion was observed but it was limited in extent.		60	C/D Fair to Poor		61.8	C/D Fair to Poor
KDB4	Instream vegetation mainly *Phragmites spp.;* Instream vegetation covered with yellow orange precipitate; Non-marginal zone contains alien invasive *Acacia spp*. Dry season high grazing pressure evident and some recovery of vegetation along main Tweelopiesspruit was observed during wet season.		53.9	D Poor		54.4	D Poor
KDB5	Large amounts of *Populus spp*. were removed prior to the site visit. High grazing pressure evident during dry season. Instream vegetation abundant and species include		59	C/D Fair to Poor			
KDB6	Riparian vegetation contains wetland, grassland and woodland species. Grazing pressure was high under the tree canopy during dry and wet season site visit. Abundance of grassland and wetland species increased in cover abundance from dry to wet season site visits. Orange yellow precipitate present on instream and marginal vegetation.		57.4	C/D Fair to Poor		59.5	C/D Fair to Poor

Sampling point	Short description of surrounding vegetation	Dry Season Photo	Dry Season Level 3 VEGRAI Score (%)	Dry Season VEGRAI EC	Wet Season Photo	Wet Season Level 3 VEGRAI Score (%)	Wet Season VEGRAI EC
KDB11	Vegetative cover in riparian area lower in dry season than in wet season. Alien invasive *Cortaderia selloana* present in marginal and non-marginal zone. Orange yellow precipitate present on instream and marginal vegetation. Bank erosion present but limited in extent.		56.3	D Poor		59.4	C/D Fair to Poor
KDB12	Maize fields present in the non-marginal zone on the left bank if facing downstream. Woody alien invasive *Eucalyptus spp.* and *Populus spp.* and invasive aquatic plants included *Persicaria* spp. Orange yellow precipitate present on instream and marginal vegetation. Marginal vegetation lush during dry and wet season survey.		48.5	D Poor		D	D Poor

Table 26:SASS5 Results for KDB5, KDB6, KDB11 and KDB12 for 2014 dry season

TAXON	QUALITY SCORE	KDB5	KDB6	KDB11	KDB12
TURBELLARIA (Flatworms)	3	X			
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Potamonautidae (Crabs)	3				
EPHEMEROPTERA (Mayflies)					
Baetidae 1 sp	4	X			
Baetidae 2 sp	6				
Caenidae (Squaregills/Cainfles)	6				
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4	X			
Aeshnidae (Hawkers & Emperors)	8				
Gomphidae (Clubtails)	6	X			
Libellulidae (Darters/Skimmers)	4	X			
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae (Diving beetles)*	5				
Elmidae/Wet opidae (Riffle beetles)*	8				
Gyrinidae (Whirligig beetles)*	5	X		X	
Haliplidae (Crawling water beetles)*	5				
Helodidae (Marsh beetles)	12				
Hydraenidae (Minute moss beetles)*	8				
HEMIPTERA (Bugs)					
Belostomatidae (Giant water bugs)*	3				
Corixidae (Water boatmen)*	3	X			X
Naucoridae (Creeping water bugs)*	7				
Veliidae/M...veliidae (Ripple bugs)*	5				
DIPTERA (Flies)					
Ceratopogonidae (Biting midges)	5	X			
Chironomidae (Midges)	2	X	X	X	
Culicidae (Mosquitoes)*	1			X	
Simuliidae (Blackflies)	5	X		X	X
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Physidae (Pouch snails)*	3				
Planorbinae (Orb snails)*	3				
SASS Score		41	2	13	8
No. of Taxa		10	1	4	2
ASPT		4.1	2	3.25	4

Table 27:SASS5 Results for KDB2, KDB6, KDB11 and KDB12 for 2015 wet season.

TAXON	QUALITY SCORE	KDB2	KDB6	KDB11	KDB12
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1		X		
Hirudinea (Leeches)	3				
CRUSTACEA					
Potamonautidae (Crabs)	3				
***EPHEMEROPTERA* (Mayflies)**					
Baetidae 1 sp	4				
Baetidae 2 sp	6				
Caenidae (Squaregills/Cainfles)	6				
***ODONATA* (Dragonflies & Damselflies)**					
Coenagrionidae (Sprites and blues)	4		X		
Aeshnidae (Hawkers & Emperors)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4		X		
***COLEOPTERA* (Beetles)**					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Wet opidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	X	X	X	X
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
***TRICHOPTERA* (Caddisflies)**					
Leptoceridae	6				X
***DIPTERA* (Flies)**					
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	X	X	X	X
Culicidae* (Mosquitoes)	1		X		
Simuliidae (Blackflies)	5				
Dixidae* (Dixid midge)	10			X	
Tabanidae (Horse flies)	5		X		
***GASTROPODA* (Snails)**					
Ancylidae (Limpets)	6				X
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
SASS Score		**7**	**22**	**17**	**19**
No. of Taxa		**2**	**7**	**3**	**4**
ASPT		**3.5**	**3.14**	**5.67**	**4.75**

The 2014 dry season the indicated that KDB2 and KDB6 both had a SASS5 *Ecological Category* of **E-F.** KDB12 had a SASS5 *Ecological Category* of **D.** KDB11 had a SASS5 *Ecological Category* of **C** which can largely be attributed to the Dixid midges present in the VEG and GSM sample (Figure 12).

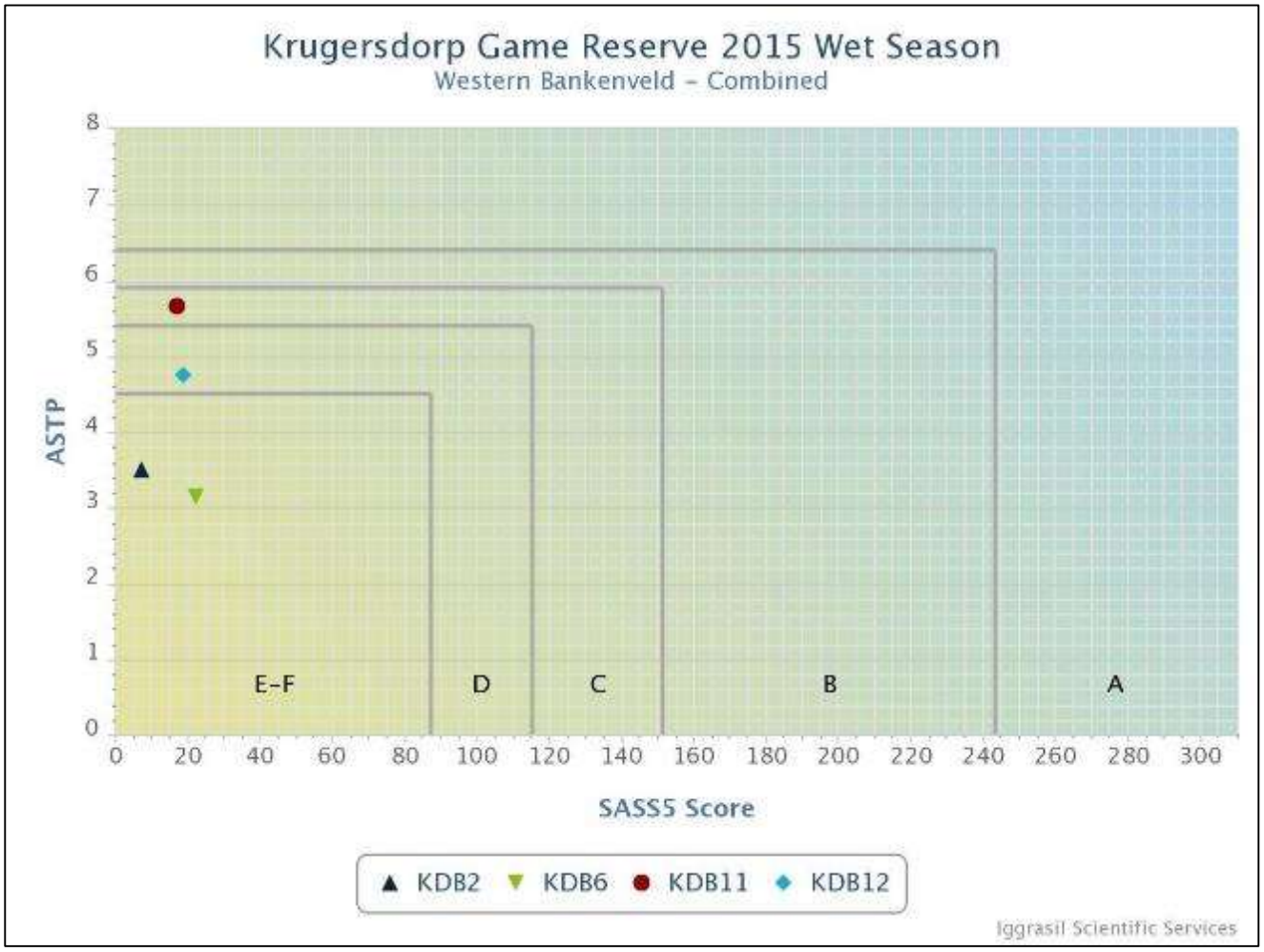


Figure 12: The SASS5 Score and ASPT for the sites sampled around Krugersdorp Nature Reserve in comparison to the biological bands for the Western Bankenveld **(Dallas 2007). See Table 21 for description of biological bands**

5.3.3 Fish Sampling

Fish sampling was conducted at sampling points KDB2, KDB4, KDB5, KDB6, KDB11 and KDB12 according to specifications for FRAI.

Despite extensive sampling according to standard protocols, no fish were found at any of the sites.

5.3.4 Overall river health and Ecological Category

The Overall Ecological Category was determined for the 2014 dry season for points KDB2, KDB4, KDB5, KDB6, KDB11 and KDB12 (Figure 13), and for the 2015 wet season at points KDB2, KDB4, KDB6, KDB11 and KDB12 (Figure 14).

Overall Ecological Category of KDB2 and KDB4 remained unchanged at E. KDB6, KDB11 and KDB12 all indicated an improvement of *Overall Ecological Category* from the 2014 dry season to the 2015 wet season. The SASS5 score was particularly high at KDB11 which can be attributed to the presence of Dixid midges which has a sensitivity score of 10.

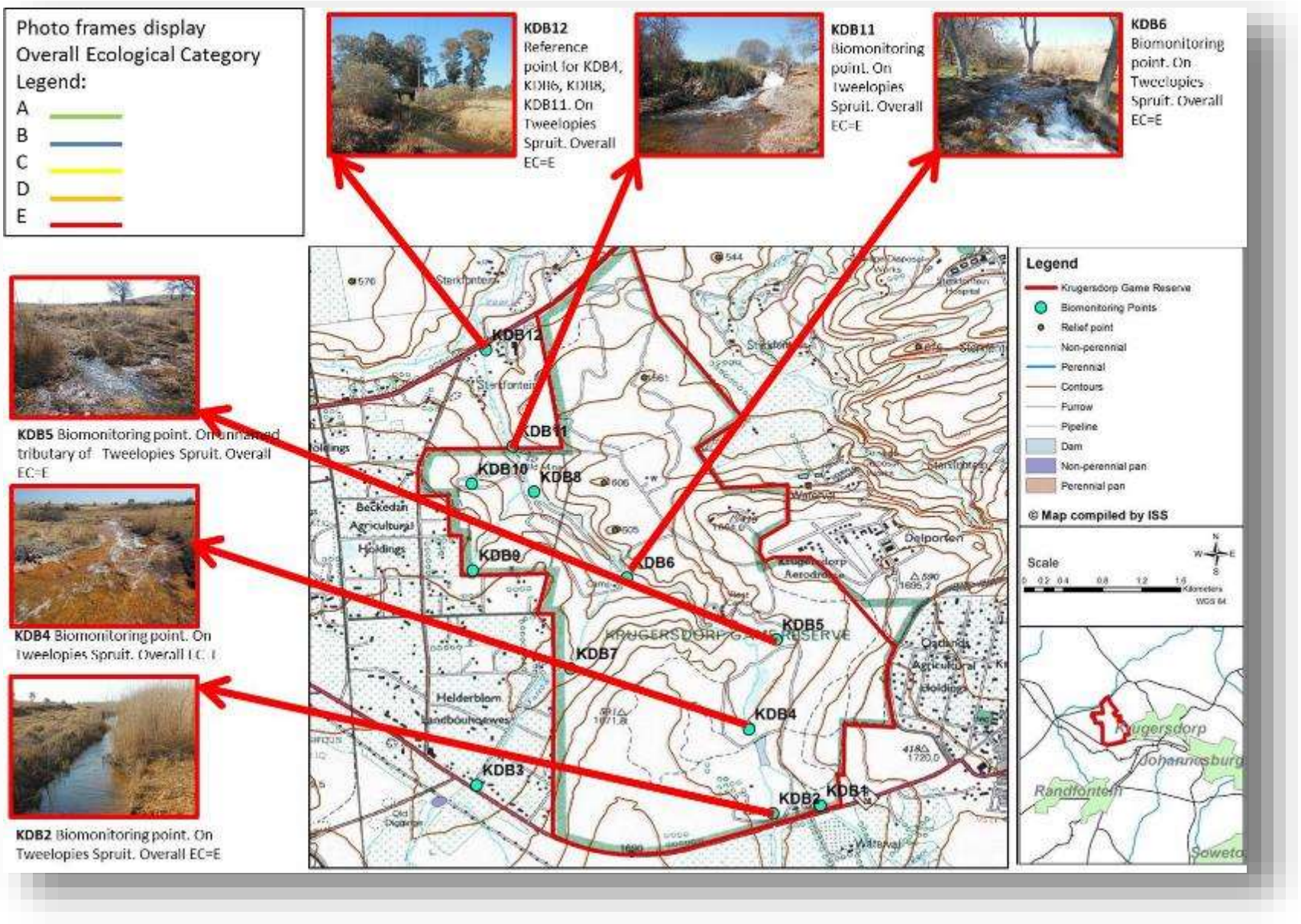


Figure 13: 2014 Dry Season Overall River Health and Ecological Category for Krugersdorp Game Reserve

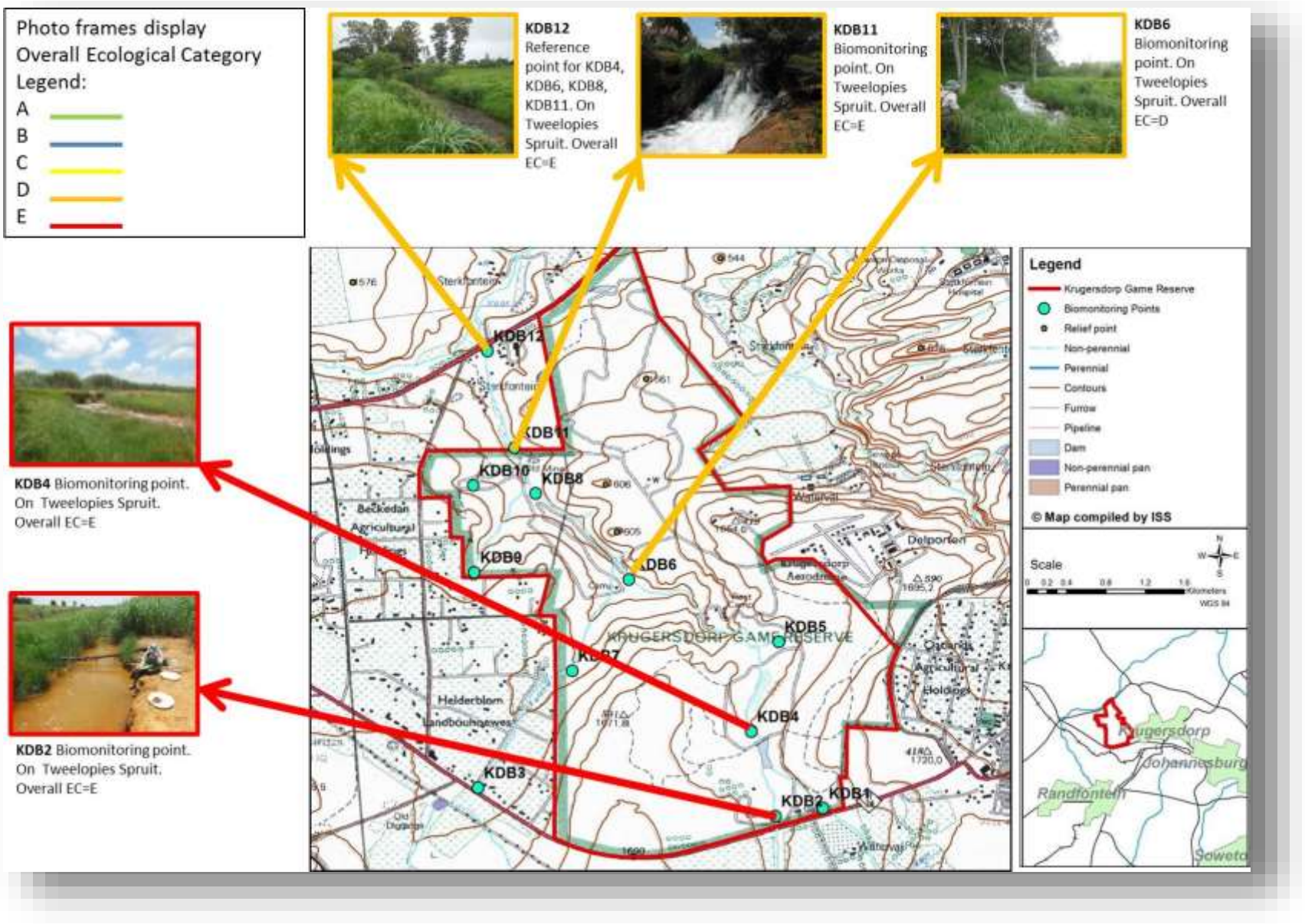


Figure 14: 2015 Wet Season Overall River Health and Ecological Category for Krugersdorp Game Reserve

5.4 Conclusion

Currently the EC and pH levels recorded during the 2014 dry season and 2015 wet season do not meet the requirements for aquatic ecosystems in terms of SAWQG. According to the PES 1999 data used by NFEPA, the Tweelopiesspruit and its unnamed tributary were not assigned a rating. However, the PES 1999 assessment rated the Bloubank Spruit to have an *Overall Ecological Category* of **C**. Since the Tweelopiesspruit is a tributary to the Bloubank Spruit is it assumed that it should also have an *Overall Ecological Category* of **C.** None of the sampling points during the dry season 2014 and wet season 2015 conformed to the *Overall Ecological Category* of **C**. This is to be expected due to the elevated EC and low pH levels recorded during the 2014 dry and 2015 wet season.

The report although reports on the results of a snapshot in time. In order to obtain a comprehensive understanding of the dynamics of the aquatic ecosystem in an area, ecological assessments should always consider investigations at different time scales (across seasons/years) and through replication, as river systems are in constant change

5.5 Recommendations

Currently the EC and pH levels recorded during the 2014 dry season and 2015 wet season do not meet the requirements for aquatic ecosystems in terms of SAWQG. The following measures are suggested to improve water quality:

- Monitoring of water quality in terms of EC, pH and temperature should be conducted on a weekly basis. This can be conducted with the use of hand held instruments and a record should be kept by the reserve.
- Obtain monthly water quality results from mines which collect water samples within the reserve. During both the 2014 dry and 2015 wet season at KDB11 samples were taken by representatives of the mine
- Inform DWS of poor water quality and ask them for assistance to improve receiving water quality upstream of the Tweelopiesspruit and its unnamed tributaries.

In terms of biomonitoring the following recommendations are made:

- Biomonitoring – SASS5 only should be conducted by the Krugersdorp Game Reserve at minimum on a bi-annual basis.
- Findings of biomonitoring should be reported in a formal manner and records of the reports should be kept as hard copies as well as electronically. This is important as should a consultant be approached to conduct a follow up survey a proper reference can be included in the consultant's report.

Although the report did not include an assessment of the health of the hippopotamus it is suggested that due to the poor water quality a veterinarian be consulted to ensure the hippopotamus are in good health. The frequency of veterinarian visits should be determined by the veterinarian.

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6 FAUNAL SURVEY METHODS

ALAN KEMP

Since many mammals and herpetofauna are either secretive, nocturnal, hibernators and/or seasonal, and some bats and birds are seasonal migrants, distributional ranges and the presence of suitable habitats were used to deduce the presence or absence of such species based on authoritative tomes, scientific literature, field guides, atlases and data bases. This can be done with a high level of confidence irrespective of season. Special attention was given to Red data list species that might potentially occur on site.

During site visits on 26 November, 2-3 December and 13-14 December 2014, mammals, birds, and reptiles and frogs, respectively, were identified by visual sightings through random transect walks and patrolling with a vehicle. No trapping or mist netting was conducted, as the terms of reference did not require such intensive work. In addition, mammals were also identified by means of spoor, droppings, burrows or roosting sites and birds by their calls, old nests, moulted feathers, spoor, droppings and other signs. Special attention was given to suitable habitats and observations of Red data species.

The probability of occurrences of mammal, birds and herpetofauna species was based on their respective geographical distributional ranges and the suitability of on-site habitats. Probability of occurrence is defined as follows:

- **High** probability: species with a distributional range overlying the study site as well as the presence of prime habitat occurring on the study site. Common species occurring at high population densities are also included
- **Medium** probability: species with a distributional range peripherally overlapping the study site, or required habitat on the site being sub-optimal. The size of the site as it relates to its likelihood to sustain a viable breeding population, as well as its geographical isolation is also taken into consideration. Species categorized as medium normally do not occur at high population numbers, but cannot be deemed as rare.
- **Low** probability: species' distributional range is peripheral to the study site and habitat is sub-optimal. Furthermore, some mammals categorized as low are generally deemed to be rare.

7.1 Mammal habitat assessment

7.1.1 Terrestrial

The terrestrial habitat is by far the most extensive, and is equivalent to the grassland and woodland landscape types. It has, however, in places been ecologically over-utilized by selective overgrazing and by planned fires. Elsewhere grass cover is good. This habitat type and can thus be rated as varying between in a "Low" to "Good" conservation condition.

7.1.2 Arboreal

The indigenous woody plants along the slopes are too modest to accommodate arboreal small mammals, whereas local mammals are not adapted to exotic trees such as the poplar trees. The indigenous riparian forest consists mostly of tall witstinkhout trees (*Celtis* woodland) that are not ideal for some small arboreal species such as tree rats and woodland dormice. The conservation status of indigenous arboreal habitat is ranked a "Good", although it is structurally not ideal for small arboreal mammals, and furthermore falls outside the distributional range of species such as woodland dormice and tree rats.

7.1.3 Rupicolous

The rupicolous habitat along the slopes and along the ridges is poorly developed and contains a dearth of refuges in the form of nooks and crannies amongst large rocks (Photo 18). However, it is most likely that less discerning species such as Namaqua rock rats and rock elephant shrews do indeed find refuge here and are therefore deemed present; red rock rabbits were in fact recorded. The basal cover of the slopes seems to be less degraded by grazing than along the lowlands and is therefore in an ecological state of repair justifying a conservation rating of "Average".

7.1.4 Wetland

Rank semi-aquatic basal cover occur in places along the river, but chemical contaminants and spilled untreated sewage deposited during floods can be expected to have an adverse effect on both the vegetative environment and consequently moisture-reliant small mammals. The aquatic environment of the Tweelopiesspruit appears to be devoid of faunal life. The conservation status of this habitat type is ranked as "Poor".

Photo 18: View northeast from rupicolous habitat on the quartzite ridge, west of the lodge in the wooded Tweelopiesspruit below, with the southeast quartzite ridge on the far side

7.2 Observed and expected mammal species richness

In the 19th century, charismatic mammals (like elephants, buffaloes, rhinos, lions, leopards, spotted hyenas and others) were extirpated by hunting. Some species such as white rhino and other antelopes were re-introduced when the game reserve was created, while other medium-sized species persisted *in situ* (black-backed jackals, Cape foxes, aardvark, duiker, steenbok and others). All the small mammals such as scrub hares, mongooses and the smaller species listed, also survived the farming era of the property.

We conclude that 66 species of mammals are still likely to be part of the present-day mammal species assemblage; the occurrence of 27 species was confirmed (Table 28).

The presence of some wetland-reliant species is in doubt as result of pollution. No spoor or signs of rough-haired golden moles, marsh mongooses, civets or the two species of otters were encountered and they are omitted from the list of occurrences. These carnivores are to a large degree reliant for prey on aquatic creatures that appear to be absent. However, cane rats, vlei rats and shrews are listed as possible occupants of the reserve since they forage away from the water amongst rank semi-aquatic vegetation.

Most of the species of the resident diversity are common and widespread (viz. dassies, scrub hares, red rock rabbits, multimammate mice, pygmy mice, genets, mongooses and others). Many of the species listed in Table 28 are robust (some with strong pioneering capabilities), cryptic, and rapid breeders.

The areas with soft red sand are conducive to burrowing mammals such as aardvarks, springhares and gerbils; indeed, old damage to termite mounds suggests that these were caused by aardvarks. Since no fresh signs were encountered it is uncertain whether aardvarks persist, but connectivity towards the western undeveloped properties could allow immigrations. Some small mammals are inclined to use moribund termite mounds for refuge, and these structures can be taken as indicative of the presence of dwarf shrews and pygmy mice.

Species that occur in the district and are likely to be at least occasional vagrants, if not residents, include carnivores (black-backed jackal, cape fox, mongooses, genets and polecats), cane rats and

springhares, and duiker and steenbok. The reserve is large enough for small antelope territories to be maintained.

Free-tailed and Vespertilionidae bats have adapted and extended their ranges to take advantage of manmade structures, including the buildings and shafts in the vicinity. Free-tailed bats roosting in rooftops can sometimes reach epidemic proportions. There are few caves or suitable structures suitable for cave-dwelling bats (Hipposideridae, Rhinolophidae, Nycteridae) on site, but they may roost nearby and hawk for invertebrates on site. However, bats normally hawk in swarms of insects rising over open water at sunset; given the poor water quality of the site, this is unlikely to be the case in the reserve.

The species richness is moderate to high for such an extensive conservation area. If the Tweelopiesspruit system was healthy the species assemblage would have been higher and closer to the historical species richness. The quality of conservation varies from "Good" in some grasslands to "Poor" in and along the river.

Table 28: Mammal diversity of Krugersdorp Game Reserve. Species deduced or observed to occupy the site. Red Data species rankings as defined in (Friedman and Daly 2004) are indicated: CR= Critically Endangered, En = Endangered, Vu = Vulnerable, CD = Lower risk conservation dependent, NT = Lower Risk near threatened, DD = Data Deficient. All other species are deemed of Least Concern. Systematics and taxonomy as proposed by (Bronner et al. 2003, Skinner and Chimimba 2005)

Common English Name	Scientific Name	Conservation Status Codes	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Elephantulus myurus	Eastern rock elephant shrew		M		
Orycteropus afer	Aardvark		L		
Procavia capensis	Dassie		H	Sighting	Rocky ridge
Lepus saxatilis	Scrub hare		H	Faecal pellets	Short grass
Pronolagus randensis	Jameson's red rock rabbit		H	Faecal pellets	Rocky ridge
Cryptomys hottentotus	African mole rat		H	Tunnel systems	Terrestrial
Hystrix africaeaustralis	Cape porcupine		H	Root diggings	Terrestrial
Thryonomys swinderianus	Greater cane rat		L		
**Pedetes capensis*	Springhare		M		
Xerus inaurus	South African ground squirrel		H	Sighting	Soft sand
Rhabdomys pumilio	Four-striped grass mouse		M		
Dasymys incomtus	African marsh rat	NT	L		
Mus minutoides	Pygmy mouse		M		
Mastomys natalensis	Natal multimammate mouse		M		
Mastomys coucha	Southern multimammate mouse		M		
Aethomys ineptus	Tete veld rat		M		
Aethomys namaquensis	Namaqua rock mouse		M		
Otomys angoniensis	Angoni vlei rat		L		

Common English Name	Scientific Name	Conservation Status Codes	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Otomys irroratus	Vlei rat		L		
Gerbilliscus brantsii	Highveld gerbil		H	Tunnels	Soft sand
Saccostomus campestris	Pouched mouse		L		
Dendromus melanotis	Grey pygmy climbing mouse		M		
Dendromus mesomelas	Brants' climbing mouse		M		
Dendromus mystacalis	Chestnut climbing mouse		M		
Cercopithecus pygerythrus	Vervet monkey		H		
Myosorex varius	Forest shrew	DD	L		
Suncus lixus	Greater dwarf shrew	DD	M		
Suncus infinitesimus	Least dwarf shrew	DD	M		
Crocidura cyanea	Reddish-grey musk shrew	DD	M		
Crocidura hirta	Lesser red musk shrew	DD	M		
Atelerix frontalis	Southern African hedgehog	NT	M		
Taphozous mauritianus	Mauritian tomb bat		L		
Sauromys petrophilus	Flat-headed free-tailed bat		L		
Tadarida aegyptiaca	Egyptian free-tailed bat		M		
Neoromicia capensis	Cape serotine bat		M		
Scotophilus dinganii	African yellow house bat		M		
Scotophilus viridis	Greenish yellow house bat		M		
Proteles cristatus	Aardwolf		L		
Parahyaena brunnea	Brown hyena	NT	L		
Panthera leo	Lion		H	Sighting	Woodland (Enclosure)
Felis silvestris	African wild cat		M		
Genetta genetta	Small-spotted genet		M		
Genetta tigrina	SA large-spotted genet		M		
Cynictis penicillata	Yellow mongoose		H	Sighting	Terrestrial
Galerella sanguinea	Slender mongoose		M		
Vulpes chama	Cape fox		H		
Canis mesomelas	Black-backed jackal		M		
Poecilogale albinucha	African weasel	DD	L		
Ictonyx striatus	Striped polecat		L		
Ceratotherium simum	White rhino		H	Sighting	Grassy plains

Common English Name	Scientific Name	Conservation Status Codes	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Equus quagga	Plains zebra		H	Sighting	Grassy plains
Potamochoerus larvatus	Bushpig		H	Routing for roots	Riparian zone
Phacochoerus africanus	Common warthog		H	Sighting	Woodland
Hippopotamus amphibious	Hippopotamus		H	Sighting	Aquatic
Giraffa camelopardalis	Giraffe		H	Sighting	Woodland
Connochaetes gnou	Black wildebeest		H	Sighting	Grassy plains
Tragelaphus strepsiceros	Kudu		H	Sighting	Woodland
Tragelaphus oryx	Eland		H	Sighting	Grassy plains
Alcelaphus buselaphus	Red hartebeest		H	Sighting	Grassy plains
Damaliscus pygargus phillipsi	Blesbok		H	Sighting	Grassy plains
Oryx gazelle	Gemsbok		H	Sighting	Grassy plains
Sylvicapra grimmia	Common duiker		H	Sighting	Grassy plains
Raphicerus campestris	Steenbok		M		
Redunca fulvorufula	Mountain reedbuck		H	Sighting	Grassy plains
Kobus ellipsiprymnus	Waterbuck		H	Sighting	Grassy plains
Aepyceros melampus	Impala		H	Sighting	Grassy plains
Antidorcus marsupialis	Springbok		H	Sighting	Grassy plains

The 23 observed species constitute a normal assemblage for a sizeable and well-established game reserve managed for eco-tourism and conservation purposes. Most of the medium- and large species have been reintroduced to their former haunts.

The Gemsbok is extralimital to Guateng. The KGR will need to decide whether stocking extralimital species is compatible with the objectives of a Nature Reserve and biodiversity conservation.

7.3 Red listed mammal species

Nine species in Table 28 enjoy Red Data status (Friedman and Daly 2004). No other Red Data or sensitive species are deemed present on the site, either since the site is too disturbed, falls outside the distributional ranges of some species, or does not offer suitable habitat.

There is insufficient knowledge of the populations of the five shrew species and the African Weasel listed in Table 28, and they listed as data-deficient as a precaution.

The conservation status of aardvark has been elevated to "Least Concern". This species is in fact fairly widespread and common, *albeit* solitary and nocturnal in habit, and occasional vagrants may occur on site.

The African marsh rat *(Dasymys incomtus)* is narrowly dependent of rank semi-aquatic vegetation. However, considering the fact that it is vulnerable to environmental disturbances, this rodent is deemed absent along the Tweelopiesspruit.

The Near Threatened hedgehog is heavily impacted by human activity and pets. Under natural conditions the passive defence mechanisms of these rather docile insectivores are sufficient to

maintain breeding populations in a healthy condition. The connectivity with adjacent grasslands to the north makes it possible that a small population of hedgehogs persists in the reserve.

The brown hyena *(Parahyaena brunnea)* is exceptionally reticent in habits and often persists close to activities of civilization. It is likely that individuals (if not breeding pairs) occurs on the reserve, at least as vagrants.

The primary cause of population decline in threatened species is destruction, degradation or fragmentation of habitat. The Krugersdorp Game Reserve therefore presents an important protected habitat for these species

The brown hyaena, South African Hedgehog, Black Wildebeest and White rhinoceros are listed as Protected Species under the National Environmental Management: Biodiversity Act (10 of 2004). In addition, Red Data species are protected under the Gauteng Department of Agriculture and Rural Development provincial regulations.

8 BIRDS

ALAN KEMP

8.1 Bird habitat assessment

8.1.1 Regional bird habitats

The habitats at the site, as identified for bird community distributions, occur at the junction of the Moist Woodland, Arid Woodland and Sour Grassland biomes (Harrison et al. 1997). Much of the surrounding area has been developed for residential, agricultural and mining activities. This confluence of habitats places the KGR at the recognised crossroads of warm wooded (north) and cool grassland (south), further divided into arid (west) and mesic (east) avifaunas (Tarboton et al. 1987) (Appendix 3: Avian distribution and abundance data). The consequence is that although recorded species richness may be high, exact composition at any one time depends on the effects of inter-annual and seasonal climate shifts from dry to wet and warm to cool.

The aerial mobility of birds also demands attention to the principal habitats surrounding the study site and their conservation status, not just those along the immediate borders but also more distant habitats that might provide sources for species visiting the site and sinks for those breeding on site. In this context, the adjacent official and private conservation areas within the Blougat Municipal and Diepsloot Nature Reserves, Roodepoort National Botanical Gardens and especially those of the IUCN World Heritage Site of the Cradle of Humankind are especially important, while further afield the Important Bird Areas of the Magaliesberg & Witwatersberg (SA 025) and Suikerbosrand Nature Reserve (SA022) (Barnes 1998), and the smaller Rietvlei Dam and Abe Bailey Nature Reserves near Centurion and Carletonville, respectively, are expected to share similar habitats and avifauna (Map 13).

8.1.2 On-site bird habitat assessment

The broader habitats adjacent to the study sites are mainly extensions of those present on site, or mentioned specifically in the habitat types described below. Generally, we did not assign aerial-feeding species, such as swifts, martins and swallows, to a specific habitat on site, except for those habitats that offered potential nesting habitats, since they feed wherever aerial wind-borne plankton is available. Only three principal avifaunal habitat types were distinguished on and/or adjacent to the site, and considered most relevant to bird ecology and community structure. These are the grasslands (including the kikuyu pastures), trees and bushes (equivalent to arboreal habitat) and the watercourses and wetlands. The geological substrate of the grasslands is unlikely to affect bird distribution, and common grassland species are likely to occur on the heavily-grazed kikuyu. The trees, including aliens, provide nesting sites, cover, and nectar or seed, but many of the alien species are bird-dispersed and a threat to the local ecosystem.

Map 13: Satellite image of the greater area considered when assessing what bird species can be expected on the KGR (yellow polygon at centre). Grids indicate cells analysed from bird species lists accumulated for national bird atlases SABAP1 and SABAP2, green – 6 QDGSs from SABAP1, orange – 10 pentads surrounding KGR, purple – 2 pentads covering KGR (cf. Appendix 2 for more details).

8.2 Observed and expected bird species richness

The site falls at the junction of four quarter-degree grid cells (QDGC) and within two pentads. This position falls on a crossroads of major habitat and bird distributions (Map 13; Appendix 2) Out of the maximum of 384 species expected for the site during 1987-1991, based on those reported for the four QDGCs (SABAP 1), and including the 342 species so far reported since 2009 for the 12 pentads on and around the site (SABAP2), 311 bird species have a **high** (132 species, 103 confirmed), **medium** (103 species, 16 confirmed) or **low probability** (76 species, 5 confirmed) to occur on site, based on the habitats available. Site visits and online records confirmed 124 species (36%) in support of general species: habitat correlations (Table 29). These numbers would be increased by more intensive surveys than the budget allocated for this study, and by repeated surveys during different seasons. **Unlikely** species which are only recorded as rare vagrants were excluded from analysis due to the sparsity of their preferred habitats. We marked species whose habitat was potentially affected by the pollution of the Tweelopiesspruit with a cross, to indicate a lower than expected value.

The three different habitat types support different assemblages of birds, excluding the 17 species (5%) classed as aerial feeders and expected to range across all habitats when feeding. For the 294 non-aerial species, 20 species (7%) are generalist, ranging across three habitats, 61 (21%) preferred two, and 213 (72%), the majority, only a single habitat type. Overall, including aerial species which feed across habitats and breed in preferred habitats, grasslands supported the highest diversity (198 expected species), with wooded tree and bush habitats the next highest (167 species), and watercourses and wetlands the lowest (132 species).

Table 29: Bird species diversity observed and expected on and around the Krugersdorp Game Reserve, Gauteng (2627BA). Based on the national list and annotations of Birdlife South Africa (2014), sorted in the order of 'Roberts VII' (Hockey et al. 2005), with probability of occurrence and habitat preferences assessed after a site visit on 3-4 December 2014 and comparison with lists from SABAP 1 & 2 (Harrison et al., 1997; www.sabap2.org). Species in

bold font were detected on the 3-4 December site visit, with additions from JCP van Wyk on 13-14 December (**) and from informal online reports (*). † = lower than expected due to Acid Mine Drainage

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Common Ostrich	***Struthio camelus***				**H**	**G**
****Coqui Francolin**	***Peliperdix coqui***				**L**	**G,T**
Orange River francolin	***Scleroptila levaillantoides***				**H**	**G**
Natal Spurfowl	*Pternistis natalensis*				L	T
Swainson's Spurfowl	***Pternistis swainsonii***				**H**	**G**
Common Quail	*Coturnix coturnix*		**NBM**		H	G
Helmeted Guineafowl	***Numida meleagris***				**H**	**G,T,W**
Fulvous Duck†	*Dendrocygna bicolor*				L†	W
***White-faced Duck†**	***Dendrocygna viduata***				**L†**	**W**
Egyptian Goose†	***Alopochen aegyptiaca***				**H†**	**W**
South African Shelduck†	*Tadorna cana*				L†	W
Spur-winged Goose†	***Plectropterus gambensis***				**H†**	**W**
Cape Teal†	*Anas capensis*				L†	W
African Black Duck†	***Anas sparsa***				**H†**	**W**
Yellow-billed Duck†	***Anas undulata***				**H†**	**W**
Cape Shoveler†	*Anas smithii*				M†	W
Red-billed Teal†	*Anas erythrorhyncha*				H†	W
Hottentot Teal†	*Anas hottentota*				L†	W
Southern Pochard†	*Netta erythrophthalma*				M†	W
Kurrichane Buttonquail	***Turnix sylvaticus***				**M**	**G**
Greater Honeyguide	*Indicator indicator*				M	T
Lesser Honeyguide	*Indicator minor*				M	T
Brown-backed Honeybird	*Prodotiscus regulus*				L	T
Red-throated Wryneck	*Jynx ruficollis*				M	G,T
Golden-tailed Woodpecker	*Campethera abingoni*				M	T
Cardinal Woodpecker	*Dendropicos fuscescens*				H	T
Bearded Woodpecker	*Dendropicos namaquus*				L	T
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*				L	T
Acacia Pied Barbet	***Tricholaema leucomelas***				**H**	**T**
Black-collared Barbet	***Lybius torquatus***				**H**	**T**
***Crested Barbet**	***Trachyphonus vaillantii***				**H**	**T**
African Grey Hornbill	***Tockus nasutus***				**H**	**T**
African Hoopoe	*Upupa africana*				H	G,T
Green Wood-hoopoe	***Phoeniculus purpureus***				**H**	**T**

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Common Scimitarbill	*Rhinopomastus cyanomelas*				M	T
European Roller	*Coracias garrulus*	NT,NT	NBM		L	G,T
Lilac-breasted Roller	*Coracias caudatus*				L	G,T
Purple Roller	*Coracias naevius*				L	G,T
Half-collared Kingfisher†	*Alcedo semitorquata*	NT,LC			H†	W
Malachite Kingfisher†	*Alcedo cristata*				H†	W
Brown-hooded Kingfisher	***Halcyon albiventris***				**H**	**T,W**
Giant Kingfisher†	*Megaceryle maxima*				M†	W
Pied Kingfisher†	*Ceryle rudis*				M†	W
White-fronted Bee-eater	*Merops bullockoides*				M	G,T
Little Bee-eater	*Merops pusillus*				L	T
Swallow-tailed Bee-eater	*Merops hirundineus*				L	G,T
European Bee-eater	***Merops apiaster***		**B/NBM**		**H**	**G,T**
White-backed Mousebird	*Colius colius*				M	T
Speckled Mousebird	***Colius striatus***				**H**	**T**
Red-faced Mousebird	***Urocolius indicus***				**H**	**T**
Jacobin Cuckoo	*Clamator jacobinus*		**BM**		H	T
Levaillant's Cuckoo	*Clamator levaillantii*		**BM**		M	T
Red-chested Cuckoo	***Cuculus solitarius***		**BM**		**H**	**T**
Black Cuckoo	***Cuculus clamosus***		**BM**		**H**	**T**
Klaas's Cuckoo	***Chrysococcyx klaas***				**H**	**T**
***Diderick Cuckoo**	***Chrysococcyx caprius***		**BM**		**H**	**G,T,W**
Burchell's Coucal†	*Centropus burchellii*				M†	W
African Palm-Swift	*Cypsiurus parvus*				M	Aerial
Alpine Swift	*Tachymarptis melba*		**BM**		H	Aerial
Common Swift	*Apus apus*		**NBM**		M	Aerial
African Black Swift	***Apus barbatus***				**H**	Aerial
****Little Swift**	***Apus affinis***				**H**	**Aerial**
Horus Swift	*Apus horus*				L	Aerial
White-rumped Swift	***Apus caffer***		**BM**		**H**	Aerial,T
Grey Go-away-bird	*Corythaixoides concolor*				M	T
Barn Owl	***Tyto alba***				**H**	**G,T**
African Grass-Owl†	*Tyto capensis*	VU,LC			L†	W
Cape Eagle-Owl	*Bubo capensis*				L	G
Spotted Eagle-Owl	*Bubo africanus*				H	G,T,W
***Marsh Owl†**	***Asio capensis***				**M†**	**G,W**

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Fiery-necked Nightjar	*Caprimulgus pectoralis*				L	T
Freckled Nightjar	*Caprimulgus tristigma*				M	T
Rufous-cheeked Nightjar	***Caprimulgus rufigena***		**BM**		**H**	**G**
European Nightjar	*Caprimulgus europaeus*				L	T
Rock Dove	***Columba livia***				**M**	**G,T,W**
****Speckled Pigeon**	***Columba guinea***				**M**	**G**
****African Olive-Pigeon**	***Columba arquatrix***				**L**	**T**
Laughing Dove	***Streptopelia senegalensis***				**H**	**G,T,W**
Cape Turtle-Dove	***Streptopelia capicola***				**H**	**G,T**
Red-eyed Dove	***Streptopelia semitorquata***				**H**	**T,W**
Namaqua Dove	*Oena capensis*				M	G,T
African Green-Pigeon	*Treron calvus*				L	T,W
Northern Black Korhaan	***Afrotis afraoides***				**H**	**G**
Blue Korhaan	*Eupodotis caerulescens*	LC,NT		*	M	G
White-bellied Korhaan	*Eupodotis senegalensis*	VU,LC			L	G
Blue Crane	*Anthropoides paradiseus*	NT,VU			L	G
African Finfoot†	*Podica senegalensis*	VU,LC			L†	W
Red-chested Flufftail†	*Sarothrura rufa*				L†	W
African Rail†	*Rallus caerulescens*				M†	W
African Crake†	*Crecopsis egregia*		**BM**		L†	W
Corn Crake	*Crex crex*		**NBM**		L	T,W
Black Crake†	*Amaurornis flavirostra*				H†	W
Baillon's Crake†	*Porzana pusilla*				L†	W
African Purple Swamphen†	*Porphyrio madagascariensis*				M†	W
Common Moorhen†	***Gallinula chloropus***				**H†**	**W**
Red-knobbed coot†	***Fulica cristata***				**H†**	**W**
African Snipe†	*Gallinago nigripennis*				H†	W
Marsh Sandpiper†	*Tringa stagnatilis*		**NBM**		M†	W
Common Greenshank†	*Tringa nebularia*		**NBM**		M†	W
Wood Sandpiper†	*Tringa glareola*		**NBM**		M†	W
Common Sandpiper†	*Actitis hypoleucos*		**NBM**		M†	W
Ruff†	*Philomachus pugnax*		**NBM**		M†	W
Greater Painted-snipe†	*Rostratula benghalensis*	VU,NT			L†	W
Spotted Thick-knee	***Burhinus capensis***				**H**	**G,T**
Black-winged Stilt†	*Himantopus himantopus*				L†	W
Common Ringed Plover†	*Charadrius hiaticula*		**NBM**		L†	W

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Kittlitz's Plover	*Charadrius pecuarius*				L	G,W
Three-banded Plover†	*Charadrius tricollaris*				L†	W
Blacksmith Lapwing	***Vanellus armatus***				**M**	**G,W**
African Wattled Lapwing†	***Vanellus senegallus***				**M†**	**G,W**
Crowned Lapwing	***Vanellus coronatus***				**H**	**G**
Temminck's Courser	*Cursorius temminckii*				M	G
Black-winged Pratincole	*Glareola nordmanni*	NT,NT	**NBM**		L	G,W
Grey-headed Gull†	*Chroicocephalus cirrocephalus*				L†	W
Whiskered Tern†	*Chlidonias hybrida*				L†	W
White-winged Tern†	*Chlidonias leucopterus*		**NBM**		L†	W
African Cuckoo Hawk	*Aviceda cuculoides*				L	T
European Honey-Buzzard	*Pernis apivorus*		**NBM**		L	T
Black-shouldered Kite	***Elanus caeruleus***				**H**	**G,T,W**
Black Kite	*Milvus migrans*		**NBM**		M	G,T
Yellow-billed Kite	*Milvus aegyptius*		**BM**		L	G,T,W
African Fish-Eagle†	*Haliaeetus vocifer*				L†	W
Cape Vulture	*Gyps coprotheres*	EN,VU			M	G,T
Black-chested Snake-Eagle	*Circaetus pectoralis*				H	G,T
Brown Snake-Eagle	*Circaetus cinereus*				M	G,T
African Marsh-Harrier†	*Circus ranivorus*	EN,LC			L†	W
Black Harrier	*Circus maurus*	EN,VU		(*)	L	G
Pallid Harrier	*Circus macrourus*	NT,NT	**NBM**		L	G
*Montagu's Harrier	*Circus pygargus*		**NBM**		L	G
African Harrier-Hawk	*Polyboroides typus*				M	T
Little Sparrowhawk†	***Accipiter minullus***				**H†**	**T**
Ovambo Sparrowhawk	***Accipiter ovampensis***				**H**	**T**
Black Sparrowhawk	*Accipiter melanoleucus*				H	T
Steppe Buzzard	***Buteo buteo***		**NBM**		**H**	**G,T**
Jackal Buzzard	*Buteo rufofuscus*			(*)	M	G,T
Verreaux's Eagle	***Aquila verreauxii***	VU,LC			**H**	**T**
African Hawk-Eagle	*Aquila spilogaster*				L	T
Ayres's hawk-Eagle	*Hieraaetus ayresii*				L	T
Booted Eagle	*Hieraaetus pennatus*		**NBM**		L	T
Wahlberg's Eagle	*Hieraaetus wahlbergi*		**BM**		L	T
Martial Eagle	*Polemaetus bellicosus*	EN,VU			L	G,T
Long-crested Eagle	*Lophaetus occipitalis*				L	T,W

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Secretarybird	*Sagittarius serpentarius*	VU,VU			H	G
Lesser Kestrel	*Falco naumanni*		**NBM**		H	G
****Rock Kestrel**	***Falco rupicolus***				**M**	**G,T**
Greater Kestrel	*Falco rupicoloides*				H	G,T
Amur Falcon	*Falco amurensis*		**NBM**		H	G
Lanner Falcon	***Falco biarmicus***	VU,LC			**H**	**G,T,W**
Peregrine Falcon	*Falco peregrinus*				M	G,W
Little Grebe†	***Tachybaptus ruficollis***				**H†**	**W**
Great crested Grebe†	*Podiceps cristatus*				L†	W
Black-necked Grebe†	*Podiceps nigricollis*				L†	W
African Darter†	*Anhinga rufa*				M†	W
Reed Cormorant†	***Phalacrocorax africanus***				**H†**	**W**
White-breasted Cormorant†	*Phalacrocorax lucidus*				M†	W
Black Heron†	*Egretta ardesiaca*				L†	W
Little Egret†	*Egretta garzetta*				M†	W
Yellow-billed Egret†	*Egretta intermedia*				M†	W
Great Egret†	*Egretta alba*				L†	W
Grey Heron†	***Ardea cinerea***				**H†**	**W**
Black-headed Heron	***Ardea melanocephala***				**H**	**G,T,W**
Purple Heron†	*Ardea purpurea*				H†	W
Cattle Egret	***Bubulcus ibis***				**H**	**G,T,W**
Squacco Heron†	*Ardeola ralloides*				M†	W
Green-backed Heron†	*Butorides striata*				M†	W
Black-crowned Night-Heron†	*Nycticorax nycticorax*				M†	W
White-backed Night-Heron†	*Gorsachius leuconotus*	VU,LC			L†	W
Little Bittern†	*Ixobrychus minutus*				L†	W
Hamerkop†	*Scopus umbretta*				M†	T,W
***Glossy Ibis†**	***Plegadis falcinellus***				**M†**	**W**
Hadeda Ibis	***Bostrychia hagedash***				**H**	**G,T,W**
African Sacred Ibis†	***Threskiornis aethiopicus***				**M†**	**W**
African Spoonbill†	*Platalea alba*				M†	W
Black Stork†	*Ciconia nigra*	VU,LC			L†	W
Abdim's Stork	*Ciconia abdimii*	NT,LC	**NBM**		M	G
White Stork	*Ciconia ciconia*		**NBM**		H	G
Black-headed Oriole	*Oriolus larvatus*				M	T
Fork-tailed Drongo	*Dicrurus adsimilis*				M	T

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
African Paradise-Flycatcher	*Terpsiphone viridis*				H	T
Black-backed Puffback	***Dryoscopus cubla***				**H**	**T**
Black-crowned Tchagra	*Tchagra senegalus*				M	T
Brown-crowned Tchagra	*Tchagra australis*				H	T
Southern Boubou	***Laniarius ferrugineus***				**H**	**T**
Crimson-breasted Shrike	*Laniarius atrococcineus*				L	T
Bokmakierie	***Telophorus zeylonus***				**H**	**G,T**
Orange-breasted Bush-Shrike	*Chlorophoneus sulfureopectus*				L	T
Grey-headed Bush-Shrike	*Malaconotus blanchoti*				L	T
Chinspot Batis	*Batis molitor*				M	T
Cape Crow	*Corvus capensis*				L	G,T
Pied crow	***Corvus albus***				**H**	**G,T**
Red-backed Shrike	*Lanius collurio*		**NBM**		H	G,T
Lesser Grey Shrike	***Lanius minor***		**NBM**		**H**	**G**
Common Fiscal	***Lanius collaris***				**H**	**G,T,W**
Black Cuckooshrike	*Campephaga flava*				L	T
Southern Black Tit	*Parus niger*				L	T
Ashy Tit	*Parus cinerascens*				L	T
Brown-throated Martin	*Riparia paludicola*				M	Aerial, W
Banded Martin	*Riparia cincta*				M	Aerial, G
Barn Swallow	***Hirundo rustica***		**NBM**		**H**	Aerial
****White-throated Swallow†**	***Hirundo albigularis***		**BM**		**L†**	**Aerial,W**
***Pearl-breasted Swallow**	***Hirundo dimidiata***				**M**	**Aerial,G**
Greater Striped Swallow	***Cecropis cucullata***		**BM**		**H**	Aerial,T
Red-breasted Swallow	*Cecropis semirufa*				L	Aerial,G
South African cliff-Swallow	*Petrochelidon spilodera*			**B(*)**	M	Aerial
Rock Martin	*Hirundo fuligula*				M	Aerial,T
Common House-Martin	*Delichon urbicum*		**NBM**		M	Aerial
Dark-capped Bulbul	***Pycnonotus tricolor***				**H**	**T**
African Red-eyed Bulbul	*Pycnonotus nigricans*				M	T
Fairy Flycatcher	*Stenostira scita*			(*)	L	T
Cape Grassbird	***Sphenoeacus afer***			(*)	**H**	**G,T**
Long-billed crombec	*Sylvietta rufescens*				M	T
Little Rush-Warbler†	*Bradypterus baboecala*				M†	W
Sedge Warbler	*Acrocephalus schoenobaenus*		**NBM**		M	W

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Eurasian Reed-Warbler†	*Acrocephalus scirpaceus*		V		M†	W
African Reed-Warbler†	***Acrocephalus baeticatus***		**BM**		**H†**	**W**
Marsh Warbler†	*Acrocephalus palustris*		**NBM**		M†	W
Great Reed-Warbler†	*Acrocephalus arundinaceus*		**NBM**		M†	W
Lesser Swamp-Warbler†	***Acrocephalus gracilirostris***				**H†**	**W**
Icterine Warbler	*Hippolais icterina*		**NBM**		M	T
Dark-capped Yellow Warbler	*Iduna natalensis*				M	T,W
Willow Warbler	***Phylloscopus trochilus***		**NBM**		**H**	**T**
****Arrow-marked Babbler**	***Turdoides jardineii***				**M**	**T**
Chestnut-vented Tit-Babbler	***Sylvia subcaerulea***				**H**	**T**
Garden Warbler	*Sylvia borin*		**NBM**		M	T
Cape White-eye	***Zosterops capensis***			(*)	**H**	**T**
Lazy Cisticola	*Cisticola aberrans*				M	G
Wailing Cisticola	***Cisticola lais***				**H**	**G**
Levaillant's Cisticola†	*Cisticola tinniens*				M†	W
Neddicky	***Cisticola fulvicapilla***				**H**	**T**
Zitting Cisticola	***Cisticola juncidis***				**H**	**G**
Desert Cisticola	***Cisticola aridulus***				**H**	**G**
Cloud Cisticola	***Cisticola textrix***			(*)	**H**	**G**
***Wing-snapping Cisticola**	***Cisticola ayresii***				**M**	**G**
Tawny-flanked Prinia†	***Prinia subflava***				**H†**	**T,W**
****Black-chested Prinia**	***Prinia flavicans***				**M**	**T**
Bar-throated Apalis	***Apalis thoracica***				**H**	**T**
Grey-backed Camaroptera	*Camaroptera brevicaudata*				M	T
Melodious Lark	*Mirafra cheniana*	LC,NT		(*)	L	G
Rufous-naped Lark	***Mirafra africana***				**H**	**G**
Eastern clapper Lark	*Mirafra fasciolata*				M	G
Spike-heeled Lark	***Chersomanes albofasciata***				**H**	**G**
Eastern Long-billed Lark	***Certhilauda semitorquata***			(*)	**H**	**G**
Chestnut-backed Sparrowlark	*Eremopterix leucotis*				M	G
Red-capped Lark	*Calandrella cinerea*				H	G
Pink-billed Lark	*Spizocorys conirostris*				M	G
Cape Rock-Thrush	*Monticola rupestris*			(*)	H	G,T
Sentinel Rock-Thrush	*Monticola explorator*			(*)	M	G,T
Short-toed Rock-Thrush	*Monticola brevipes*				L	G,T

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Groundscraper Thrush	*Psophocichla litsitsirupa*				M	T
Kurrichane Thrush	***Turdus libonyanus***				**H**	**T**
****Karoo Thrush**	***Turdus smithi***			(*)	**H**	**T**
Southern Black flycatcher	*Melaenornis pammelaina*				M	T
Fiscal Flycatcher	***Sigelus silens***			(*)	**H**	**T**
Spotted flycatcher	***Muscicapa striata***		**NBM**		**H**	**T**
Cape Robin-Chat	***Cossypha caffra***				**H**	**T**
White-throated Robin-Chat	*Cossypha humeralis*				M	T
African StoneChat†	***Saxicola torquatus***				**H†**	**W**
****Mountain Wheatear**	***Oenanthe monticola***				**H**	**T**
Capped Wheatear	*Oenanthe pileata*				M	G
****Familiar Chat**	***Cercomela familiaris***				**M**	**G,T**
***Ant-eating Chat**	***Myrmecocichla formicivora***				**M**	**G**
Mocking cliff-Chat	*Thamnolaea cinnamomeiventris*				L	T
Red-winged Starling	*Onychognathus morio*				M	T
Cape Glossy Starling	***Lamprotornis nitens***				**H**	**G,T**
Violet-backed Starling	*Cinnyricinclus leucogaster*				M	T
Pied Starling	*Lamprotornis bicolor*			(*)	H	G
***Wattled Starling**	***Creatophora cinerea***				**H**	**G,T,W**
Common Myna	***Acridotheres tristis***		**I**		**H**	**G,T,W**
Red-billed Oxpecker	*Buphagus erythrorhynchus*				L	G,T
Amethyst Sunbird	*Chalcomitra amethystina*				H	G,T
Malachite Sunbird	*Nectarinia famosa*				L	G,T
Greater Double-collared Sunbird	*Cinnyris afer*			(*)	L	G,T
White-bellied Sunbird	***Cinnyris talatala***				**H**	**G,T**
Marico Sunbird	*Cinnyris mariquensis*				M	G,T
White-browed Sparrow-Weaver	***Plocepasser mahali***				**H**	**G,T**
****Cape Weaver**	***Ploceus capensis***			(*)	**M**	**G,W**
Southern Masked-Weaver	***Ploceus velatus***				**H**	**G,T,W**
Red-billed Quelea	***Quelea quelea***				**H**	**G,W**
Yellow-crowned Bishop†	*Euplectes afer*				H†	G,W
Southern Red Bishop	***Euplectes orix***				**H**	**G,T,W**
White-winged Widowbird	***Euplectes albonotatus***				**H**	**G,T**
Red-collared Widowbird	***Euplectes ardens***				**H**	**G,T,W**
Long-tailed Widowbird	***Euplectes progne***				**H**	**G**

Common English Name	Scientific Name	Status Codes (see below)			Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
		RD	S	E		
Thick-billed Weaver	*Amblyospiza albifrons*				M	T,W
Orange-breasted Waxbill	*Amandava subflava*				M	W
African Quailfinch	*Ortygospiza fuscocrissa*				H	G
Red-headed Finch	*Amadina erythrocephala*				H	T
Common Waxbill	***Estrilda astrild***				**H**	**G,T,W**
African Firefinch	***Lagonosticta rubricata***				**H**	**T**
Jameson's Firefinch	*Lagonosticta rhodopareia*				M	T
Bronze Mannikin	***Spermestes cucullata***				**H**	**T**
****Pin-tailed Whydah**	***Vidua macroura***				**H**	**G,T,W**
Dusky Indigobird	*Vidua funerea*				H	T
Purple Indigobird	*Vidua purpurascens*				L	T
Cuckoo Finch	*Anomalospiza imberbis*				M	G
House Sparrow	*Passer domesticus*		**I**		H	T
Cape Sparrow	***Passer melanurus***				**H**	**G,T**
Southern Grey-headed Sparrow	***Passer diffusus***				**H**	**T**
Cape Wagtail	***Motacilla capensis***				**H**	**W**
Cape Longclaw	***Macronyx capensis***				**H**	**G**
Striped Pipit	*Anthus lineiventris*				M	T
African Pipit	***Anthus cinnamomeus***				**H**	**G,T,W**
Plain-backed Pipit	*Anthus leucophrys*				M	G,T
***Buffy Pipit**	***Anthus vaalensis***				**M**	**G,T**
Long-billed Pipit	*Anthus similis*				M	T
***Yellow-fronted Canary**	***Crithagra mozambica***				**H**	**T**
Black-throated Canary	***Crithagra atrogularis***				**H**	**T**
Yellow Canary	*Crithagra flaviventris*				M	T
****Streaky-headed Seedeater**	***Crithagra gularis***				**H**	**T**
Cinnamon-breasted Bunting	***Emberiza tahapisi***				**H**	**G,T**
Cape Bunting	*Emberiza capensis*				M	G,T

Red Status	Status in south Africa (S)	Endemism in South Africa (E)
NA = Not Assessed	BM = breeding migrant	Endemism in South Africa (E) (not southern Africa as in field guides)
LC = Least Concern	NBM = non-breeding migrant	
NT = Near-Threatened	V = vagrant	* = endemic
VU = Vulnerable	I = introduced	

Common English Name	Scientific Name	Status Codes (see below) RD	S	E	Probability of occurrence: High, Medium or Low	Preferred Habitats G: Grassland T: Trees W: Wetland
EN = Endangered	R = rare					
CR = Critically Endangered	PRB = probable rare breeder	B* = breeding endemic				
EX = Extinct Regionally	RB = rare breeder					
NR = Not Recognised	RV = rare visitor	W* = winter endemic				
Red Status is from *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland*, Taylor (2014).						

8.3 Red listed bird species identified

A total of 20 Red Data avifaunal species (Taylor 2014) are expected possibly to use the site and its surroundings given the habitats available (Table 29). Fifteen of these species have already been reported for the 12 pentads on and around the two pentads (2600-2740 and 2605-2740) within which the site falls during the period of the ongoing Southern African bird atlas project started in 2009 (SABAP2).

Most of these threatened species fall into a few obvious categories by habitat preference and their likelihood of occurrence on site (Table 29), especially once one appreciates what habitats are useful and available to them on site (Table 31).

Table 30: List of threatened species that will possibly make use of the habitats on and around the Krugersdorp Game Reserve, and there expected frequency of occurrence on site based on the quality and quantity of habitats available. Note one species may have more than one habitat preference. * indicates species recorded for the site's two pentads, ** recorded from the site and the surrounding pentads (sabap2.org.za) since 2009.

Threatened Status	Species	Preferred Habitat Type(s)			Expected frequency of occurrence on site			
		Grasslands	Trees and Bushes	Watercourse & Wetlands	Regular resident	Frequent visitor	Erratic visitor	Infrequent vagrant
Least Concern	Blue Korhaan	X						+
Near Threatened	European Roller**	X	X				+	
	Half-collared Kingfisher**			X			+	
	Blue Crane**	X		X			+	
	Black-winged Pratincole	X		X				+
	Pallid Harrier	X						+
	Abdim's Stork**	X				+		
	Melodious Lark**	X			+			
Vulnerable	African Grass-Owl**	X		X			+	
	White-bellied Korhaan**	X				+		
	African Finfoot*			X			+	
	Greater Painted-Snipe**			X			+	
	Verreauxs' Eagle**		X			+		
	Secretarybird*	X				+		
	Lanner Falcon*	X	X			+		
	White-backed Night-Heron			X			+	
	Black Stork*			X				+
Endangered	Cape Vulture**	X	X			+		
	African Marsh-Harrier*	X		X			+	
	Martial Eagle	X	X	X			+	
TOTALS	**20**	**15**	**5**	**11**	**1**	**6**	**9**	**4**

Table 31: Estimated suitability of favoured habitats to support requirements of threatened bird species on and around the Krugersdorp Game Reserve based on the quantity and quality of habitats available and assessed as Good (G), Mediocre (M), Poor (P), Absent (A) or Not Applicable (NA). * indicates species recorded for the site's two pentads, ** recorded from the site and the surrounding pentads (sabap2.org.za) since 2009.* indicates species recorded for the site pentad since 2009 (sabap2.org.za).

Threatened Status	Species	Potential support for:			
		Movement	Feeding	Roosting	Breeding
Least Concern	Blue Korhaan	Good	Mediocre	Good	Poor
Near Threatened	European Roller**	Good	Mediocre	Mediocre	N/A
	Half-collared Kingfisher**	Mediocre	Poor	Good	Absent
	Blue Crane**	Good	Mediocre	Mediocre	Poor
	Black-winged Pratincole	Good	Mediocre	Poor	N/A
	Pallid Harrier	Good	Mediocre	Mediocre	N/A
	Abdim's Stork**	Good	Mediocre	Good	N/A
	Melodious Lark**	Good	Good	Good	Mediocre
Vulnerable	African Grass-Owl**	Mediocre	Poor	Poor	Absent
	White-bellied Korhaan**	Good	Good	Good	Mediocre
	African Finfoot*	Mediocre	Poor	Mediocre	Absent
	Greater Painted-Snipe**	Mediocre	Poor	Poor	Absent
	Verreauxs' Eagle**	Good	Good	Poor	Absent
	Secretarybird*	Good	Good	Mediocre	Poor
	Lanner Falcon*	Good	Good	Mediocre	Poor
	White-backed Night-Heron	Mediocre	Poor	Mediocre	Absent
	Black Stork*	Mediocre	Poor	Absent	Absent
Endangered	Cape Vulture**	Good	Mediocre	Absent	Absent
	African Marsh-Harrier*	Mediocre	Poor	Poor	Poor
	Martial Eagle	Good	Good	Mediocre	Poor
TOTALS	**20**	**G13;M7**	**G6;M7;P7**	**G5;M8;P5;A2**	**M2;P6;A8;N/A4**

These analyses indicate that the habitats most favoured by nationally threatened bird species are the natural grasslands, followed by the watercourses and wetlands (Table 30). Good stands of natural grasslands are the least protected terrestrial habitat in South Africa after wetlands, especially of the types present that are so surrounded by agricultural, mining and urban development. The thickening of woody vegetation in parts of the reserve, especially around the lion enclosure where herbivore numbers are lower, is therefore of concern as the grassland habitat could be replaced by a woody, savanna habitat.

However, while half the threatened species depend on the watercourses and wetlands, the present poor water quality makes this habitat hostile for their existence in various ways and so, until remediated these habitats cannot fulfil their conservation potential. Furthermore, the extension of this negative effect into the Rietspruit and other aquatic corridors linked to KGR can only exacerbate the problem.

The following species expected on the KGR are listed under the NEMBA 2004 Act as:
Endangered species: Blue Crane, Cape Vulture.
Vulnerable species: Black Stork, Blue Korhaan, Lesser Kestrel, Martial Eagle, Grass Owl.
Protected species: African Marsh Harrier

According to GDARD's requirements for Biodiversity Assessments (GDARD 2012) and C-Plan Version 3.3 (GDARD 2011), the priority Red Data avifaunal species for Gauteng that are expected on the KGR are (In Roberts VII order and nomenclature; Hockey et al. 2005):

Half-collared Kingfisher, African Grass-Owl, White-bellied Korhaan, Blue Crane, African Finfoot, Cape Vulture, African Marsh-Harrier, Martial Eagle, Secretarybird, Lesser Kestrel, White-backed Night-Heron, and Black Stork.

These species were presumably selected from the 1998 Red Data book for South African birds (Barnes 2000) but have been superseded by the latest 2014 revision (Taylor 2014).

8.4 Conclusions

The expected diversity of the avifauna on the KGR results from its being at a major crossroads of bird distribution in South Africa. For example, species of the northern bushveld (African Grey Hornbill, breeding), arid west (Rufous-cheeked Nightjar, common), southern grasslands (Long-tailed Widow, widespread) and mesic east (Cloud and Wing-snapping Cisticolas) were all present on the KGR. However, the general impression of the avifauna on the KGR was that most species occurred at relatively low densities. This might be explained by a combination of the lower productivity expected for the mainly rocky substrate and the drier grasslands expected from the limited rainfall (especially on the dolomitic and hilly areas). This also means that smaller populations of individual species are expected, even for the smallest species that normally occur at the highest densities. These observations indicating low productivity were supported by the low number of arthropods encountered on the grasslands while walking through them. Burrow-nesting grassland species were conspicuous by their absence or rarity during the site visits (Capped Wheatear, Banded Martin, Pearl-breasted Swallow, Ant-eating Chat), suggesting low numbers of small sessile mammals, despite good numbers of ground squirrels and yellow mongoose, maybe due to the rocky substrates in most areas.

The woody vegetation seemed as healthy and abundant as the substrates allowed, especially along the lower dolomitic reaches of the Tweelopiesspruit where the large trees formed what must be some of the oldest and most climactic riparian and valley forest within the area. The lion enclosure further served to offer the climax and densest versions of the wooded, herbaceous and grassy vegetation types both on the slope and in the valley. In terms of avian biomass (excluding the introduced Ostrich and lone exotic Emu), the Kikuyu-grass areas in the north supported the highest density and concentration of open, grass-loving species (plovers, pipits, larks), and the most sinkholes with their important stopover potential for woodland species.

The avian potential of the Tweelopiesspruit watercourse looks excellent, but is negated by the contaminated water entering the reserve and its effects on plant and faunal composition and numbers, not only in the river and dam beds but also in the marginal wetland vegetation.

The 1 300 ha of grassland, bushveld and riparian woodland within the reserve offers important residential (for small species) and temporary (for large species) habitats for birds, especially when embedded within large areas of dense and relatively hostile agricultural, suburban, urban, mining and industrial development. Being on the west of this Johannesburg-centred development, the KGR forms an important link in the mosaic of natural habitats that extend south from the mountains and bushveld of the Magaliesberg to the grasslands of the Vaal River basin, and east from the drier western savanna and grassland of North West to the mesic hills and grasslands south and east of Johannesburg. For larger species especially, it offers at least a temporary safe haven as they move around in search of food and nest sites, such as the pair of Verreauxs' Eagles that visit to hunt on its hills.

About half of the bird species expected on site are predicted to be attracted primarily by the wetland habitats available, at their most extensive during the site visit after good rains, but surely much reduced and altered during drier seasons and years. The majority of wetland-favouring species are adapted to such fluctuating and ephemeral habitats, which, by their linear and/or

patchy distribution, always require the ability to move between sites that temporarily present the habitat requirements of particular species.

Grassland habitats, whether with more sandy or rocky substrates, are important to the other half of the bird species expected on site. Historically they were more extensive and interconnected than at present, so their fragmentation and general degradation and/or transformation by agriculture and development has created a narrower range of grassland quality and stability than previously available. In general, the grasslands on site are in moderate to good condition, with only local evidence of high grazing or burning pressures. There are relatively small areas of disturbed habitat, such as fallow lands or overgrazed patches, which do attract their own species, including gamebirds, to the annual grasses/herbs and the plentiful seeds and corms they provide, although such habitat remains plentiful on surrounding (Van Niekerk 2002, 2011).

8.5 Recommendations

The contaminated water of the Tweelopiesspruit significantly reduced the abundance and diversity of aquatic species. Until the quality of water entering the reserve can be addressed, not much can be done about this aspect, but improvement of the river margins is possible, and has already started with clearing of wattle patches along the southern reaches above the falls. Elimination of alien woody vegetation along the river, control of Kikuyu-grass along the banks, and re-establishment of natural wetland ground cover, especially *Imperata cylindrica* cotton-grass clumps, will anticipate results necessary to restore this potentially important wetland system.

From a conservation and management perspective, protection of wetland habitats will always be a priority, regardless of their size, since they all form an essential part of a mosaic of wetland patches in support of these mobile wetland avifaunas. For these reasons, it seems important to recognise the wetland systems on the site as ecologically sensitive areas for birds, and to refrain and protect them from any negative developments surrounding them (see Section 6: Wetlands).

9 HERPETOFAUNA

JACO VAN WYK

The local occurrences of reptiles and amphibians are closely dependent on broadly defined habitat types, in particular terrestrial, arboreal (tree-living), rupicolous (rock-dwelling) and wetland-associated vegetation cover. It is thus possible to deduce the presence or absence of reptile and amphibian species by evaluating the habitat types within the context of global distribution ranges.

9.1 Herpetofauna habitat assessment

The habitats have been described elsewhere (Section 1.5.6). The moribund termitaria on the northern dolomitic plains are good indicators of herpetofauna habitat, and reptile and amphibian population density for the study site should be high. At the time of the site visit the cover was generally poor in many places due to overgrazing and fires and would not provide adequate cover for small terrestrial herpetofauna. In places like the lion enclosure the opposite is true due to absence of grazing.

The kikuyu plains provide poor habitat for herpetofauna, although there is still habitat in the heavily grazed natural grasslands around the kikuyu.

The rocky ridges near the lodge, especially on the eastern side of KGR as well as near the Tweelopiesspruit, provide excellent natural rupicolous habitat for herpetofauna species. The buildings and ruins around the reserve also provide excellent artificial rupicolous habitat. Due to the presence of natural rupicolous habitat, some species like yellow-throated plated lizard, common girdled lizard and southern rock agama were added to the species list in Table 32.

The wooded areas of the park provide good arboreal habitat, including fallen logs and leaf litter which provide shelter and food for some herpetofauna. Arboreal species like the common flap-neck chameleon should inhabit the site.

Except for drinking tanks and the Tweelopiesspruit, the water sources on the reserve should support most water-dependent herpetofauna on the study site. Although some wetlands are artificial, they are functional with several wetland plant species and also wetland fauna. The manmade water bodies are not contaminated and thus attract a full complement of herpetofauna species.

However, given the poor water quality in the Tweelopiesspruit, much of this aquatic habitat is far from natural and the numbers and richness of herpetofauna in the drainage area appear to be much lower than expected (See section 7: Aquatic Biomonitoring).

With the exception of the N14 Road in the north, the R24 in the south and Robert Broom Drive to the south-east, connectivity is fair, especially to the north-eastern side. Although polluted, real opportunities for migration exist along the Tweelopiesspruit and its buffer area. Game fences do not restrict the movement of most herpetofauna.

9.2 Observed and expected herpetofauna species richness

Of the 59 reptile species that may occur on the study site (Table 32), three were confirmed during the site visit and of the possible 15 amphibian species which may occur on the study site, three were confirmed during the site visit.

The 64 herpetofauna species are recorded as potential occupants of the study site. Most of these herpetofauna species are robust generalists with the ability to capitalise on disturbed environments. It should be noted that potential occurrence is interpreted as being possible over a period of time, as a result of expansions and contractions of population densities and ranges, which stimulate migration.

The American red-eared terrapin (*Trachemys scripta elegans*) and the Brahminy blind snake (*Ramphotyphlops braminus*) are the only two feral reptile or amphibian species known to occur in South Africa (De Moor and Bruton 1988, Picker and Griffiths 2011), but with only a few populations, they are not expected to occur on this particular site.

The species assemblage is typical of what can be expected in extensive natural areas with sufficient habitat to sustain populations. Most of the species of the resident diversity are fairly common and widespread (viz. marsh terrapin, common house snake, mole snake, common egg eater, rinkhals, rhombic night adder speckled rock skink, southern rock agama, common platanna, common river frog, Boettger's caco, bubbling kassina, guttural toad and red toad). The relatively high species richness is due to the fair size of the study site and all four different habitat types occurring on the study site.

Table 32: Reptile and Amphibian diversity. The species observed or deduced to occupy the site. Systematic arrangement and nomenclature according to (Bates et al. 2014). Red data status according to (Minter et al. 2004) are indicated: CR= Critically Endangered, En = Endangered, Vu = Vulnerable, NT = Near Threatened, DD = Data Deficient. All other species are deemed of Least Concern

Common English Name	Scientific Name	Conservation status	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
REPTILES	CLASS: REPTILIA				
TORTOISES & TERRAPINS	Order: TESTUDINES				
Side-necked Terrapins	Family: Pelomedusidae				
Marsh Terrapin	*Pelomedusa subrufa*		H	Sighting	Dams in NE
SCALE-BEARING REPTILES	Order: SQUAMATA				
LIZARDS	Suborder: LACERTILIA				
Geckos	Family: Gekkonidae				
Common Dwarf Gecko	*Lygodactylus capensis*		M		
Spotted Dwarf Gecko	*Lygodactylus ocellatus*		L		
Transvaal Gecko	*Pachydactylus affinis*		H		
Cape Gecko	*Pachydactylus capensis*		H		
Old World Lizards or Lacertids	Family:Lacertidae				
Holub's Sandveld Lizard	*Nucras holubi*		M		
Delalande's Sandveld Lizard	*Nucras lalandii*		L		
Ornate Sandveld Lizard	*Nucras ornata*		L		
Spotted Sand Lizard	*Pedioplanis lineoocellata*		M		
	Family: Cordyidae				

Common English Name	Scientific Name	Conservation status	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Coppery Grass Lizard	*Chamaesaura aenea*	NT	M		
Common Girdled Lizard	*Cordylus vittifer*		H		
Common Crag Lizard	*Pseudocordylus melanotus*		L		
Plated Lizards	Family: Gerrhosauridae				
Yellow-throated Plated Lizard	*Gerhosaurus flavigularis*		H		
Skinks	Family: Scincidae				
Thin-tailed Legless Skink	*Acontias gracilicauda*		L		
Wahlberg's Snake-Eyed Skink	*Afroablepharus wahlbergii*		H		
Sundevall's Writhing Skink	*Mochlus sundevallii*		L		
Cape Skink	*Trachylepis capensis*		H		
Speckled Rock Skink	*Trachylepis punctatissima*		H	Sighting	Natural and artificial rupicolous habitat
Variable Skink	*Trachylepis varia*		H		
Monitors	Family: Varanidae				
Southern Rock Monitor	*Varanus albigularis*		L		
Nile Monitor	*Varanus niloticus*		H		
Chameleons	Chamaeleonidae				
Common Flap-Neck Chameleon	*Chamaeleo dilepis*		H		
Agamas	Family: Agamidae				
Eastern Ground Agama	*Agama aculeate distanti*		H		
Southern Rock Agama	*Agama atra*		H	Sighting	Natural rupicolous habitat
SNAKES	Suborder: SERPENTES				
Blind Snakes	Family: Typhlopidae				
Bibron's Blind Snake	*Afrotyphlops bibronii*		M		
Delalande's Beaked Blind Snake	*Rhinotyphlops lalandei*		L		
Thread Snakes	Family: Leptotyphlopidae				
Distant's Thread Snake	*Leptotyphlops distanti*		M		
Peter's Thread Snake	*Leptotyphlops scutifrons*		H		
Pythons	Family: Pythonidae				

Common English Name	Scientific Name	Conservation status	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Southern African Python	*Python natalensis*		L		
Adders	Family: Viperidae				
Puff Adder	*Bitis arietans*		M		
Horned Adder	*Bitis caudalis*		L		
Rhombic Night Adder	*Causus rhombeatus*		H		
	Family: Lamprophiidae				
Black-headed Centipede Eater	*Aparallactus capensis*		M		
Bibron's Stiletto Snake	*Atractaspis bibronii*		L		
Spotted Harlequin Snake	*Homoroselaps lacteus*		M		
Striped Harlequin Snake	*Homoroselaps dorsalis*	NT	L		
Common House Snake	*Boaedon capensis*		H		
Common File Snake	*Gonionotophis capensis*		L		
Aurora Snake	*Lamprophis aurora*		M		
Olive House Snake	*Lamprophis inornatus*		M		
Brown Water Snake	*Lycodonomorphus rufulus*		H		
Cape Wolf Snake	*Lycophidion capense*		H		
Short-Snouted Grass Snake	*Psammophis brevirostris*		H		
Crossed-Marked Grass Snake	*Psammophis crucifer*		H		
Fork-Marked Sand Snake	*Psammophis trinasalis*		L		
Spotted Grass Snake	*Psammophylax rhombeatus*		H		
Striped Grass Snake	*Psammophylax tritaeniatus*		L		
South African Slug-Eater	*Duberria lutrix*		L		
Sundevall's Shovel-Snout	*Prosymna sundevallii*		L		
Mole Snake	*Pseudaspis cana*		H		
Cobras, Mambas and Others	Family: Elapidae				
Sundevall's Garter Snake	*Elapsoidea sunderwallii*		L		
Rinkhals	*Hemachatus haemachatus*		H		
Snouted Cobra	*Naja annulifera*		L		
Mozambique Spitting Cobra	*Naja mossambica*		L		

Common English Name	Scientific Name	Conservation status	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
	Family: Colubridae				
Red-Lipped Snake	*Crotaphopeltis hotamboeia*		H		
Rhombic Egg Eater	*Dasypeltis scabra*		H		
Boomslang	*Dispholidus typus*		L		
Eastern Green Snake	*Philothamnus natalensis*		L		
Spotted Bush Snake	*Philothamnus semivariegatus*		L		
AMPHIBIANS	CLASS: AMPHIBIA				
FROGS	Order: ANURA				
Toads	Family: Bufonidae				
Western Olive Toad	*Amietaophrynus poweri*		L		
Guttural Toad	*Amietaophrynus gutturalis*		H	Vocalisation; sighting (adults and tadpoles)	Near natural and artificial ponds
Raucous Toad	*Amietaophrynus rangeri*		H		
Red Toad	*Schismaderma carens*		H	Sighting (adults and tadpoles)	Near artificial ponds
Reed Frogs	Family: Hyperoliidae				
Bubbling Kassina	*Kassina senegalesis*		H		
Puddle Frog	Family Phrynobatrachidae				
Snoring Puddle Frog	*Phrynobatrachus natalensis*		L		
Grass Frogs	Family Ptychadenidae				
Plain Grass Frog	*Ptychadena anchietae*		L		
Clawed Frogs	Family: Pipidae				
Common Platanna	*Xenopus laevis*		H		
	Family: Pyxicephalidae				
Common River Frog	*Amietia angolensis*		H		
Cape River Frog	*Amietia fuscigula*		M		
Striped Stream Frog	*Strongylopus fasciatus*		L		
Boettger's Caco	*Cocosternum boettgeri*		H	Vocalisation	Aquatic habitat and rainwater pools
Giant Bullfrog	*Pyxicephalus adspersus*	NT	L		

Common English Name	Scientific Name	Conservation status	Probability of occurrence (High, Medium, Low)	Observed on site	Location of observed species
Tremolo Sand Frog	*Tomopterna cryptotis*		H		
Natal Sand Frog	*Tomopterna natalensis*		H		

All six species in Table 32 should be abundant on the study site and elsewhere in their range.

9.3 Red listed herpetofauna identified

The study site falls marginally outside the natural range of the Southern African python (*Python natalensis*), which has been upgraded from Vulnerable to Least Concern. According to Broadley (1990), Southern African pythons favour moist, rocky, well-wooded valleys, plantations or bush country, but seldom if ever stray far from permanent water. The KGR therefore presents suitable habitat and a large enough area for permanent territories. Occasional vagrants may occur.

There is a possibility that the globally threatened striped harlequin snake (*Homoroselaps dorsalis*) occurs in the termitaria of the reserve, although there is no record of it in the relevant quarter degree square. The site also provides ideal habitat for the Near Threatened coppery grass lizard (*Chamaesaura aenea*), which has been recorded in the quarter degree square.

Despite the availability of potential breeding sites, there is no record of the giant bullfrog (*Pyxicephalus adspersus*) (recently upgraded from Near Threatened to Least Concern) on the reserve for at least 17 years (Stephan du Toit, Mogale Municipality, pers. Comm.). There are, however, populations of giant bullfrogs in the grasslands north of the N14, near the reserve (personal observation). Giant bullfrogs prefer shallow, temporary waterbodies for breeding and there may be an opportunity to reintroduce the species to the reserve using the old artificial pond known as Dry Dam (Stephan du Toit, pers. Comm.). The sandy soil of the reserve is ideal for burrowing in some parts where it is not too shallow (Map 7) for both daily activities and aestivation.

Part 3: Conclusions and Recommendations

10 VELD MANAGEMENT PLAN

ALAN SHORT

10.1Introduction

The National Environmental Management: Protected Areas Act (Act 57 of 2003) has, as its preamble, the aim

> *To provide for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes…*

It is therefore crucial that a veld management plan be adopted which maintains the ecological processes and biodiversity of a healthy, functioning ecosystems.

Numerous studies have demonstrated that, all other factors being equal, stocking rate is one of the most important variables influencing veld condition (O'Reagain and Turner 1992, Briske et al. 2008, O'Connor 2015). In a small game reserve like Krugersdorp Game Reserve, manipulation of grazing patterns is limited to fire, placement of water points and placement of licks.

Stocking rate, animal type and fire also have significant effects on plant diversity and composition (Uys et al. 2004, Martindale 2007, O'Connor et al. 2010, 2011). Higher stocking pressures often decrease plant species richness, and can shift species composition to more grazing-tolerant species (Scott-Shaw and Morris 2014). Selective grazers (sheep) can significantly reduce species richness. Grasslands are resilient to varying fire regimes, unless fire is completely excluded (Short et al. 2003, Fynn et al. 2004, Uys et al. 2004).

10.2Recommended stocking rates

Stocking rates for conservation areas should be lower than those for wildlife areas, for three reasons

1. The effect of stocking rate on species diversity;
2. The differing home range requirements of certain species;
3. The difficulty of manipulating stock movement around the landscape.

Krugersdorp Game Reserve is too small to be considered a self-sustaining ecosystem. For example, free-ranging large predators cannot be included in the system. Therefore, game numbers will have to be manipulated by introductions and removals.

Camp and McCulloch (2008) recommend stocking grasslands in KZN at 70% of the recommended stocking rate for biodiversity conservation. However, the evolutionary history of grazing in Highveld grasslands is important (Milchunas and Lauenroth 1993, Fuhlendorf and Engle 2001, O'Connor 2005).

At 70% of the agricultural stocking rates, the recommended stocking rate for the KGR is **216 AU** (Table 33) for grazers.

Table 33: Maximum grazing capacity of Krugersdorp Game Reserve. Note that the carrying capacity is calculated by the average carrying capacity of each polygon, weighted by area. Average carrying capacities in ha/AU are

arithmetical means and are presented as guidelines. The landscapes and areas are as in Map 6. The discrepency in the total area is due to rounding errors

Landscape	Area (ha)	Agricultural grazing capacity (AU)	Conservation grazing capacity (AU)
Dam	2.9	0	0
Structure	771.7	172	120
Gentle grasslands	74.5	50	35
Kikuyu	301.6	60	42
Steep grasslands	13.5	0	0
Watercourse	27.9	3	2
Wooded	135.2	34	24
Working for Water	21.1	2	1
Less Lion Enclosure	***-64.1***	***-13***	***-9***
Total	**1284.3**	**308**	**216**

10.3Stocking density and herbivore composition

10.3.1 Current density and composition

The proportion of grazers to mixed feeders to browsers, and bulk grazers to selective grazers, is important to balance the grazing pressure of the herbivores on the reserve.

Table 34: The stocking density of the Krugersdorp Game Reserve in April 2015. Note that lions and Emus have been excluded from the calculations. Grazing AU refers to the proportion of metabolic stocking density allocated to grazing (including part of mixed feeders). Masses, AU equivalents and proportion grass from Bothma (1996), except ostrich

Category	Species	Mass (kg)	AU	Proportion grass	Count 2015	Grazing AU	Browsing AU	Total AU	Proportion of total AU
Bulk grazer	Waterbuck	180	0.50	1.0	36	18	0	18	
	Zebra	260	0.66	1.0	28	18	0	18	
	Hippo*	1 340	5.00	1.0	2	10	0	10	
	Ostrich**	115	0.25	1.0	8	2	0	2	
Bulk Total					**74**	**48**	**0**	**48**	**0.09**
Selective grazer	Black Wildebeest	160	0.46	1.0	296	136	0	136	
	Blesbuck	61	0.22	1.0	553	122	0	122	
	Warthog**	70	0.25	1.0	8	2	0	2	
Selective Total					**857**	**260**	**0**	**260**	**0.49**
Mixed feeder	Eland	500	1.08	0.4	48	21	31	52	
	Gemsbok	210	0.56	0.9	12	6	1	7	
	Impala	50	0.19	0.5	143	12	15	27	
	Red hartebeest	120	0.37	0.6	284	63	42	105	
	Springbok	37	0.15	0.5	106	8	8	16	
Mixed Total					**593**	**110**	**97**	**207**	**0.39**
Browser	Giraffe	830	1.58	0.0	5	0	8	8	
	Kudu	200	0.54	0.2	12	1	5	6	
Browser Total				**1.0**	**17**	**1**	**13**	**14**	**0.03**
Grand Total					**1 541**	**419**	**110**	**529**	**1.00**

* Hippopotamus are given a metabolic mass of 2.24 by GDARD. However, Chansa et al. (2011) report daily intake as 50kg, which is equivalent in daily intake to 5 AU (Meissner et al. 1983)
**From the June 2014 count.

Table 34 gives the estimated stocking density in AU of animals in the reserve in 2015. The total **grazing density** is 419 AU, which is 193% above the recommended grazing capacity of 216 AU (Table 33).

Note that the estimated animal units and grazing capacity differ from the results in du Toit (2015). The discrepancy is likely due to the assumptions and models included in the GDARD spreadsheet used by du Toit (2015), which, for example, excludes extra-limital species from calculations. For this reason, all figures contained in this report were calculated according to the published models cited here.

10.3.2 Proposed density and composition

A proposed adjustment of the animal numbers in KGR was prepared for Mogale Municipality (du Toit 2015) (Table 35). The resulting grazing pressure would be below the estimated grazing capacity of the reserve (Table 33). The resulting grazing pressure would be **115 AU**, or 53% of the recommended grazing density. This course of action is strongly recommended as it would:

- Relieve the excessive grazing pressure on the veld for several seasons until animal numbers recover to recommended levels. This would give management an opportunity to revisit the veld management strategy, alien plant strategy and winter feeding strategies
- Cut down dramatically on winter feeding costs
- Allow introduction of new stock to prevent inbreeding.

Table 35: Proposed adjustment of animal numbers (du Toit 2015)

Category	Species	Mass (kg)	AU	Proportion grass	Proposed number	Proposed Grazing AU	Proposed Browsing AU	Proposed Total AU	Proportion of Total AU
Bulk grazer	Waterbuck	180	0.50	1.0	14	7	0	7	
	Zebra	260	0.66	1.0	28	18	0	18	
	Hippo*	1 340	5.00	1.0	2	10	0	10	
	Ostrich**	115	0.25	1.0	8	2	0	2	
Bulk Total					**52**	**37**	**0**	**37**	**0.25**
Selective grazer	Black Wildebeest	160	0.46	1.0	50	23	0	23	
	Blesbuck	61	0.22	1.0	120	26	0	26	
	Warthog**	70	0.25	1.0	8	2	0	2	
Selective Total					**178**	**51**	**0**	**51**	**0.35**
Mixed feeder	Eland	500	1.08	0.4	8	3	5	9	
	Gemsbok	210	0.56	0.9	12	6	1	7	
	Impala	50	0.19	0.5	40	3	4	8	
	Red hartebeest	120	0.37	0.6	40	9	6	15	
	Springbok	37	0.15	0.5	40	3	3	6	
Mixed Total					**140**	**24**	**19**	**44**	**0.30**
Browser	Giraffe	830	1.58	0.0	5	0	8	8	
	Kudu	200	0.54	0.2	12	1	5	6	
Browser Total					**17**	**1**	**13**	**14**	**0.10**
Grand Total					**387**	**115**	**32**	**147**	**1.00**

* Hippopotamus are given a metabolic mass of 2.24 by GDARD. However, Chansa et al. (2011) report daily intake as 50kg, which is equivalent in daily intake to 5 AU.

10.3.3 Browsers to mixed feeders to grazers

GDARD recommends a ratio of 2:2:1 for grazers:browsers:mixed feeders (measured in terms of AU) (Patrick Duigan, GDARD, pers. Comm). However, this broad recommendation does not take into account the actual amount of browse available. Browse capacity was not directly calculated during the survey.

The **current** grazer:mixed feeder:browser ratio in 2015 was 6:4:0.1.

The **proposed** grazer:mixed feeder:browser ratio is 6:3:1. Although this differs from the recommended GDARD figures, there is a great deal more grazing than browsing available in the reserve.

10.3.4 Bulk grazers to selective grazers

Selective grazers are smaller animals that are highly selective about the plants, and parts of plants that they eat. A high proportion of selective grazers can have a detrimental effect on the veld by concentrating on palatable plants, which can heavily impact those plants and allow non-palatable plants to increase. Bulk grazers graze more plants with less precision, allowing palatable plants to compete with non-palatable plants.

The **current** bulk:selective grazer ratio is 1:9.

The **proposed** bulk:selective grazer ratio is 1:2.5.

Currently the proportion of bulk grazers to selective grazers in the reserve (which includes mixed feeders, corrected for the proportion of grass in their diets) is 1:9. That is, there is nine times more selective grazing pressure than bulk grazing pressure in the reserve.

The proposed bulk to selective grazer ratio is nearly 1:3. While this is an improvement on the current situation, more bulk grazers should be introduced, or selective grazers removed. The proportion of bulk grazers should be substantially increased and the proportion of selective grazers decreased to 1:1 at the most, or preferably more bulk grazers than selective grazers (Malherbe 1971, Hardy 1995, Lütge et al. 1996, Short 2010).

Bulk grazers include those listed in the table above, but consideration should be given to cattle, which have been used in conservation areas in KZN to provide bulk grazing for biodiversity areas (Short and Rushworth 2004). Nguni cattle are beautiful animals, have a strong heritage and educational value, and have reasonably high commercial value. Possible diseases would need to be considered. Buffalo may be too dangerous to introduce into the Krugersdorp Game Reserve.

10.4 Fire management

A holistic fire management plan is required which takes into account the ecological, legal and safety aspects of fire management for the KGR.

The Conservation of Agricultural Resources Act (Act 43 of 1983) deals with the conservation aspect of burning, while the safety aspect falls under the National Veld and Forest Fire Act (Act 101 of 1998).

10.4.1 Season and frequency of burning

Ecologically, burning can be done any time during the dormant season, which will maintain the ecological integrity of the grassland system (the effect of fire on woody plants will be discussed below) (Everson and Tainton 1984, Fynn et al. 2005, Manson et al. 2007).

Burning during the dormant season encourages a green flush of growth which will concentrate animals on the burnt areas (Archibald and Bond 2003, O'Connor et al. 2004, Vermeire et al. 2004). This can be a powerful tool for shifting grazing pressure around the reserve (discussed below under distribution of burning).

Frequency of burning (usually described as the average interval in years between burns) is equally important to grassland dynamics. Most of the research on fire in grasslands has occurred in the mesic grasslands of KwaZulu-Natal (Morris and Tainton 1991), or more arid grasslands of the central highveld (e.g. Snyman 2003). The grasslands of Gauteng have been less well researched.

Frequency of burning has little effect on grassland composition and structure, until long intervals of 5-10 years or more are reached (Short et al. 2003, Fynn et al. 2004, Uys et al. 2004). Fire exclusion has dramatic effects on vegetation composition and structure everywhere in the higher rainfall areas of the country (Short et al. 2003, Fynn et al. 2004, Trollope et al. 2014) with the grassland species being completely replaced by shrubs and woody species, and existing grass species almost completely replaced by a different suite of grass species.

Fire and grazing cannot be separated, as the grazing animals influence the amount of grass (the fuel load) and fire influences grazing distribution. In general, however, a burning frequency of 2-5 years for any one location on Krugersdorp Game Reserve is recommended.

10.4.2 Patch burning and heterogeneity

Patch burning (Figure 15) is increasingly being used in conservation areas to encourage heterogeneity in vegetation structure and time-since-last-burn (Fuhlendorf and Engle 2004, Collins and Smith 2006, Parr and Andersen 2006).

For an area the size of KGR, adequate firebreaks around burning blocks are crucial. Patch burning occurs when a fire is ignited at a point and allowed to spread outwards, according to the shifting wind and landscape conditions. This results in a patchy, uneven burn, creating a mosaic of burnt and unburnt patches of varying size and age (Figure 15). The mosaic of patches benefits small animals and birds and can encourage heterogeneity and species diversity (Fuhlendorf et al. 2006).

10.4.3 Hot versus cool burns

The environmental conditions and the fuel load of the grass have a direct influence on the amount of energy released by the fire, which directly influences safety and the ecological impact of burning.

Four factors have the most influence on the energy of the burn (Trollope and Trollope 2007):

- fuel load (the kg/ha of combustible material, especially grass);
- Fuel moisture (the percentage moisture of the grass fuel, which will be lower in the winter);
- Relative humidity
- Wind speed.

Higher fuel loads, lower fuel moisture, lower relative humidity and higher wind speeds create conditions of much greater fire intensity.

The higher the fire intensity, the more dangerous the fire. However, higher-intensity fires are also useful for controlling woody plant encroachment. The combination of fire and browsing can control the recruitment of small woody plants (Trollope and Dondofema 2003).

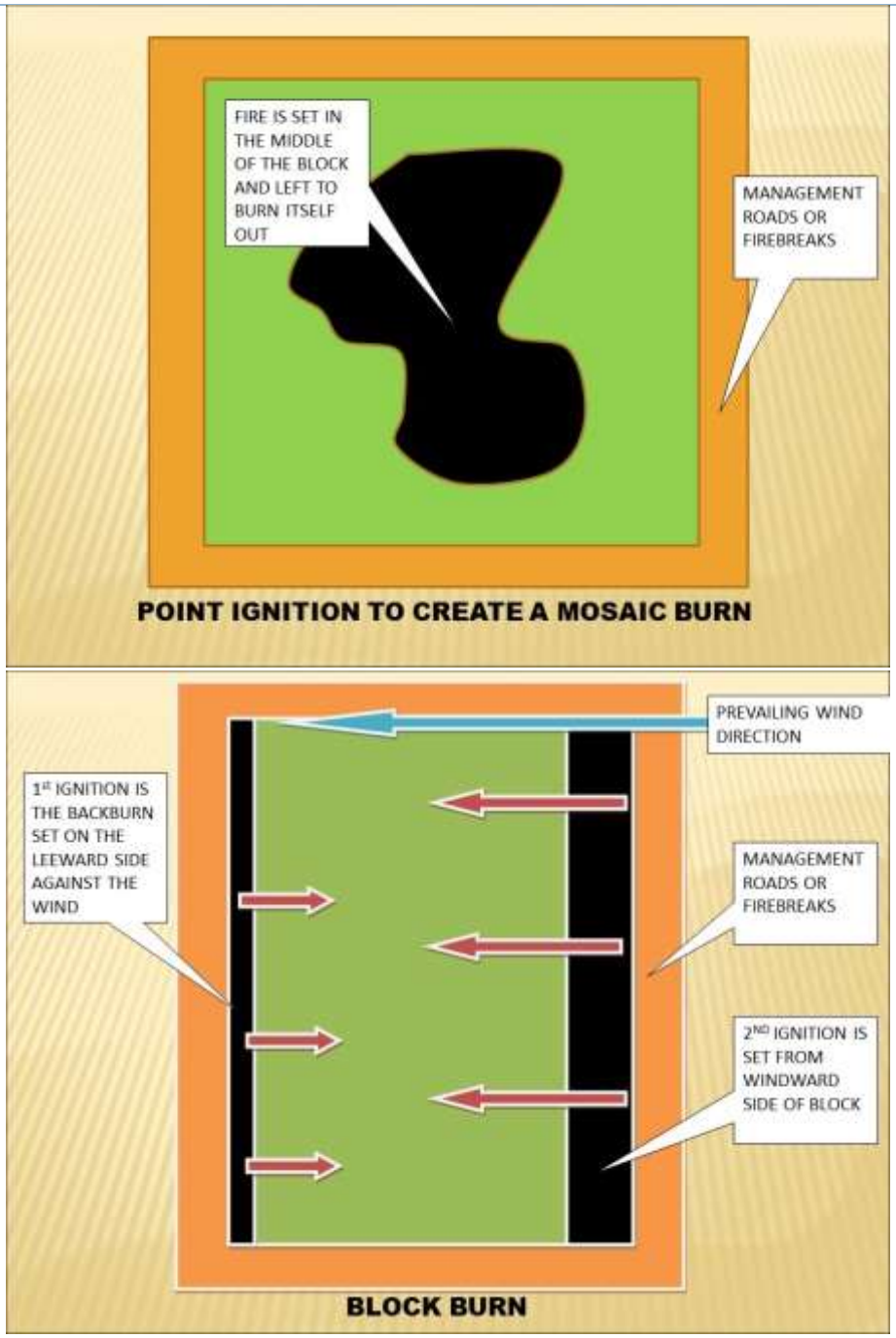


Figure 15: Top: A point burn creates a mosaic of burnt and unburnt patches within a block. Bottom: a traditional block burn is easier to control and quicker, and creates a clean burn (source: Panagos 2014)

10.5 Recommended fire and grazing management plan

10.5.1 Burning blocks

Based on the principles above, the following veld and fire management plan is proposed:

- Divide the reserve into five burning blocks (Map 14). These blocks may be combined, or further subdivided, as needs require in any given year
- Establish firebreaks around each block and around tourist and management infrastructure
- Choose one block each year. Ignite the block from one or more points in the block, allowing the fire to spread naturally in all directions until it reaches the firebreaks (patch burning). Ensure that all fire safety precautions regarding the weather conditions are followed before igniting the fire.

10.5.2 Determining when to burn

The reserve can either burn each block on a **fixed rotation** (one block each year). However, it is better to follow **ecological principles** for determining when to burn.

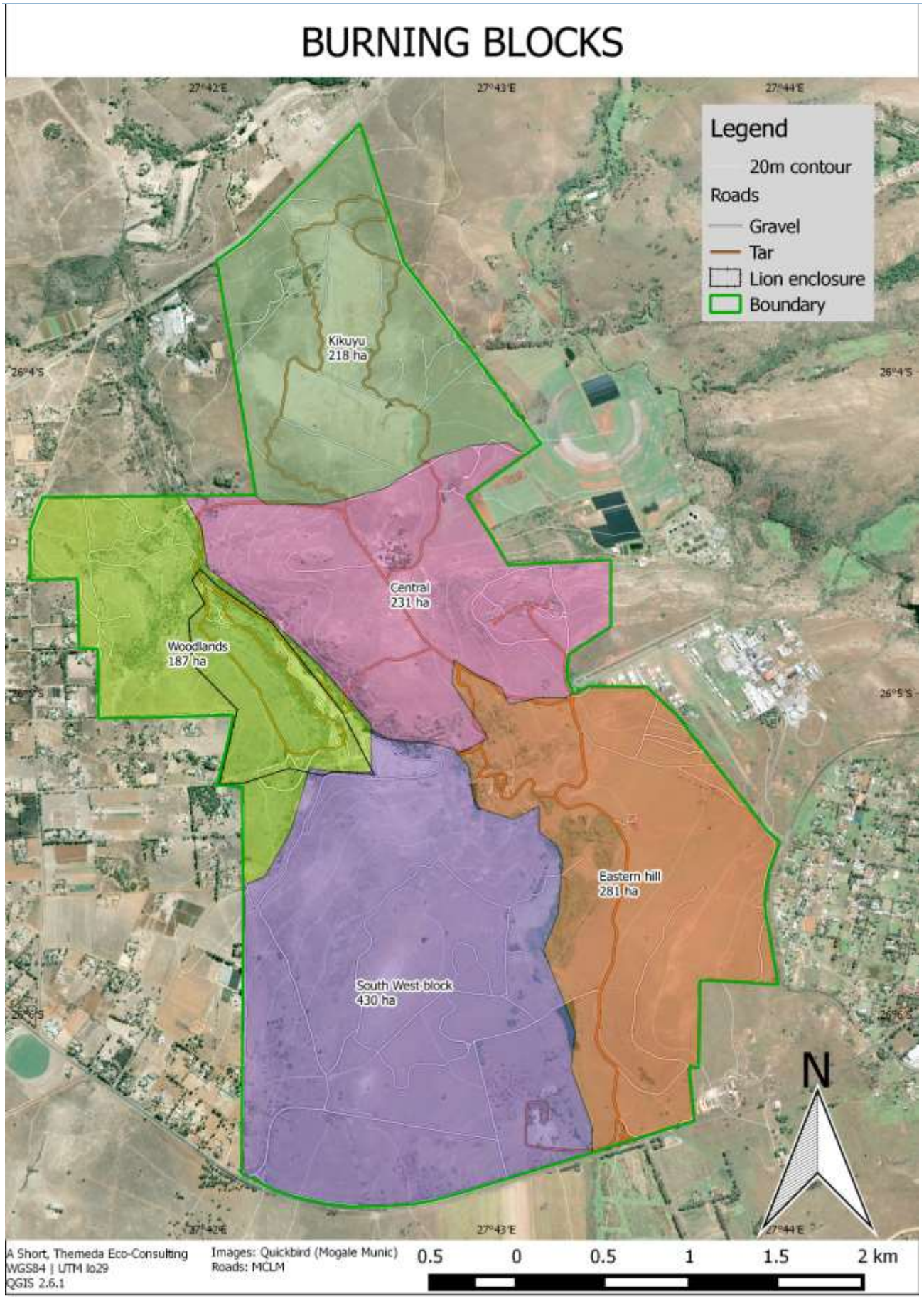
- Examine each block at the end of each summer.
- Determine the proportions of the different ecological categories of grasses (Table 3).
- Estimate the fuel load. This can be done using a standard disc pasture meter (Table 36).

Together the fuel load and the veld condition are used to determine whether or not to burn a block.

- A cool fire (< 4000 kg/ha, air temp < 20°C and relative humidity > 50%) is recommended to remove moribund grass and encourage grazing on a particular block
- A hot burn (> 4000 kg/ha, air temp > 25°C and relative humidity < 30%) is recommended to control bush thickening (Trollope and Trollope 2007)

Table 36: Conversion from disc height of a standard disc meter to fuel load for a short, dense grassland at the end of summer (Kreuter 1985)

Disc height (cm)	Fuel load (kg/ha)	Disc height (cm)	Fuel load (kg/ha)
1		**11**	2298
2		**12**	2575
3	85	**13**	2852
4	362	**14**	3129
5	638	**15**	3405
6	915	**16**	3682
7	1192	**17**	3959
8	1468	**18**	4235
9	1745	**19**	4512
10	2022	**20**	4789



Map 14: Proposed burning blocks of Krugersdorp Game Reserve.

11 ALIEN PLANT CONTROL

11.1Introduction to the legislation and current infestation

Declared weeds and invader plant species can have detrimental impacts on natural vegetation. These species can outcompete indigenous species, thereby transforming the structure, composition and function of natural ecosystems. Furthermore, legislation is in place that place the onus on the land owner to eradicate and control certain invasive species.

The National Environmental Management: Biodiversity Act (NEMBA) is the most recent legislation pertaining to alien invasive plant species. In August 2014 the list of Alien Invasive Species was published in terms of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (Government Gazette No 78 of 2014). The Alien and Invasive Species Regulations was published in the Government Gazette No. 37886, 1 August 2014. The legislation calls for the removal and/or control of alien invasive plant species (Category 1 species). In addition, unless authorised thereto in terms of the National Water Act, 1998 (Act No. 36 of 1998), no land user shall allow Category 2 plants to occur within 30 meters of the 1:50 year flood line of a river, stream, spring, natural channel in which water flows regularly or intermittently, lake, dam or wetland. Category 3 plants are also prohibited from occurring within close proximity to a watercourse.

Below is a brief explanation of the three categories in terms of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA):

Category 1a: Invasive species requiring compulsory control. Remove and destroy. Any specimens of Category 1a listed species need, by law, to be eradicated from the environment. No permits will be issued.

Category 1b: Invasive species requiring compulsory control as part of an invasive species control programme. Remove and destroy. These plants are deemed to have such a high invasive potential that infestations can qualify to be placed under a government sponsored invasive species management programme. No permits will be issued.

Category 2: Invasive species regulated by area. A demarcation permit is required to import, possess, grow, breed, move, sell, buy or accept as a gift any plants listed as Category 2 plants. No permits will be issued for Category 2 plants to exist in riparian zones.

Category 3: Invasive species regulated by activity. An individual plant permit is required to undertake any of the following restricted activities (import, possess, grow, breed, move, sell, buy or accept as a gift) involving a Category 3 species. No permits will be issued for Category 3 plants to exist in riparian zones.

Therefore, it is important that these plants are controlled and eradicated by means of an eradication and monitoring programme.

The alien plant species identified on the study site are listed in Table 37 below. Four category 1b species were recorded within the KNR at the time of the field survey. Note that according to the regulations, a person who has under his or her control a category 1b listed invasive species must immediately:

1. Notify the competent authority in writing
2. Take steps to manage the listed invasive species in compliance with
    - section 75 of the Act;
    - the relevant invasive species management programme developed in terms of regulation 4; and
    - any directive issued in terms of section 73(3) of the Act.

Table 37: Alien species recorded during the baseline survey

Species	Common name	Category /notes
Acacia mearnsii	Black Wattle	Category 2 invader (NEMBA)
Bidens pilosa	Blackjack	Widespread, naturalised weed.
Pennisetum clandestinum	Kikuyu Grass	Category 1b in wetlands and protected areas
Physalis viscosa	Sticky Gooseberry	Weed of disturbed grassland and waste places. Origin: North America
Populus x canescens *	Grey Poplar	Category 2 invader of moist areas
Robinia pseudoacacia	Black Locust Tree	Category 1b invader commonly planted as an ornamental
Shinus molle	Pepper Tree	Not listed. This tree was historically planted
Solanum elaegnifolium	Silverleaf Bitter Apple	Widespread in ploughed and disturbed areas
Solanum pseudocapsicum	Jerusalem Cherry	Weed originally from Europe and Asia and now naturalised in RSA
Solanum sisymbrifolium	Wild Tomato	Category 1b that proliferates in disturbed places
Tagetes minuta	Khaki Weed	Weed in disturbed places. Has become naturalised and due to the vast amount of seed set, difficult to control
Verbena brasiliensis	Brazilian verbena	Category 1b invader of disturbed and moist places

11.2 Creating an alien invasive plant management plan

KGR needs to control and eradicate alien invasive plant species in order to protect the diversity of species and the vegetation structure within the KNR, but also has a legal obligation to eradicate declared invasive species.

The alien invasive plant management plan should address the following.

11.2.1 Control phases

From the onset, it is important to note that combating alien infestation is a dynamic process and needs to be reviewed periodically. An alien control program should ideally include three phases as listed in

Table 38. Each stage is equally important in removing and controlling the spread of alien plants. The aim of control is to reach a point where, ideally, the plants concerned no longer occur in that particular area or, at least, where the plants can no longer grow, produce viable seeds or spores, coppice, sprout or produce root suckers, reproduce vegetatively, propagate themselves in any other way, or spread into other areas. If this is not possible, the plants have to be contained and their multiplication limited as far as possible.

Table 38: Phases of alien plant control

Phase	Actions
Initial Control	Drastic reduction of the existing populations
Follow-up Control	Control of seedlings, root suckers and coppice re-growth
Maintenance Control	Sustain low (or no) alien plant numbers/density with low annual control costs. At this phase, alien plants are no longer considered a problem. However, regular monitoring to ensure that no new infestation take place is essential.

The initial control in most cases, involves mechanical methods and in the case of heavy infestations, machinery. The initial control aims to drastically reduce the number of adult and often large individuals of invasive plants.

After initial clearance, tree stumps can readily coppice and in the absence of follow-up treatments, the infestation will proliferate and negate the initial control efforts. In addition, some invasive plant species produce large number of seeds that can lie dormant in the soil for a number of years. Soil disturbance and the removal of large trees that shaded the soil, often result in the bulk germination of weedy plant species, which can easily be removed or sprayed when young. Follow-up control of alien seedlings and coppice re-growth is thus essential to achieve and sustain the progress made with initial control work.

Once the invasion is maintained, regular monitoring followed by maintenance control where needed, should prevent the re-colonisation of alien plants species or the infestation by newly introduced alien species. In the absence of regular monitoring, new infestations might not be noticed until the infestation becomes severe. Subsequently, initial control will have to be implemented again which is both costly and detrimental to rehabilitation efforts.

11.2.2 Control and eradication methods

Three commonly used methods for alien plant removal are mechanical, chemical and biological control. An effective approach often entails a combination of these methodologies.

1. **Mechanical control:** This involves tree felling and a 'hands on' removal approach often paired with the use of fire or application of herbicides on the cut stump. Mechanical and chemical methods are seen to have short-medium term effectiveness and follow-up removals are needed periodically to prevent the re-colonization of alien invasive plants.
2. **Chemical control:** This entails the use of environmentally safe herbicides, while adhering to all relevant health and safety regulations pertaining to the use of hazardous chemicals. When controlling weeds and invaders, damage to the natural vegetation and watercourses must be avoided. Mechanical and chemical methods are often combined.
3. **Biological control:** This method involves introducing species-specific insects and diseases that would control the alien plant in its country of origin. Biological control involves the use of host-specific natural enemies of weeds or invaders from the plant's country of origin, to either kill or remove the invasive potential of these plants. It may only be initiated by and carried out under the supervision of an academic or research institute or organisation established by legislation, which practices and researches biological control of weeds and invader plants (e.g. Agricultural Research Council).

11.2.3 Mapping and prioritisation:

In order to eradicate the most invasive species which should be removed according to law, and to safeguard biodiversity, the Alien Invasive Plant Management Plan should be based on priorities for removal.

The alien invasive species listed in this document were recorded within sample areas for the baseline vegetation assessment. Therefore, it is recommended that an alien vegetation plant survey and mapping be undertaken, which will focus the eradication on priority areas/species. *As an example,*

priorities are explained below, but should be refined based on the species and level of infestation identified during the alien survey and mapping.

Priority 1: Remove Category 1 weeds, as well as Category 2 weeds were they occur within wetland and riparian areas. Note that in some areas, especially along river, removal of large trees could destabilise soils and it is recommended that infestations be cleared over a number of years, instead of clear felling.

Priority 2: Remove Category 2 species from all areas where they occur as well as lesser aggressive weeds from largely natural vegetation and natural open space

Priority 3: Remove minor, yet harmful weeds from all areas. These are annual or biennial plants which are predominantly weeds of waste places (ruderals) and cultivated lands (agrestals). They are only able to invade and persist in severely and recently disturbed areas and rarely invade or persist in established vegetation.

The priorities should also align with the current working for water programme.

11.3 Rehabilitation and monitoring

Once the initial removal efforts are complete, the following measures ought to be applied:

11.3.1 Replanting

As the removal of alien plants leaves the ground bare, it is usually necessary to re-vegetate these bare areas immediately. This is particularly important where large areas are cleared. Re-vegetation ought to be with indigenous plants that previously occurs on site, and are well adapted to the local conditions. For the grass layer, grass seeds from the surrounding indigenous vegetation, may be used in the re-planting efforts. However, in the herb layer, young and established indigenous trees and shrubs should be planted instead of seed. This is due to the longer germination and growth times of herbaceous plants from seed.

11.3.2 Monitoring

Follow-up control and on-going monitoring is necessary to ensure that the indigenous plants are establishing themselves, and that alien plants are not returning to the site. This is necessary because the seeds of alien plants may remain dormant in the soil for years to come. The stringent removal methods outlined previously should be undertaken with each removal effort to ensure an alien plant is effectively removed.

12 CONCLUSIONS

12.1 Vision and mission

The Krugersdorp Nature Reserve will need a clear vision and mission in order to define policies and future management strategies.

While a vision and mission statement was beyond the scope of this study, some general principles can be suggested.

The National Environmental Management: Protected Areas Act (57 of 2003) opens with the statement:

> *To provide for the protection and conservation of ecologically viable areas representative of South Africa's biodiversity and its natural landscapes and seascapes…*

12.1.1 Biodiversity objectives

The KGR is an important reservoir of biodiversity in a biome that is increasingly threatened by transformation. The main purpose of the reserve should be to maintain the ecological integrity of the grassland ecosystem and associated habitats, to protect and improve biodiversity, and to provide connectivity with surrounding untransformed grasslands to the Cradle of Humankind.

Grasslands provide a range of ecosystem services and these services need to be factored into the total value of the KGR.

Mogale Municipality and Gauteng Province are obligated to meet a range of national and international environmental standards and KGR is a key strategic addition to these obligations.

12.1.2 Social objectives

The KGR is an affordable, accessible and beautiful open space for the residents of Krugersdorp and Gauteng. It should be maintained as a public space for people to relax and enjoy themselves while learning to appreciate nature. Beauty and sense of space have significant but difficult to quantify benefits to the residents of cities (City of Tshwane Metropolitan Municipality 2005).

12.1.3 Financial objectives

In an economy strapped for resources, the KGR will need to be financially viable. This will require careful balancing of biological, social and financial objectives and sustainable funding models.

Currently, the KGR is best known as an accessible, low-impact game-viewing destination close to an urban metropolis. It offers opportunities to watch about 30 species of mammals and 200 species of birds, including some of the Big Five large mammals and especially the Sunday morning lion feeding. The animals are relaxed for viewing and photography, thanks to the varied routes for normal and 4x4 vehicles, horse backing, ballooning, mountain biking, day/night safari drives and social functions, from either the lodge, kiosk or camping areas. A walk-in aviary is currently closed (since about 2002 when at least 10 indigenous species were released), but options might be considered for reopening and/or creating more photographic hides and opportunities for the densest urban population of birders in the country. A vulture restaurant, to help support this endangered group, might also be considered, especially for the Cape Vulture living so close to the urban edge. Above all, extending all these ventures to take full advantage of the river and wetlands must be the first challenge for any future and innovative conservation and management plans.

12.1.4 Recommendations

1. Define limits of tourism activities, sensitive areas, and excluded activities. Studies have been done in numerous places on the acceptable limits of visitors and impacts. These studies (e.g. Kruger National Park) can be used to guide Mogale Municipality
2. Map zones of high, medium and low impact
3. 4x4 trails are frequented by large numbers of enthusiasts. Significant damage and soil erosion is being caused.
4. Risk assessment will be required to balance various competing options.
5. Day visitors with little sense of conservation are a challenge to the reserve. A strategy will be needed to change visitor behaviour to be more conservation-friendly

12.2 Soils and geology

12.2.1 Soils

Soil erodibility is a priority. Several severe and active erosion gullies are present on the banks of the Tweelopiesspruit. The low organic matter and clay content of the soils makes them highly dispersive and increases the risk of erosion. Any activities that disturb the soil surface (including alien plant control) must have erosion control as a priority remediation activity.

Roads and runoffs need to be properly engineered to prevent further erosion. Already 4x4 tracks are showing severe degradation.

12.2.2 Geology

The main geological issues relate to the movement of AMD contaminated decant through the dolomite compartments. The formation of sinkholes is a real possibility.

It has been suggested that the hippo dam wall may be subsiding, possibly as a result of sinkhole formation. The dam will is situated on the boundary of Black Reef and dolomite formations where several springs emerge.

Gravity and geophysical studies are urgently required to investigate the structure of the dolomite formations.

12.3 Water quality

Acid Mine Drainage is the single biggest factor affecting the ecosystem of the Krugersdorp Game Reserve and surrounds. The biological and geophysical effects of AMD include:

- Drastically reducing the ecological integrity of the aquatic systems and removing much aquatic biota from the food chain.
- Potential health effects on animals which need to be investigated
- Potentially serious development of dangerous sinkholes in the dolomite compartments underneath KGR and surrounds (including the adjacent N14 highway)
- Movement of contaminants through the subsoil
- Contamination of aquifers near the mine voids

The pollution of the river is the result of activities upstream and the reserve management can do very little to ameliorate it without assistance from various stakeholders.

The effects of AMD on the water quality, the hydrology, and the soil were discussed in the report, and have been extensively researched elsewhere (e.g. Hobbs and Cobbing 2007, McCarthy et al. 2010). Improving the water quality will require substantial interventions from several parties. However, some potential mitigation measures were proposed for the reserve itself, which should be investigated; specifically, using wetlands to ameliorate the effects of AMD through bioremediation (Section 4.7: Wetland recommendations).

The poor quality of the water was revealed in the SASS5 scores, and in the fact that no fish were found in either the dry or wet season surveys, using standard and thorough survey methods.

12.3.1 Recommendations

The potential health effects of the AMD on animals and humans needs to be urgently investigated. There is also concern about the movement of pollutants through the soil from the Tweelopiesspruit, and concerns about the health effects of the water on animals and humans.

Wetlands, water courses and aquifer need to be managed to protect from other sources of pollution and degradation, in particular sedimentation from construction or roads, erosion, and waste disposal from tourist activities. Recommendations for maintenance of wetlands are provided in sections 6 and 7.

Monitoring of the AMD in the Tweelopiesspruit, as well as the water quality of adjacent aquifers, is critical to the welfare of humans and animals who use the water.

Bioremediation measures should be investigated for reducing the pollutant levels in the water.

12.4Biodiversity and heterogeneity

The reserve is sizeable at 1 346 ha, which is conducive to species richness and viable populations, at least for smaller species. Connectivity to the west and east is good for smaller terrestrial animals, although the game fence around the entire reserve is effective in preventing the migration of larger mammals, particularly antelope. Connectivity for aerial species, bats, birds and arthropods, is not affected by fences.

While the KGR is too small to support viable populations of larger vertebrate species, any effort to optimise management of the natural habitats will protect many smaller species, and offer an attractive patch of habitat in a mosaic of corridors for recolonisation and/or visitation by aerially mobile species.

The quality of water in the Tweelopiesspruit significantly reduces aquatic diversity by almost eliminating the aquatic food chain. A range of impacts on animal health are also possibly due to the poor water quality.

The dearth of predators, including snakes and raptors, is of concern and may be related to the management of the grasslands which provide habitat for small prey animals.

Several structures and sinkholes exist which could support some species of cave-roosting bats. However, the poor quality of the Tweelopiesspruit reduces the insect population required to support these populations. Management of the sinkholes is also of concern, as some sinkholes may have been used for rubbish disposal.

12.4.1 Recommendations

Develop a zoning plan which moves high-impact activities away from sensitive areas, particularly wetlands.

Correct the stocking density and composition of large herbivores, and implement a managed fire regime to restore the functioning of the grassland and wetland systems.

Develop remediation measures for the Tweelopiesspruit to rebuild the aquatic ecosystem.

Manage bush encroachment and alien plant encroachment (see below).

Encourage citizen science initiatives to collect data on endangered species from visitors.

Some focused attention on bat conservation is required, including a bat survey.

12.5 Alien species control

To maximize the health of vertebrate populations, it would be wise to continue eradicating aliens, in particular wattles and other invasive species. Non-invasive larger trees might remain to provide some shade, shelter, perches, roosts, food and breeding sites, even once they die.

The kikuyu plains increase grazing pressure on the reserve by providing a substantial forage supply, especially in winter. The effect of the increased grazing pressure can be especially seen on the fringes of the kikuyu plains and around licks and water points (the so-called "piosphere" effect), where significantly increased grazing pressure has reduced veld condition and plant diversity and encouraged the encroachment of exotics such as *Richardia brasiliensis* and kikuyu itself. The kikuyu can be seen spreading out from the original planted areas and invading drainage lines.

12.5.1 Recommendations

Maintain existing alien plant control programmes and develop new programmes for species like Kikuyu, including follow up control and rehabilitation.

Monitor for the encroachment of new species (e.g. pom-pom weed).

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14 APPENDIX 1: VEGETATION SURVEY RESULTS

14.1Species composition

Cover abundance refers to the percentage cover of each species within a 10x10m plot

Nested plot refers to the percentage cover of additional species within a 50x50m plot, for those plots where a nested plot was required

Presence/absence refers to the presence of species noted at a site (no specific area). A 1 indicates presence. Not all species were noted in presence/absence surveys

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite woodland	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
Cover abundance																												
		Bare Ground	5	20	50	1	1	20	5		10	1	2		1	0		0		0.1	2	20		20	5	50		0
		Litter	4	5	10	20	5	10	30		20		1		2	0		5	25	1	20	10		10	1	20		10
		Unknown		1.01	0.01	2		0.01			0.01									5	0.1				1			0.01
	Acanthacea	Chaetacanthus setiger							0.1												1							
	Amaryllidaceae	Crinum graminicola			0.1																							
	Anacardiaceae	Seersia lancea					1																0.1					
		Seersia pyroides				1	10															3	10		3	3		
	Anthericacecae	Anthericum cooperi					0.01																					
	Apocynaceae	Brachystelma sp.						0.01																				
		Gomphocarpus fruticosus																							0.1			
	Araliaceae	Cussonia paniculata																					3		4			
	Asparagaceae	Asparagus cooperi					0.1															1		0.01				
		Asparagus laricinus																										2

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
	Asteraceae	Artemisia afra																					0.1					
		Asteraceae									0.01				0.1													
		Bidens pillosa				1	2																		1			
		Cirsium vulgare																										0.01
		Felicia filifolia	0.01			0.1	0.01																					
		Felicia muricata																						0.1				
		Helichrysum sp.																		10.1								
		Nidorella anomala																										0.1
		Schistostephium crataegifolium													0.01													
		Senecio									0.01																	
		Senecio venosus																				0.01		0.1				
		Serephium plumosum			0.01						0.01																	
		Sonchus sp.													0.1													
		Tagetes minuta					2														0.01							
	Celastraceae	Gymnosporia buxifolia																							2	5		
		Gymnosporia polyacantha																					1					
	Celtidaceae	Celtis africana																				0.01			0.1	80		
	Chrysobalanaceae	Parinari capensis					0.1	1					8															
	Commelinaceae	Commelina africana				0.1	0.1	0.1													1							
		Commelina benghalensis					0.1															1						
		Commelina subulata																		1								
		Cyanotis speciosa			0.1		0.1								0.1						0.1							
		Floscopa glomerata																										0.1

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
	Cyperaceae	Bulbostylis burchellii	0.1		0.1	0.01		0.1																0.1				
		Cyperus esculentus				10	0.1					10				10		20		10		5						
		Cyperus rupestris var. rupestris					1																					
		Cyperus sp.																						0.1				0.1
		Kylinga alba																						0.1				
	Dichapetalaceae	Dichapetalum cymosum			0.01		0.1						1															
	Dipsacaceae	Scabiosa columbaria																						0.1				
	Ebenaceae	Diospyros lycioides										0.01			0.01						0.01	6	40			0.01		
		Euclea crispa																								5		
	Eriospermaceae	Eriospermum abyssinicum						0.1																				
	Euphorbiaceae	Euphorbia striata																										0.1
		Phyllanthus parvulus											0.01															
	Fabaceae	Chamaecrista comosa var. capricornia		1	0.1	0.1							0.1															
		Indigofera comosa			1																							
		Indigofera hedyantha																				0.1						
		Indigofera melanadenia											0.1															
		Lotononis sp.		0.1																								
		Tephrosia elongata var. elongata			0.01																							
		Vigna vexillata			0.01						0.01																	
	Hyacinthaceae	Ledebouria cooperi			0.01																							
		Ledebouria ovatifolia			0.01																							
	Hyaconthaceae	Albuca sp.				0.1																		0.1				
	Hypoxidaceae	Hypoxis rigidula					1				0.1											1						

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
	Hypoxidadeae	Hypoxis obtusa				0.1																						
	Lamiaceae	Becium obovatum var. obovatum																						0.01				
		Rotheca hirsuta											0.01															
	Liliaceae	Aloe greatheadii var. davyana																						0.01				
	Malvaceae	Hermannia transvaalensis																						0.1				
	Mimosaceae	Acacia karroo									0.01												0.01		5			
		Acacia mearnsii																					1					
	Orobanchaceae	Graderia subintegra			0.01																							
	Oxalidaceae	Oxalis corniculata										0.1																
		Oxalis sp.									0.1												0.01					
	Poaceae	Alloteropsis semialata			10						50																	
		Andropogon appendiculatus																						5				
		Andropogon eucomis																										0.1
		Aristida congesta subsp. Barbicollis											2															
		Aristida congesta subsp. Congesta	3																									
		Aristida junciformis						8	5											1	1	0.1						
		Arundinella nepalensis																						2				
		Brachiaria serrata	0.1		1	0.1	0.1				5	0.1												0.1				

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
		Bromus catharticus																		1			0.1					
		Cynodon dactylon	1					1				80	20		2	2				10	5							
		Digitaria tricholaenoides			1																1							
		Elionurus muticus									2		0.1								5							
		Eragrostis chloromelas			5		20	10	50			1			1						10							
		Eragrostis curvula	6	75	5	40	60	10				3			0.1			5				2	20					
		Eragrostis gummiflua		0.1								3																
		Eragrostis lehmanniana	1				0.1					1			1					0.1	50			25				
		Eragrostis plana									5				1	1												
		Eragrostis racemosa				0.1		5			2																	
		Eragrostis rigidior				1																						
		Eragrostis trichophora						10					15															
		Eulalia villosa			1																							
		Helictotrichon hirtulum																		1								
		Heteropogon contortus				2																		5				
		Hyparrhenia filindepula				0.1																						
		Hyparrhenia hirta	10				0.01				0.01																	
		Imperata cylindrica																										90
		Koeleria capensis											0.1															
		Loudetia simplex			2	5																						
		Melinis repens					0.1																					
		Panicum coloratum																					30					

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
		Panicum ecklonii						2																				
		Panicum maximum																				0.1	20					
		Paspalum dilatatum																	20	5								
		Paspalum notatum																		5								
		Pennisetum clandestinum													60	75		70	50	30								
		Pennisetum thunbergii																		0.1								
		Pogonarthria squarrosa				0.1																						
		Setaria incrassata	0.1																									
		Setaria lindenbergiana																							90			
		Setaria nigrirostris																				20						
		Setaria sphacelata						1			5													60				
		Setaria sphacelata var. torta					1																					
		Stipa dregeana var. elongata																								20		
		Themeda triandra	0.1		0.1	1	2				5									1	1			10				
		Tristachya leucothrix					0.1																					
		Tristachya rehmannii				0.1					0.1				1						5							
		Unidentified grass		0.01											5													
	Polygalaceae	Polygala amatymbica																						0.1				
	Proteaceae	Protea welwitschii						0.1																				
	Rhamnaceae	Ziziphus mucronata																				3	6		1			
	Rosaceae	Leucosidea sericea																					2					

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
	Rubiaceae	Anthospermum hispidulum										0.01			0.1													
		Kohautia amatymbica			0.1																	0.01						
		Kohautia sp.										0.1																
		Oldenlandia herbacea var. herbacea										0.01	0.01		0.01													
		Richardia braziliensis										3	33		5													
	Rutaceae	Zanthoxylum capense																								0.01		
	Salicaceae	Populus sp.																	5									
	Selaginaceae	Selago densiflora			1							1	0.1		0.1						1							
	Sinopteridaceae	Cheilanthes sp.				0.1	0.1	1														0.1						
		Cheilanthes sp. 2																					0.01					
		Pellaea sp.				0.1	0.1	0.1			0.01																	
	Solanaceae	Physalis viscosa					0.1					1			2	2												
		Solanum elaeagnifolium																		0.1	2							
		Solanum panduriforme					1																					
		Solanum pseudocapsicum																							0.01			
		Solanum retroflexum																					0.01					
		Solanum sisymbrifolium	0.1	0.01	0.01								1		1	1												
	Sterculiaceae	Hermannia depressa													0.01									5				
	Velloziaceae	Xerophyta retinervis					0.1	1														1						
	Verbenaceae	Clerodendrum glabrum							0.01																			
		Verbena brasiliensis																		0.1								0.1

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
Cover abundance Total			31	102	88	85	109	81	90		104	104	84		83	91		100	100	82	105	73	133	143	103	113	183	
Nested plot																												
	Anacardiaceae	Seersia chirindensis																										
		Seersia lancea																										
		Seersia pyroides																						1				
	Asparagaceae	Asparagus cooperi																						1				
		Asparagus laricinus																						1	1			
	Boraginaceae	Ehretia rigida																							2			
	Buddlejaceae	Buddleja saligna																							2			
		Buddleja salviifolia																										
	Celtidaceae	Celtis africana																								80		
	Cyperaceae	Schoenoplectus corymbosus																										
	Ebenaceae	Diospyros lycioides																						1				
		Euclea crispa																							2	1		
	Mimosaceae	Acacia caffra																							20			
		Acacia karroo																						1		10		
		Acacia mearnsii																										
	Oleaceae	Olea europaea subsp. africana																						1				
	Poaceae	Dactyloctenium aegyptium																										
		Phragmites australis																										
	Proteaceae	Protea caffra																										
	Rhamnaceae	Ziziphus mucronata																						1				

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
	Rutaceae	Zanthoxylum capense																							1			
	Sinopteridaceae	Pellaea sp.																										
	Solanaceae	Solanum mauritianum																										
	Typhaceae	Typha capensis																										
Nested plot Total																								7		28	91	
Presence/absence																												
		Bare Ground												1														
	Anacardiaceae	Seersia magalismontana								1																		
	Asteraceae	Gerbera piloselloides								1																		
		Senecio venosus								1																		
	Chrysobalanaceae	Parinari capensis								1																		
	Commelinaceae	Commelina africana								1																		
		Cyanotis speciosa								1																		
	Cyperaceae	Bulbostylis burchellii								1																		
		Cyperus esculentus																									1	
		Sedge												1														
	Dipsacaceae	Cephalaria zeyherriana								1																		
	Ebenaceae	Diospyros lycioides								1																	1	
	Fabaceae	Indigofera hedyantha								1																		
	Hypoxidaceae	Hypoxis rigidula								1																		
	Mimosaceae	Acacia karroo																									1	
	Poaceae	Alloteropsis semialata								1																		
		Cynodon dactylon												1													1	

		Cluster	1-Grassland									1.1-Cynodon			1.2-Kikuyu						1.3-Eragrostis	2.1-Riverine Shrubland		2.2 Sparse dolomite	2.3.1 Open dolomite	2.3.2 Celtis woodland	2.4-Acacia woodland	3-Wetland
Method	Family	Species	11	13	20	23	24	32	18B	20A	28C	1	6	16	12	15	16A	17A	17B	20B	18	34	36	28	27	2A	28 A	37
		Eragrostis curvula												1													1	
		Hyparrhenia hirta												1														
		Pennisetum clandestinum															1											
		Themeda triandra																									1	
	Rhamnaceae	Ziziphus mucronata																									1	
	Rubiaceae	Kohautia amatymbica								1																		
	Scrophulariaceae	Nemesia fruticans								1																		
	Sinopteridaceae	Cheilanthes sp.								1																		
	Velloziaceae	Xerophyta retinervis								1																		

14.2Site descriptions

Cluster	Site no	Lat	Long	Aspect	Vegetation pattern	Soil Form	Soil depth (mm)	Topography	Encroachment	Slope (%)	Management system and comments
1-Grassland	11	-26.07283	27.710879	NE	Low closed grassland			Topslope		6	
	13	-26.056881	27.706811	N	Low closed grassland	Mispah	150	Footslope		4	
	20	-26.101718	27.726915	W	Low closed grassland			Midslope		7	Selectively grazed, large bare patches. Vigorous A. semialata (indicating selective grazing by smaller grazers). Signs of recolonisation (small tufts of Themeda, Brachiaria serrata, Indigofera)
	23	-26.081355	27.71481	W	Low sparse shrubland			Midslope		12	
	24	-26.078375	27.713766	W	Low open woodland	Mispah	100	Midslope		17	
	32	-26.0972	27.706724	NW	Low closed grassland			Midslope		11	Steep, rocky, heavily grazed, selectively grazed, not burnt
	18B	-26.093245511	27.725607233	W	Low closed grassland	Hutton	1000	Footslope		6	Darkening in subsoil Possibly historically cultivated in distant past (>100 years ago). No sign of cultivation contours. However, soil is deep enough for cultivation and sward is dominated by Eragrostis.
	20A	-26.101105	27.726832	W	Low closed grassland			Topslope		4	Rocky Ridge
	28B	-26.073475	27.696384	E	Tall sparse shrubland	Oakleaf	500	Midslope		8	80% rocks. Rocky dolomite hill Soil samples KG03 and KG04
	28C	-26.076	27.693306	E	Low open woodland			Midslope		8	
	6B	-26.100587	27.710599	W	Low closed grassland	Hutton	500	Topslope		3	Manganese nodules. Possibly previously cultivated, or some other disturbance. Dominated by Eragrostis Soil samples KG11, KG12
	Wet 6 R	-26.0897777 8	27.7198333 3	SW	Low closed grassland	Mispah	200	Bottomland	Poplar	3	Recently cleared of poplar but plants coppicing and follow-up control needed. Very shallow red soils, Significant carbon accumulation but no gleying. Adjacent to area cleared of poplars. Under poplars, topsoil horizon was wet but red. Debated whether it
1.1-Cynodon	1	-26.061268	27.710367	N	Low closed grassland	Hutton		Midslope		4	
	6	-26.099605	27.71025	N	Low closed grassland	Mispah	50	Footslope		2	Grazing lawn, large herd of blesbok on site

Cluster	Site no	Lat	Long	Aspect	Vegetation pattern	Soil Form	Soil depth (mm)	Topography	Encroachment	Slope (%)	Management system and comments
	16	-26.068461	27.712914	NE	Low closed grassland	Hutton	100	Midslope		6	Heavily grazed, short grass, termites. Cynodon, Hyparrhenia, bare soil, sedge, Eragrostis curvula Manganese nodules in soil profile
1.2-Kikuyu	12	-26.067199	27.710373	E	Low closed grassland			Midslope		6	Larger geology is dolomite. Site is on a quartzite outcrop Heavily disturbed (Impala midden).
	15	-26.066789	27.705858	N	Low closed grassland	Mispah	200	Crest		3	Pedestal = Average height of pedestals of grass tufts - an index of sheet erosion Kikuyu pastures planted in the 1960s for rhino. Now spreading and escaping. Heavily grazed by blesbok, hartebeest, wildebeest
	16A	-26.067475	27.713622	NE	Low closed grassland	Hutton	1500	Footslope	Kikuyu	6	More clay accumulation in topsoil. Drainage line downslope from borrow pit. Kikuyu dominated.
	17A	-26.093668	27.719693	NE	Low closed grassland	Hutton	350	Footslope	Kikuyu	4	Planted or encroached kikuyu pasture. Topsoil darkened with OM. No mottling
	17B	-26.0956812 8	27.7197272 6	E	Short closed grassland	Oakleaf	150	Bottomland	Poplar, kikuyu	3	Cleared of poplars recently. Coppicing requires follow-up Higher clay content, neocutanic shallow with mottling
	20B	-26.10334	27.724	NW	Low closed grassland	Bainsvlei	1000	Bottomland		1	Last site: Vlei next to road. We changed neocutanic to red apedal for Bainsvlei form
	31A	-26.08727	27.709936	N	Short closed grassland	Hutton	1500	Midslope		10	Deep hutton, no depth recorded
	KDB6	-26.084751	27.708728	NW	Tall closed woodland	Milkwood		Bottomland		1	Marginal vegetation grassland and wetland species; Non-marginal vegetation contains indigenous woody species. High grazing pressure observed during dry season site visit;
1.3-Eragrostis grassland	18	-26.093245	27.728489	W	Low closed grassland	Mispah	50	Midslope		5	
2.1-Riverine Shrubland	34	-26.086905	27.715563	W	Low thicket	Clovelly	1500	Footslope		15	Edge of riverine woodland. Steep rocky slope, surrounded by disturbance, deep erosion gully immediately to the south. Mature wattle trees. Soil survey was done on erosion gully
	36	-26.086364	27.712361	N	Low closed woodland			Bottomland		11	Riverine habitat
2.2 Sparse dolomite woodland	28	-26.076279	27.697895	E	Low sparse woodland			Footslope		8	Partly burnt
2.3.1 Open dolomite woodland	27	-26.083106	27.708596	W	Short closed woodland			Midslope		20	Steep slope, unburnt, probably no grazing
2.3.2 Celtis woodland											

Cluster	Site no	Lat	Long	Aspect	Vegetation pattern	Soil Form	Soil depth (mm)	Topography	Encroachment	Slope (%)	Management system and comments
2.3.3 Unclassified riverine woodland	35A	-26.075915	27.699326	E	Short forest		1500	Bottomland		5	Riparian woodland Active erosion gullies Signs of disturbance (a layer of bricks exposed about 20cm below soil surface) Orthic /Neocutanic /Pedocutanic. No soil form for this sequence. Check with Marine what she calls it Soil samples KG06, KG07
	KDB11	-26.072849	27.698396	N	Short closed woodland	Oakleaf		Bottomland	Wattle, Cortaderia selloana	1	Marginal vegetation contained grassland and wetland species. Non-marginal mainly woody species.
2.4-Acacia woodland	28A	-26.075156	27.697011	E	Short closed woodland	No manci	100	Footslope	Acacia karroo	8	Substantial recruitment of small A. karroo, Ziziphus mucronata, Diospyrus lycoides very shallow humic. Depth not recorded. Cool woodland area Soil sample KG05
3-Wetland	37	-26.098165	27.720171	NW	Short closed grassland			Bottomland		1	Community heterogeneity is very high and patches of dominant species change within meters. Draw an idealised diagram of the general layout of communities on the bank of the river. Patches of Dactylotinium, Typhus, Phragmites australis, Poplar, Imperata, L
	KDB1	-26.105578	27.726325	NW	Low closed grassland	Bainsvlei	1000	Bottomland	Wattles removed	1	Marginal vegetation wetland and grassland species; Non-marginal mostly grassland species; In valley bottom; No channel present; No surface water observed during 2014 dry or 2015 wet season site visits
	KDB2	-26.106161	27.722031	NW	Low closed grassland			Bottomland	Wattle, Eucalyptus	1	High grazing pressure visible in dry season; Alien invasive Acaia and Eucalyptus spp. present; Instream vegetation limited; Vegetation recovered after summer rains. Bank erosion was observed but it was limited in extent.
	KDB3	-26.103669	27.694889								
	KDB4	-26.098527	27.719646	N	Low closed grassland			Bottomland	Wattle	1	Marginal zone containing grassland and wetland species; Non-marginal zone containing mainly grassland species.
	KDB5/Wet7	-26.090628	27.722243	SW	Short closed grassland	Tukulu	1500	Bottomland	Poplar	3	Cleared of poplars but young plants coppicing. Follow-up control needed. Also site of wetland survey and aquatic survey Soil samples KG08, KG09
	KDB7	-26.093047	27.70363	NW	Low closed grassland			Bottomland	Wattle	1	Grassland and wetland species present.

14.3Photographs

1-Grassland

Site 20

Site 32

Site 11

Site 24

Site 23

1.1 Cynodon

Site 6

Site 1

1.2 Kikuyu

Site 15

Site 12

2.1 Riverine shrubland

Site 34

Site 34

2.2 Sparse dolomite woodland

Site 28

Site 28

2.3.1 Open dolomite woodland

Site 27

2.3.2 Celtis woodland

Site 2A

2.4 Acacia woodland

Site 28A

3 Wetland

Site 37

15 APPENDIX 2: SOIL LABORATORY ANALYSIS

The soil laboratory analysis results were conducted by NviroTek Labs, Ottosdal. The final alphanumeric code of each reference number refers to the sample site (e.g. reference number KG01 KGR**15K** refers to site 15K). Refer to Section 2: Soils for discussion of results.

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Lab No	Reference no	pH (KCl)	pH(H2O)	PBray1	K	Na	Ca	Mg	S-Value	T	Density	Clay	Silt	Sand	Organic C
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(+)/kg	cmol(+)/kg	g/cm3	%	%	%	%
36925	KG01 KGR15K	5,62	6,45	108	292	8	699	113	5,20	5,20	0,96	28	8	64	3,70
36926	KG03 28BW	4,78	5,60	5	118	12	618	133	4,53	4,53	0,96	32	9	59	3,09
36927	KG04 28 BW	5,80	6,62	1	36	8	616	113	4,13	4,13	1,10	34	9	57	0,75
36928	KG05 28 AW	5,74	6,55	1	1285	15	3298	461	23,62	23,62	0,88	24	9	67	3,75
36929	KG06 35AR	6,18	6,83	1	190	17	3868	422	23,36	23,36	0,85	26	18	56	6,11
36930	KG07 35AR	6,21	6,96	2	38	19	908	280	7,02	7,02	1,15	32	16	52	0,41
36931	KG08 Topsol Antoinette 7	4,71	5,51	1	57	14	571	105	3,92	3,92	1,15	26	14	60	3,05
36932	KG09 Subsoil Antoinette 7	4,54	5,36	1	24	6	231	63	1,76	1,76	1,33	28	8	64	0,63
36933	KG10 17BR	6,18	6,98	1	76	71	2101	218	12,79	12,79	0,86	34	7	59	5,76
36934	KG11 6BGG	4,19	5,20	3	57	4	109	25	0,91	1,11	1,14	26	4	70	1,25
36935	KG12 6BGG	4,14	4,78	2	31	2	81	23	0,68	1,06	1,15	28	2	70	0,74

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16 APPENDIX 3: AVIAN DISTRIBUTION AND ABUNDANCE DATA

Map 15: Satellite image showing green rectangles displaying the coordinates, name, location and extent of each of the six QDGCs from which bird species lists compiled for SBAP1 were extracted (also cf. Photo 10 above; Retief 2013). The orange rectangle shows the outline of the 12 pentad grids from which bird species lists for SABAP2 were extracted. In the center is the yellow polygon of the KGR (cf. Map 13).

Table 39: Table of bird species diversity reported during SABAP1 on the six QDGCs around the Krugersdorp Game Reserve, Gauteng (2627BA). Based on the national list and annotations of Birdlife South Africa (2014), sorted in the order of 'Roberts VII' (Hockey et al. 2005), with the reporting rate for each species and grid cell as an index of relative abundance within that species, after Harrison et al. (1997; - where reporting rate <1). The grid cells are tabulated from north to south and west to east, to indicate the faunal crossroads around the KGR as evinced by the reporting rates of individual species, and the data for the grid cell containing the KGR is coloured purple. Note that additional species have been recorded for these areas but not within the SABAP1 project.

Common English Name	Scientific Name	Status Codes (see below)			SABAP1 reporting rate for QDGCs 25/2627					
		RD	S	E	DC	DD	BA	BB	BC	BD
Common Ostrich	*Struthio camelus*				2	0	0	0	-	-
Coqui Francolin	*Peliperdix Coqui*				42	39	2	1	-	-
Red-winged francolin	*Scleroptila levaillantii*				13	2	0	1	-	-
Shelley's francolin	*Scleroptila shelleyi*				9	0	0	0	-	-
Orange River francolin	*Scleroptila levaillantoides*				0	1	3	2	11	13
Natal Spurfowl	*Pternistis natalensis*				24	2	1	-	-	-
Swainson's Spurfowl	*Pternistis swainsonii*				50	56	33	19	20	38
Common Quail	*Coturnix coturnix*		NBM		4	1	8	1	4	0
Harlequin Quail	*Coturnix delegorguei*				0	0	-	-	-	-
Helmeted Guineafowl	*Numida meleagris*				64	79	49	49	34	71
Fulvous Duck	*Dendrocygna bicolor*				-	-	3	-	1	3
White-faced Duck	*Dendrocygna viduata*				20	40	27	5	18	27
White-backed Duck	*Thalassornis leuconotus*				1	1	6	0	1	3
Maccoa Duck	*Oxyura maccoa*	NT, NT			-	3	46	2	16	24
Egyptian Goose	*Alopochen aegyptiaca*				29	51	64	49	50	50
South African Shelduck	*Tadorna cana*				-	-	13	0	10	4
Spur-winged Goose	*Plectropterus gambensis*				17	16	22	4	21	35
Comb Duck	*Sarkidiornis melanotos*				1	2	1	0	1	0
Cape Teal	*Anas capensis*				-	3	8	0	18	6
African Black Duck	*Anas sparsa*				19	38	6	16	2	5
Mallard	*Anas platyrhynchos*		I		-	0	0	2	-	19
Yellow-billed Duck	*Anas undulata*				33	54	67	23	51	58
Cape Shoveler	*Anas smithii*				-	7	43	1	29	26
Red-billed Teal	*Anas erythrorhyncha*				-	8	42	5	42	23
Hottentot Teal	*Anas hottentota*				-	0	45	-	16	-
Southern Pochard	*Netta erythrophthalma*				-	11	20	4	24	21
Kurrichane Buttonquail	*Turnix sylvaticus*				-	0	-	0	-	-
Greater Honeyguide	*Indicator indicator*				8	2	0	2	1	-
Lesser Honeyguide	*Indicator minor*				13	6	3	3	1	1
Brown-backed Honeybird	*Prodotiscus regulus*				1	0	0	1	1	0
Red-throated Wryneck	*Jynx ruficollis*				5	18	12	31	8	42
Bennett's Woodpecker	*Campethera bennettii*				1	0	-	-	-	-
Golden-tailed Woodpecker	*Campethera abingoni*				28	5	2	7	-	-
Cardinal Woodpecker	*Dendropicos fuscescens*				18	10	3	9	11	7
Bearded Woodpecker	*Dendropicos namaquus*				2	3	-	1	-	-
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*				61	16	2	8	-	-
Acacia Pied Barbet	*Tricholaema leucomelas*				14	14	4	5	15	3
Black-collared Barbet	*Lybius torquatus*				89	73	24	65	32	53
Crested Barbet	*Trachyphonus vaillantii*				73	82	56	88	39	76
Southern Yellow-billed Hornbill	*Tockus leucomelas*				-	2	-	0	-	-

Common English Name	Scientific Name	Status Codes (see below)			SABAP1 reporting rate for QDGCs 25/2627					
		RD	S	E	DC	DD	BA	BB	BC	BD
African Grey Hornbill	*Tockus nasutus*				77	28	3	0	-	-
African Hoopoe	*Upupa africana*				40	48	32	66	32	63
Green Wood-hoopoe	*Phoeniculus purpureus*				68	53	19	48	3	37
Common Scimitarbill	*Rhinopomastus cyanomelas*				1	1	-	1	2	-
European Roller	*Coracias garrulus*	NT, NT	NBM		0	0	0	0	-	1
Lilac-breasted Roller	*Coracias caudatus*				0	1	0	0	1	0
Purple Roller	*Coracias naevius*				0	0	-	-	-	-
Half-collared Kingfisher	*Alcedo semitorquata*	NT,LC			3	2	2	1	-	-
Malachite Kingfisher	*Alcedo cristata*				5	14	1	3	9	2
Woodland Kingfisher	*Halcyon senegalensis*		BM		12	8	1	2	--	-
Brown-hooded Kingfisher	*Halcyon albiventris*				71	44	7	13	-	-
Striped Kingfisher	*Halcyon chelicuti*				9	-	-	-	-	-
Giant Kingfisher	*Megaceryle maxima*				12	25	3	1	4	0
Pied Kingfisher	*Ceryle rudis*				25	35	10	11	8	3
White-fronted Bee-eater	*Merops bullockoides*				4	7	1	0	-	-
Little Bee-eater	*Merops pusillus*				21	7	1	1	-	-
Swallow-tailed Bee-eater	*Merops hirundineus*				-	-	1	-	-	-
European Bee-eater	*Merops apiaster*		B/NBM		22	21	2	15	1	0
White-backed Mousebird	*Colius colius*				4	3	0	2	13	23
Speckled Mousebird	*Colius striatus*				62	71	39	76	23	51
Red-faced Mousebird	*Urocolius indicus*				51	34	30	53	49	47
Jacobin Cuckoo	*Clamator jacobinus*		BM		4	3	-	0	1	-
Levaillant's Cuckoo	*Clamator levaillantii*		BM		-	4	-	-	-	-
Great Spotted Cuckoo	*Clamator glandarius*		BM		4	-	-	-	-	-
Red-chested Cuckoo	*Cuculus solitarius*		BM		29	23	10	21	12	18
Black Cuckoo	*Cuculus clamosus*		BM		2	12	0	4	-	-
African Cuckoo	*Cuculus gularis*		BM		0	1	-	0	-	-
Klaas's Cuckoo	*Chrysococcyx klaas*				8	1	0	2	1	-
Diderick Cuckoo	*Chrysococcyx caprius*		BM		32	28	23	22	23	26
Burchell's Coucal	*Centropus burchellii*				45	38	10	50	3	11
Meyer's Parrot	*Poicephalus meyeri*				0	0	-	-	-	-
Rose-ringed Parakeet	*Psittacula krameri*		I		-	-	-	0	-	-
African Palm-Swift	*Cypsiurus parvus*				8	9	1	12	-	1
Alpine Swift	*Tachymarptis melba*		BM		11	1	-	0	3	2
Common Swift	*Apus apus*		NBM		-	0	2	0	3	1
African Black Swift	*Apus barbatus*				10	4	3	6	1	1
Little Swift	*Apus affinis*				6	31	16	31	39	16
Horus Swift	*Apus horus*				7	2	0	2	1	3
White-rumped Swift	*Apus caffer*		BM		18	21	24	28	26	30
Grey Go-away-bird	*Corythaixoides concolor*				74	58	10	70	1	5
Barn Owl	*Tyto alba*				31	26	0	7	10	3
African Grass-Owl	*Tyto capensis*	VU,LC			7	4	2	0	-	0
African Scops-Owl	*Otus senegalensis*				-	0	-	-	-	-
Southern White-faced Scops-Owl	*Ptilopsis granti*				0	1	-	-	-	-
Cape Eagle-Owl	*Bubo capensis*				2	0	-	-	-	-
Spotted Eagle-Owl	*Bubo africanus*				26	14	3	15	1	2

Common English Name	Scientific Name	Status Codes (see below)			SABAP1 reporting rate for QDGCs 25/2627					
		RD	S	E	DC	DD	BA	BB	BC	BD
Verreaux's Eagle-Owl	*Bubo lacteus*				-	0	0	-	-	1
Pearl-spotted Owlet	*Glaucidium perlatum*				14	4	-	-	-	-
Marsh Owl	*Asio capensis*				11	13	2	1	6	6
Fiery-necked Nightjar	*Caprimulgus pectoralis*				0	1	-	0	1	2
Freckled Nightjar	*Caprimulgus tristigma*				3	1	-	2	-	-
Rufous-cheeked Nightjar	*Caprimulgus rufigena*		BM		2	3	-	0	-	0
European Nightjar	*Caprimulgus europaeus*				-	0	-	-	-	-
Rock Dove	*Columba livia*				8	12	27	39	38	40
Speckled Pigeon	*Columba guinea*				79	57	78	66	68	55
African Olive-Pigeon	*Columba arquatrix*				27	8	7	12	-	-
Laughing Dove	*Streptopelia senegalensis*				96	94	95	94	74	96
Cape Turtle-Dove	*Streptopelia capicola*				75	75	83	83	51	88
Red-eyed Dove	*Streptopelia semitorquata*				47	48	28	45	49	47
Emerald-spotted Wood-Dove	*Turtur chalcospilos*				8	0	-	-	-	-
Namaqua Dove	*Oena capensis*				14	3	9	0	14	2
Red-crested Korhaan	*Lophotis ruficrista*				0	-	-	-	-	-
Northern Black Korhaan	*Afrotis afraoides*				4	34	10	3	19	14
Blue Korhaan	*Eupodotis caerulescens*	LC,NT		*	1	0	-	-	-	-
White-bellied Korhaan	*Eupodotis senegalensis*	VU,LC			0	2	2	1	-	1
Blue Crane	*Anthropoides paradiseus*	NT,VU			10	2	-	1	3	0
African Finfoot	*Podica senegalensis*	VU,LC			0	0	-	0	-	-
Red-chested Flufftail	*Sarothrura rufa*				4	2	--	-	-	-
African Rail	*Rallus caerulescens*				-	2	2	1	5	6
African Crake	*Crecopsis egregia*		BM		-	0	-	-	-	-
Black Crake	*Amaurornis flavirostra*				2	56	2	4	3	13
Baillon's Crake	*Porzana pusilla*				-	-	-	-	-	0
African Purple Swamphen	*Porphyrio madagascariensis*				-	8	8	4	34	22
Common Moorhen	*Gallinula chloropus*				11	28	49	26	54	40
Red-knobbed coot	*Fulica cristata*				11	42	63	35	59	61
African Snipe	*Gallinago nigripennis*				2	9	10	3	10	9
Black-tailed Godwit	*Limosa limosa*	NA, NT	V		-	-	-	-	2	-
Marsh Sandpiper	*Tringa stagnatilis*		NBM		-	4	13	1	13	11
Common Greenshank	*Tringa nebularia*		NBM		-	5	5	0	15	6
Green Sandpiper	*Tringa ochropus*		V		--	-	-	0	-	-
Wood Sandpiper	*Tringa glareola*		NBM		2	8	13	2	23	13
Common Sandpiper	*Actitis hypoleucos*		NBM		0	6	6	1	2	7
Little Stint	*Calidris minuta*		NB		-	2	4	0	12	7
Curlew Sandpiper	*Calidris ferruginea*		NBM		-	0	4	-	12	9
Ruff	*Philomachus pugnax*		NBM		0	5	17	1	19	13
Greater Painted-snipe	*Rostratula benghalensis*	VU, NT			-	0	0	0	-	-
African Jacana	*Actophilornis africanus*				-	5	-	0	-	1
Spotted Thick-knee	*Burhinus capensis*				36	45	32	39	17	36
Black-winged Stilt	*Himantopus himantopus*				-	6	25	0	23	13
Pied Avocet	*Recurvirostra avosetta*				-	1	4	3	16	6
Common Ringed Plover	*Charadrius hiaticula*		NBM		-	1	1	0	5	1
Kittlitz's Plover	*Charadrius pecuarius*				-	1	-	-	17	-

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		RD	S	E	DC	DD	BA	BB	BC	BD
Three-banded Plover	*Charadrius tricollaris*				4	26	34	7	38	21
Blacksmith Lapwing	*Vanellus armatus*				45	71	77	50	77	71
African Wattled Lapwing	*Vanellus senegallus*				30	45	19	27	20	31
Crowned Lapwing	*Vanellus coronatus*				52	80	80	86	92	90
Temminck's Courser	*Cursorius temminckii*				2	1	0	0	1	0
Black-winged Pratincole	*Glareola nordmanni*	NT, NT	NBM		-	-	-	0	2	2
Grey-headed Gull	*Chroicocephalus cirrocephalus*				-	16	52	7	10	22
Caspian Tern	*Sterna caspia*	VU,LC			-	0	-	-	-	-
Whiskered Tern	*Chlidonias hybrida*				-	5	4	0	1	1
White-winged Tern	*Chlidonias leucopterus*		NBM		-	8	2	1	16	28
Osprey	*Pandion haliaetus*		NBM		-	3	-	0	-	-
African Cuckoo Hawk	*Aviceda cuculoides*				-	0	-	-	-	-
Black-shouldered Kite	*Elanus caeruleus*				68	72	61	46	63	80
Black Kite	*Milvus migrans*		NBM		2	9	2	3	6	2
Yellow-billed Kite	*Milvus aegyptius*		BM		8	17	6	9	11	8
African Fish-Eagle	*Haliaeetus vocifer*				4	30	-	0	-	2
White-backed Vulture	*Gyps africanus*	EN,EN			-	3	-	-	-	-
Cape Vulture	*Gyps coprotheres*	EN,VU			45	34	6	2	1	-
Lappet-faced Vulture	*Aegypius tracheliotos*	EN,VU			-	-	0	-	-	-
Black-chested Snake-Eagle	*Circaetus pectoralis*				3	8	1	0	-	0
Brown Snake-Eagle	*Circaetus cinereus*				-	4	-	-	-	-
African Marsh-Harrier	*Circus ranivorus*	EN,LC			-	2	-	-	1	1
Black Harrier	*Circus maurus*	EN,VU		(*)	-	-	-	-	-	0
Montagu's Harrier	*Circus pygargus*		NBM		-	-	-	-	1	-
African Harrier-Hawk	*Polyboroides typus*				14	1	2	1	-	-
Lizard Buzzard	*Kaupifalco monogrammicus*				-	-	1	-	-	-
Southern Pale Chanting Goshawk	*Melierax canorus*				-	1	-	-	-	-
Gabar Goshawk	*Melierax gabar*				1	1	-	2	-	-
Shikra	*Accipiter badius*				1	1	-	0	-	2
Little Sparrowhawk	*Accipiter minullus*				7	11	1	0	-	-
Ovambo Sparrowhawk	*Accipiter ovampensis*				2	4	3	2	-	-
Black Sparrowhawk	*Accipiter melanoleucus*				3	2	-	2	-	-
Steppe Buzzard	*Buteo buteo*		NBM		12	11	5	6	10	9
Jackal Buzzard	*Buteo rufofuscus*			(*)	5	1	-	1	-	1
Verreaux's Eagle	*Aquila verreauxii*	VU, LC			26	7	-	16	-	3
African Hawk-Eagle	*Aquila spilogaster*				1	1	-	-	-	-
Booted Eagle	*Hieraaetus pennatus*		NBM		1	0	0	0	-	-
Wahlberg's Eagle	*Hieraaetus wahlbergi*		BM		2	2	-	0	-	-
Martial Eagle	*Polemaetus bellicosus*	EN,VU			1	1	-	0	-	-
Secretarybird	*Sagittarius serpentarius*	VU, VU			7	3	1	0	3	3
Lesser Kestrel	*Falco naumanni*		NBM		-	-	-	-	16	5
Rock Kestrel	*Falco rupicolus*				17	7	3	0	21	3
Greater Kestrel	*Falco rupicoloides*				4	6	1	1	11	5
Amur Falcon	*Falco amurensis*		NBM		7	0	0	0	1	-
Eurasian Hobby	*Falco subbuteo*		NBM		0	0	-	-	-	-

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		RD	S	E	DC	DD	BA	BB	BC	BD
Lanner Falcon	*Falco biarmicus*	VU,LC			7	0	3	1	1	-
Peregrine Falcon	*Falco peregrinus*				0	0	-	1	-	-
Little Grebe	*Tachybaptus ruficollis*				26	34	60	29	56	47
Great crested Grebe	*Podiceps cristatus*				-	13	30	8	18	11
Black-necked Grebe	*Podiceps nigricollis*				-	-	6	0	2	2
African Darter	*Anhinga rufa*				8	34	22	17	36	9
Reed Cormorant	*Phalacrocorax africanus*				28	58	50	35	48	54
White-breasted Cormorant	*Phalacrocorax lucidus*				7	40	33	12	17	22
Black Heron	*Egretta ardesiaca*				-	4	-	0	1	4
Little Egret	*Egretta garzetta*				3	18	29	9	31	13
Yellow-billed Egret	*Egretta intermedia*				0	7	38	5	20	6
Great Egret	*Egretta alba*				0	14	10	1	10	1
Grey Heron	*Ardea cinerea*				27	48	56	21	39	36
Black-headed Heron	*Ardea melanocephala*				36	45	59	39	62	66
Goliath Heron	*Ardea goliath*				-	4	2	-	6	13
Purple Heron	*Ardea purpurea*				6	16	8	6	6	7
Cattle Egret	*Bubulcus ibis*				64	83	76	59	94	83
Squacco Heron	*Ardeola ralloides*				0	8	19	1	6	3
Green-backed Heron	*Butorides striata*				12	13	6	1	-	-
Black-crowned Night-Heron	*Nycticorax nycticorax*				5	4	22	2	6	7
White-backed Night-Heron	*Gorsachius leuconotus*	VU,LC			1	-	-	-	-	-
Little Bittern	*Ixobrychus minutus*				2	3	3	0	-	1
Hamerkop	*Scopus umbretta*				48	58	13	24	12	13
Greater Flamingo	*Phoenicopterus roseus*	NT,LC			-	-	-	0	12	10
Lesser Flamingo	*Phoeniconaias minor*	NT, NT			-	-	-	-	-	3
Glossy Ibis	*Plegadis falcinellus*				10	13	54	14	25	50
Hadeda Ibis	*Bostrychia hagedash*				76	88	62	92	75	75
African Sacred Ibis	*Threskiornis aethiopicus*				21	58	70	42	30	64
African Spoonbill	*Platalea alba*				3	32	34	7	6	20
Pink-backed Pelican	*Pelecanus rufescens*	VU,LC			-	-	-	-	1	-
Yellow-billed Stork	*Mycteria ibis*	EN,LC			-	1	3	0	-	-
Black Stork	*Ciconia nigra*	VU,LC			-	1	0	-	-	-
Abdim's Stork	*Ciconia abdimii*	NT,LC	NBM		5	4	2	0	1	0
White Stork	*Ciconia ciconia*		NBM		20	11	5	1	3	3
Eurasian Golden Oriole	*Oriolus oriolus*		NBM		-	0	-	1	-	-
Black-headed Oriole	*Oriolus larvatus*				42	12	8	7	-	-
Fork-tailed Drongo	*Dicrurus adsimilis*				68	46	12	6	14	-
African Paradise-Flycatcher	*Terpsiphone viridis*				32	34	11	13	2	4
Brubru	*Nilaus afer*				11	11	5	5	1	-
Black-backed Puffback	*Dryoscopus cubla*				54	35	15	13	-	-
Black-crowned Tchagra	*Tchagra senegalus*				61	36	8	7	-	-
Brown-crowned Tchagra	*Tchagra australis*				13	15	3	1	3	-
Southern Boubou	*Laniarius ferrugineus*				60	43	9	24	-	-
Crimson-breasted Shrike	*Laniarius atrococcineus*				14	10	0	0	-	-
Bokmakierie	*Telophorus zeylonus*				44	47	63	77	48	87

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		RD	S	E	DC	DD	BA	BB	BC	BD
Orange-breasted Bush-Shrike	*Chlorophoneus sulfureopectus*				-	1	-	0	-	-
Grey-headed Bush-Shrike	*Malaconotus blanchoti*				3	1	2	-	-	-
White-crested Helmet-Shrike	*Prionops plumatus*				-	0	-	-	-	-
Cape Batis	*Batis capensis*				0	-	-	-	-	-
Chinspot Batis	*Batis molitor*				46	25	5	10	1	3
Cape Crow	*Corvus capensis*				5	9	2	4	14	0
Pied crow	*Corvus albus*				53	76	32	80	18	34
Red-backed Shrike	*Lanius collurio*		NBM		1	5	2	0	3	1
Lesser Grey Shrike	*Lanius minor*		NBM		1	2	3	0	1	1
Common Fiscal	*Lanius collaris*				87	93	89	91	86	96
Magpie Shrike	*Corvinella melanoleuca*				-	0	-	-	-	-
Black Cuckooshrike	*Campephaga flava*				5	4	0	4	-	-
Grey Penduline-Tit	*Anthoscopus caroli*				-	0	-	-	-	-
Cape Penduline-Tit	*Anthoscopus minutus*				0	-	-	-	-	-
Southern Black Tit	*Parus niger*				18	7	-	-	-	-
Ashy Tit	*Parus cinerascens*				10	9	-	3	3	1
Sand Martin	*Riparia riparia*		NBM		-	1	1	0	8	4
Brown-throated Martin	*Riparia paludicola*				15	10	10	9	23	19
Banded Martin	*Riparia cincta*				4	2	5	1	19	12
Barn Swallow	*Hirundo rustica*		NBM		35	37	41	33	35	48
White-throated Swallow	*Hirundo albigularis*		BM		3	29	32	22	27	23
Pearl-breasted Swallow	*Hirundo dimidiata*				3	12	1	0	-	-
Greater Striped Swallow	*Cecropis cucullata*		BM		28	40	34	34	38	39
Lesser Striped Swallow	*Cecropis abyssinica*		BM		51	39	10	22	-	-
Red-breasted Swallow	*Cecropis semirufa*				22	20	5	4	8	4
South African Cliff-Swallow	*Petrochelidon spilodera*			B(*)	3	8	4	2	23	7
Rock Martin	*Hirundo fuligula*				18	20	10	27	2	0
Common House-Martin	*Delichon urbicum*		NBM		2	4	7	3	9	4
Dark-capped Bulbul	*Pycnonotus tricolor*				95	91	73	94	46	74
African Red-eyed Bulbul	*Pycnonotus nigricans*				1	2	5	2	26	13
Fairy Flycatcher	*Stenostira scita*			(*)	3	4	1	3	4	1
Cape Grassbird	*Sphenoeacus afer*			(*)	27	17	12	7	1	1
Long-billed crombec	*Sylvietta rufescens*				11	18	3	1	12	-
Burnt-necked Eremomela	*Eremomela usticollis*				1	0	-	-	-	-
Little Rush-Warbler	*Bradypterus baboecala*				5	7	7	2	14	8
Sedge Warbler	*Acrocephalus schoenobaenus*		NBM		-	3	1	1	7	6
African Reed-Warbler	*Acrocephalus baeticatus*		BM		0	5	2	2	13	9
Marsh Warbler	*Acrocephalus palustris*		NBM		-	0	1	1	1	3
Great Reed-Warbler	*Acrocephalus arundinaceus*		NBM		5	3	0	1	-	4
Lesser Swamp-Warbler	*Acrocephalus gracilirostris*				1	8	27	9	28	17
Icterine Warbler	*Hippolais icterina*		NBM		2	1	-	0	-	-
Willow Warbler	*Phylloscopus trochilus*		NBM		14	13	8	9	10	4
Arrow-marked Babbler	*Turdoides jardineii*				71	33	5	0	-	-
Chestnut-vented Tit-Babbler	*Sylvia subcaerulea*				12	18	6	1	21	-
Garden Warbler	*Sylvia borin*		NBM		1	2	1	1	1	1
Common Whitethroat	*Sylvia communis*		NBM		-	-	-	-	1	-
Cape White-eye	*Zosterops capensis*			(*)	78	78	43	77	32	38

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		RD	S	E	DC	DD	BA	BB	BC	BD
Lazy Cisticola	*Cisticola aberrans*				12	3	1	3	-	4
Rattling Cisticola	*Cisticola chiniana*				7	2	0	1	1	1
Wailing Cisticola	*Cisticola lais*				2	2	3	5	19	4
Levaillant's Cisticola	*Cisticola tinniens*				17	22	34	13	39	43
Neddicky	*Cisticola fulvicapilla*				50	40	31	15	50	49
Zitting Cisticola	*Cisticola juncidis*				14	18	22	10	36	27
Desert Cisticola	*Cisticola aridulus*				0	9	3	1	10	4
Cloud Cisticola	*Cisticola textrix*			(*)	-	6	7	2	26	14
Wing-snapping Cisticola	*Cisticola ayresii*				-	2	2	1	11	4
Tawny-flanked Prinia	*Prinia subflava*				57	52	13	21	5	6
Black-chested Prinia	*Prinia flavicans*				6	28	27	16	39	43
Bar-throated Apalis	*Apalis thoracica*				29	10	7	12	4	0
Grey-backed Camaroptera	*Camaroptera brevicaudata*				1	0	-	-	-	-
Barred Wren-Warbler	*Calamonastes fasciolatus*				-	--	-	0	-	-
Melodious Lark	*Mirafra cheniana*	LC,NT		(*)	-	1	0	0	6	1
Rufous-naped Lark	*Mirafra africana*				26	36	31	9	46	32
Flappet Lark	*Mirafra rufocinnamomea*				5	-	-	-	-	-
Eastern clapper Lark	*Mirafra fasciolata*				2	8	2	1	20	6
Sabota Lark	*Calendulauda sabota*				0	4	1	0	3	2
Spike-heeled Lark	*Chersomanes albofasciata*				3	3	10	2	27	18
Eastern Long-billed Lark	*Certhilauda semitorquata*			(*)	-	3	3	1	16	4
Chestnut-backed Sparrowlark	*Eremopterix leucotis*				-	-	0	-	-	-
Red-capped Lark	*Calandrella cinerea*				-	9	15	2	32	16
Pink-billed Lark	*Spizocorys conirostris*				-	1	2	1	16	9
Cape Rock-Thrush	*Monticola rupestris*			(*)	19	3	1	12	-	-
Sentinel Rock-Thrush	*Monticola explorator*			(*)	-	0	-	0	-	0
Short-toed Rock-Thrush	*Monticola brevipes*				15	2	0	0	-	-
Groundscraper Thrush	*Psophocichla litsitsirupa*				50	9	4	2	1	10
Kurrichane Thrush	*Turdus libonyanus*				49	38	8	13	-	-
Karoo Thrush	*Turdus smithi*			(*)	50	51	49	85	21	66
Marico flycatcher	*Bradornis mariquensis*				1	0	-	0	-	-
Southern Black flycatcher	*Melaenornis pammelaina*				16	4	-	0	-	-
Fiscal Flycatcher	*Sigelus silens*			(*)	42	52	26	49	48	38
Spotted flycatcher	*Muscicapa striata*		NBM		8	12	4	4	11	2
Cape Robin-Chat	*Cossypha caffra*				65	64	48	75	37	63
White-throated Robin-Chat	*Cossypha humeralis*				1	7	-	0	-	-
White-browed Scrub-Robin	*Erythropygia leucophrys*				9	7	1	0	-	-
Kalahari Scrub-Robin	*Erythropygia paena*				0	1	-	0	26	0
African StoneChat	*Saxicola torquatus*				38	41	46	16	44	62
Mountain Wheatear	*Oenanthe monticola*				14	3	38	16	40	27
Capped Wheatear	*Oenanthe pileata*				2	3	14	2	21	13
Familiar Chat	*Cercomela familiaris*				50	19	4	3	12	0
Ant-eating Chat	*Myrmecocichla formicivora*				4	14	27	2	35	52
Mocking cliff-Chat	*Thamnolaea cinnamomeiventris*				29	13	5	4	-	1
Red-winged Starling	*Onychognathus morio*				42	28	11	15	10	2
Cape Glossy Starling	*Lamprotornis nitens*				50	46	42	53	47	68
Violet-backed Starling	*Cinnyricinclus leucogaster*				19	11	1	1	-	-

Common English Name	Scientific Name	Status Codes (see below)			SABAP1 reporting rate for QDGCs 25/2627					
		RD	S	E	DC	DD	BA	BB	BC	BD
Pied Starling	*Lamprotornis bicolor*			(*)	-	13	48	31	52	74
Wattled Starling	*Creatophora cinerea*				1	2	0	1	12	10
Common Myna	*Acridotheres tristis*		I		1	29	52	91	76	61
Amethyst Sunbird	*Chalcomitra amethystina*				58	60	14	36	1	11
Malachite Sunbird	*Nectarinia famosa*				8	2	2	12	14	1
Greater Double-collared Sunbird	*Cinnyris afer*			(*)	37	7	3	8	-	2
White-bellied Sunbird	*Cinnyris talatala*				60	33	6	25	8	8
Marico Sunbird	*Cinnyris mariquensis*				2	4	-	1	-	-
Scaly-feathered Finch	*Sporopipes squamifrons*				-	0	1	0	20	-
White-browed Sparrow-Weaver	*Plocepasser mahali*				7	4	17	0	39	30
Lesser Masked-Weaver	*Ploceus intermedius*				0	1	-	-	-	-
Cape Weaver	*Ploceus capensis*			(*)	23	14	14	32	23	13
Southern Masked-Weaver	*Ploceus velatus*				71	82	84	91	74	90
Village Weaver	*Ploceus cucullatus*				0	2	0	1	-	0
Red-billed Quelea	*Quelea quelea*				11	9	13	2	29	9
Yellow-crowned Bishop	*Euplectes afer*				1	7	24	3	37	24
Southern Red Bishop	*Euplectes orix*				26	48	57	49	76	68
Yellow Bishop	*Euplectes capensis*				-	1	0	0	-	-
White-winged Widowbird	*Euplectes albonotatus*				30	26	12	3	9	-
Red-collared Widowbird	*Euplectes ardens*				21	24	14	19	17	18
Long-tailed Widowbird	*Euplectes progne*				8	39	61	18	79	72
Thick-billed Weaver	*Amblyospiza albifrons*				-	-	-	1	1	3
Orange-breasted Waxbill	*Amandava subflava*				9	9	21	2	29	14
African Quailfinch	*Ortygospiza fuscocrissa*				8	10	21	2	38	16
Red-headed Finch	*Amadina erythrocephala*				21	2	40	1	45	30
Cut-throat Finch	*Amadina fasciata*				29	4	-	-	-	-
Swee Waxbill	*Coccopygia melanotis*			(*)	1	1	-	0	1	-
Black-faced Waxbill	*Estrilda erythronotos*				-	0	-	0	-	-
Common Waxbill	*Estrilda astrild*				23	23	22	7	28	23
Blue Waxbill	*Uraeginthus angolensis*				67	42	5	2	2	-
Green-winged Pytilia	*Pytilia melba*				-	5	0	-	12	1
Red-billed Firefinch	*Lagonosticta senegala*				18	3	1	0	1	-
African Firefinch	*Lagonosticta rubricata*				2	4	2	1	2	-
Jameson's Firefinch	*Lagonosticta rhodopareia*				9	3	-	0	1	-
Bronze Mannikin	*Spermestes cucullata*				32	19	9	7	3	0
Pin-tailed Whydah	*Vidua macroura*				20	31	31	18	39	46
Long-tailed Paradise-Whydah	*Vidua paradisaea*				11	5	1	0	10	0
Shaft-tailed Whydah	*Vidua regia*				-	1	-	-	-	-
Village Indigobird	*Vidua chalybeata*				3	1	-	0	-	-
Dusky Indigobird	*Vidua funerea*				2	1	0	0	-	-
Purple Indigobird	*Vidua purpurascens*				-	-	-	-	1	-
Cuckoo Finch	*Anomalospiza imberbis*				-	1	1	0	-	-
House Sparrow	*Passer domesticus*		I		46	55	46	66	83	57
Great Sparrow	*Passer motitensis*				1	3	-	-	-	-
Cape Sparrow	*Passer melanurus*				52	74	91	90	66	93
Southern Grey-headed Sparrow	*Passer diffusus*				36	57	44	13	32	28
Yellow-throated Petronia	*Gymnoris superciliaris*				4	4	-	0	-	-

Common English Name	Scientific Name	Status Codes (see below)			SABAP1 reporting rate for QDGCs 25/2627					
		RD	S	E	DC	DD	BA	BB	BC	BD
African Pied Wagtail	*Motacilla aguimp*				5	2	-	0	3	1
Cape Wagtail	*Motacilla capensis*				48	62	74	76	79	77
Yellow Wagtail	*Motacilla flava*				-	2	-	-	-	2
Cape Longclaw	*Macronyx capensis*				37	34	53	17	52	56
Striped Pipit	*Anthus lineiventris*				1	-	-	4	-	-
African Pipit	*Anthus cinnamomeus*				17	22	22	6	57	31
Plain-backed Pipit	*Anthus leucophrys*				0	1	1	0	1	1
Buffy Pipit	*Anthus vaalensis*				-	2	2	1	1	1
Long-billed Pipit	*Anthus similis*				9	5	3	1	30	5
Bushveld Pipit	*Anthus caffer*				1	1	-	0	-	-
Cape Canary	*Serinus canicollis*				-	0	0	0	-	1
Yellow-fronted Canary	*Crithagra mozambica*				56	40	9	6	4	6
Black-throated Canary	*Crithagra atrogularis*				50	45	37	23	44	48
Yellow Canary	*Crithagra flaviventris*				-	-	3	0	26	11
Streaky-headed Seedeater	*Crithagra gularis*				36	19	12	19	12	21
Cinnamon-breasted Bunting	*Emberiza tahapisi*				27	11	8	10	28	6
Cape Bunting	*Emberiza capensis*				13	2	1	2	10	2
Golden-breasted Bunting	*Emberiza flaviventris*				15	6	2	0	-	0

Red Status	Status in south Africa (S)	Endemism in South Africa (E)
NA = Not Assessed	BM = breeding migrant	Endemism in South Africa (E) (not southern Africa as in field guides)
LC = Least Concern	NBM = non-breeding migrant	
NT = Near-Threatened	V = vagrant	* = endemic
VU = Vulnerable	I = introduced	
EN = Endangered	R = rare	(*) = near endemic (i.e. ~70% or more of population in RSA)
CR = Critically Endangered	PRB = probable rare breeder	B* = breeding endemic
EX = Extinct Regionally	RB = rare breeder	B(*) = breeding near endemic
NR = Not Recognised	RV = rare visitor	W* = winter endemic
Red Status is from *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland*, Taylor (2014).		

Map 16: Satellite image showing orange rectangles displaying the coordinates, location and extent of each of the 12 pentads from which bird species lists compiled for SBAP2 were extracted (also cf. Photo 10 above; Retief 2013). The two purple pentad grids in the center are the ones that cover the yellow polygon of the KGR, bisecting it at about the junction of the dolomitic and quartzite substrate, just south of the lion enclosure (small red polygon) (cf. Map 13).

Table 40: Table of bird species diversity reported during SABAP2 on the 12 pentads around the Krugersdorp Game Reserve, Gauteng (2627BA). Based on the national list and annotations of Birdlife South Africa (2014), sorted in the order of 'Roberts VII' (Hockey et al. 2005), with the reporting rate for each species and grid cell as an index of relative abundance within that species, after www.sabap2.org. (accessed September 2014; - where reporting rate <1, blank unrecorded). The grid cells are tabulated from north to south and west to east, to indicate the faunal crossroads around the KGR as evinced by the reporting rates of individual species, and the data for the grid cell containing the KGR is coloured purple. Note that additional species have been recorded for these areas but not within the SABAP1 project.

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Common Ostrich				31	35	57		23		4	6	1			2
Coqui Francolin				3	4	2			8	17	5	1			1
Crested Francolin				16							1		7		1
Red-winged francolin				3	9	2		2	14		4				2
Orange River francolin				3	13	5	32	26	5	30	22	19	57	14	8
Natal Spurfowl				38	9			2	1		1				5
Swainson's Spurfowl				31	52	50	53	56	45	52	30	1	50	14	5
Common Quail		NBM		3							1				1
Helmeted Guineafowl				38	74	90	95	88	95	96	88	86	86	86	75
Fulvous Duck											1		7		1
White-faced Duck				22	4	5	11	7	15	22	11		14	14	4
White-backed Duck				9			5				1			10	1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Maccoa Duck	NT,NT			3	4						4			57	2
Egyptian Goose				56	52	76	79	79	74	61	76	91	57	86	62
South African Shelduck							5			4	2	3	7		1
Spur-winged Goose				39	4	2	16			13	9		43	57	4
Cape Teal											2			5	1
African Black Duck				28	9	12	5	37	14	9	18	24		5	42
Mallard		I								4	3	6		14	4
Yellow-billed Duck				53	13	55	42	56	42	43	44	19	79	86	17
Cape Shoveler						2					6		7	52	3
Red-billed Teal				16	4		11	7		26	13	1	36	33	4
Hottentot Teal											4			43	2
Southern Pochard						2	5				2		7	9	1
Greater Honeyguide				19	4	5	5		1		1			5	2
Lesser Honeyguide				16					1	4	1			5	8
Brown-backed Honeybird				3	4						1				2
Red-throated Wryneck				9	4	2	11	19	24	4	15	14	7	5	21
Bennett's Woodpecker															
Golden-tailed Woodpecker				28		2			3	4	1				8
Cardinal Woodpecker				28				2	10		3				11
Bearded Woodpecker				3											
Yellow-fronted Tinkerbird				59		2		2	3		1				19
Acacia Pied Barbet				3		2		2	1		1	1			6
Black-collared Barbet				72	35	55	21	47	62	26	46	55	29	19	63
Crested Barbet				69	39	64	47	74	69	43	67	86	43	67	84
African Grey Hornbill				72	26	29		14	37	35	13	2			13
African Hoopoe				6	39	14	32	14	36	22	31	49	14	29	36
Green Wood-hoopoe				44		17	5	23	44	22	26	1	21		29
Common Scimitarbill								2	1		1				1
European Roller	NT,NT	NBM							1		1				
Lilac-breasted Roller						2		2			1				
Broad-billed Roller									1		1				
Half-collared Kingfisher	NT,LC					2									1
Malachite Kingfisher						7			5		2	2			2
Woodland Kingfisher		BM		9		12	5				1				1
Brown-hooded Kingfisher				22		14		14	13		5				21
Striped Kingfisher															
Giant Kingfisher				16		2		2	9		3	2			4
Pied Kingfisher				3	4	12	5		4	4	3		14	5	2
White-fronted Bee-eater				13	9			12			2				1
Little Bee-eater						2			5		1				
European Bee-eater		B/NBM		22	17	21		19	3	9	6	4		5	16
White-backed Mousebird								5			1				1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Speckled Mousebird				38	30	24	11	35	36	39	39	57	29	19	69
Red-faced Mousebird				59	30	31	42	56	45	30	52	76	21	48	56
Jacobin Cuckoo		BM		3				2			1	1			1
Levaillant's Cuckoo		BM		3	4			2			1				1
Red-chested Cuckoo		BM		22	22	17	5	14	9	13	9	8		5	23
Black Cuckoo		BM			4	7		7	1						8
Common Cuckoo															1
African Cuckoo		BM													1
Klaas's Cuckoo						2									3
Diderick Cuckoo		BM		16	26	33	11	28	24	22	18	10	14	19	27
Burchell's Coucal				3	4	7	11	9	9	9	8	10		5	15
Rose-ringed Parakeet		I					11				1				1
African Palm-Swift				25	17	45	11	54	28	39	32	35	7	19	39
Alpine Swift		BM			4	5				4	1				1
Common Swift		NBM									1	1			1
African Black Swift						2		5	4		3	5			15
Little Swift				3	17	21	16	16	3	9	14	13	14	29	25
Horus Swift											1	1	7	5	1
White-rumped Swift		BM		9	39	43	42	30	28	17	31	41	21	19	40
Grey Go-away-bird				59	35	45	11	33	81	43	55	81	14	33	76
Barn Owl				3	4		5		28	4	8	2			1
African Grass-Owl	VU,LC			3					1		1				
Spotted Eagle-Owl							5		13		16	43	7		7
Verreaux's Eagle-Owl															1
Pearl-spotted Owlet				22											
Marsh Owl				6		2	5	9	15	9	6				1
Fiery-necked Nightjar									1		1				1
Freckled Nightjar									3		1				1
Rufous-cheeked Nightjar		BM				2		7	17		5				1
European Nightjar									1		1				
Rock Dove				9	22	10	42	33	28	39	51	78	64	62	55
Speckled Pigeon				19	57	57	53	79	78	65	76	84	86	90	61
African Olive-Pigeon				6		5		14	4		4	4			18
Laughing Dove				75	78	93	100	93	95	91	96	97	100	100	95
Cape Turtle-Dove				75	69	50	95	70	77	87	85	93	100	95	86
Red-eyed Dove				75	70	71	89	67	60	74	78	90	93	90	92
Emerald-spotted Wood-Dove				3											1
Namaqua Dove				6	4	2	16	5			1				
African Green-Pigeon				6					1		1				1
Northern Black Korhaan				16	39	43		67	33	17	22	4	7	19	5
White-bellied Korhaan	VU,LC			9		7			4		1				
Blue Crane	NT,VU					2			5		1				
African Finfoot	VU,LC			6											
Red-chested Flufftail											1	1			1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
African Rail							37				4				2
African Crake		BM				2									
Black Crake						17	11	9	1	4	6	1		24	3
Baillon's Crake										4	1				
African Purple Swamphen					4	5	5				7	1	21	48	3
Common Moorhen				6	4	40	47	33	3	13	33	39	29	81	25
Red-knobbed coot				59	9	50	32	16	14	70	47	69	79	86	26
African Snipe				13				2	4	4	5		21		2
Common Greenshank		NBM						7	3		2				1
Wood Sandpiper		NBM		3			5	23		4	6		7		
Terek Sandpiper		NBM													2
Common Sandpiper		NBM				2			4		1				1
Little Stint		NB						2							1
Ruff		NBM						2			3		7		1
Greater Painted-snipe	VU,NT									4	1				
African Jacana											1	5			1
Spotted Thick-knee				6	22	10	26	28	46	26	44	76	14	24	33
Black-winged Stilt				3			11	5			4		7		1
Pied Avocet											1				1
Three-banded Plover				6		2	5	35	5		15	13	7	19	6
Blacksmith Lapwing				66	91	74	95	91	85	96	85	77	86	95	78
African Wattled Lapwing				9	43	67	26	81	77	30	69	83	79	10	69
Crowned Lapwing				50	87	74	100	91	85	91	88	84	93	91	73
Temminck's Courser							5	5		4	1	1			1
Grey-headed Gull							11	9	1		16	20	57	52	8
Whiskered Tern									1	9	3		7	5	1
European Honey-Buzzard		NBM						2			1				
Black-shouldered Kite				45	78	57	95	49	46	87	44	15	50	33	24
Black Kite		NBM				12		2			1		3		
Yellow-billed Kite		BM			4	15		5			1		4		1
African Fish-Eagle				3											
White-backed Vulture	EN,EN					5									
Cape Vulture	EN,VU			44	39	76		9	1		1				
Black-chested Snake-Eagle					9	7		9	3		2			5	1
Brown Snake-Eagle				3	13										
African Marsh-Harrier	EN,LC														1
African Harrier-Hawk				3	4	2			3		1	2			1
Gabar Goshawk						5		2							1
Shikra				3							1	1			1
Little Sparrowhawk							5	7			1	1			2
Ovambo Sparrowhawk				3		2		5	1	4	1				2
Black Sparrowhawk				3	4	2			3	13	2				2
Steppe Buzzard		NBM		6	17	14	5	12	5	6		3	14		10
Jackal Buzzard			(*)		4				1						1
Tawny Eagle	EN,LC					2									
Verreaux's Eagle	VU,LC							5	3	4	3	3			46

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
African Hawk-Eagle															1
Wahlberg's Eagle		BM													1
Long-crested Eagle				3		7					1			5	1
Secretarybird	VU,VU							2			1				
Lesser Kestrel		NBM		3				2			1				
Rock Kestrel						2				4	1			10	1
Greater Kestrel						2		2			1				1
Amur Falcon		NBM		9	17	7	16	26	3	22	10	3	7	24	1
Eurasian Hobby		NBM													1
Lanner Falcon	VU,LC					2									1
Peregrine Falcon															4
Little Grebe				59	13	36	16	5	17	35	26	29	29	76	30
Great crested Grebe					4										1
African Darter				3	4	29	11		14	9	9	9	7	24	9
Reed Cormorant				50	17	50	47	19	49	39	39	32	36	86	41
White-breasted Cormorant				3	4	2	21		17	4	12	14		29	7
Black Heron											1	2			1
Little Egret				6		2	16	5	3	17	5				2
Yellow-billed Egret					4	2	5				1		7		
Great Egret							5				2		36	5	1
Grey Heron						29	53	19	8	13	19	1	43	57	9
Black-headed Heron				34	61	62	84	53	24	82	48	28	86	81	25
Goliath Heron					4	17			4		1	1		5	1
Purple Heron						7			1	17	7	3	21	33	5
Cattle Egret				31	78	90	79	77	73	74	65	51	64	57	38
Squacco Heron											3	1		14	1
Green-backed Heron				3			5		8		3			10	9
Black-crowned Night-Heron						2					3			19	2
Little Bittern											1				1
Hamerkop				9	4	5	16	14	10	13	9	8		5	8
Greater Flamingo	NT,LC										1			19	1
Lesser Flamingo	NT,NT										1				1
Glossy Ibis					4	2	37	35	12	30	22	2	36	43	8
Hadeda Ibis				69	78	88	89	98	85	87	92	99	93	100	96
African Sacred Ibis				19	9	83	84	81	53	43	60	53	71	52	33
African Spoonbill				3			11		1		1				1
Black Stork	VU,LC					7									
Abdim's Stork	NT,LC	NBM				5		19			2				
White Stork		NBM		3	9	2	5	7	3		2			5	1
Marabou Stork	NT,LC							2			1				
Eurasian Golden Oriole		NBM		3											1
Black-headed Oriole				31	13	2	26	7	12	26	9	1		14	27
Fork-tailed Drongo				44	22	10		7	4	57	6			10	1
African Paradise-Flycatcher				25	9	7		7	3		3	35			24
Brubru								2	3		1				1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Black-backed Puffback				25		2		5	1		2				22
Black-crowned Tchagra				34	43	21		32	19	9	12	10			10
Brown-crowned Tchagra				28		5		5	3	4	2	2			6
Southern Boubou				69	48	41	16	30	10	35	17	14	7		63
Crimson-breasted Shrike				9	4	7			8		2				2
Bokmakierie				53	91	52	53	58	42	57	51	59	64	29	54
Orange-breasted Bush-Shrike				9		2									1
Grey-headed Bush-Shrike				13	4	2		2	1		1				5
White-crested Helmet-Shrike				3											
Chinspot Batis				36		7		7	23		8	2			12
Pied crow				31	70	95	32	42	68	57	50	61	36	19	68
Red-backed Shrike		NBM				10		2	1	4	1				1
Lesser Grey Shrike		NBM			4	5		2		4	1				1
Common Fiscal				56	100	88	95	95	99	100	95	94	100	86	92
Black Cuckooshrike				22							1				10
Southern Black Tit				19											
Ashy Tit															1
Sand Martin		NBM									1				1
Brown-throated Martin				3		7	5	28	9		11	4		19	7
Banded Martin				16	9	19		9		9	4		21	5	1
Barn Swallow		NBM		22	35	52	21	49	29	43	33	21	36	33	24
White-throated Swallow		BM		22	35	38	47	35	36	17	27	17		29	22
Pearl-breasted Swallow				6		24		16	8		4				1
Greater Striped Swallow		BM		34	57	67	32	58	38	57	51	63	43	33	52
Lesser Striped Swallow		BM		6	4	31		21	17	13	8	1			7
Red-breasted Swallow				3	4	24		2	1		1				
South African Cliff-Swallow			B(*)	3		2		2		4	1	1		5	1
Rock Martin				13		14		26	8	9	17	29	14	14	38
Common House-Martin		NBM				2		2		4	1	1			1
Dark-capped Bulbul				97	87	100	63	88	96	78	86	93	78	81	93
African Red-eyed Bulbul								2		4	1				1
Fairy Flycatcher			(*)		4	7			3		1	1			11
Cape Grassbird			(*)	34	13	2	5	14	4	13	6	4			1
Long-billed Crombec				9		2		2			1				2
Little Rush-Warbler						17	11	5	1	4	5			24	5
African Reed-Warbler		BM				7	16	14		9	6	4		5	3
Marsh Warbler		NBM			4	5		7			1	1			1
Great Reed-Warbler		NBM				10					1			5	1
Lesser Swamp-Warbler				9	4	12	32	5		9	16	10		67	13
Icterine Warbler		NBM													1
Willow Warbler		NBM		9		2		2	43	13	6	7	7	5	13
Arrow-marked Babbler				63	39	5	5	12	3		5				1
Chestnut-vented Tit-Babbler				9				2	27		6				1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Garden Warbler		NBM													2
Cape White-eye			(*)	72	39	57	26		49	35	52	68	14	48	77
Lazy Cisticola				21		2		5	3		2	3		5	5
Rattling Cisticola				3		2			3		1	1			1
Wailing Cisticola				3	26	14		2	1	9	2	1			6
Levaillant's Cisticola				47	26	24	68	60	32	47	50	39	57	71	27
Neddicky				41	48	45	16	47	26		31	26	50	38	32
Zitting Cisticola				31	35	45	16	44	38	48	34	22	35	43	19
Desert Cisticola				6	4	7	5	9	4	13	6	1	7	14	2
Cloud Cisticola			(*)	9	9	36	16	37	4	26	17	3	36	38	5
Wing-snapping Cisticola				6	9	19	5	21	24	13		1	7	10	2
Tawny-flanked Prinia				59	57	57	32	60	49	35	40	37	14	33	65
Black-chested Prinia				34	30	33	21	30	12	22	20	18	29	19	24
Bar-throated Apalis				34	9	5		7	4		6	7			44
Grey-backed Camaroptera				6		2									
Barred Wren-Warbler															
Monotonous Lark															
Melodious Lark	LC,NT		(*)				5	2	1		2	1		10	1
Rufous-naped Lark				25	52	62	63	67	40	65	44	16	57	48	13
Flappet Lark				6											
Eastern clapper Lark				3		7	5	12	1	9	5			19	2
Sabota Lark									1		1				1
Fawn-coloured Lark															
Dusky Lark		NBM													
Spike-heeled Lark				3			5				5	2	7	14	2
Eastern Long-billed Lark			(*)								1	1			1
Chestnut-backed Sparrowlark										4	1				
Red-capped Lark				3			5	14		13	6		57	5	1
Cape Rock-Thrush			(*)	13				5			2				7
Short-toed Rock-Thrush								2			1				
Groundscraper Thrush				22	30		16	5	8	57	11	6	21	5	2
Kurrichane Thrush					9	17		2	3	17	4	4			48
Karoo Thrush			(*)	13		19	26	30	36	35	51	90	21	76	80
Marico flycatcher								2			1				
Southern Black flycatcher				16				2			1				1
Fiscal Flycatcher			(*)	25	52	36	16	28	52	13	35	34	21	19	50
Spotted flycatcher		NBM		13	4	12		2	6		3				13
Grey Tit-flycatcher				13											
Cape Robin-Chat				50	22	50	58	63	56	35	62	87	36	43	82
White-browed Scrub-Robin				3	4	2			1		1				1
Kalahari Scrub-Robin								2			1				1
African StoneChat				59	65	88	63	67	58	61	53	19	29	95	23
Mountain Wheatear					9	38	5		15		21	52		24	11
Capped Wheatear				6	35	26	47	14	1	22	11	1	36	29	3
Familiar Chat				22	30	60		5	54		16	7	14	5	5
Ant-eating Chat				22	9	38	11	12	3	30	9	2	14	19	2

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Mocking cliff-Chat				9		26		30	9		6	1			
Red-winged Starling				41	35	29		28	32	13	18	17		19	44
Cape Glossy Starling				25	43	74	53	60	83	61	70	88	57	43	67
Violet-backed Starling				16		2									2
Pied Starling			(*)	3		5	11	23	12	48		8	29	76	14
Wattled Starling					4		21	2	1	4	7		43	43	2
Common Myna		I		38	87	93	89	72	90	96	88	94	93	95	89
Amethyst Sunbird				34	22	33	11	33	54	26	33	37	14	14	46
Malachite Sunbird				9				2			3	8			13
Greater Double-collared Sunbird			(*)	6	26	2		2	3		1	1			16
White-bellied Sunbird				56	35	12	5	28	22	9	22	28	7	14	61
Marico Sunbird					4						1				1
White-browed Sparrow-Weaver					17		58	47	62	48	32		36	14	4
Cape Weaver			(*)	19	9	21	5	2	17		9	9	7	5	40
Southern Masked-Weaver				81	83	98	100	93	96	100	96	95	79	95	96
Village Weaver									1		1	1			1
Red-billed Quelea				16	9	17	47	9	21	39	13	1	7		2
Yellow-crowned Bishop				9	17	12	16	12	6	22	12	4	14	29	6
Southern Red Bishop				25	35	76	58	63	35	52	59	67	57	67	68
White-winged Widowbird				25	39	43	42	35	17	52	15	2		5	2
Red-collared Widowbird				28	39	33	5	40	28	26	24	23		10	24
Long-tailed Widowbird				44	22	43	26	47	28	52	35	3	93	52	11
Thick-billed Weaver				3	9	14	5	12	4	9	19	43		33	29
Orange-breasted Waxbill				6			11		1		4	6		10	3
African Quailfinch				34	13	26	26	44	5	52	20		71	14	4
Red-headed Finch						2	11	7	12	13	21	45	7	29	19
Cut-throat Finch									1		1				
Common Waxbill				34	22	12	11	26	17	17	21	18	7	29	12
Violet-eared Waxbill															1
Blue Waxbill				19	4			5	3	4	2				1
Green-winged Pytilia				3											
Red-billed Firefinch							5			4	1				
African Firefinch				6			11		3		1				1
Jameson's Firefinch				19				7	3		1				1
Bronze Mannikin				3					5		1				9
Pin-tailed Whydah				19	22	36	32	28	28	39	24	10	36		12
Long-tailed Paradise-Whydah											1				1
Purple Indigobird				6											1
Cuckoo Finch						2									1
House Sparrow		I		22	13	50	37	21	40	30	42	49	35	86	32
Cape Sparrow				28	96	69	100	81	78	96	90	99	100	90	92
Southern Grey-headed Sparrow				35	61	62	37	47	71	70	38	18	21	14	24
Yellow-throated Petronia				3				2			1				
African Pied Wagtail															1

Common English Name	Status Codes (see below)			SABAP2 reporting rate for 16 pentads 2555-2735 to 2610-2745											
	RD	S	E	2555-2735	2555-2740	2555-2745	2600-2735	2600-2740	2600-2745	2605-2735	2605-2740	2605-2745	2610-2735	2610-2740	2610-2745
Orientation				NW	NC	NE	W	C	E	W	C	E	SW	SC	SE
Cape Wagtail				19	35	50	58	63	50	35	60	72	36	86	66
Yellow Wagtail								2			1				
Grey Wagtail		V													2
Cape Longclaw				50	65	57	63	77	45	61	45	6	86	48	12
Striped Pipit				3	4			5	4		4				4
African Pipit				34	57	69	74	72	27	70	38	6	79	33	9
Plain-backed Pipit				9	13	7	5	7		13	2				1
Buffy Pipit				6		10		2	4		2			10	1
Long-billed Pipit				13	13	14		7	4		2			5	2
Yellow-fronted Canary				25	17	12		5	8	9	4	1			17
Black-throated Canary				25	48	38	42	56	24	52	28	12	36	29	15
Yellow Canary				13	4				1		1				1
Streaky-headed Seedeater				22	30	29		28	14		10	7			31
Cinnamon-breasted Bunting				16	22	12		14	5		8	11	7	10	12
Cape Bunting					4	2		2	3		1	1			1
Golden-breasted Bunting				19	9			2	1	4	1				

Red Status	Status in south Africa (S)	Endemism in South Africa (E)
NA = Not Assessed	BM = breeding migrant	Endemism in South Africa (E) (not southern Africa as in field guides)
LC = Least Concern	NBM = non-breeding migrant	
NT = Near-Threatened	V = vagrant	* = endemic
VU = Vulnerable	I = introduced	
EN = Endangered	R = rare	(*) = near endemic (i.e. ~70% or more of population in RSA)
CR = Critically Endangered	PRB = probable rare breeder	B* = breeding endemic
EX = Extinct Regionally	RB = rare breeder	B(*) = breeding near endemic
NR = Not Recognised	RV = rare visitor	W* = winter endemic
Red Status is from The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland, Taylor (2014).		