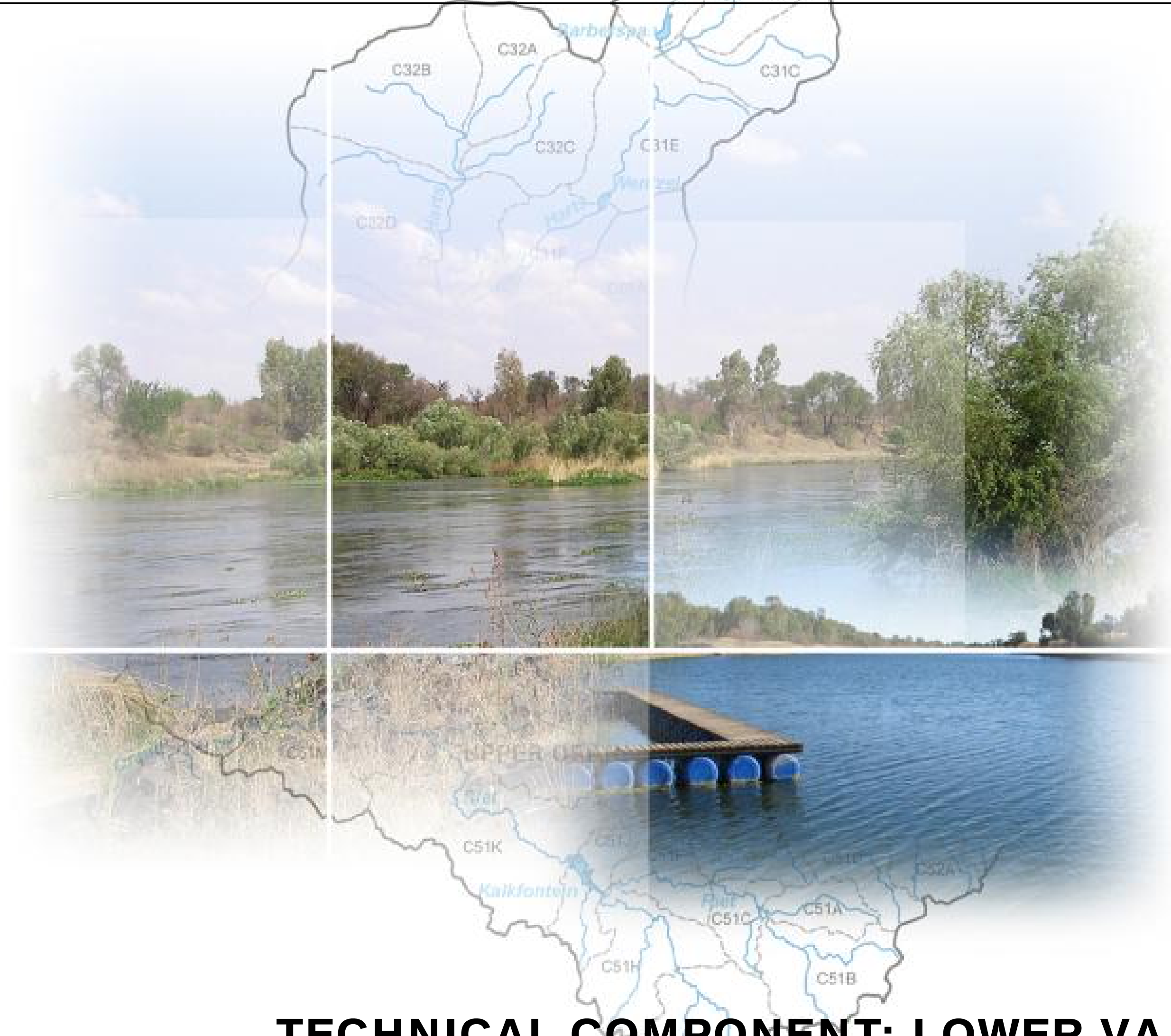
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

WETLANDS/PANS ASSESSMENT



TECHNICAL COMPONENT: LOWER VAAL

REPORT NO.: RDM/WMA10/10C000/01/CON/0209

PROJECT NO.: 8829/1

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This report should be cited as:

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study for the integrated Vaal River System, Middle and Lower Vaal Comprehensive Reserve determination: Surface Water Wetland/Pans Assessment report. Report no: RDM/ WMA10/10C000/ 01/CON/ 0209. Pretoria, South Africa.

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ACKNOWLEDGEMENTS

The following individuals are thanked for their contributions to the document

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EXECUTIVE SUMMARY

The Department of Water Affairs and Forestry (DWAF) is the custodian of all South Africa's water resources, including wetlands. Wetland Reserve (environmental flow determination) studies are increasingly required to be undertaken by or on behalf of DWAF (Wet-priorities).

This study should be seen and read in collaboration with the Comprehensive Vaal River Ecological Reserve determination studies undertaken on the main water courses in the Vaal catchment and the wetlands associated closely with these water courses.

This study intends to prioritize wetlands and pans in the Lower and Upper Vaal River Catchments, especially those that provide essential goods and services (directly or indirectly) to the area. Other aspects that will contribute towards prioritizing of wetland systems were also taken into account:

- Wetlands with high conservation values;
- Wetlands functional attributes (goods and services);
- The wetlands that are ecologically important;
- The present health and integrity of wetlands (threats); and
- Representative wetlands of the area.

This study identified 347 699 wetlands in the Middle and Lower Vaal Catchment areas. All six palustrine wetland types occur in the study area. Pans and dolomitic eyes were some of the more important wetland types indentified in the catchment areas.

According to this study pans are fairly widespread in the study area, although they occur in clumps in some areas. Most pans in the study area are inundated ephemerally and irregularly. Pans in the study area tend to be large, dry, and floodplain-like features, elongated along river courses.

The study also identified ground water driven eye systems, such as the Kuruman Eye and the Ventersdorp Eye. These eyes are unique in that it is influenced by karst and fed by perennial dolomitic springs, which supply a constant source of groundwater into wetland systems downstream. These wetlands are hydraulically isolated from most of the main river channels they feed into and are not influenced by any flood events in the rivers. Hydrological regimes in these wetland types are not characterized by extreme hydrological disturbances such as floods that would have created a distinctive channel with a mosaic of different habitats and associated plant species. The occurrence of peat in these systems also demonstrates that they have been perennially inundated for many years and been subjected to a very stable low energy hydrological regime.

Through an extensive process of criteria application, the study identified and listed 13 wetlands of importance. Identified wetlands were presented in a workshop with the specialist whereby the proposed list of priority wetlands was discussed and adapted according the specialists' experience in the field. These candidate wetland sites for determining an Ecological Reserve should occur in areas where impacts on the aquifer is high and the aquifer is vulnerable to drought (Marneweck, 2006). The level of determining the Reserve is still to be determined. However, given the possible groundwater component of these systems, further refinement of existing Reserve determination methods would be required. Then, reserve studies can be undertaken at the selected wetland sites. Further infield verification will be necessary and should include Ecological Integrity and Sensitivity (EIS) Category assessments and Wetland Habitat Integrity (PES) assessment where applicable; this information will add value to future Ecological Reserve assessments.

ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry
NLC	National Land Cover
NSBA	National Spatial Biodiversity Assessment
PES	Present Ecological Status
SANBI	South African National Biodiversity Institute
WRC	Water Research Commission

GLOSSARY

Anaerobic	Without air.
Biodiversity	The variety of life: the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part.
Catchment	Area from which rainfall flows into river.
Clastic	Composed of broken fragments that have been derived from pre-existing rocks by weathering and erosion and transported some distance from their place of origin.
Denitrification	Conversion of nitrate to nitrogen gas. Denitrification is a natural process carried out by many microorganisms when sufficient oxygen is lacking. Instead of using oxygen as the final electron acceptor in metabolism nitrate is used.
Dolomitic eyes	Water bodies fed by groundwater originating from fractures in the underlying dolomite.
Endorheic	Closed (no outlet) nature of the drainage system of pans.
Eutrophication	A process where water bodies receive excess nutrients that stimulate excessive plant growth
Exotic	From another part of the world; foreign.
Fens	System sustained by surface and groundwater, but also by the influx of lateral drainage from surrounding areas as well as precipitation.
Geology	The study of the composition, structure, physical properties, dynamics, and history of Earth materials, and the Processes by which they are formed, moved, and changed.
Hydro-geomorphic	Refers to the water source and geology forms.
Invasive	Any species of insects, animals, plants and pathogens, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.
Karst	Karst is a distinctive topography in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock (usually limestone, dolomite, or marble).
Limestone	Common sedimentary rock of biochemical origin. It is composed mostly of the mineral calcite.
Lotic	Refers to moving water.
Mires	Peatlands where peat is actively being formed and accumulating.
Palustrine	Relating to a system of inland non-tidal wetlands characterized by the presence of trees, shrubs and emergent vegetation.
Pan	Pans are shallow, usually seasonal bodies of open water; often circular and not directly connected to river systems by surface flow. Essentially they are internally draining systems that may contain either fresh or saline water depending on local soil conditions. They

	may be temporary or perennial. Pans on different soils and at varying altitudes have substantially different ecological characteristics.
Peat	Dead and partially decomposed plant remains that have accumulated in situ as a result of being waterlogged.
Peatlands	Landscape with a layer of peat on the surface of at least 30-cm in depth.
Pedology	The branch of soil science that treats soils and all their properties as natural phenomena.
Perennial	Persisting for several years usually with new herbaceous growth.
Phreatic caves	Layer(s) of soil or rock below the water table in which voids are permanently saturated with groundwater.
Ramsar	An international treaty for the conservation and sustainable utilization of wetlands.
Riparian	Interface between land and a stream.
Saline	Water containing significant concentration of salts.
Topographical maps	Detailed description of land features shown on a map.
Topography	Detailed description of land features.
Volatilization	Change from solid or liquid to gas.
Wetlands	Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface.

1. BACKGROUND TO THE STUDY AREAS

1.1. Middle Vaal WMA

The Middle Vaal WMA forms part of the Orange River watercourse. It covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System in which water is being transferred *via* the Vaal River through to Bloemhof Dam (DWAF[1], 2007). The Middle Vaal WMA comprises eight tertiary-catchments as listed in Table 1. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments. The location and general layout of the WMA is depicted in **Appendix A.**

Table 1: Sub-catchments and related quaternary drainage regions within the Middle Vaal WMA

Primary catchment	Sub-catchment areas	Quaternary catchments	Average gross area (Km^2)
C	Renoster	C70A-K	6656
	Vals	C60A-J	7871
	Schoon Spruit	C24C-G	5644
	Middle Vaal	C24A-B, C24H-J, C25A-C	8281
	Bloemhof	C25D-F	4959
	Allemanskraal	C42A-E	3628
	Erfenis	C41A-E	4724
	Sand	C42F-L	3927
	Vet	C41F-J, C43A-D	6873

The climate in the Middle Vaal WMA can vary considerably from west to east. The average temperature for the WMA is 16˚C, with the mean annual temperatures ranging between 18˚C in the west to 14˚C in the east. Mean annual precipitation per year ranges between 500mm in the west and 700mm in the east of the WMA as shown in **Appendix C**. Mean annual evaporation ranges from 1800mm in the east to a high of 2600mm per year in the dry western parts of the WMA, and is well in excess of rainfall (DWAF[1], 2007).

The western parts of the WMA are characterised by pans and other drainage regions such as the Sand River, Groot Vet River, Heuningspruit, Elandspruit, etc. The WMA is dominated by the "pure grassveld" veld type with sparse bushveld in patches. The northern areas have some regions of "false grassveld", while the area upstream of Bloemhof Dam includes some "tropical bush and savanna". Maize, wheat and fodder crops are the main crops in the WMA (DWAF[1], 2007).

Current land use in the WMA is characterised by extensive dry land cultivation in the central parts of the WMA. The largest urban areas are Welkom, Klerksdorp (North West Goldfields) and Kroonstad (Free State Goldfields). Irrigation is practiced downstream of dams and along the main tributaries and at locations along the Vaal River. The WMA is characterised by a large number of goldmines (DWAF[1], 2007).

The Middle Vaal WMA's water quality and flow is mainly controlled by activities that take place in the upper Vaal WMA. The Middle Vaal WMA is dependent on the Upper Vaal WMA for meeting the bulk water requirements of its mining, industrial and urban sectors. Large quantities of water are transferred into the WMA to augment local water resources. These upstream activities include releases from the Vaal Dam and Vaal River Barrage, waste water treatment works discharges, urban runoff and gold mining activities on the Witwatersrand. In the middle Vaal WMA discharges and decants from gold mining activities in the Mooi and Koekemoer Spruits have an impact on the continued salinity build up in the Vaal River. These impacts are subject to many catchment studies that have been undertaken by DWAF as well as a current Integrated Water Quality Management Plan for the Vaal River system. Management of water quality and quantity in the Middle Vaal WMA is therefore integrally linked to both the Upper and Lower Vaal WMAs.

The Middle Vaal WMA is rural in nature with the land use typically characterised by extensive livestock farming, dry land agriculture and some irrigation farming **(Appendix C)**. The economy of the Middle Vaal WMA contributes about 4% of the GDP of South Africa with the most dominant economic activity being the mining sector, contributing more than 45% of the GDP in the WMA, trade (12,3%), and agriculture (8,9%) (DWAF, 2003). Due to a decline in gold mining activity, a decline in population is also projected for the WMA, with a concomitant effect on the regional economy. Manufacturing activities in the WMA relate to the mining and agriculture sectors as well as items for local consumption. No dramatic changes to the economy of the WMA are foreseen for the medium term. The agricultural sector in the region is relatively stable and will continue to make an important contribution to the regional economy. A minimal change in water requirements is therefore projected (DWAF[1], 2007).

1.2. Lower Vaal WMA

The Lower Vaal WMA covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment and the Vaal River catchment. These two catchments as part of the Vaal River System cover a catchment area of 53 500km^2 within the Lower Vaal WMA (DWAF[2], 2007). The C drainage region of the Lower WMA comprises four sub-catchments as listed in **Table 2**. The location and general layout of the WMA is depicted in **Appendix B.**

Table 2: Sub-catchments and related quaternary drainage regions of the C Drainage primary catchment within the Lower Vaal WMA

PRIMARY CATCHMENT	SUB-CATCHMENT	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (Km^2)
C	Dry Harts	C32A-D	10 205
	Harts	C31A-F	11 023
	Vaalharts	C33A-C	9843
	Vaal downstream Bloemhof	C91A-E, C92A-C	22 427

The average temperature for the WMA is 16˚C. The rainfall is strongly seasonal occurring mainly in the summer months. Mean annual rainfall precipitation ranges between 100mm in the west and 500mm to the east of the WMA (**Appendix C**). Mean annual evaporation can reach as high as 2800 mm per year which is in excess of rainfall. The WMA has no climatic barriers and thus climate varies gradually according to the larger regional patterns, and is fairly uniform from east to west (DWAF[2], 2007).

The WMA has relatively flat terrain with no distinct topographic features (**Appendix E**). As a result of the arid climate, vegetation over the WMA is sparse, consisting mainly of grassland and some thorn trees (notably the majestic camel thorns). The WMA is dominated by tropical bush and savannah with small areas of pure grassveld to the east (DWAF[2], 2007) as indicated in **Appendix F**.

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River, joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area (DWAF[2], 2007).

Most of the water is used for urban, agricultural and mining purposes within the WMA. Water is also transferred into the WMA from the Upper Orange WMA into Douglas Weir.

The water quality of the rivers in the WMA is of acceptable quality, but do exhibit high turbidity at times. Current land use in the WMA, due to the arid climate is characterised by extensive livestock farming as the main activity and large scale dry land cultivation in the north eastern part of the WMA. Intensive irrigation (about 80% of water use) is practised at Vaalharts, as well as at locations along the Vaal River. The most significant urban area in the WMA is Kimberley to the South. Several towns as well as scattered rural settlements are found mainly in the central and eastern part of the WMA. Iron ore, diamonds and manganese are mined in the WMA (DWAF[2], 2007).

The economy of the Lower Vaal WMA is relatively small, with the WMA generating about 2% of the Gross Domestic Product of South Africa (DWAF, 2003). The economy is still dominated by mining, however much of the beneficiation is done in other areas. Most of the economic activity is concentrated in Kimberley and at other major mining areas. Manufacturing activities in the WMA include cement and cheese factories and relate to the agriculture sectors as well as items for local consumption. The trade sector is concentrated in wholesale of primary products and related services to the community. No significant changes to the economy of the WMA are foreseen over the medium term. The agricultural and mining sectors in the region are strong and will continue to make an important contribution to the regional economy (DWAF[2], 2007).

2. TERMS OF REFERENCE

The terms of reference of this study as per the Inception Report is to study conditions of wetland/pans in the study area.

The brief is set out as:

- Review existing information that can contribute to the identification of wetlands and to the extent thereof in the study area.
- Identify and prioritize pans/wetlands of importance for Reserve determination in terms of the following:

- Conservation
- Water use
- Threats
- Abundance
- Health
- Function
- Importance
- Sensitivity
- Present state.

- Compile a priority list of the most important wetland and pans from which the final selection can be done for which future rapid or higher level reserve determinations will be determined (the actual Reserve determinations for these wetlands and pans do not form part of the scope for this study).

3. APPROACH

The intent of this report is to give a broad scope of the wetlands and pans in the study area and prioritize those that require further detailed assessment. No field verification was done and the data information is based on desktop studies. No detailed approach existed and several workshops were held to formulate it.

3.1. Desktop Methodology

To locate wetlands and pans, data from the National Spatial Biodiversity Assessment (NSBA) and the South African National Biodiversity Institute (SANBI) was used. Data from the National Land Cover 2000 (NLC 2000) was used as a tool to guide wetland and pan identification and on screen delineation.

The DWAF Rivers shape file was then overlaid with the Wetland Probability shape file (NLC2000). All the wetlands that intersect with rivers were removed from the Wetland Probability shape file. To do this a 100m buffer was generated around rivers and all wetlands within this buffer or intersected with the buffer were removed from the Wetland Probability shape file. Thus the wetlands that fell within river channels and their surroundings were excluded. These areas will be addressed by the monitoring points in the river.

Environmental Impact Studies on some of the wetlands provided valuable information, especially those related to dolomitic eyes in the study area. Ramsar status information (Ramsar, 1975) and Important Bird Areas (Barnes, 1998) information was very useful in providing biodiversity data. After GIS buffer analysis the wetland size, biodiversity as well as desktop information was used to prioritize the wetlands to a list of 22 wetlands and pans. The 22 wetlands and pans were described and discussed in a workshop attended by wetland specialists, officials of the Department of Environmental Affairs and Tourism and the Department of Water Affairs and Forestry held during 14 November 2007 in Parys.

Site knowledge was used to add wetlands and pans or remove wetlands and pans from the list until a shortlist of priority wetlands for further study and investigation was produced. This list will be proposed in this document for further investigation.

3.2. Classifying the wetlands

Wetlands and pans are described in terms of their position in the landscape, and the classification was done according to its hydro-geomorphic setting (Kotze, Marneweck, Batchelor, Lindley & Collins, 2004).

Due to the course nature of this research, the lack of substantial data and very little ground truthing opportunity, a detailed classification was not viable. A general description of the wetlands and pans that can be expected in the catchments is based on a rough delineation and assessment exercise. By making use of the scoring system in Wetland-Assess the generic expected goods and services of the wetland types are described and discussed.

3.3. Current status of the wetlands

Since no baseline information on the status of these wetlands and pans is available, a generic attempt in assessing the current status or integrity of the wetlands was done. Basic principles of the Present Ecological Status (PES) were used to give guidance in this regard (WRC, 2008). Further, the procedure for determination of Resource Directed Measures for Wetland Ecosystems (DWAF, 1999) provided the basic criteria followed.

Land use activities in and around the different types of wetlands was used to make assumptions from and to supplement findings.

3.4. Requirements for wetland Reserve determination in the Middle and Lower Vaal River Catchments

The Department of Water Affairs and Forestry (DWAF) is the custodian of all South Africa's water resources, including wetlands. Wetland Reserve (environmental flow determination) studies are increasingly required to be undertaken by or on behalf of DWAF (Wet-priorities).

Wetlands and pans need to be prioritized, especially those that provide essential goods and services (directly or indirectly) to the area. Other aspects that will contribute towards prioritizing of wetland systems for this purpose would be:

- Wetlands with high conservation values;
- Wetlands functional attributes (goods and services);
- Wetlands that are ecologically important;
- Present health and integrity of wetlands (threats); and
- Representative wetlands of the area.

4. FINDINGS

4.1. Wetland Types and distribution

For this report a wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt (Ewart-Smith, Ollis, Day and Malan. 2006).

Palustrine wetlands do occur in the study area and refers to non-tidal wetlands dominated by emergent plants (e.g. reeds), shrubs or trees and includes a variety of systems commonly described as marsh, floodplain, vlei or seep (Ewart-Smith, *et al.* 2006).

A total of 347 699 palustrine wetlands and pans were identified in the Middle and Lower Vaal Catchment areas (Figure 1). All six palustrine wetland types occur in the study area: floodplain, valley bottom with a channel, valley bottom without a channel, hill slope seepage feeding a watercourse, hillslope seepage not feeding a watercourse and depressions that includes pans. These wetland types are discussed in

and its relation to the topography of the area is indicated in **Figure 2**. This classification is based on their hydro-geomorphic setting (Kotze, et al, 2004).

Although pans conform to the requirements of the wetland definition they do differ from the rest of the palustrine wetlands in that they normally are in a basin shaped area that increases in depth from the perimeter to a central area of greatest depth (may be flat-bottomed or round-bottomed) where water typically concentrates. They are endorheic in that inward-draining is taking place with no surface transport of water into downstream systems via channeled outflow and/or overland flow (Ewart-Smith, *et al.* 2006).

Allan, Seaman & Kaletja (1996) gives an overview of several pan types in South Africa on the basis of physical characteristics and faunal and floral composition. These include salt-pans, temporary pans, grass pans, sedge pans, reed pans and semi-permanent pans. Most of these pans occur in the study area.

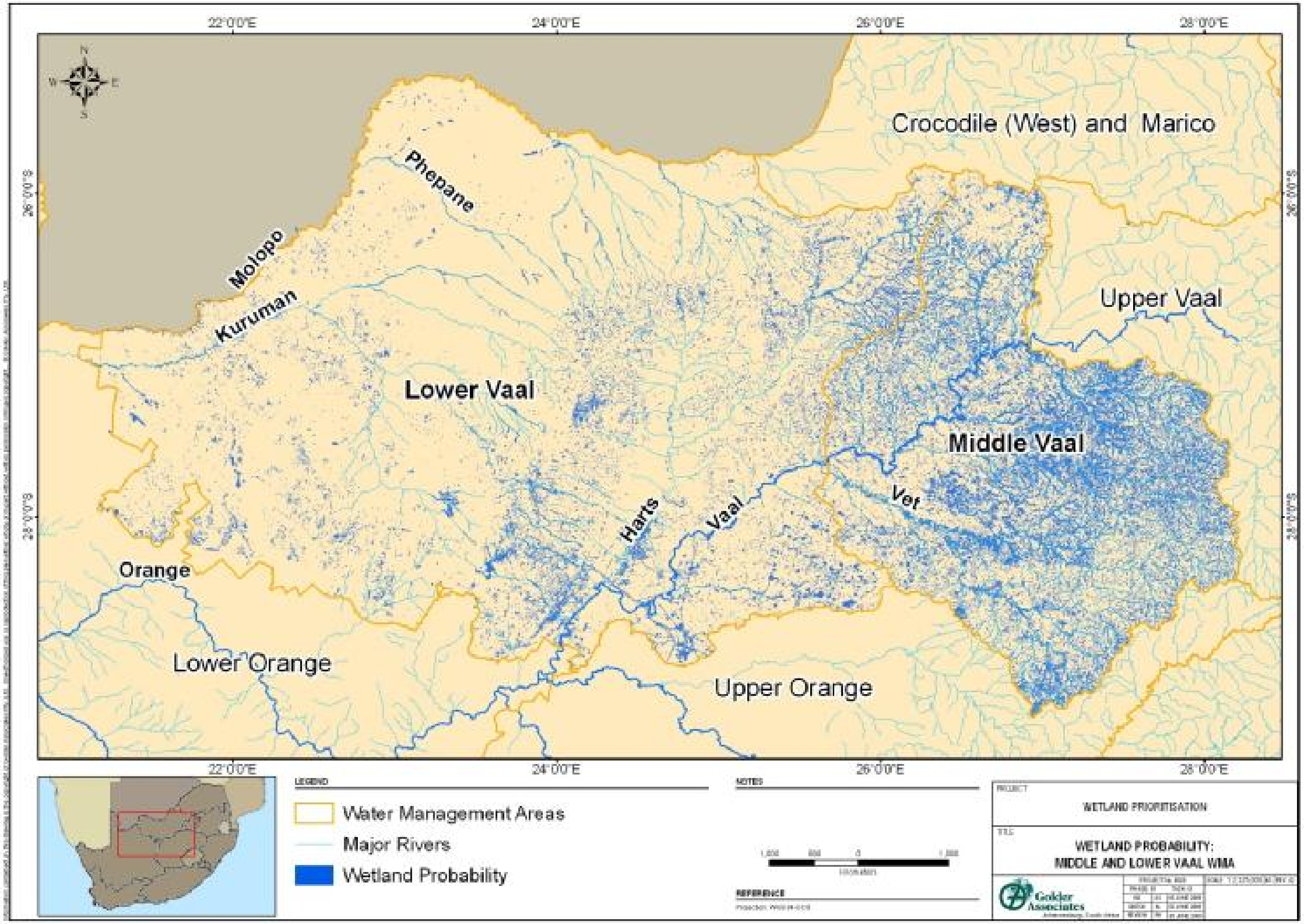
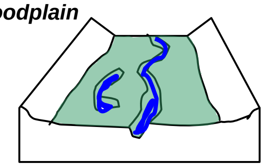
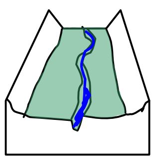
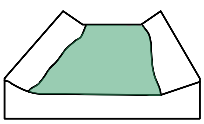
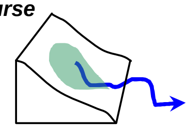
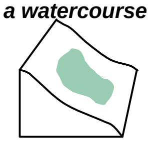
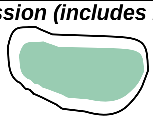


Figure 1: Map indicating wetlands and pans occurring in the Middle and Lower Vaal river catchments

Table 3: Wetland hydro-geomorphic types found in the study area (modified from Brinson, 1993; Kotze, 1999; and Marneweck and Batchelor, 2002)

Hydro-geomorphic types	Description	Source of water maintaining the wetland	
		Surface	Sub-surface
Floodplain 	Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*
Valley bottom with a channel 	Valley bottom areas with a well defined stream channel but lacking characteristic floodplain features. May be gently sloped and characterized by the net accumulation of alluvial deposits or may have steeper slopes and be characterized by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*/ ***
Valley bottom without a channel 	Valley bottom areas with no clearly defined stream channel, usually gently sloped and characterized by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.	***	*/ ***
Hillslope seepage feeding a watercourse 	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from subsurface flow and outflow is usually via a well defined stream channel connecting the area directly to a watercourse.	*	***
Hillslope seepage not feeding a watercourse 	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs mainly from subsurface flow and outflow either very limited or through diffuse subsurface and/or surface flow but with no direct surface water connection to a watercourse.	*	***

Hydro-geomorphic types	Description	Source of water maintaining the wetland	
		Surface	Sub-surface
Depression (includes Pans) 	A basin shaped area with a closed elevation contour that allows for the accumulation of surface water (i.e. it is inward draining). It may also receive sub-surface water. An outlet is usually absent	*/ ***	*/ ***

Water source: * Contribution usually small
*** Contribution usually large
*/*** Contribution may be small or important depending on the local circumstances.

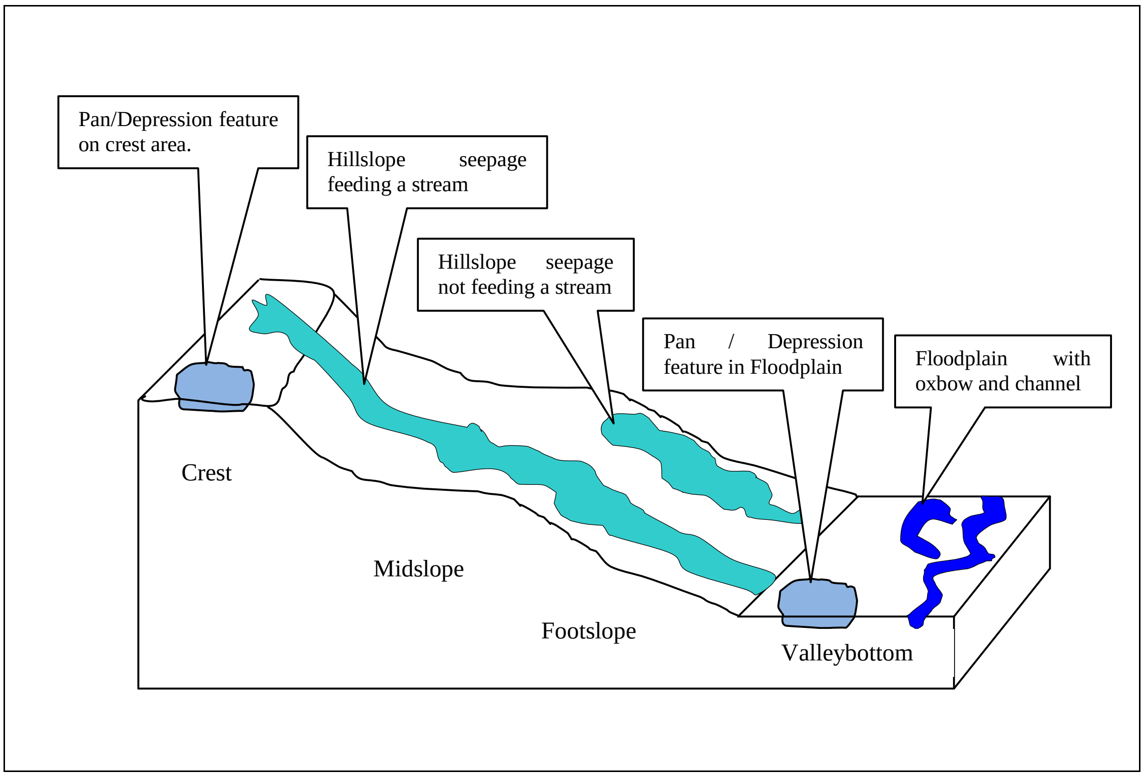


Figure 2: Wetlands in relation to the topography of the study area (Modified from Palmer, Turpie, Marnewick and Batchelor, 2002)

4.1.1. Hillslope seepage wetlands

The slopes on hillsides, sometimes host seepage wetlands which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from subsurface flow and outflow is usually via a well defined stream channel connecting the area directly to a watercourse.

4.1.2. Valleybottom Wetlands with and without channels

Valley bottom wetlands with a well defined stream channel but lacking characteristic floodplain features is very common in the study area. These wetlands are in most cases gently sloped and characterized by the net accumulation of alluvial deposits or may have steeper slopes and be characterized by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.
Valley bottom areas with no clearly defined stream channel, are usually gently sloped and characterized by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.

4.1.3. Floodplains

These are Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees (as depicted in Figure 3)and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Thus, consists of alluvial deposits of unconsolidated clay silts and course gravels. Water inputs originate from the main channel (when channel banks overspill) and from adjacent slopes. Floodplain systems like the Harts River occur in the study area (Figure 3).

Figure *3*: The Harts River floodplain wetland system close to the Barberspan Bird Sanctuary

4.1.4. Pans

Pans are fairly widespread in the study area, although they occur in clumps in some areas (Figure 1). Most pans in the study area are inundated ephemerally and irregularly. The most ubiquitous wetlands seem to be endorheic pans. The term endorheic refers to the closed (no outlet) nature of the drainage system of pans. These are characterized by saline deposits on their floors, and many have been mined for salt in the past. Pans in the study area tend to be large, dry, floodplain-like features, elongated along river courses (McCartney, Cairncross, Huizenga & Batchelor, 2007).

There is some pattern to the distribution of pans. Some occur in clumps and some is arranged in a linear fashion coinciding with the fossil courses of dry rivers, e.g. Barberspan, along the ancestral path of the Harts River (Allan, Seaman & Kaletja, 1996). This feature indicates their ancient origin.

There are four factors in pan distribution, namely bedrock, drainage, slope and climate. Climatically most pans are to be found on the arid side of both the 500 mm mean annual rainfall isohyets and the 1000 mm mean annual free-surface evaporation loss isoline (Allan, Seaman & Kaletja, 1996).
Typically their shape is circular to oval, and where two or more pans have spread and combined, they form characteristically kidney-shaped or lobed wetlands, e. g. Barberspan. They are shallow, even when fully inundated, and usually less than about three meters deep. Barberspan is the largest pan exceeding 1000 ha and are considered as major and striking feature of the local landscape with Leeupan just upstream thereof (Figure 4)

Figure *4*: Leeupan occurring adjacent to Barberspan

Almost all the pans identified are associated with shale, organic sedimentary rock and andesite, trachyte, phonolite lithologies (**Appendix G**).

4.1.5. Dolomitic Eye Systems

The eye systems occurring in the study area, such as the Kuruman Eye (Figure 5) and the Ventersdorp Eye, can according to the National Wetland Classification System for South Africa, based on the Cowardin system of the United States of America (Cowardin, Carter, Golet & LaRoe, 1979), be classified as Palustrine Persistent Emergent Wetlands. According to the Ramsar Classification System these eyes are non-forested peatlands. This type of wetland is dominated by emergent plant species, which normally remain standing at least until the beginning of the next growing season (Cowardin *et al*. 1979).

Figure 5: The Kuruman Eye dolomitic spring feeding into a reed and water lily dominated wetland downstream

The dominance and abundance of emergent plant species such as *Phragmites australis* support this classification. At a finer level of classification, these wetlands can also be classified as valley-bottom fens. The dominance of reeds may be a recent directional change in the structure and composition of the wetland that may have been caused by increased sediments and/or changes in the available nutrients in the ground or surface water entering these wetlands (Engelbrecht & Linström, 2007).

Fens are mires that have developed to a state where it is not only sustained by surface and groundwater, but also by the influx of lateral drainage from surrounding areas as well as precipitation. Mires are peatlands where peat is actively being formed and accumulating. Fens, as in these cases have reached a point of maturity where limited accumulation of peat occurs. A peatland can be described as a landscape with a layer of peat on the surface of at least 30-cm in depth. Peat is defined as dead and partially decomposed plant remains that have accumulated in situ as a result of being waterlogged. Mires are therefore expected to support vegetation that is known to form peat. Mires and peatland are characterised by their unique ability to accumulate and store dead organic plant matter as peat, under almost permanent waterlogged conditions. It is difficult to test in practice whether or not peat is actually accumulating. The dominance in the vegetation species, (whose remains are also found in the sediments) together with the incidence of almost permanent waterlogged conditions, can be taken as a good indication of peat formation (Joosten and Clark, 2000). These eye wetlands can therefore be described as tall emergent (reed) fens with fibrous reed peat.

5. GEOHYDROLOGY OF THE PANS AND WETLANDS IN THE CATCHMENTS

5.1. Depressions and Pans

The existence of pans depends entirely on the water regime and factors such as rainfall intensity, evaporation rate and groundwater level. All these influence the duration of inundation (Allan, *et al,* 1995). Inundation of the pans in the study area is characteristically ephemeral. Some of the pans can stand dry for years between temporary flooding. Water loss from pans, of course, is largely due to evaporation, and the higher evaporation rates in the study area contribute as much as low precipitation to their usually desiccated state.

Depressions and pans can receive both surface and groundwater flows, which accumulate in the depression owing to a generally impervious underlying layer which prevents the water draining away (Goudie and Thomas, 1985; Marshal and Harmse, 1992). The relative contributions of these different water sources may vary considerably amongst different depressions. The opportunity for attenuating floods is limited by the position of pans in the landscape, which is generally isolated from stream channels. However, they do capture runoff because of their inward draining nature, and thus they reduce the volume of surface water that would otherwise reach the stream system and contribute to stormflows. This inward draining nature, together with their generally impermeable underlying layer, however, also means that pans are unlikely to play a significant role in streamflow regulation. In addition, pans are also not considered important locations for sediment trapping, with many pans, in fact, originating from the removal of sediment by wind, thus creating what are referred to as deflation basins (Goudie and Thomas, 1985; Marshal and Harmse, 1992).

The pans receive water in a number of different ways. Rain falling directly onto a pan surface adds water. Each pan is surrounded by its own watershed, and some of the rainwater falling within this catchment forms surface run-off and flows directly into the pan, whilst the remainder percolates into the ground to become groundwater. This groundwater regime forms an important part of pan hydrology. Some groundwater migrates through the joint system into the pans, but this source is probably the least important. Most of the groundwater collects in the weathered rock and soil (the **regolith**) overlying the bedrock. The thickness of the regolith layer is greatest on the higher ground surrounding the pans, and becomes thinner on the slopes towards the pan, where it may disappear completely, giving way to an rocky outcrop (Figure 6). Spaces between the regolith grains become filled with groundwater, which saturates the material below a certain depth, known as the **water table**. The groundwater gradually migrates down slope under the influence of gravity. Because of thinning of the regolith down slope, the zone of saturation eventually impinges on the land surface, and here the groundwater seeps out (fig. 3). This process gives rise to the hill-slope wetlands that surround the pans. Seeped water flows slowly across these wetlands into the pan (McCartney, Cairncross, Huizenga & Batchelor, 2007).

Layers of ferricrete in the soil profiles may give rise locally to perched groundwater, in which case isolated wetland patches may form high up on the hill slopes around the pans, as groundwater is forced to surface and re-enters the ground further down the slope.

During very wet periods, water depth in the pans increases, and some may overflow into neighboring pans along the old drainage lines (like in the case of Barberspan to Leeupan). There may also be some seepage from one pan to another through the sand dunes that obstruct these former river valleys, although this has not been conclusively established. Notwithstanding this, the most important manner in which water leaves the pans is by evaporation off the pan surface and by transpiration from plants in the vicinity, because each pan is essentially a closed system as far as water is concerned. Indeed, in extreme droughts the pans may dry up completely.

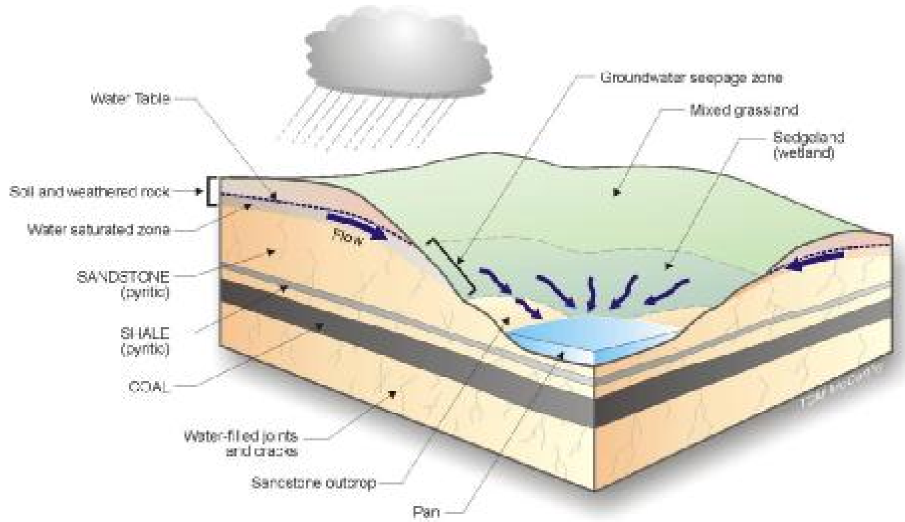


Figure 6: Diagram illustrating the geology and hydrology of a typical pan (McCartney, Cairncross, Huizenga & Batchelor, 2007)

Temporary pans allow for the precipitation of minerals, including phosphate minerals due to the concentrating effects of evaporation. Nitrogen cycling is likely to be important with some losses due to denitrification, and volatilization in the case of high pH's. Water quality in pans is influenced by the pedology, geology, and local climate (Allan *et al.*, 1995). These factors in turn, also influence the response of these systems to nutrient inputs. In pans that dry out completely at some stage or another (non-perennial pans), some of the accumulated salts and nutrients (such as organic nitrogen, and various phosphate and sulphate salts) can be transported out of the system by wind and be deposited on the surrounding slopes. Those remaining may dissolve again when waters enter the system as the pan fills after rainfall events (Kotze *et al*, 2005)).

As a result of the highly unpredictable seasonal changes in the water regime, the pans may range from being freshwater systems, when the wet season prevails, to virtually saline systems, as the dry season progresses and evaporation intensifies. The physical and chemical properties of the substrata and water of pans therefore varies seasonally and regionally. Furthermore, within each inundation considerable changes in the physical and chemical properties of the pans also take place (Allan *et al.*, 1995).

5.2. Dolomitic eye systems

Superficially, the eye systems appear to be similar to other wetlands occurring on the Highveld grasslands. However, it is unique in that it is influenced by karst landforms and fed by perennial dolomitic springs, which supply a constant source of groundwater into the wetland system downstream. These wetlands are hydraulically isolated from most of the main river channels it feeds into and is not influenced by any flood events in the rivers.

The existence of peatlands in karst topography has been described worldwide and can be attributed to the dissolution of the underlying limestone causing a slumping of the land surface, thereby creating distinct basins, which may or may not be connected to surface water. Lost streams (e.g. streams that disappear underground) and underground caverns are common in karst areas, contributing to being influenced by a much wider landscape. Connectivity between these underground caverns and streams can influence the water quantity and quality discharged by these eyes.

Fen peatlands are known to develop through a directional change from open water mires to fens, in a process where the open water is slowly displaced by the accumulation of peat in the system (Figure 7).

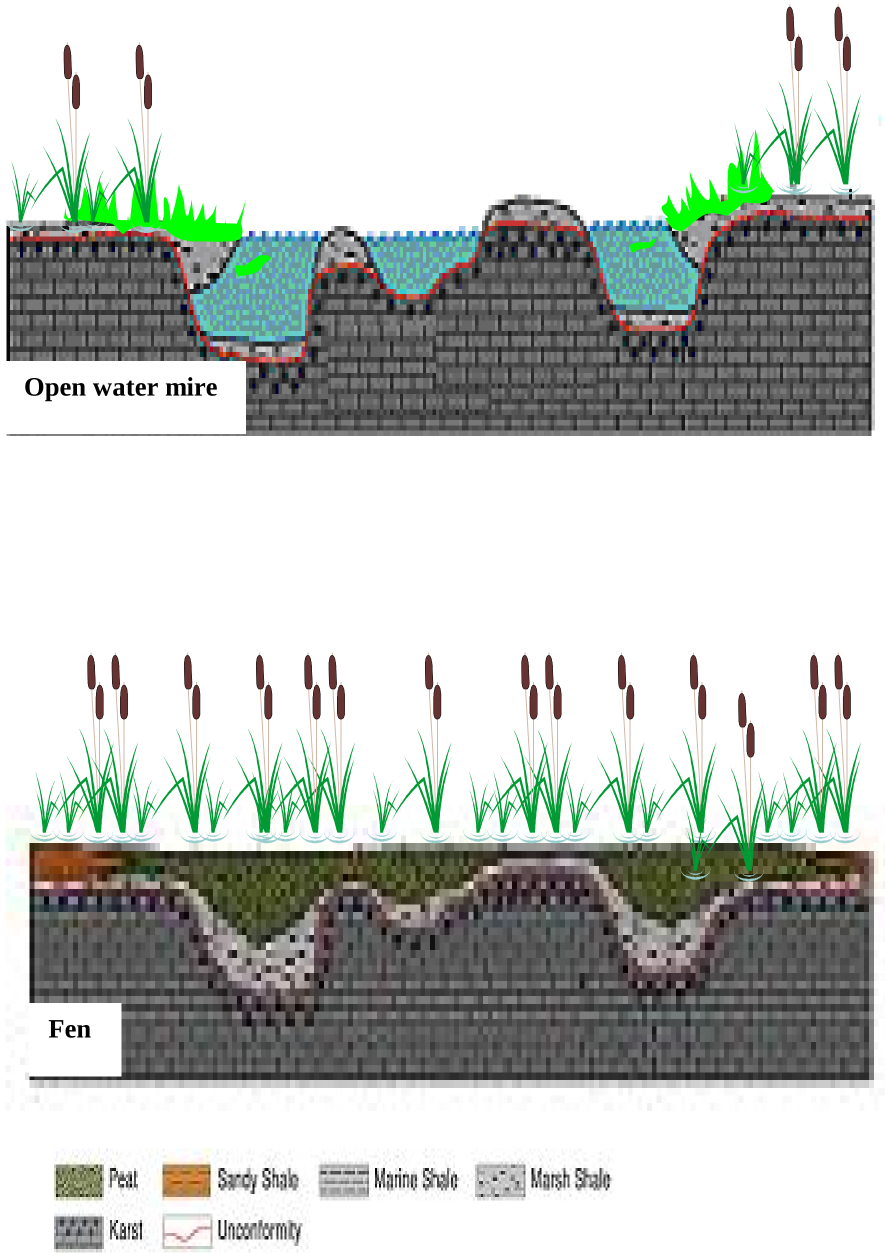


Figure 7: Illustration of the directional change from open water mire to a fen peat land

Hydrological regimes in these wetland types are not characterized by extreme hydrological disturbances such as floods that would have created a distinctive channel with a mosaic of different habitats and associated plant species. The occurrence of peat also demonstrates that these systems have been perennially inundated for many years and been subjected to a very stable low energy hydrological regime for a long time.

These systems are considered to be hydraulically stable lotic wetlands largely driven by water coming from dolomitic springs. No noticeable channels, sediment, or other features that would indicate significant stream action above the wetland occur. Therefore it is concluded that the catchments above the springs do not have a significant influence on the hydrology of these wetlands.

The present hydrological regime for these eye systems can be summarized as follow (Figure 8):

- The main and by far the greatest contribution of water feeding these wetlands come from several perennial dolomitic springs in and around the wetlands.
- Some lateral seasonal saturation from seeps occurring around the wetlands.
- Some seasonal influx of rainwater as a result of runoff during high rainfall events from the shallow gradient catchment areas above the wetland and lateral sheet wash into the wetland due to precipitation.
- No observable ephemeral river features such as channels, alluvial sediments, etc. exist above the wetlands.

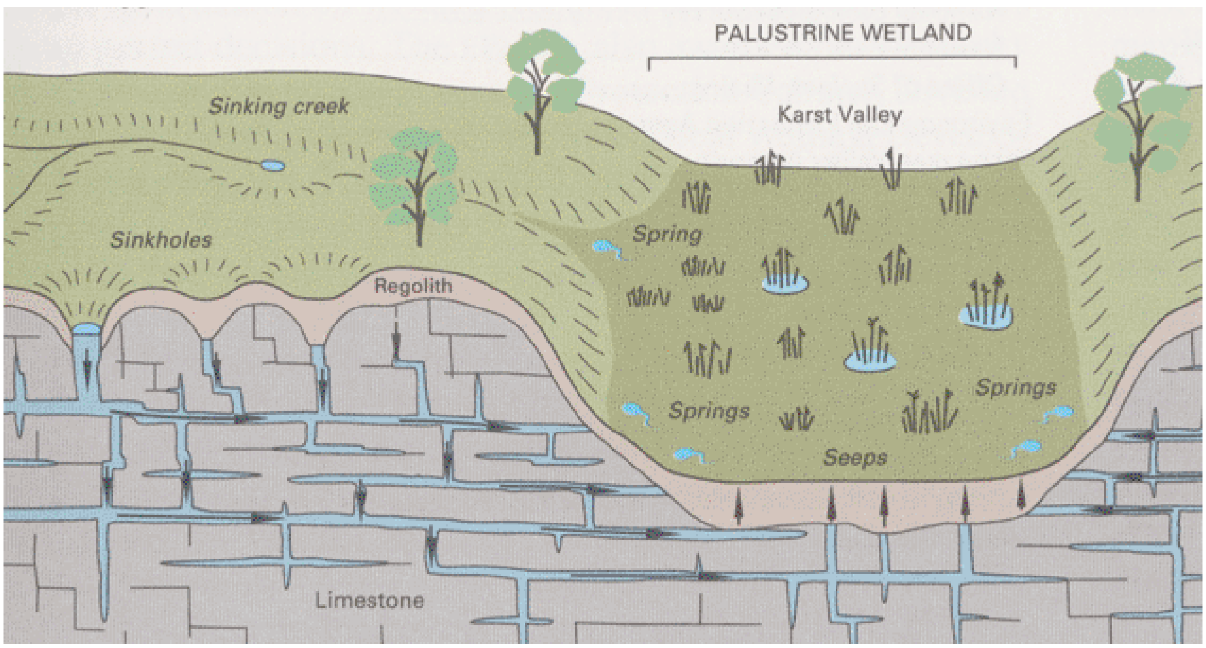


Figure 8: Hydrogeomorphological features supporting Fen Peat Wetlands

Some of these wetlands differ to the majority of other Highveld systems because of the abundance and depth of peat, the aridity of the surrounding landscapes and the influence of karst and dolomitic springs in the region, which supply a constant source of groundwater to these systems. Most of the time the large monospecific stands of the common reed *Phragmites australis* and *Carex acutiformis* indicate a mature fen with a very uniform hydrological regime that is not subjected to any extreme hydrological disturbances that would have created a mosaic of different habitats and associated plant species. The abundance and depth of peat demonstrate that these systems have been perennially inundated for many years and have been subjected to a very stable low energy hydrological regime for a long time.

6. LIKELY ECOSYSTEM SERVICES PROVIDED BY THE PANS AND WETLANDS

6.1. Pans and Depressions

By their physical presence and shape, and the vegetation they support, pans may act as sediment traps. Pans can be very productive and it may be because they provide abundant supplies of both nutrients and water in a stable environment.

Pans also provide important habitat for the life cycles of a significant number of species. The pans edge, characterized by emergent plants including sedges, grasses and herbaceous species that is usually <1m tall and the shallow open water (<1.5 m) containing floating or submerged aquatic plants, provides an area of highest biodiversity in an otherwise species poor habitat, dominated by reeds. The above-mentioned area provides a refuge for a variety of species such as fish, small mammals, and birds. This is a benefit of the pan in terms of biodiversity protection.

Pans are also important stopover sites for waterfowl, with over 320 recorded species including Palearctic species, Red Knot *Calidris canutus* and Black Godwit *Limosa limosa* visiting the Barberspan. Species present include all indigenous waterfowl species except the Tropical Dwarf Goose *Nettapus auritus*. Barberspan is the only locality in South Africa where the Pintail *Anas acuta* has been recorded. Some waterfowl species breed in the wetland.

Pans have aesthetic significance as a landscape component. While these pans are an aesthetically pleasing landscape feature in the area, they do not appear to be perceived as having any particular value by the overall community. Biodiversity in the form of water birds does attract birdwatchers. This may become important to planners and entrepreneurs to attract tourists. A camping and picnic site, a trail and bird hides have been established on and around some pans. Pans are popular angling sites and recreational areas in the study area.

6.2. Dolomitic eye systems

Wetland benefits are those functions, products, attributes and services provided by the ecosystem that have a value to humans in terms of worth, merit, quality and importance. These benefits may be derived from outputs that can be consumed directly, indirect uses that arise from the attributes or functions occurring within the ecosystem, or possible future direct outputs or indirect uses.

A very general assumption could be made that the larger the wetland, the greater will be the provision of benefits. However, the importance that size has in the provision of benefit varies considerably depending on the particular benefit and the local circumstances at the wetland (Table 4) (Kotze et al, 2006).

Table 4: Importance of wetland size in contributing to the provision of particular benefits

Ecosystem services	Importance of size		Ecosystem services	Importance of size
Flood attenuation	****		Biodiversity maintenance	**
Streamflow regulation	**		Carbon storage	***
Sediment trapping	****		Water supply	**
Phosphate assimilation	****		Harvestable resources	**
Nitrate assimilation	***		Cultural significance	*
Toxicant assimilation	***		Tourism & recreation	**

Erosion control	***		Education & research	*

Size is seldom important * Size is usually very important ***
Size is usually moderately important ** Size is always very important ****

The wetlands in the study area include different hydro-geomorphic types that include springs and seeps, and valley bottom with/without channels (channels mainly overgrown with reeds). The assessment of the wetlands current condition and functions will help to interpret the importance of their existence.

6.2.1. Wetland Benefits

These wetlands, in this case the dolomitic eye systems; contribute towards the bigger ecosystem services by means of the following wetland functions:

Water supply: Eyes supply water to rivers and dams. Flows from these eyes are relatively constant and will have a significant contribution to the flow in the rivers especially during dry periods. Water is also diverted through channels for irrigation purposes.

Flow regulation: These wetlands regulate base flow in the system by retaining and slowly releasing water into the system. The "plugging effect" of key-point areas increases the storage capacity of upstream areas, and prolongs the contribution of water to down-stream systems during low flow periods. In these cases the contribution will not only be in the wet-season but also in the dry season.

Erosion control: The physical characteristics of the wetland vegetation reduce the erosion of banks and substrate (organic soils). Roots stabilise the substrate, binds the accumulated plant matter and the trapped sediments. This function relates closely to the integrity of the wetland and is an important benefit that the wetland provides.

Sediment and nutrient removal and/or retention: The physical properties of eyes (e.g. topography, vegetation, size and peat extent and depth) tend to slow the velocity of water flow. The run-off from immediate adjacent hill slopes are locally important as clastic sedimentation and nutrient input take place from the surrounding landscape. The removal of toxicants and nutrients from the system relates to the deposition of sediment since these processes operate simultaneously and sometimes because of sediment removal. Nutrients, especially nitrogen and inorganic phosphorous, may be stored in the wetland substrate and sediment, absorbed by wetland vegetation or transformed by chemical and biological processes. The removal of excess nutrients maintains water quality and prevents eutrophication. This is a benefit of these eye systems since there is a high concentration of inorganic nitrogen present in the water flowing from the springs.

Toxicant removal and/or retention: Water from springs spread diffusely across its wetland downstream, resulting in extensive areas of the wetland permanently saturated. Since many toxicants that enter wetlands bind to sediments or within the molecular lattice of clay, the process of removal is associated with sediment trapping. Nitrate and toxicant removal is also expected to be higher owing to the greater contact of the wetland, particularly because there is a significant groundwater contribution to available nutrients. Absorption of toxins by carbon in organic sediments is also a well-known phenomenon. Toxicants may also be stored, transformed or absorbed by plants in the wetland, thereby maintaining or even enhancing water quality. The hardness and high pH of the karst water effectively detoxify most heavy metals in the system by forming insoluble products that will be trapped in the sediments. Open shallow waters will promote sunlight penetration, contributing to the photo degradation of certain toxicants (Figure 9).

Figure 9: Shallow water promote sunlight penetration and photo degradation

Maintenance of Biodiversity Significant For Conservation: These wetlands provide important habitat for the life cycles of a significant number of species (Figure 10). The wetlands edge, characterized by emergent plants including sedges, grasses and herbaceous species that is usually <1m tall and the shallow open water (<1.5 m) containing floating or submerged aquatic plants, provides an area of highest biodiversity in an otherwise species poor habitat, dominated by reeds. The above-mentioned area provides a refuge for a variety of species such as fish, small mammals, and birds. This is a benefit of the wetland in terms of biodiversity protection.

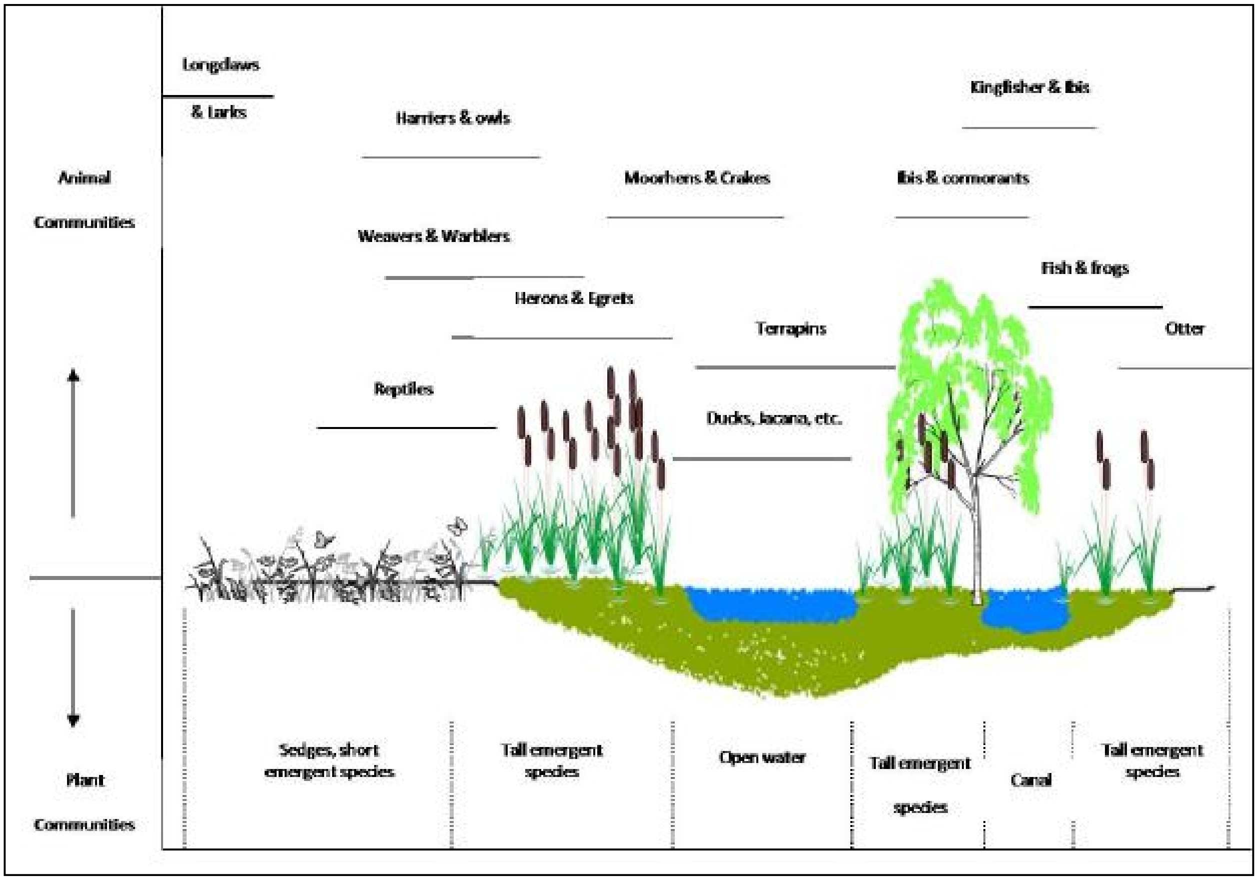


Figure 10: Mosaic of Wetland Habitats with associated plant and animal assemblages (Engelbrecht & Linström, 2007)

Socio-cultural significance: These wetlands have aesthetic significance as a landscape component. While these wetlands are an aesthetically pleasing landscape feature in the area, they do not appear to be perceived as having any particular value by the overall community. Biodiversity in the form of water birds does attract birdwatchers. This may become important to planners and entrepreneurs to attract tourists.

Carbon Sink: Permanently anaerobic soil conditions in these wetlands have resulted in the accumulation of large amounts of peat (carbon sequestration). Carbon locked in this material is prevented from contributing to the levels of carbon dioxide and other greenhouse gases in the atmosphere. Opening up or disturb these areas can release carbon dioxide and these other greenhouse gases into the atmosphere.

Good representative example of a specific class of wetland: In order to maximise the benefits to people and the environment, it is important to maintain a network of sites, which include good representatives of all the different wetland types. Historically these wetlands were good representative examples of a scarce wetland type, namely a Highveld karst peatland.

The Wet-EcoServices (Kotze et al, 2006) assessment tool was used to indicate the most likely ecosystem services of a dolomitic eye system (Figure 11). Dolomitic eye wetlands (this includes the eye and the peat/reed valley bottom area downstream) contribute in particular towards ecosystem services such as streamflow regulation, nitrate removal, erosion control, carbon storage, and the maintenance of biodiversity.

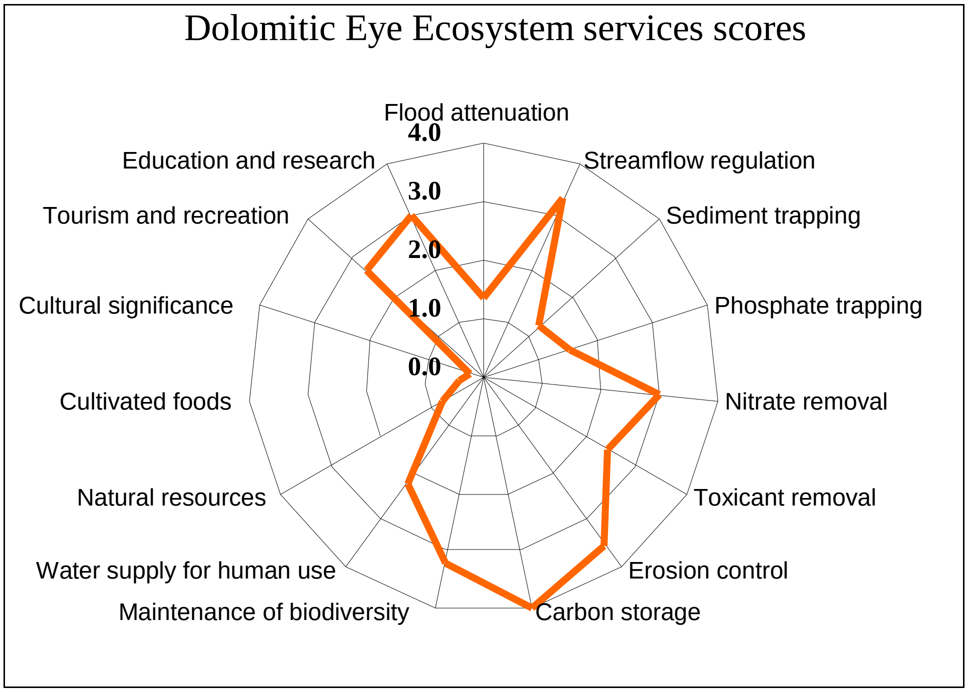


Figure 11: Wetland ecosystem services scores most likely performed by dolomitic eyes in the Middle and Lower Vaal River Catchments

7. THREATS TO THE PANS AND WETLANDS

Several anthropogenic threats to Pan Ecosystems and their associated biota have been identified and in some cases quantified.

a) Agricultural developments

A major threat to endorheic pans comes from agricultural development. Many pans in crop farming regions are surrounded by fields that often encroach onto the periphery of these wetlands and even impinge into the actual basins of smaller, well vegetated pans. Such pans are subjected to contamination and eutrophication by pesticides and fertilizers. The endorheic nature of pans exacerbates this problem and toxic substances concentrate in their basins. Poisons in particular pose a serious threat to wildlife. Ploughing, overgrazing and excessive trampling b livestock damages the shore vegetation, increase wind erosion and leads to the siltation of pan basins. Many pans are dammed or excavated to provide a water supply for livestock. The construction of fence lines across pan basins to control livestock movements is ubiquitous and these structures are a danger to flying water birds that frequently collide with or are becoming entangled in them.

b) Water pollution

The release of untreated sewage into aquatic systems has got detrimental effects on biota downstream thereof and especially in pans because of its endorheic nature. This is a major problem since raw sewage is being dumped into river systems in the study area. Barberspan especially is at risk because the Harts River is diverted to flow into the pan. This can result in the pan to become a sewage settling pond.

c) Urbanization

Factors associated with urbanization, such as recreational and residential developments, are encroaching rapidly on my pans. Such developments directly disturb wildlife and lead to excessive littering. In urban areas, pans provide convenient sites for municipal dumps. Rubble is frequently dumped in pan basins to provide a foundation for constructions. Farm dumps in pan located in rural areas, however, are usually insignificant. In many rural areas homesteads are frequently built close to pans and this increases littering and disturbance to wildlife.

d) Road-building operations

Another major threat, particularly in the central Highveld, is road construction. Pan are frequently seen as 'lines of least resistance' by road planners.

8. REFERENCE CONDITIONS OF THE WETLANDS

8.1. Dolomitic springs with associated wetland habitat downstream

These wetlands most likely developed under very constant flow conditions provided by dolomitic springs in and around the wetland. Rainfall events in the catchments of these wetlands contribute little to the available water in the systems. Flood conditions in these systems are also an unlikely event, except maybe during extreme rainfall events (Engelbrecht & Linstrom, 2007).

Unregulated wetland fires occur and layers of ash occur in the upper portions of the peat indicating recent desiccation. Fences and grazing have a minor impact on these wetlands. Adjacent agricultural activities and roads in and around the wetland have increased the presence of invasive exotic plant species. Some invasive species do occur in some of these peat wetlands, especially in the disturbed areas on the perimeter.

Although most of these wetlands are still in a very good condition, these wetlands are presently dominated by an almost monotypic stand of reeds. Available information suggests that this may be the result of recent directional change from a more diverse wetland with a mosaic of vegetation patches to an almost uniform reed dominated wetland.

Because of stable hydrological conditions and a history of anthropogenic disturbance in and adjacent to these wetlands, directional changes from floristically more diverse systems towards an almost monotypic reed dominated system may have occurred. However, several habitat types and vegetation communities still occur in these systems, such as:

- Active channels with some floating leafed, short emergent vegetation and small pockets of open water. The common reed (*Phragmites australis*) can dominate the vegetation in this habitat and it can contain patches of species such as *Typha capensis, Juncus effusus* and *Juncus punctorius.* The alien invasive watercress *(Rorippa nasturtium-aqauticum)* can also occur in this habitat type.
- The permanently wet habitat type consists mainly of tall emergent species dominated by the common reed *Phragmites australis.* This habitat type is mostly underlain with clayey course.
- A narrow but ecologically extremely important transitional grass-sedge dominated transitional zone occurs between wetland and terrestrial habitats.
- A grass-sedge wetland area occurs containing a mixture of wetland grass, sedges and other facultative hydrophytic species. The buttercup *Ranunculus multifidus* and *Ranunculus meyeri* can be common in this habitat type.

- Seepage areas can occur along the margin of these wetlands with the presence of both seasonally and temporary wet zones. Within these, semi-circular monospecific stands of Cottonwool grass *Imperata cylindrica* can be common.
- Natural open water habitat largely associated with dolomitic springs in the wetland. A characteristic deposit of white sulphur reducing bacteria normally occur in the substrate of the eyes.
- Typical riparian species associated with rocky habitat occurs around the eyes.
- Terrestrial habitat occurs adjacent to the wetland area.

8.2. Pans

Pans and depressions are of ecological importance as part of the broader landscape of arid regions and of further ecological interest within the pans themselves for their own biota, specifically during the periods that they hold water, and because of the briefness of those periods and the limited availability of water. Hydrological variability is a predominant feature affecting the ecology of pans. The physical and chemical properties of the substrata and water of pans therefore varies seasonally and regionally. Furthermore, within each inundation considerable changes in the physical and chemical properties of the pans also take place (Allan, Seaman & Kaletja, 1996).

The Barberspan Pan (Figure 12) is used to identify some reference conditions that will be applicable to some of the other important pans as well:

Figure 12: Visual of Barberspan that is connected with the Harts River (Google, 2007)

Overview of the Barberspan site

The reserve is 3118 ha in extent, of which about 2 000 ha is water. The pan is connected with the Harts River via a channel and is the largest of a series of depressions along this channel. The pan itself is about 600m wide and 1 550m long. It is a natural, shallow, alkaline lake which is perennial. Other pans in the vicinity are non-perennial. It is one of the few permanent natural water bodies on the western Highveld and provides food and shelter during the dry months for large numbers of waterfowl. Migrating aquatic species use the pan as an important stopover.

Almost 300 species of birds have been recorded here, about one-fifth being migrants. A research station was established during 1952 for the ringing and study of waterfowl but is no longer operational. Approximately 40 000 birds of 190 species were ringed annually for study of their distribution and migration.

Physical Features: Barberspan is the largest of a series of pans on the fossil bed of the Harts River. The reserve is underlain by amygdaloidal lava of the Ventersdorp System (age 2 100 million years). This is covered by surface limestone (age 100 million years) and classified as vlei or pan limestone according to origin. The quality varies from pure limestone to calcrete. It is hard and massive on the surface but softer and granular beneath the crust. There are no known economic deposits of any minerals. The depth varies from 5m to 9,5m flooding an area of 1 000 ha to 1 700ha. The storage capacity varies according to depth from $0.033 \times 10^6 m^3 – 0.096 \times 10^6 m^3$.
Conservation: The whole of the pan is protected as a Provincial nature reserve proclaimed in 1954 and is therefore State controlled. It was proposed that funds be raised to purchase the farms compromising the nearby Leeupan which is a natural extension of Barberspan. This is however unlikely. The possibility of a conservancy should be investigated. However, a major problem is the farmers negative attitude towards conservation as much of the land forming the reserve was in fact expropriated from them.
The pan is already a designated Ramsar Site and was listed during 1975. The pan qualifies as a wetland of international importance according to the Ramsar Convention of 1971. In order to be listed as such, Barberspan needs to comply with certain specifications, such as:

- It is an example of a specific type of wetland which is rare or unusual in the biogeographical area.
- It maintains a large number of threatened plants and/or animals.
- It is of special value for the maintenance of the ecological diversity of the region.
- It is of special value as habitat to plants and animals in a critical part of their life cycles.
- It maintains large numbers of individuals of specific groups of water birds which indicate the value, productivity and diversity of the wetland.

Threats: Threats are mainly external with pressure on the system arising from agricultural activities. The main threat is agricultural pollutants such as fertilizers, pesticides and herbicides. Littering by anglers is also a problem. Quarrying occurred previously and should be prohibited in the future.
Social and cultural values: Social and cultural values are extremely subjective concepts. The main value of the area lies in the pan itself. The conservation value of the site is perceived to be exceptionally high and may be of national and even sub-continental importance.

Signs of previous human occupation of the area have been discovered. Primitive implements made of lava dating mostly to the Early Stone Age (50 000 years B.P.) and Middle Stone Age (10 - 40 000 years B.P.) have been found in quarries and on pebble outcrops. As yet no major cultural historic or archaeological finds have been made. However, the remains of General Smuts's house are present which may be of interest to some.

The area is used mainly for research on birds and angling. The pan is also a popular angling resort and recreational area in the Western Transvaal.

9. PRESENT ECOLOGICAL STATE AND ECOLOGICAL IMPORTANCE AND SENSITIVITY OF THE PANS AND WETLANDS

Pans have received little attention and this applies in particular to pans associated with the study area. As a result little research or conservation effort has been focused on these ecosystems and there has been an underestimation of their conservation value, despite their unique nature. Their importance, which extends far beyond their value as wildlife refuges, and the vulnerability of these ecosystems motivate strongly for the detailed study and protection of these resources.

Williams (1985) put forward the following significant stressors at one time or another in the life of organisms inhabiting temporary waters:

Desiccation
Chemical variation (high salinity, variation in ionic proportions)
High temperatures
Low oxygen concentrations
High light intensities
Variation in environmental factors (a phenomenon involving both short-term instability and long-term unpredictability)
Habitat isolation
Astatic levels

According to Geldenhuys (1982), the limnology under varying conditions of salinity, plant cover and length of flooded periods are among the aspects that need to be studied for each pan type. Current potential effects on the integrity of pans and depressions occur in the form of restriction of water run-off by cultivated fields and small dams, accumulation of pesticide residues, physical damage such as boreholes, ploughing and dumping, and industrial effluent.

Barberspan is the only pan which is registered as a Ramsar wetland of international importance and registered as a Nature Reserve under the Protected Areas Act.

Groundwater dependent ecosystems, like dolomitic eyes, are facing increasing pressure from consumptive uses for agriculture, mining, urban and commercial developments. Collectively, anthropogenic changes in the groundwater regime pose a significant, but largely unknown threat to groundwater dependent ecosystems.

The water in these systems originates from precipitation in the area, which is poor in nutrients and slightly acid. Once in contact with the geosphere, the quality of this water changes, depending on the chemical properties of the catchment areas (determined by climate, bedrock, soil, vegetation, and land use) and the residence time of the water (determined by the extent, bedrock, and relief of the catchment), the water changes in electrolyte and Oxygen concentrations, nutrient richness, pH, and temperature (Engelbrecht & Linstrom, 2007).

The chemistry of the groundwater originating from these eyes will give an indication of the geology, hydrology and biology of the aquifers and phreatic caves within the karst system supplying the water to the wetlands. In addition, some water chemistry parameters may be indicative of pollution. Changes in the quality of the water in the associated wetlands downstream may also give some indications to the sequestration of some chemicals via wetland functions and the release of other chemicals due to natural processes or disturbances (Engelbrecht and Linstrom, 2007).

10. PRIORITY WETLAND AND PANS THAT REQUIRE RESERVE ASSESSMENTS

*Wetlands identified were classified and listed according to size, IBA status, Ramsar criteria consideration, uniqueness in the study area and threats. The wetland polygons in the study area were sorted by size and the largest were investigated and assessed on Google Earth (Google, 2007). Aspects that can possible influence the wetland functionality and integrity was identified. A cross reference was then made between the larger wetlands found on GIS with those received via correspondence from specialists. From the above process a list of ~21 wetlands was generated. The identified wetlands were presented at a workshop with the specialist whereby the proposed list of 21 wetlands was discussed and adapted to 9 wetlands according the specialists' experience in the field (***Table 5**, **Table 6** *and* **Figure 8**.

Table 5: Priority Wetlands and Pans identified in the Lower and Middle Vaal River Catchments

Catchment Area	Priority Wetlands	Reasons	Location (GPS)
Middle Vaal	Witpan	Flamingo roosting	Lat -27.83849 Lon 26.44054
	Annaspan	Flamingo roosting	Lat -28.53552 Lon 25.79727
	Schoonspruit/Ventersdorp	Dolomitic Eye & peatland.	Lat -26.30686 Lon 26.83603
Lower Vaal	Barberspan	Ramsar Site & Important Bird Sanctuary.	Lat -26.58111 Lon 25.58929
	Harts River Floodplain	Unique feature and birdlife.	Lat -26.71755 Lon 25.53948
	Heuning Vlei	Unique birdlife.	Lat -26.31345 Lon 23.14362
	Kamferpan	Lesser flamingo breeding site.	Lat -28.67388 Lon 24.76290
	SA Lombard NR	Important Floodplain system.	Lat -27.59514 Lon 25.47673
	Kuruman Eye	Dolomitic Eye and peatland.	Lat -27.46166 Lon 23.43061

Table 6: Remaining identified pans in the study area

Number	Name and/or Site locality	Area (ha)	Latitude	Longitude
1	Gamaleeppan	846.18	-27.79942	22.03481
2	Gannapan	863.21	-28.05952	25.59059
3	Ganspan	670.74	-27.92797	26.43119
4	Groot-Malahalipan	755.30	-27.65575	21.99938
5	Inkpan	632.12	-28.30205	25.84828
6	Karee Pan	92.29	-27.14711	25.77211
7	Klippan	471.25	-26.05144	26.95746
8	Kykompan	637.29	-27.96962	21.27920
9	Rietfontein se Pan	594.55	-28.37795	25.32322
10	Soutpan	569.68	-27.74814	25.32292
11	Swartpan	740.19	-27.37794	27.10176
12	Swinkpan	1420.65	-28.48147	25.61810
13	Telleriepan	1596.20	-27.39501	21.40675
14	SE of Kimberley	1637.37	-28.84439	24.78051
15	Bultfontein	577.26	-28.29356	26.17035
16	South of Welkom	716.92	-28.19315	26.70971
17	Spitskop	474.61	-28.49321	25.37122
18	SE of Besonderskop	485.06	-28.42407	25.48038
19	West of Bultfontein	446.29	-28.31567	25.69010

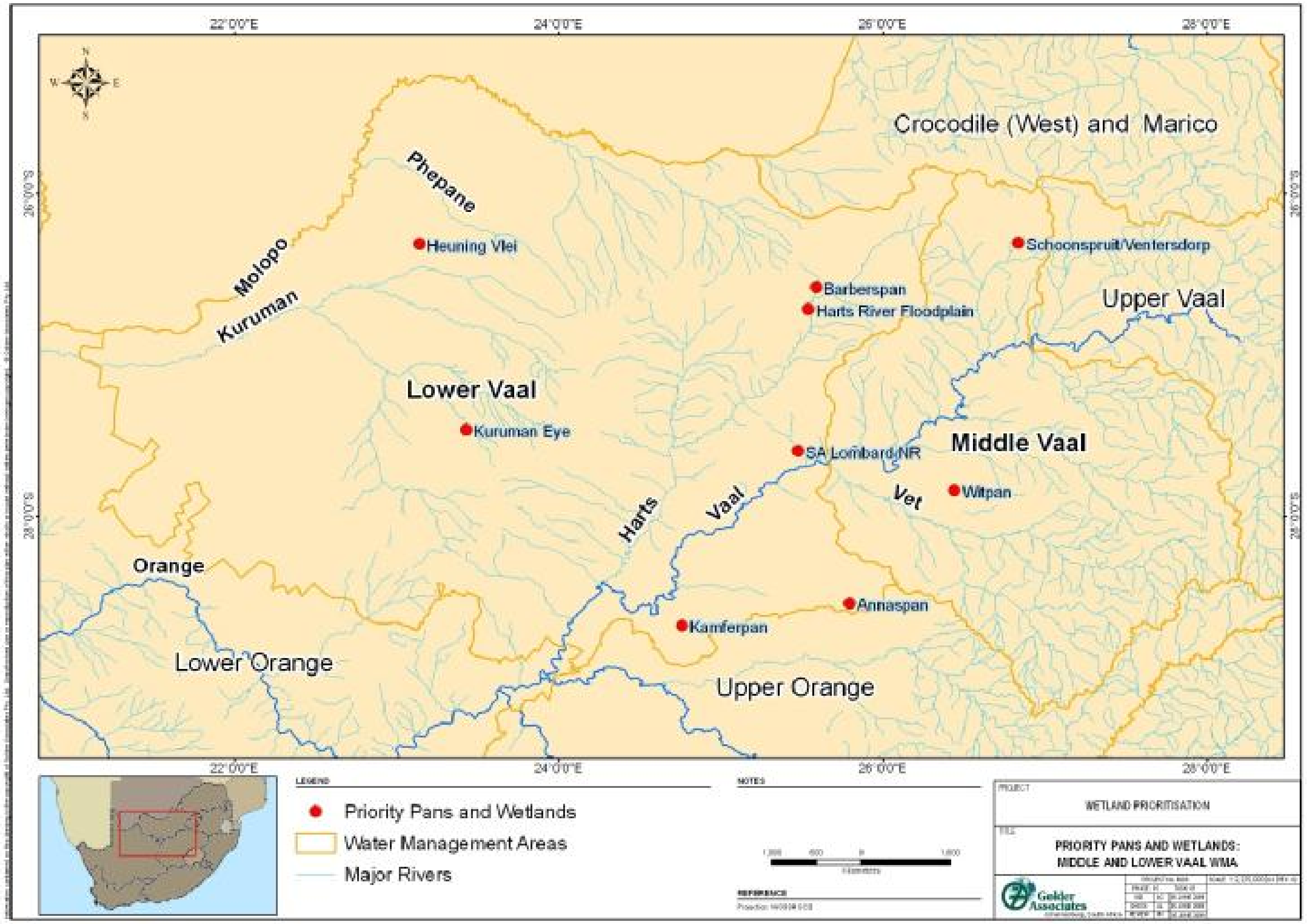


Figure 13: Priority Pans and Wetlands in the study area

11. CONSERVATION AND MANAGEMENT RECOMMENDATIONS

Much remains to be done concerning the conservation of pans and wetlands. The entire network of pans requires conservation, so that there is always some suitable habitat available to act as refuge for the species adapted to these ecosystems somewhere within their ranges. Management strategies aimed at land in private ownership, is as important as land acquisition for formal nature reserves. However, some of the larger, and perhaps a suite of representative, pans should be given formal conservation protection if for no other reasons than for their tourism and education potential. Consideration should be given to including many of the more important pans in the formal nature reserve system, including municipal reserves. It is important that pans set aside as reserves in the latter areas are managed as nature areas and not as city parks with their attendant planting of alien trees and lawns, uncontrolled disturbance.

Legislation and its effective enforcement should be considered to halt the wanton environmental degradation of pans and other wetlands in the study area. The education of landowners and other parties who impact on these systems, as to full value of wetland habitats has been sorely neglected. For example, trampling by livestock transforms well-vegetated pan shorelines to open mud. Vegetated shorelines provide important feeding and/or breeding site for many birds, and probably other organisms. Landowners could be persuaded to permanently fence off large areas of shoreline so as to promote diversity of habitats and, for example, bird species. This would be especially valuable n creating breeding habitat for ducks.

Systematic and representative monitoring projects need to be established to maintain a constant watch over the environmental health of pans. Such monitoring needs to be pro-active and identify threats from developments while these are still in the early planning stages.

A particularly topical issue at present is the problem of aerial spraying of problem seedeater flocks with avicedes. Large flock of these species frequently roost in pan reed beds, especially in the Barberspan area, and the potential exists for a major ecological disaster to non-target species should any of these sites be sprayed. Such operations should be banned at pans and indeed at any wetland sites.

Basic management actions should be taken to project pans and wetlands in the study area, such as:

- Correct burning regimes of pan shores should be implemented to promote its vitality. This will remove moribund and/or unacceptable grass material; and to eradicate and/or prevent the encroachment of undesirable plants.

- Many wetlands have been degraded by invasive exotic vegetation. Given the high hydrological/functional importance of these pans and wetlands, an urgent rehabilitation programme should be investigated in cooperation with Working for Wetlands.

- Buffer zones between pans/wetlands and roads, agricultural activities, developments, mining activities, etc. This will protect the water resources and promote the integrity of these systems.

- Investigate the laying out of roads in and around pans/wetlands. If possible, roads should be closed and rehabilitated in pan/wetland areas.

12. WAY FORWARD

Very little information with regards to wetlands in the Lower and Middle Vaal River catchments exists. Be it a wetland inventory or baseline data or general information. Further studies with regards to completing a wetland inventory are necessary and should include the verification of the existence of wetlands in some areas and to at least indicate the priority wetlands. Thus infield verification will be necessary.

Infield verification should also include Ecological Integrity and Sensitivity (EIS) Category assessments and Wetland Habitat Integrity (PES) assessment where applicable; this information will add value to future Ecological Reserve assessments.

Candidate wetland sites for determining an Ecological Reserve should occur in an area where impacts on the aquifer is high and the aquifer is vulnerable to drought (Marneweck, 2006). Impacts can be in the form of draining channels, water abstraction, mining activities, wrong burning regimes, etc. The level of determining the Reserve is still to be determined. However, given the groundwater component of the dolomitic eye systems, some of the valley bottom systems, endorheic pan, etc. would require further refinement of existing Reserve determination methods.

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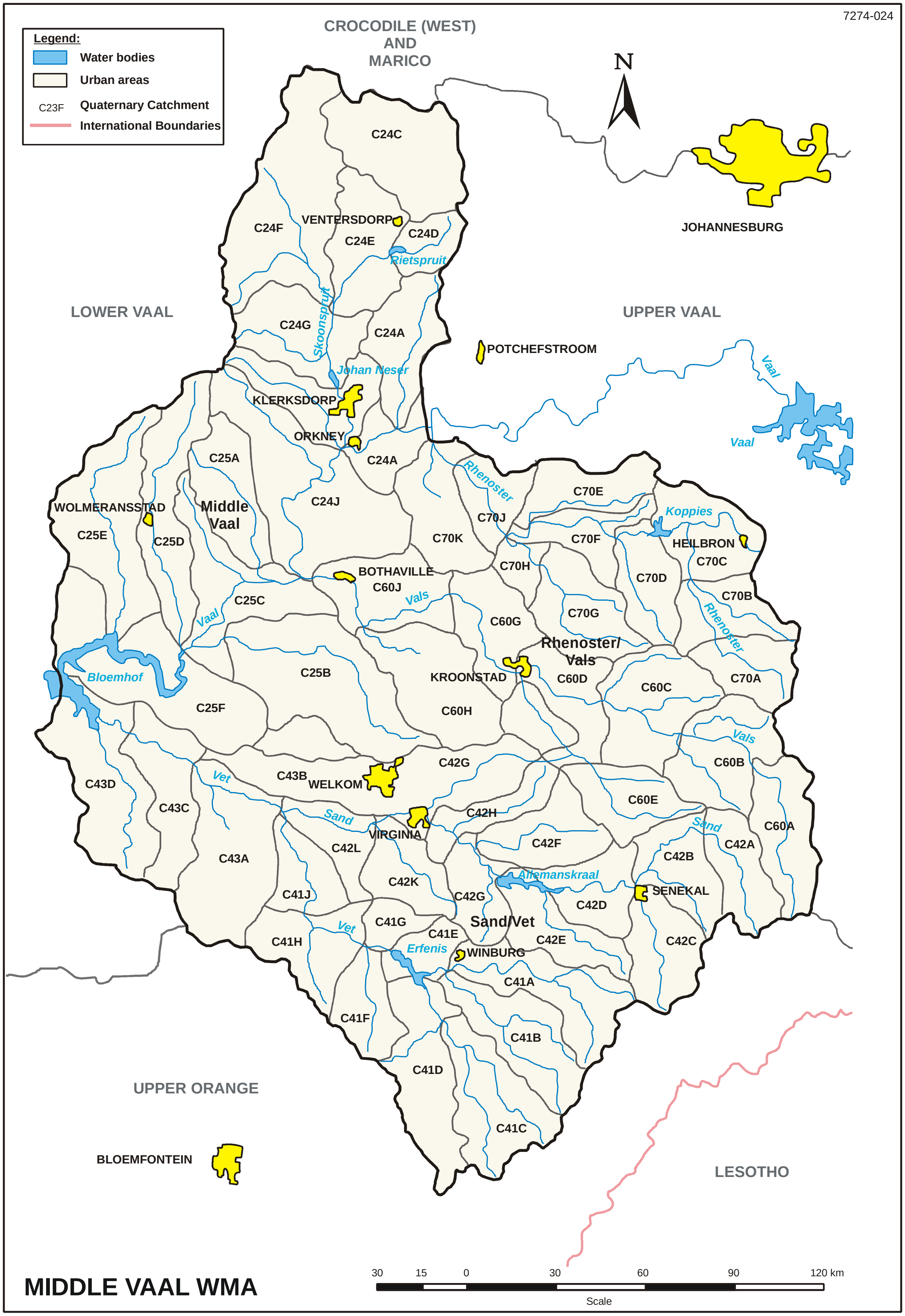
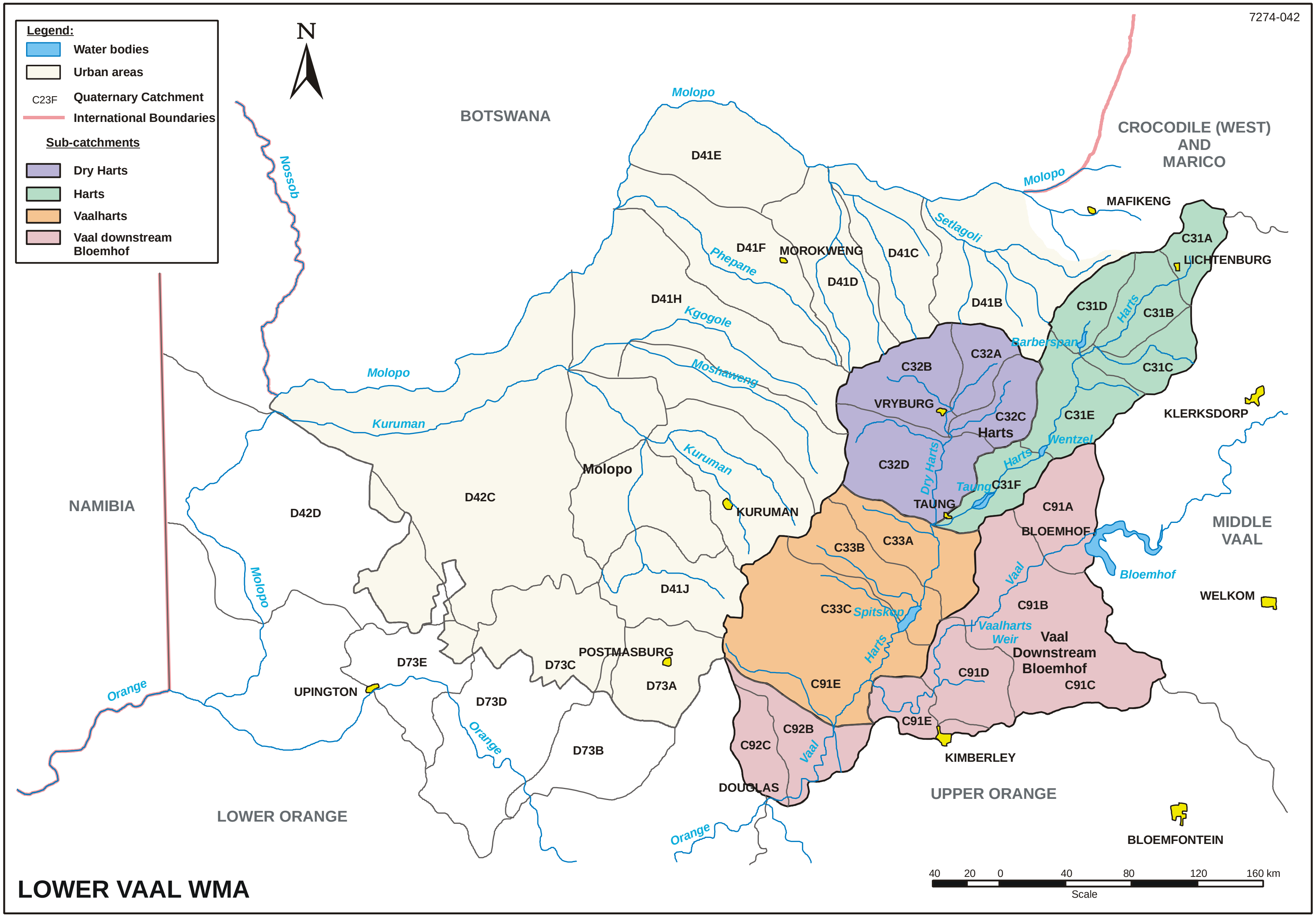
APPENDIX A
MIDDLE VAAL STUDY AREA (DWAF[1]. 2007)



MIDDLE VAAL WMA

APPENDIX B
LOWER VAAL STUDY AREA (DWAF[2]. 2007)


7274-042
Legend:
Water bodies
Urban areas
C23F Quaternary Catchment
International Boundaries
Sub-catchments
Dry Harts
Harts
Vaalharts
Vaal downstream Bloemhof
N
BOTSWANA
CROCODILE (WEST) AND MARICO
NAMIBIA
MIDDLE VAAL
LOWER ORANGE
UPPER ORANGE
Molopo
Nossob
Setlagoli
Phepane
Kgogole
Moshaweng
Kuruman
Orange
Vaal
Harts
Dry Harts
Barberspan
Wentzel
Taung
Spitskop
Vaalharts Weir
Bloemhof
MAFIKENG
LICHTENBURG
MOROKWENG
VRYBURG
KLERKSDORP
KURUMAN
TAUNG
BLOEMHOF
WELKOM
POSTMASBURG
UPINGTON
KIMBERLEY
DOUGLAS
BLOEMFONTEIN
D41E
D41F
D41C
D41D
D41B
D41H
D42C
D42D
D41J
D73E
D73C
D73A
D73D
D73B
C31A
C31B
C31C
C31D
C31E
C31F
C32A
C32B
C32C
C32D
C33A
C33B
C33C
C91A
C91B
C91C
C91D
C91E
C92B
C92C
Molopo
Harts
Vaal Downstream Bloemhof
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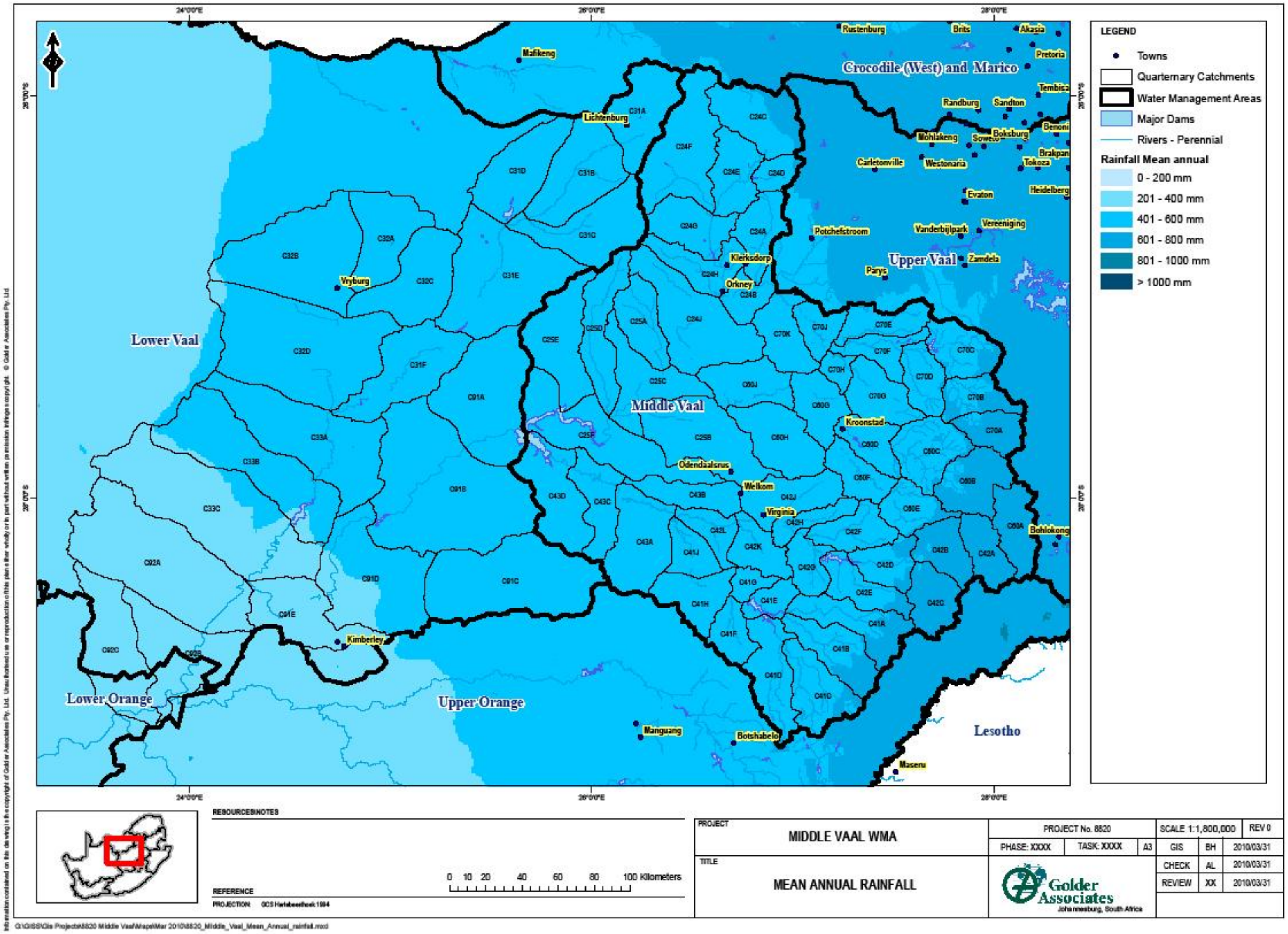
Scale
LOWER VAAL WMA

APPENDIX C
RAINFALL FOR THE STUDY AREA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Towns
Quarternary Catchments
Water Management Areas
Major Dams
Rivers - Perennial
Rainfall Mean annual
0 - 200 mm
201 - 400 mm
401 - 600 mm
601 - 800 mm
801 - 1000 mm
> 1000 mm
Lower Vaal
Middle Vaal
Upper Vaal
Crocodile (West) and Marico
Lower Orange
Upper Orange
Lesotho
Kimberley
Vryburg
Mafikeng
Lichtenburg
Klerksdorp
Orkney
Potchefstroom
Kroonstad
Welkom
Virginia
Odendaalsrus
Bohlokong
Botshabelo
Maseru
Manguang
RESOURCES/NOTES
REFERENCE
PROJECTION: GCS Hartebeesthoek 1994
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PROJECT
MIDDLE VAAL WMA
TITLE
MEAN ANNUAL RAINFALL
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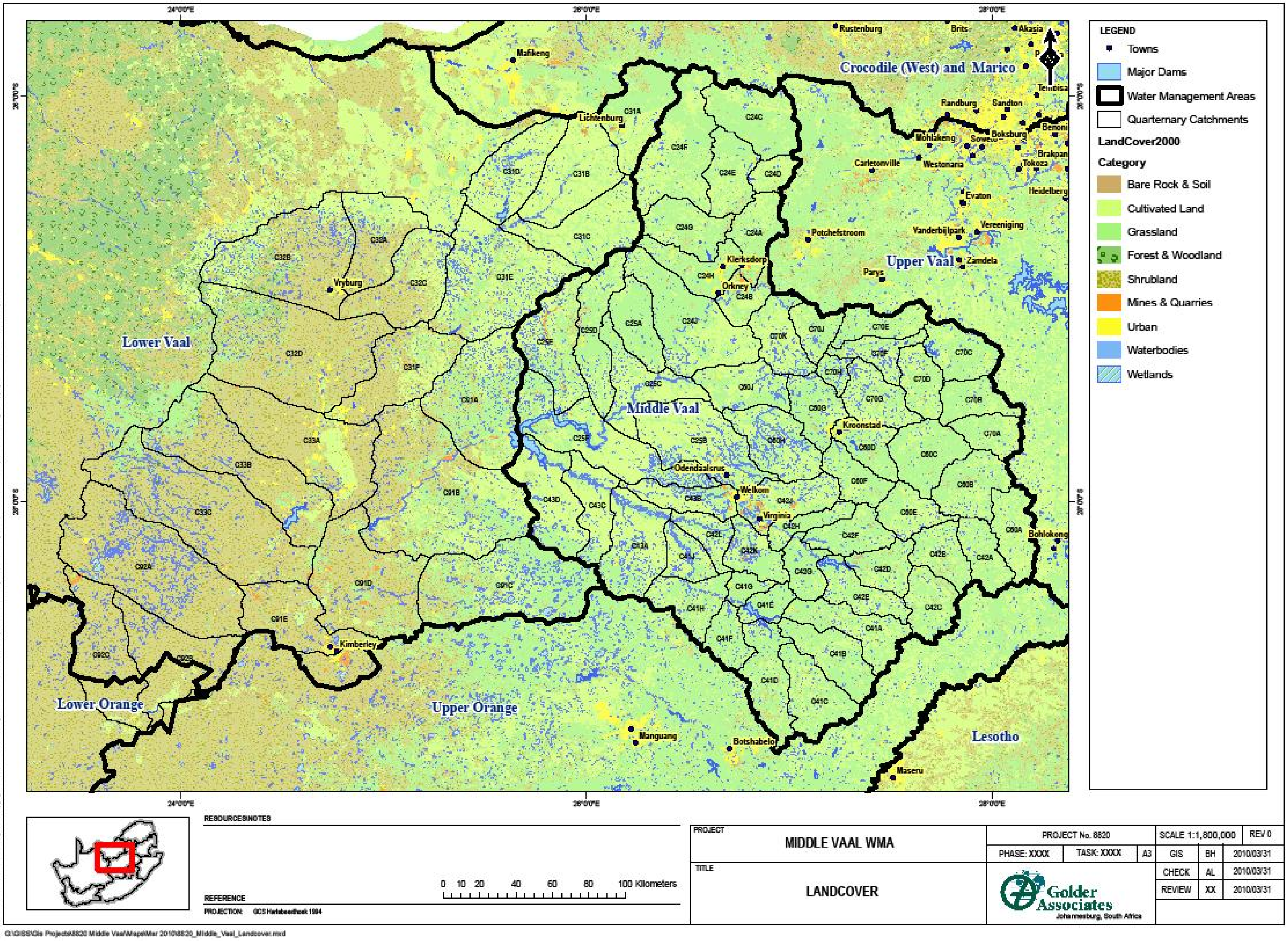
Golder Associates
Johannesburg, South Africa

APPENDIX D
LANDCOVER FOR THE STUDY AREA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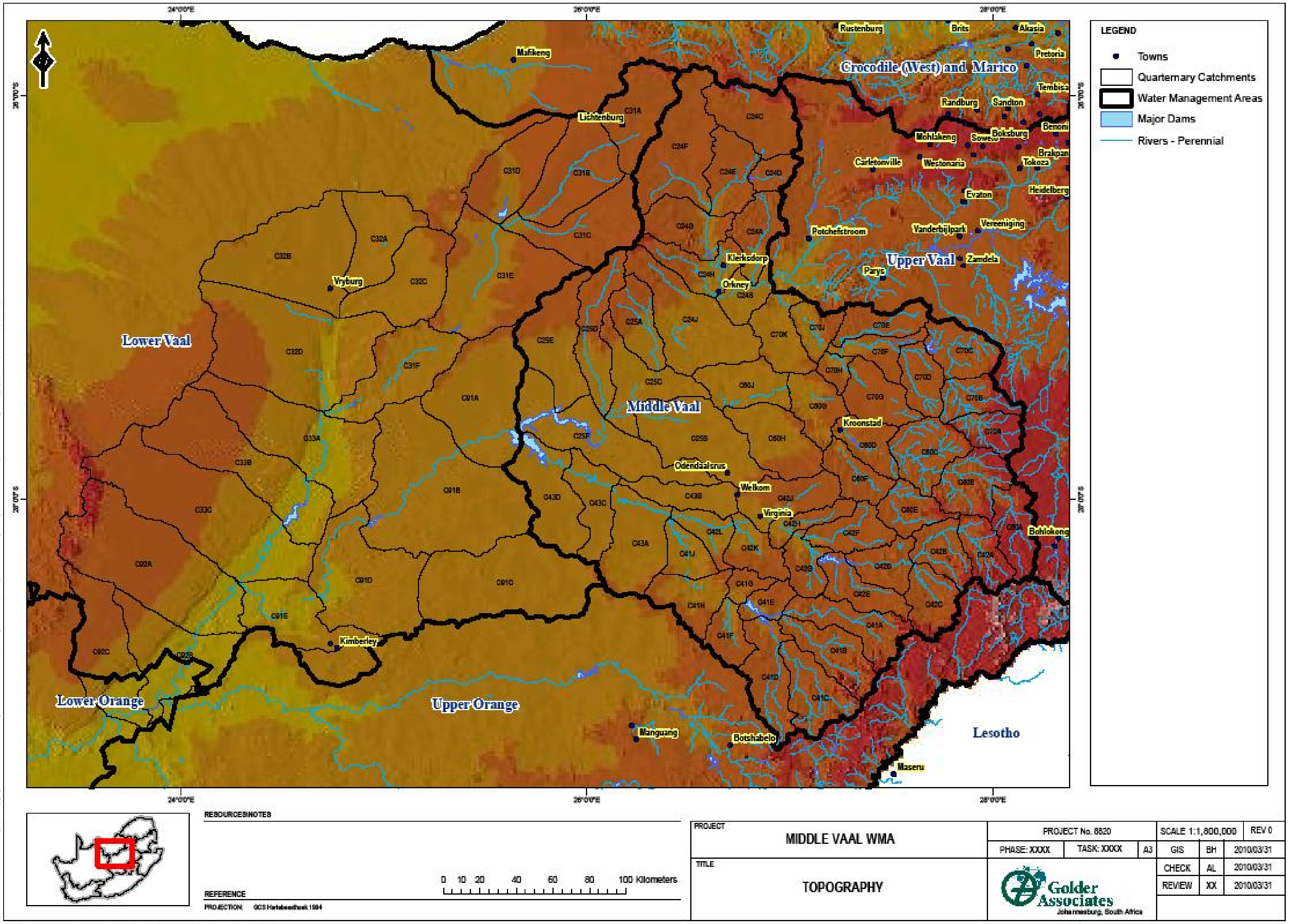
Towns
Major Dams
Water Management Areas
Quaternary Catchments
LandCover2000
Category
Bare Rock & Soil
Cultivated Land
Grassland
Forest & Woodland
Shrubland
Mines & Quarries
Urban
Waterbodies
Wetlands
Crocodile (West) and Marico
Upper Vaal
Middle Vaal
Lower Vaal
Lower Orange
Upper Orange
Lesotho
PROJECT
MIDDLE VAAL WMA
TITLE
LANDCOVER
PROJECT No. 8820
SCALE 1:1,800,000
Golder Associates

APPENDIX E
TOPOGRAPHY FOR THE STUDY AREA


LEGEND
Towns
Quaternary Catchments
Water Management Areas
Major Dams
Rivers - Perennial
Lower Vaal
Middle Vaal
Upper Vaal
Crocodile (West) and Marico
Lower Orange
Upper Orange
Lesotho
Mafikeng
Lichtenburg
Vryburg
Kimberley
Klerksdorp
Orkney
Potchefstroom
Carletonville
Westonaria
Mohlakeng
Soweto
Randburg
Sandton
Rustenburg
Brits
Akasia
Pretoria
Tembisa
Benoni
Boksburg
Brakpan
Tokoza
Heidelberg
Evaton
Vereeniging
Vanderbijlpark
Zamdela
Parys
Kroonstad
Odendaalsrus
Welkom
Virginia
Bohlokong
Manguang
Botshabelo
Maseru
24°00'E
26°00'E
28°00'E
RESOURCES/NOTES
REFERENCE
PROJECTION: GCS Hartebeesthoek 1994
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PROJECT
MIDDLE VAAL WMA
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TOPOGRAPHY
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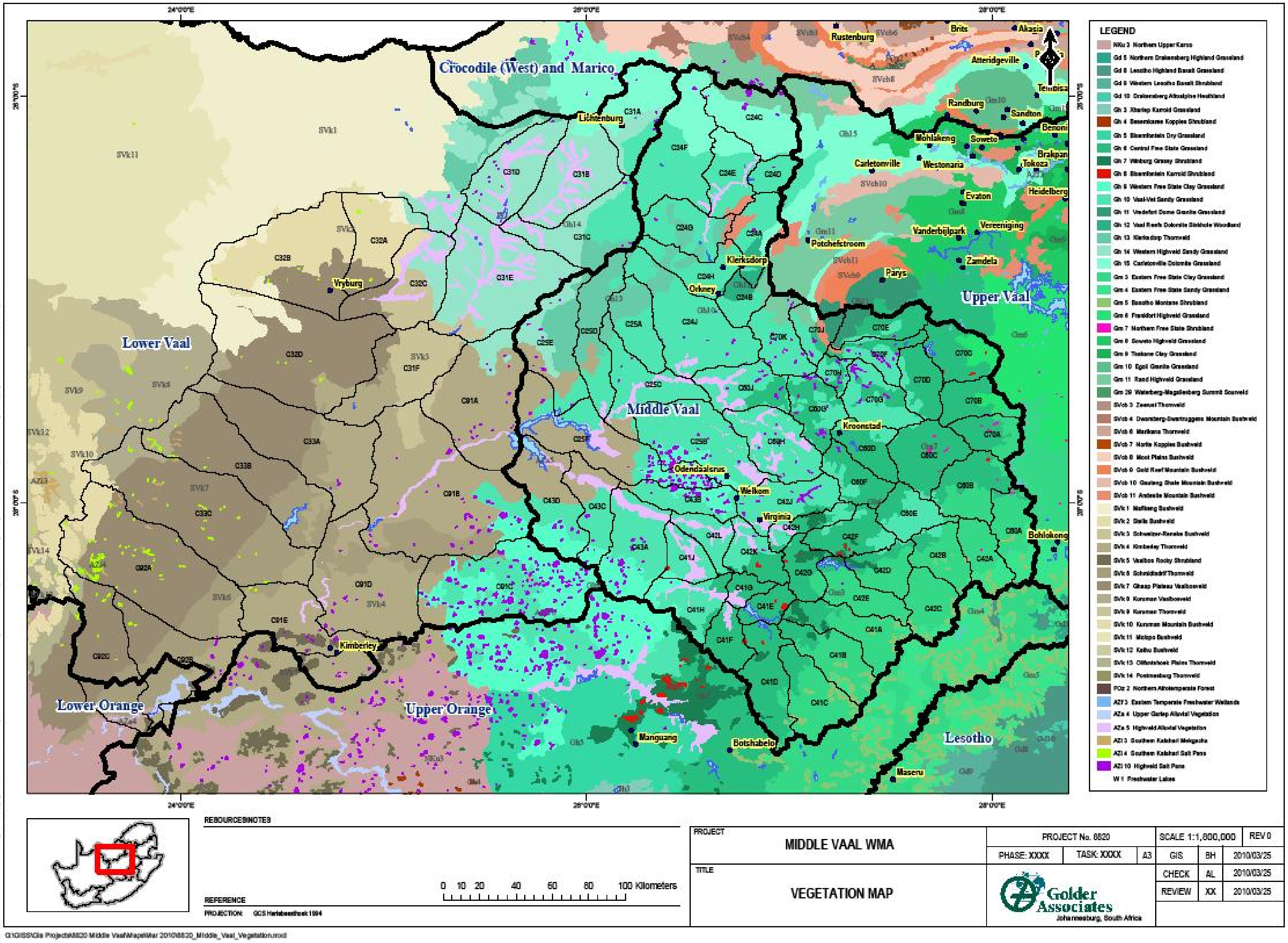
REVIEW XX 2010/03/31
Golder Associates
Johannesburg, South Africa

APPENDIX F
VEGETATION OF THE STUDY AREA



Crocodile (West) and Marico
Lower Vaal
Middle Vaal
Upper Vaal
Lower Orange
Upper Orange
Lesotho
Lichtenburg
Vryburg
Kimberley
Klerksdorp
Orkney
Potchefstroom
Carletonville
Westonaria
Mohlakeng
Soweto
Randburg
Sandton
Rustenburg
Brits
Akasia
Atteridgeville
Tembisa
Benoni
Brakpan
Tokoza
Heidelberg
Evaton
Vanderbijlpark
Vereeniging
Zamdela
Parys
Kroonstad
Odendaalsrus
Welkom
Virginia
Bohlokong
Manguang
Botshabelo
Maseru
LEGEND
NKu 3 Northern Upper Karoo
Gd 5 Northern Drakensberg Highland Grassland
Gd 8 Lesotho Highland Basalt Grassland
Gd 9 Western Lesotho Basalt Shrubland
Gd 10 Drakensberg Afroalpine Heathland
Gh 3 Xhariep Karroid Grassland
Gh 4 Besemkaree Koppies Shrubland
Gh 5 Bloemfontein Dry Grassland
Gh 6 Central Free State Grassland
Gh 7 Winburg Grassy Shrubland
Gh 8 Bloemfontein Karroid Shrubland
Gh 9 Western Free State Clay Grassland
Gh 10 Vaal-Vet Sandy Grassland
Gh 11 Vredefort Dome Granite Grassland
Gh 12 Vaal Reefs Dolomite Sinkhole Woodland
Gh 13 Klerksdorp Thornveld
Gh 14 Western Highveld Sandy Grassland
Gh 15 Carletonville Dolomite Grassland
Gm 3 Eastern Free State Clay Grassland
Gm 4 Eastern Free State Sandy Grassland
Gm 5 Basotho Montane Shrubland
Gm 6 Frankfort Highveld Grassland
Gm 7 Northern Free State Shrubland
Gm 8 Soweto Highveld Grassland
Gm 9 Tsakane Clay Grassland
Gm 10 Egoli Granite Grassland
Gm 11 Rand Highveld Grassland
Gm 29 Waterberg-Magaliesberg Summit Sourveld
SVcb 3 Zeerust Thornveld
SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld
SVcb 6 Marikana Thornveld
SVcb 7 Norite Koppies Bushveld
SVcb 8 Moot Plains Bushveld
SVcb 9 Gold Reef Mountain Bushveld
SVcb 10 Gauteng Shale Mountain Bushveld
SVcb 11 Andesite Mountain Bushveld
SVk 1 Mafikeng Bushveld
SVk 2 Stella Bushveld
SVk 3 Schweizer-Reneke Bushveld
SVk 4 Kimberley Thornveld
SVk 5 Vaalbos Rocky Shrubland
SVk 6 Schmidtsdrif Thornveld
SVk 7 Ghaap Plateau Vaalbosveld
SVk 8 Kuruman Vaalbosveld
SVk 9 Kuruman Thornveld
SVk 10 Kuruman Mountain Bushveld
SVk 11 Molopo Bushveld
SVk 12 Kathu Bushveld
SVk 13 Olifantshoek Plains Thornveld
SVk 14 Postmasburg Thornveld
FOz 2 Northern Afrotemperate Forest
AZf 3 Eastern Temperate Freshwater Wetlands
AZa 4 Upper Gariep Alluvial Vegetation
AZa 5 Highveld Alluvial Vegetation
AZi 3 Southern Kalahari Mekgacha
AZi 4 Southern Kalahari Salt Pans
AZi 10 Highveld Salt Pans
W 1 Freshwater Lakes
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RESOURCES/NOTES
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PROJECT
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TITLE
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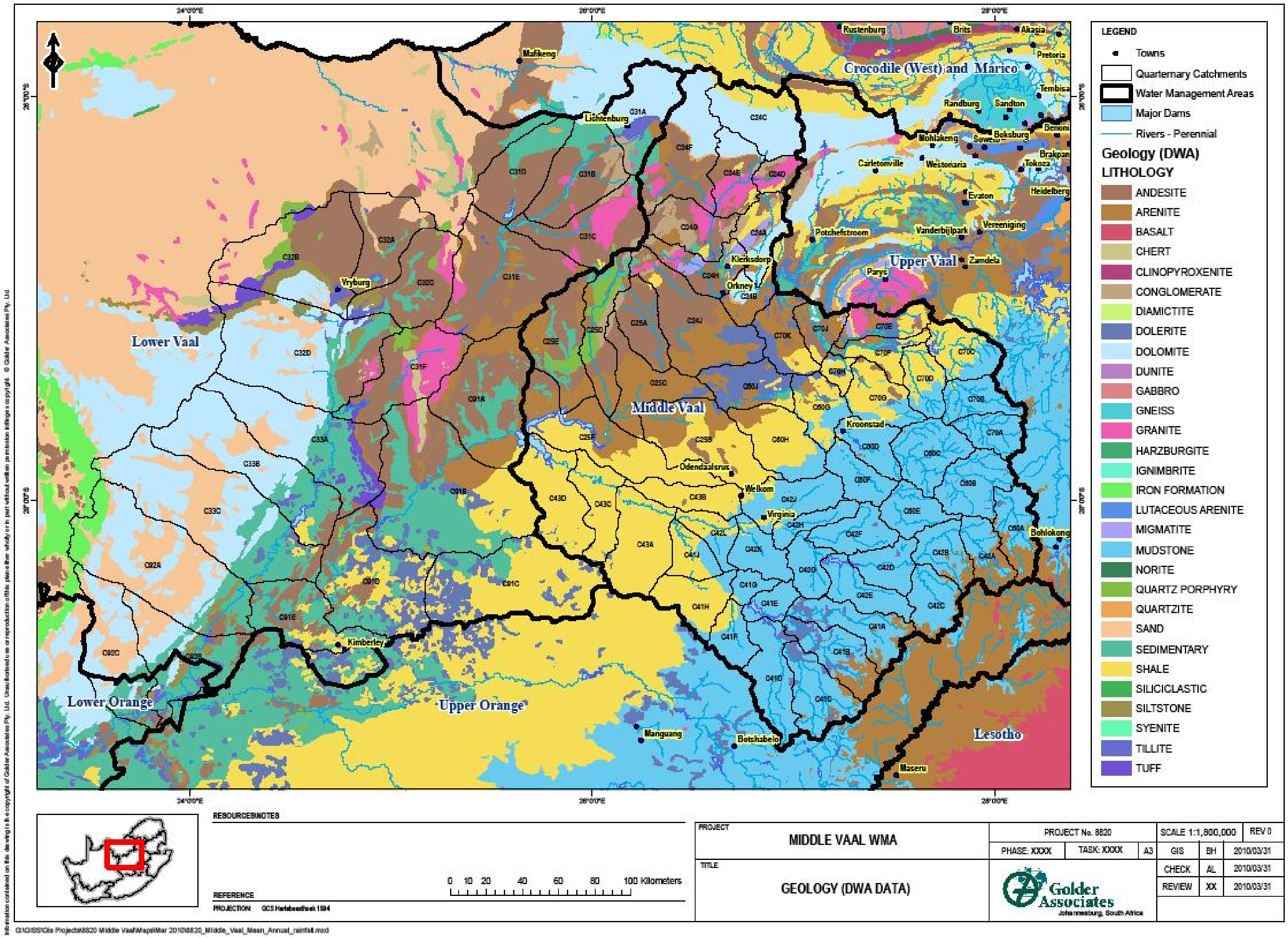
Golder Associates
Johannesburg, South Africa

APPENDIX G
LITHOLOGY AND SOILS OF THE STUDY AREA


LEGEND
Towns
Quarternary Catchments
Water Management Areas
Major Dams
Rivers - Perennial
Geology (DWA)
LITHOLOGY
ANDESITE
ARENITE
BASALT
CHERT
CLINOPYROXENITE
CONGLOMERATE
DIAMICTITE
DOLERITE
DOLOMITE
DUNITE
GABBRO
GNEISS
GRANITE
HARZBURGITE
IGNIMBRITE
IRON FORMATION
LUTACEOUS ARENITE
MIGMATITE
MUDSTONE
NORITE
QUARTZ PORPHYRY
QUARTZITE
SAND
SEDIMENTARY
SHALE
SILICICLASTIC
SILTSTONE
SYENITE
TILLITE
TUFF
Crocodile (West) and Marico
Upper Vaal
Middle Vaal
Lower Vaal
Lower Orange
Upper Orange
Lesotho
Mafikeng
Lichtenburg
Rustenburg
Brits
Akasia
Pretoria
Tembisa
Randburg
Sandton
Benoni
Boksburg
Brakpan
Tokoza
Heidelberg
Carletonville
Westonaria
Evaton
Vereeniging
Vanderbijlpark
Potchefstroom
Klerksdorp
Orkney
Parys
Zamdela
Vryburg
Kroonstad
Odendaalsrus
Welkom
Virginia
Kimberley
Manguang
Botshabelo
Maseru
Bohlokong
0 10 20 40 60 80 100 Kilometers
RESOURCES/NOTES
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PROJECTION: GCS Hartebeesthoek 1994
PROJECT
MIDDLE VAAL WMA
TITLE
GEOLOGY (DWA DATA)
PROJECT No. 8820
PHASE: XXXX
TASK: XXXX
A3
SCALE 1:1,800,000
REV 0
GIS BH 2010/03/31
CHECK AL 2010/03/31
REVIEW XX 2010/03/31
Golder Associates
Johannesburg, South Africa