CLASSIFICATION OF SIGNIFICANT WATER RESOURCES IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS (WP 10506)

ECOLOGICALLY SUSTAINABLE BASE CONFIGURATION (ESBC) SCENARIO REPORT

FINAL

REPORT NO.: **RDM/WMA1, 3/00/CON/CLA/0412**

Directorate: Water Resource Classification

SEPTEMBER 2013

water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Published by

Department of Water Affairs
Private Bag X313
Pretoria, 0001
Republic of South Africa

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This report is to be cited as:

Directorate Water Resource Classification. Department of Water Affairs, South Africa, September 2013. **CLASSIFICATION OF SIGNIFICANT WATER RESOURCES IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS:** Ecologically Sustainable Base Configuration (ESBC) Report. Report No: RDM/WMA1, 3/00/CON/CLA/0412

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Title:	*Ecologically Sustainable Base Configuration (ESBC) Report*
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***Project Name**:*	*Classification of significant water resources in the Crocodile (West), Marico Mokolo and Matlabas catchments: (WP 10506)*
DWA Report No:	*RDM/WMA1, 3/00/CON/CLA/0412*
***Status of Report**:*	*Final*
First Issue:	*April 2013*
Final Issue:	*September 2013*

Professional Service Providers: **Golder Associates Africa/ RMM Stassen/ Zitholele Consulting/ Prime Africa and Wetland Consulting Services**

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LIST OF ABBREVIATIONS AND ACRONYMS

CD: RDM	Chief Directorate: Resource Directed Measures
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological importance and sensitivity
ESBC	Ecologically Sustainable Base Configuration
EWR	Ecological Water Requirements
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
KNP	Kruger National Park
MC	Management Class
NFEPA	National Freshwater Ecosystem priority areas
NWA	National Water Act
PES	Presentation Ecological State
REC	Recommended Ecological Category
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
WMA	Water Management Area
WRCS	Water Resource Classification System
WRYM	Water Resources Yield model

GLOSSARY

Some key terms and definitions as for Water Resource Classification as applied in the study:

Ecological Importance and Sensitivity (EIS)	Key indicators in the ecological classification of water resources. Ecological importance relates to the presence, representativeness and diversity of species of biota and habitat. Ecological sensitivity relates to the vulnerability of the habitat and biota to modifications that may occur in aspects such as flow, water levels and physico-chemical conditions.
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Ecological Water Requirement Sites	Specific points on the river as determined through the site selection process. An EWR site consists of a length of river which may consist of various cross-sections for both hydraulic and ecological purposes. These sites provide sufficient indicators to assess environmental flows and assess the condition of biophysical components (drivers such as hydrology, geomorphology and physico-chemical) and biological responses (*viz*. fish, invertebrates, riparian vegetation).
Integrated unit of analysis (IUAs)	The basic unit of assessment for the classification of water resources. The IUAs incorporates socio-economic zones and are defined by catchment area boundaries.
Management Class (MC)	The MC is representative of those attributes that the DWA (as the custodian) and society require of different water resources (consultative process). The process requires a wide range of trade-offs to assessed and evaluated at a number of scales. Final outcome of the process is a set of desired characteristics for use and ecological condition each of the water resources in a given catchment. The WRCS defines three management classes, Class I, II, and III based on extent of use and alteration of ecological condition from the predevelopment condition.
Present Ecological State (PES)	The current state or condition of a water resource in terms of its biophysical components (drivers) such as hydrology, geomorphology and water quality and biological responses *viz*. fish, invertebrates, riparian vegetation). The degree to which ecological conditions of an area have

	been modified from natural (reference) conditions.
Recommended Ecological Category (REC)	The Recommended Ecological Category is the future ecological state (Ecological Categories A to D) that can be recommended for a resource unit depending on the EIS and PES. The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of.
River Node	These are modelling point's representative of an upstream reach or area of an aquatic eco-system (rivers, wetlands, estuaries and groundwater) for which a suite of relationships apply.
Scenario	Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition.
Significant Water Resources	Water resources that are deemed to be significant from a water resource use perspective, and/or for which sufficient data exist to enable an evaluation of changes in their ecological condition in response to changes in their quality and quantity of water. Water resources are deemed to be significant based on factors such as, but not limited to, aquatic importance, aquatic ecosystems to protect and socio-economic value.
Sub-nodes	Finer scale of modelling pointsdefined within a particular IUA at which flows and water qualities will be set to protect a particular ecological subarea that is identified as important and sensitive.
Sub-quaternary catchments	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments). The update of the PES and EIS (2010) status has been determined per sub-quaternary.
Trade-offs	Balancing of all factors in relation to the water resource and/or and IUA(s) that are not necessarily attainable at the same which may involve a giving up of one benefit, advantage, etc. in order to gain another regarded as more desirable. This may include balancing of those factors between use and protection (which may or may not be conflicting), between

downstream impacts and upstream uses and vice versa, between possible use of resources within a catchment and between catchments, and between possible resource uses between different parts of the country. Decisions on these trade-offs will have different implications for different stakeholders at local, regional and national levels.

Water Resource Yield Model (WRYM)

The WRYM is a yield model, developed by the Department of Water Affairs, to assess system yield. In terms of the WRCS process it will be used to assess the yield for each IUA for the different catchment configuration scenarios.

EXECUTIVE SUMMARY

Background

Chapter 3 of the National Water Act (NWA, Act 106 of 1998) provides for the protection of water resources through the implementation of resource directed measures (RDM) which includes the Classification of water resources, setting the Reserve and Resource Quality Objectives. Classification of water resources aims to ensure that a balance is reached between the need to protect and sustain water resources and the need to develop and use them.

The Chief Directorate: Resource Directed Measures (RDM) has initiated the Classification of Significant Water Resources Study for the Crocodile (West) Marico Water Management Area (WMA) and Matlabas and Mokolo catchments of the LimpopoWMA.The purpose of this study is to coordinate the implementation of the 7 step process of the Water Resource Classification System (WRCS)in these WMAs in order to determine a suitable management class(MC) for all significant water resources. As part of the Classification process Step 4 requires that the Ecologically Sustainable Base Configuration (ESBC) Scenario is defined.

In terms of the classification of water resources, an ESBC scenario is established in order to understand what the result would be in terms of system yield of implementing the minimum base level of ecological protection required to ensure sustainable use of the catchments' water resources (which includes the consideration of ecological, water quality and quantity needs). It is not the target scenario but informs the minimal protection level required, constructed as a starting point for the hydrological analysis of the water resource system.

Once this sustainable ecological protection level is understood, various levels of resource directed protection can be assessed in terms of the overall socio-economic implications to the Integrated Units of Analysis (IUAs) and the WMA.

This report describes the approach to be used for the establishment of the ESBC scenario and the system water balance that will results from implementation of the scenario. The modelled results will be presented at the PSC in March 2013.

Approach

The process followed in terms of the establishment of the ESBC is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWAF, February 2007a and 2007b).

The ESBC scenario, which would permit the maximum water use scenario, requires that the base condition for each water resource is at minimum established as either a D category or as whichever higher category is required to maintain all downstream nodes in at least a D category. However where the ecological condition requires it, a higher ecological category needs to be set.

The ESBC scenario is established once this base condition is hydrologically and ecologically tested to ensure that it is feasible and can be achieved. In other wordsthe results will reflect whether the catchment water balance would be in surplus or deficit by implementing a D category EWR.

In terms of the Crocodile (West), Marico, Mokolo and Matlabas catchments, the D ecological category (EC) was not selected as the default ESBC. Rather the selected EC per IUA was based on the assessment of the present ecological state (PES) and ecological/conservation importance of water resources within the IUAs. These selected ECs at the outlet of the IUAs are listed in Table E1. The proposed IUA management classes (MCs) associated with this ESBC scenario are also indicated.

Table E1: EC (PES) for the ecological sustainable base configuration (aggregated per IUA)

IUA	Catchment area	Ecological Category (ESBC)	IUA Management Class associated with scenario
1	Upper Crocodile/Hennops/Hartebeespoort	D	III
2	Magalies	C	II
3	Crocodile/Roodekopjes	C/D	III
4	Hex/Waterkloofspruit/Vaalkop	C	II
5	Elands/Vaalkop	C	II
6a	Klein Marico/Kromellemboog	B/C	II
6b	Groot Marico	B/C	II
7	Kaaloog-se-Loop	B	I
8	Malmaniesloop	-	I
9	Molopo	C	II
10	Dinokeng Eye/Ngotwane Dam	-	II
11a	Groot Marico/Molatedi Dam	C/D	III
11b	Groot Marico/seasonal tributaries	C	II
12	Bierspruit	D	III
13	Lower Crocodile	C/D	III
14	Tolwane/Kulwane/Moretele/Klipvoor	D	III
15	Upper Mokolo	B/C	II
16	Lower Mokolo	B/C	II
17a	Mothlabatsi/Mamba	B/C	I
17b	Matlabas/Limpopo	B/C	II

Having established the ECs required for the sustainable use of the water resources in the WMAs (the EC represented per IUA above), the ESBC scenario (Scenario 1) to be tested in the WRYM include the following parameters:

Table E2: Ecological sustainable base configuration criteria

Sub-catchment	**Present day water requirements**	**EWR**
Crocodile West	2008: Water Requirements as per Reconciliation Strategy (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Marico, Molopo	2009: Updated hydrology for the Marico,	PES EC

Sub-catchment	Present day water requirements	EWR
& Ngotwane	Ngotwane and Molopo catchments (present day water use)	Include all flow components (maintenance low and floods/freshets)
Mokolo	2007: Updating the hydrology and yield analysis of the Mokolo River catchment(present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Matlabas	2004: ISP documents and WR2005 information (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)

The yield model will be setup for the various catchments within the WMAs and tested before the changes are made for the ESBC scenario. The assessment will allow for evaluation of the changes in yield with the inclusion of the EWRs for maintaining the PES ecological category. This will allow for the assessment of the water balance (surpluses/deficits).

Results of Scenario 1 (ESBC):

The yield model for the Crocodile West, Marico, Mokolo and Matlabas catchments were setup and run for the ESBC scenario to evaluate the changes in yield that would result with the EWRs for the PES ecological category. This configuration of ecological categories ensures that a sustainable level of ecosystem functioning is maintained. The yield analysis results with the ESBC scenario indicate varying degrees of water surpluses and deficits for the major dams in the catchments.

Table E3: Impact of EWR (PES) at major dams

Major Dam	Catchment	Yield without EWR (million m^3/a)	Yield with EWR (million m^3/a)
Klein Maricopoort	A31D	5.38	3.98
Kromelmboog	A31E	2.61	2.44
Marico Bosveld	A31B	21.54	9.19
Molatedi	A32C	11.37	11.9
Mokolo	A42F	38.7	3.48
Hartbeespoort	A21H	237.9	231.0
Roodekopjes	A21L	59.0	55.0
Lindleyspoort	A22E	3.4	2.7
Bospoort	A22H	1.3	0.9
Vaalkop	A22J	6.5	3.4
Roodeplaat	A23A	37.5	35.0
Klipvoor	A23J	24.5	28.0

* All other water user requirements (irrigation, domestic, industrial, mining, power generation and forestry) within the catchments were included for both yield with and without EWR.

The yields in the major dams of the Crocodile West catchment show a slight decrease with the largest decrease in the Elands River catchment at Vaalkop Dam. The yield from Klipvoor Dam increased mainly due to EWR releases.

The yield in the Marico Bosveld dam reduced by almost 60% with the inclusion of the EWRs but shows a slight increase in yield at Molatedi Dam downstream

This configuration of ecological categories will ensure a sustainable level of ecosystem functioning in the Crocodile (West), Marico, Mokolo and Matlabas catchments.

Alternate Catchment Configuration Scenarios

Having established the ESBC, the classification process requires that additional catchment scenarios are configured for the IUAs within the WMAs to assess the resulting yields of alternate ecological protection categories; conservation targets and future use and developments to determine what is most feasible and achievable in terms of a MC. The alternative catchment configuration scenarios to be assessed are listed in Table E4.

Table E4: Alternative catchment configuration scenarios

Scenario	Water Requirements	EWR
2	Present day water requirements	Recommended Ecological Category (REC) Include all flow components (maintenance low and floods/freshets)
3	Present day water requirements	Class III throughout the system (EWR D Category, include all flow components - maintenance low and floods/freshets)
4	Future Water Requirements	PES EC Include all flow components (maintenance low and floods/freshets)
5	Future Water Requirements	Recommended Ecological Category (REC) Include all flow components (maintenance low and floods/freshets)

The focus of this report is scenario 1, the ESBC scenario. Scenarios 2 to 5 are listed here but will be discussed in more detail in Task 5 of the WRCS process.

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1 INTRODUCTION

1.1 Background

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the water resource systems. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of resource directed measures (RDM). As part of the RDM, a management class (MC) must be determined for a significant water resource, as the means to ensure a desired level of protection. The purpose of the MC is to establish clear goals relating to the water quantity and quality of the relevant water resource.

The classification system, the Reserve and Resource Quality Objectives (RQOs) together are intended to ensure comprehensive protection of all water resources. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical and affordable.

The Chief Directorate: Resource Directed Measures (CD:RDM) of the Department of Water Affairs (DWA) is tasked with the responsibility of ensuring that the water resources are classified in terms of the Water Resource Classification System (WRCS) to ensure that a balance is sought between the need to protect and sustain water resources and the need to develop and use them. The CD: RDM has identified the need to undertake the classification of significant water resources (rivers, wetlands, groundwater and lakes) in the Crocodile (West), Marico, Mokolo and Matlabas catchments in accordance with the WRCS.

The MC and associated RQOs will assist the DWA in making more informed decisions regarding the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

1.2 Study Area

The spatial extent for the classification study includes the Crocodile (West), Marico (including the Ngotwane and Upper Molopo), Mokolo and Matlabas catchments (Figure 1). The following tertiary catchments are included:

- Crocodile (West) – A21, A22, A23 and A24;
- Marico – A31 and A32;
- Matlabas – A41;
- Mokolo – A42;
- Upper Molopo – quaternary catchment D41A; and
- Ngotwane – A10.

Mokolo catchment

The Mokolo catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River, and includes the Mokolo Dam and a number of smaller tributaries that join the main Mokolo River up to its confluence with the Limpopo River, including the Tambotie, Sterkspruit, Poer-se- Loop, and Rietspruit. The catchment covers an area of 8 387 km^2.

Exxaro's Grootegeluk Colliery the largest open cast coal mine of its kind in the world, with a current annual production of 15.3 Mt/a, is currently the only commercial coal mining operation in the Waterberg Basin and is being expanded to supply the new Medupi Power Station with coal. However, the Lephalale area has been selected by Sasol to access the vast coal reserves in the Waterberg coal fields for its Maphuta coal to liquid fuel projects (Mafutha). This project is currently on the backburner. Additional to Matimba and Medupi three new Eskom power stations CF3, CF4 and CF5 are envisaged for the future.

Matlabas catchment

The Matlabas catchment is situated in a predominantly flat area of the Limpopo WMA. Matlabas River originates in the Waterberg mountain range and the altitude varies from 1 400 m to approximately 840 m at the confluence with the Limpopo River. The catchment is largely undeveloped with limited water resources and limited water use. The area covers approximately 6 014 km^2.

The Steenbokpan area, quaternary catchment A41E in the Matlabas catchment, is part of the Lephalale coalfield and numerous mining developments are foreseen for this region. Current and future developments around the available coal reserves in the Steenbokpan area will require adequate planning for future water needs.

Crocodile (West) catchment

The Crocodile (West) catchment covers a total area of 29 332 km^2. The main tributaries are the Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies, Elands and Bierspruit which together make up the A20 secondary drainage catchment, with 40 quaternary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mozambique.

The Crocodile River originates at the high altitude of Johannesburg in the Gauteng Province, with the central and western parts of the catchment in North West Province and the north and north eastern parts in the Limpopo Province.

There are 9 major dams in the catchment with the largest being Hartbeespoort Dam situated in the upper reaches of the Crocodile River. Some of the other major dams are Roodeplaat and Klipvoor dams on the Pienaars and Moretele Rivers, Vaalkop Dam on the Lower Elands River and Roodekopje Dam in the middle reaches of the Crocodile River. Most of these dams are utilised for irrigation purposes.

Large metropolitan and industrial areas are situated in the catchment of the Crocodile River (Tswane, Johannesburg and Rustenburg). A number of mines are situated in the Rustenburg and Thabazimbi areas. Water, mostly potable water is transferred into the catchment from the Upper Vaal via the Rand Water bulk distribution system. Large volumes of water are drawn for irrigation and other purposes from the dolomitic aquifer that stretches along thesouthern parts of the catchment. The sandy aquifers occurring in theLower Crocodile River supply water for irrigation purposes. These aquifers are recharged from rainfall as well as river flow. Stock and game farming dominate land-use in the drier northern and western regions.

Marico catchment

The Marico River catchment falls within tertiary catchments A31 and A32, with the Klein Marico River and Polkadraaispruit the only major tributaries of the Marico River. The flow in the Marico River is highly variable and intermittent apart from the almost constant discharges from dolomitic eyes at its source. There are a number of major dams in the catchment, namely Marico Bosveld Dam in the upper Marico River, Molatedi Dam in the lower reaches of Marico River and Klein Maricopoort and Kromelmboog dams on the Klein Marico River.

The upper part of the Marico River catchment comprises commercial irrigation with rural subsistence agriculture in the middle to lower reaches. Some water is released from Molatedi Dam at Tswasa Weir for irrigation in the lower reaches of the catchment. Water is also transferred from Molatedi Dam to Botswana.

Zeerust and the town of Groot Marico are the only major towns in the catchment. Madikwe Game Reserve is situated in the middle to lower reaches of the catchment.

Upper Molopo catchment

The Molopo River is a tributary of the Orange River. The Molopo Eye in quaternary catchment D41A is the source of the Molopo River. Most of the water from the eye is diverted for urban use and only a small proportion is left in the river. The Molopo River flows ceases as a surface flow at the border of South Africa and Botswana. There are large dolomitic aquifers present in the Upper Molopo.

Mafikeng, the capital of the North West Province is situated in the Upper Molopo catchment. The remainder of the towns are small settlements with subsistence farming and grazing the main activities. Commercial irrigation from the dolomitic aquifers occurs in the northern and western areas of the catchment.

Ngotwane catchment

The Ngotwane River is a tributary of the Limpopo River and comprises quaternary catchment A10A, A10B and A10C that forms the border between South Africa and Botswana. The catchment is rural with some cattle grazing and subsistenceagriculture.

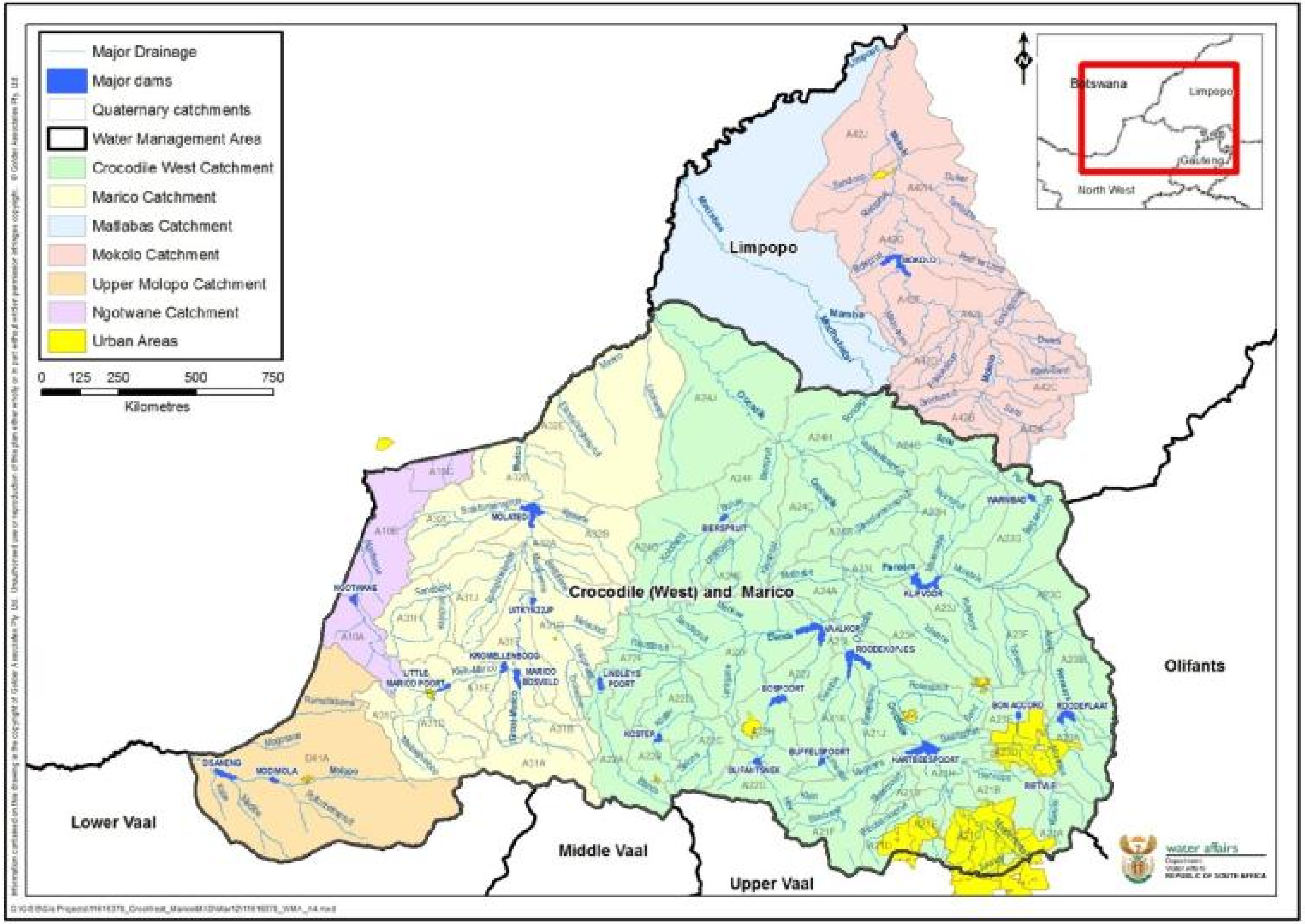


Figure 1: Study area – The Crocodile (West), Marico, Mokolo, Matlabas, Molopo and Ngotwane catchments

1.3 Purpose of the Study: Classification of Significant Water Resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments

The purpose of this study is to coordinate the implementation of the 7 step process of the WRCS (Figure 2) in the Crocodile (West), Marico, Mokolo and Matlabas catchments, in order to determine a suitable MC for the significant water resources and in so doing, deliver the Integrated Water Resource Management (IWRM) template with recommendations for presentation to the delegated authority of DWA.

The determination of the MC is necessary to facilitate a balance between protection and use of water resources. In determining the class, it is important to recognise that different water resources will require different levels of protection. In addition to achieving ecological sustainability of the significant water resources through classification, the process will allow due consideration of the social and economic needs of competing interests by all who rely on the water resources.

The WRCS will be applied taking account of the local conditions, socio-economic imperatives and system dynamics within the context of the South African situation. The process will also require a wide range of complex trade-offs to be assessed and evaluated at a number of scales.

The water resources of these WMAs are highly utilised and regulated and like many other WMAs in South Africa its water resources are becoming more stressed due to an accelerated rate of development resulting in the scarcity of water resources. The classification of these significant resources will ensure that the water resources are able to sustain their level of uses and be maintained at their desired states. The MC of the significant water resources in these WMAs will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users. The MC of the water resource will therefore set the boundaries for the volume, distribution and quality of the Reserve and RQOs, and thus the potential allocable portion of a water resource for use.

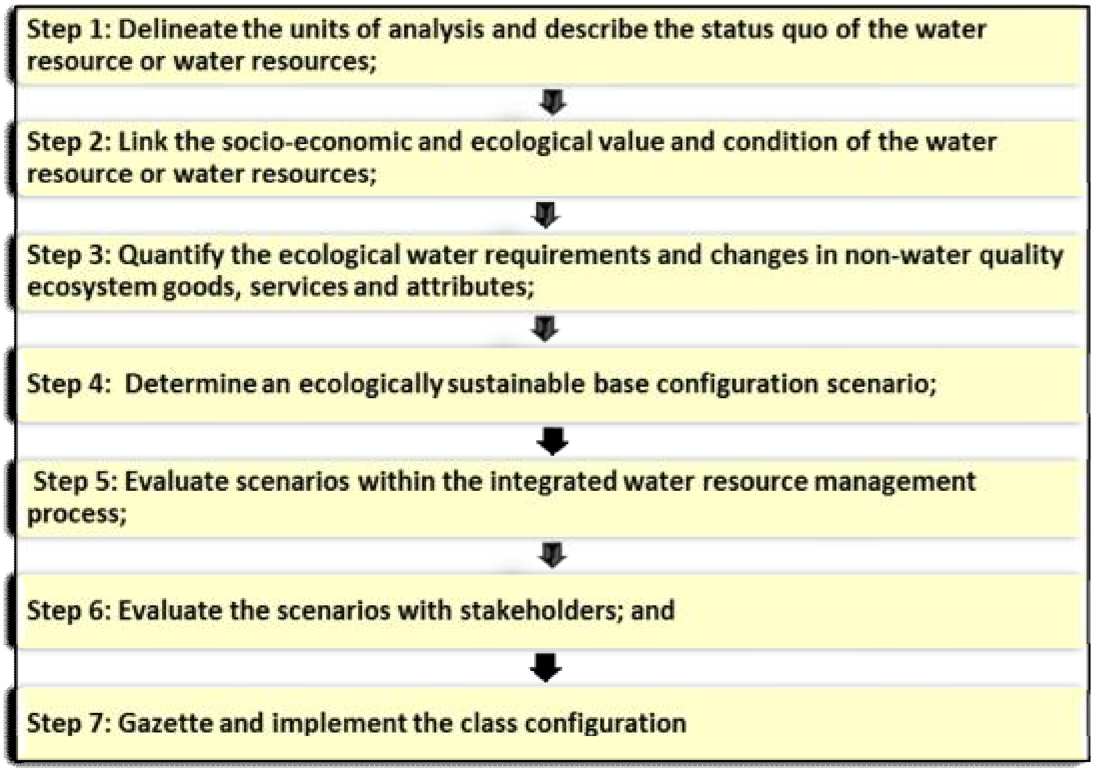


Figure 2: Steps in determining the Management Class (MC)

2 INTEGRATED UNITS OF ANALYSIS AND THE RIVER NODES

2.1 Integrated Units of Analysis (IUAs)

As part of the classification process to date, twenty Integrated Units of Analysis (IUAs) have been defined for the Crocodile (West), Marico, Mokolo and Matlabas catchments (Figure 3 and Table 1). These have been based on socio-economics of the areas, water uses and users, envisaged level of protection required and significance of the resource. The availability of representative Ecological Water Requirement (EWR) sites within each IUA and catchment boundaries and catchment modelling schematics were also considered. The WRCS Guideline, Volume 2, Ecological, hydrological and water quality guidelines for the 7-step classification procedure (February 2007) was followed in terms of IUA delineation. The scale definition of the IUAs is secondary drainage regions.

The IUAs are approximate socio-economic boundaries, and are delineated to facilitate the integration of ecological and socio-economic aspects that is required for the evaluation of scenarios as part of the Classification process.

Table 1: Catchments included in the twenty IUAs defined for the Crocodile (West), Marico, Mokolo and Matlabas catchments

IUA	IUA name	Quaternary Catchment
1	Upper Crocodile/ Hennops/ Hartbeespoort	A21A-E; A21H;A23A; A23B; A23D and A23E
2	Magalies	A21F and A21G
3	Crocodile/Roodekopjes	A21J
4	Hex/Waterkloofspruit/Vaalkop	A21K; A22G; A22H; A22J
5	Elands/Vaalkop	A22A -F
6a	Groot Marico	A31D and A31E
6b	Klein Marico/Kromellemboog	A31B
7	Kaaloog-se-Loop	A31A
8	Malmaniesloop	A31C
9	Molopo	D41A
10	Dinokana Eye/Ngotwane Dam	A10A; A10B and A10C
11a	Groot Marico/Molatedi Dam	A31F-J; and A32A-C
11b	Groot Marico/seasonal tributaries	A32D; A32E
12	Bierspruit	A24D-F
13	Lower Crocodile	A21L: A24A-C and A24G-J
14	Tolwane/Kulwane/Moretele/Klipvoor	A23C; A23F-L
15	Upper Mokolo	A42A-F
16	Lower Mokolo	A42G-J
17a	Mothlabatsi/Mamba	A41A and A41B
17b	Matlabas	A41C and A41D

2.2 River Nodes

The WRCS process requires that river nodes be established through the network of significant water resources within the IUAs delineated. Rivers nodes are established to account for interactions between ecosystems and to account for specific catchment issues or impacts and to serve as modelling points for the Classification process in a catchment. The nodes are used to assess the response of upstream water resources to changes in water quality, quantity and timing (DWA, 2007). River nodes could either be biophysical nodes or allocation nodes. Biophysical nodes should be located at interactions between ecosystems and at the end points of eco-system reaches to account for interactions. Management or allocation nodes should be located at the downstream edge of a reach of interest, as required for modelling and to allow for meaningful trade-offs.

The establishment of biophysical and management (allocation) nodes is guided by a number of considerations. The key considerations are:

- Significant water resources
- Biophysical and eco-regional characteristics;
- Location of Ecological Water Requirement (EWR) sites and ecological information;
- Ecological Importance and Sensitivity categories of water resources;
- Present Ecological State;
- Broad-scale hydrological and geomorphological characteristics;
- Water infrastructure; and
- Water management, planning and allocation information.

A total of 62 nodes were identified for the Crocodile (West) – Marico and Limpopo (Mokolo and Matlabas) WMAs (Figure 3).The selected river nodes listed in Table 2 are located at the end points of ecosystems and allocation reaches and have been included in the yield modelling. The assessment of scenarios will determine if the required flows at the river nodes can be met and evaluate trade-offs that may have to be made.

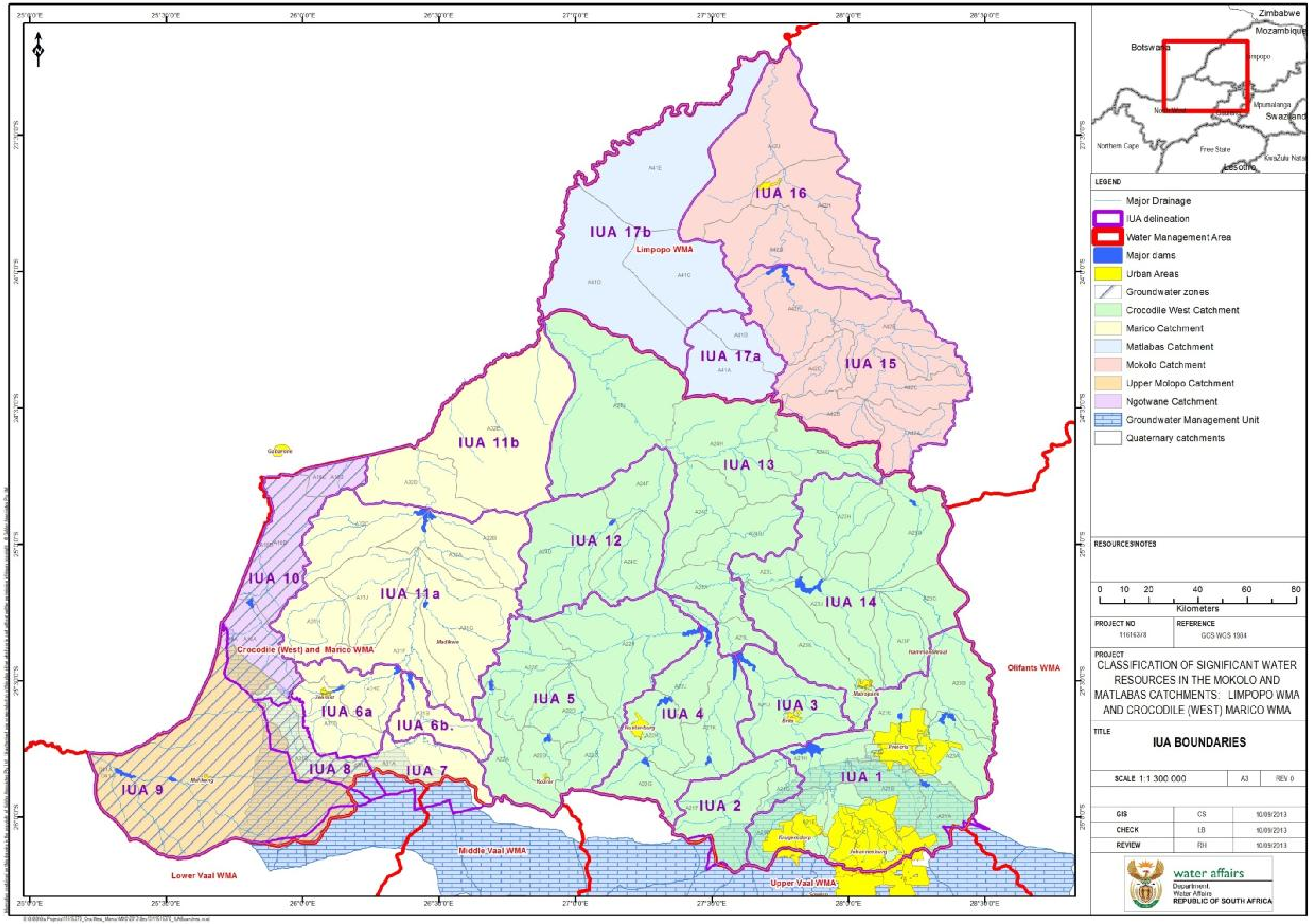


Figure 3: IUAs delineated within the Crocodile (West), Marico, Mokolo and Matlabas catchments indicating river nodes and EWR sites

Table 2: River nodes selected that define the network of significant water resources for scenario analysis

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	Low	Low	C	Management, urban impacts, Rietvlei Dam	Quantity/quality, dolomitic
	HN2	A21B	Sesmylspruit with its' tributaries to confluence with Hennops	Moderate	Moderate	E	Biophysical, urban impacts	Quality
	HN3	A21C	Modderfonteinspruit to confluence with Jukskei	Moderate	Moderate	E	Biophysical, urban, industrial;	Quality
	HN4	A21C	Klein Jukskei at confluence with Jukske	Moderate	Moderate	E	Biophysical. semi urban	Quality
	HN5	A21C	Jukskei River at CROC_ EWR2	Moderate	Moderate	E	Biophysical, WWTW	Quantity/quality
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Moderate	Moderate	D	Biophysical, acid mine drainage, dolomitic, Botanical gardens, Cradle of Humankind	Quality/quantity
	HN7	A21A, B, H	Hennops (source) to confluence with Crocodile	Moderate	Moderate	D	Biophysical, urban, industrial	Quantity/quality
	HN8	A21H	Swartspruit to Hartbeespoort Dam	Moderate	Moderate	D	Semi urban	Quality
	HN9	A21E, H	Crocodile (source) to CROC_EWR1	Moderate	Moderate	D	Biophysical, urban	Quantity/quality
	HN10	A21H, J	Crocodile at Hartbeespoort Dam, outlet of IUA1	High	High	C/D	Hartbeespoort Dam, Management	Quantity/quality
	HN11	A23A	Pienaars(source) and including Moreletaspruit and Edendalespruit to outlet of Roodeplaat Dam	Low	Low	E	Management, urban, industrial; WWTW, canalised, Roodeplaat Dam	Quantity/quality
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	High	High	C	Management, sand mining	Quantity/quality
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	High	High	C	Biophysical	Quantity/quality
	HN14	A23D	Skinnerspruit (source) to confluence with Apies	Low	Low	E	Biophysical, urban, canalised urban river	Quantity/quality
	HN15	A23D, E	Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Low	Low	F	Management, dolomitic at source	Quantity/quality,
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	Very high	Very high	B	Biophysical, dolomitic at source	Quantity
	HN17	A21G, F	Magalies (CROC_EWR15)	Low	Low	C/D	Management	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN18	A21G, F	Skeerpoort at outlet of IUA2	Low	Low	C/D	Management	Quantity/quality
3	HN19	A21J	Rosespruit at confluence with Crocodile	High	High	C/D	Biophysical	Ecological
	HN20	A21J	Crocodile from Hartbeespoort Dam to upstream Roodekopjes Dam, outlet of IUA3	Moderate	Moderate	D	Biophysical	Ecological
4	HN21	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11)	High	High	C	Biophysical	Quantity/quality
	HN22	A21K	Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	High	High	C	Management	Quantity/quality
	HN23	A22G	Hex (source) to Olifantsnek Dam	Moderate	High	C	Management, Olifantsnek Dam	Quantity/quality
	HN24	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex	Low	Low	B/C	Biophysical, wetland, nature reserve	Wetland driven
	HN25	A22H	Hex from Olifantsnek Dam to Bospoort Dam	Moderate	Moderate	D	Management, urban, mining, Bospoort Dam	Quantity
	HN26	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6)	Moderate	Moderate	D	Biophysical, Bospoort Dam	Quantity/quality
	HN27	A22J	Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	Moderate	Moderate	D	Management, Vaalkop Dam	Quantity/quality
5	HN28	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10)	High	High	C	Management	Quantity
	HN29	A22A	Elands from Swartruggens Dam to Lindleypoort Dam	Moderate	High	C	Management, Swartruggens Dam, WWTWs	Quantity/quality, management
	HN30	A22B	Koster (source) to Koster Dam	Moderate	High	C	Biophysical, wetland	Wetland driven
	HN31	A22C, A22D	Selons to confluence with Elands	Moderate	High	C	Biophysical	Quantity/quality
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	Low	Low	C	Management, Lindleyspoort Dam	Quantity/quality, management
6b	HN33	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6)	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN34	A31B	Marico from MAR_EWR2 to N4 road at town	Very High	Very High	B	Biophysical	Quantity/quality
	HN63	A31B	Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	Very High	Very High	B	Biophysical	Quantity/quality
6a	HN64	A31D	Malmaniesloop to confluence with Klein Marico Klein Marico and tributaries upstream of	High	High	C	Biophysical, groundwater, WWTW, urban	Groundwater node

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
			Zeerust					
	HN35	A31D	Klein Marico from Zeerust to Klein Maricopoort Dam	High	High	C	Biophysical	Quantity/quality
	HN65	A31E	Klein Mario from Klein Maricopoort Dam to	High	High	C	Management, Klein Maricopoort Dam	Quantity/quality
	HN36	A31E	Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	Moderate	Moderate	C	Management, Kromellemboog Dam	Quantity/quality
7	HN37	A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico	Very High	Very High	B	Biophysical, dolomitic	Quantity
	HN38	A31A	Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	High	High	B	Biophysical, dolomitic	Quantity
8	-	A31C	Groundwater	-	-	-	Management, groundwater	Groundwater node
9	HN66	D41A	Molopo at outlet of wetland	-	-	-	Management, groundwater	Groundwater node
	HN67	D41A	Molopo at Modimola	Low	Low	E	Biophysical	Quality
	HN39	D41A	Molopo at outlet of IUA9	Low	Low	E	Management	Quality
10	HN68 -	A10A A10A, B, C	Ngotwane from Dinokana to Ngotwane Dam Ngotwane from Dinokana to outlet of IUA10	- -	- -	- -	Management, groundwater, Ngotwane Dam Management	Groundwater node
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	High	High	C/D	Management, Madikwe Nature Reserve, Marico-Bosveld Dam	Quantity
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	High	High	C	Management, Molatedi Dam, Twasa weir, international, Madikwe Nature Reserve	Quantity/quality
12	HN42	A24D, E, F	Bierspruit to confluence with Crocodile River, outlet of IUA12	Moderate	Moderate	D	Mining	Seasonal rivers, quantity
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Moderate	Moderate	C	Biophysical	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	Moderate	Moderate	D	Management, irrigation, mining, transfer	Quantity/quality,
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	Moderate	Moderate	C	Management for international, groundwater	Quantity/quality
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	Moderate	Moderate	B/C	Biophysical	Quantity
	-	A23C, A23F	Wetland at Pienaars & Apies confluence and inflow to Klipvoor Dam	Moderate	Moderate	C	Biophysical; floodplain	Quantity/wetland
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	Moderate	Moderate	C	Biophysical	Quantity
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	High	High	D	Management, Klipvoor Dam, Borakalalo Nature Reserve	Quantity/quality
	HN49	A23K	Tolwane to confluence with Moretele	High	High	D	Biophysical	Quantity/quality
15	HN50	A42A	Sand (source) to confluence with Grootspruit	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN51	A42B	Grootspruit (source) to confluence with Sand	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	High	High	C/D	Biophysical	Quantity/quality
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	High	High	B/C	Biophysical	Quantity/quality
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	High	High	B/C	Biophysical, Ecological	Quantity,
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	Very high	Very high	B/C	Biophysical	Quantity/quality
16	HN56	A42G	Rietspruit (source) to Mokolo confluence	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN57	A42G	Mokolo below dam (MOK_EWR3) to Rietspruit confluence (MOK_EWR4)	Very High	Very High	B/C	Management, Mokolo Dam	Quantity/quality
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	Very High	Very High	C	Biophysical, floodplain	Use wetlands requirements for river
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	Very High	Very High	B	Biophysical, Marekele National Park	Quantity,
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	Moderate	Moderate	B/C	Biophysical	Quantity

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	High	High	B/C	Biophysical	Quantity/quality
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	Moderate	Moderate	B	Management, international	Quantity/quality

Note: The PES and EIS included in the above table are at the EWR sites as determined during the Reserve studies with the rest of the PES, EI and ES from the desktop assessments undertaken for that specific reach during 2010-2012

3 GEOLOGY

The geology as published by the Council for Geoscience on 1:250 000 scale maps for the study area is shown in **Figure 4** in relation to the delineated IUAs (Figure 3). Major fault zones are also indicated as increased groundwater yield potential is generally present at these structures. The groundwater resource potential of the major faults is often not recognised.

3.1 Matlabas and Mokolo catchments

The Limpopo Mobile Belt is present in the northern sections of IUAs 16 and 17b which comprisegneissic, granites, granulites, serpentenites, metapelites and horneblende gneisses that have undergone high grade granulite metamorphism. The Beit Bridge Complex consists of metaquartzite, calcsilicate, amphibolite, meta-pelite and pink hornblende gneisses and represents part of the Greenstone Belts. These Greenstone Belts are infolded mainly into grey granitic gneisses which dominate the early Archaean terranes

To the south of the Limpopo Mobile Belt the area is underlain by Waterberg Group sandstones which cover most of IUAs 15, 17a and the southern portion of IUA 16, consisting of a wide variety of different lithology's.

Karoo Super Group rocks consisting of shale, shaley sandstone conglomerate with coal in places, occur in the central portions of IUAs16 and 17b.

3.2 Crocodile (West) and Marico ctachments

North of the Magaliesberg the geology is largely dominated by the Bushveld Complex, a massive layered igneous complex. The lower portion of the intrusive complex comprises of ultramafic rocks known as the Rustenburg Layered Suite, which is overlain by acidic rocks that form the Rashoop Granophyre Suite and Leboa Granite. The Rustenburg Layered Suite is rich in minerals and a number of mines have been developed. Platinum, chrome and vanadium mining in particular are taking place at a large scale. The Rashoop Granophyres and Leboa Granite represent weathered and fractured aquifers which often contain excessive fluoride in groundwater from geological origin, rendering the water unsuitable for human consumption.

In the Upper Crocodile sub-catchment, dolomite formations of the Malmanie Subgroup are found in the Rietvlei Dam catchment and to the north and west of Krugersdorp (Tarlton area). These dolomite formations also occur in the south-western parts of the Marico catchment. The dolomite formations are compartmentalised by intrusive dykes and represent productive karst aquifers. Dolomite formations are also found at the confluence of the Tolwane and Pienaars rivers as well as the origin of the Apies River (Pretoria Fountains) in the Apies/Pienaars sub-catchment.

The water rich dolomite compartments are used extensively for domestic (Pretoria, Centurion and Zeerust areas) and irrigation water supplies. Spring flows from dolomite compartments have largely been secured for bulk municipal supply purposes. These flows have been diverted into pipelines, thereby limiting or curtailing their contribution to the original receiving surface water catchments.

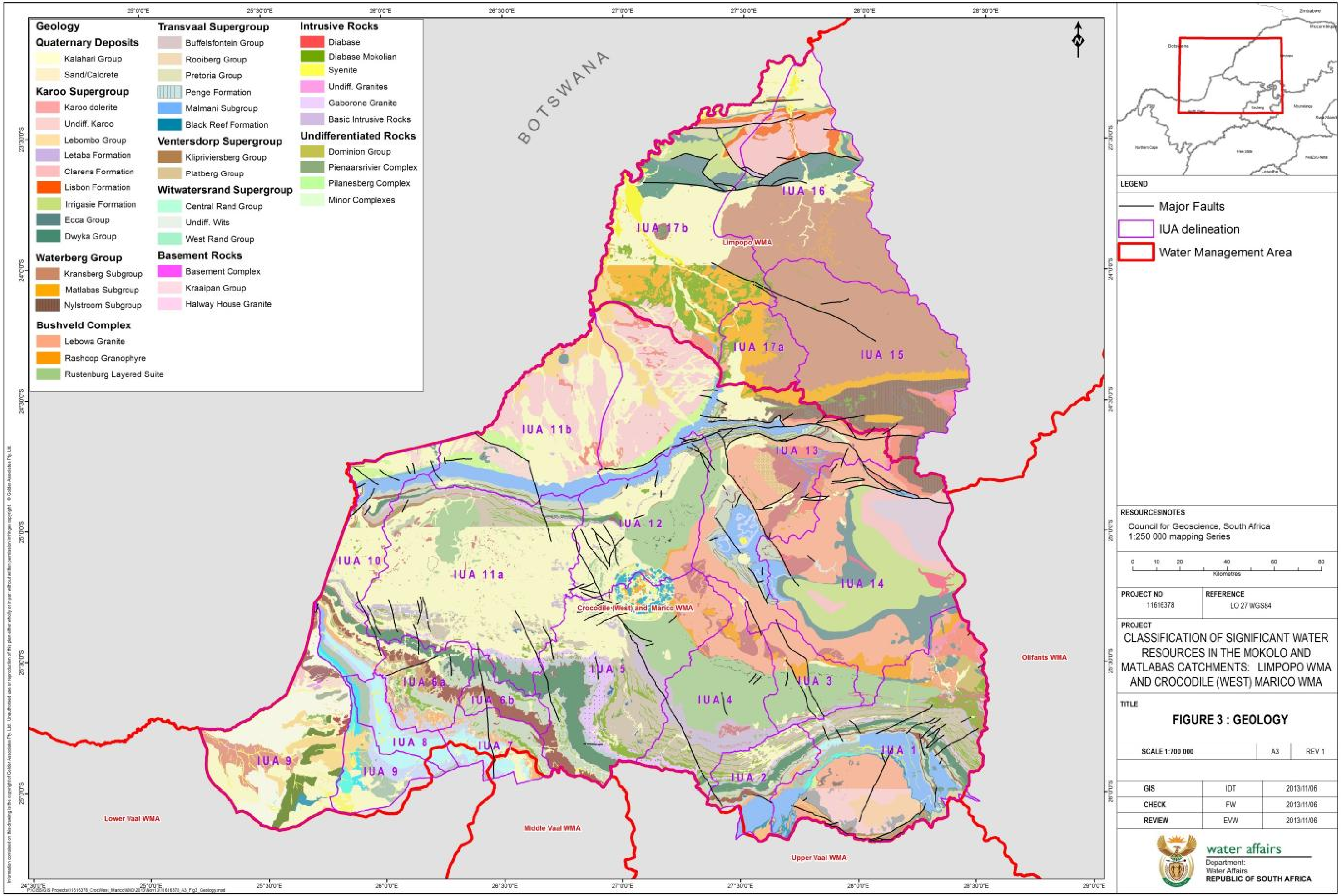


Figure 4: Geology of the study area

The Lower Crocodile River in catchment A24J traverses and is incised into an alluvial flood plain underlain by mainly basement complex granites, termed the Makoppa Granite Dome. The total reach of the river is some 92 km. Hobbs (1986) reports that the alluvial aquifer is in hydraulic connection with the river, which recharges the aquifer during flow events. The alluvial aquifer is partially underlain by highly productive secondary aquifers, associated with highly fractured granite bedrock.

The valley of the Crocodile River, upstream of Thabazimbi in catchments A24H, A24C and A24B, contains extensive alluvial deposits for approximate 80 km in length - termed the Crocodile River Valley Aquifer. The area is known for intensive irrigation which relies heavily on both surface and groundwater resources.

The rest of the catchment consists mainly of sedimentary rocks. The quartsitic Magaliesberg forms prominent topographic features.

4 SIGNIFICANT GROUNDWATER RESOURCES

4.1 Aquifer Types

The main aquifer types in the study area include:

- Karst aquifers associated with the Malmanie Subgroup dolomite formations in the southern parts of the Crocodile (West) Marico WMA, are highly productive, especially in chert rich horizons with extensive karst zones where sustainable borehole yields between 5 and 20 l/s are common. High yielding production boreholes with abstraction rates > 40 l/s for 24 hours per day are in use for domestic and irrigation water supply.
    - § A large number of intrusive dykes, with low to impervious hydraulic conductivity, compartmentalize the dolomite aquifer which may or may not be hydraulically linked. Several dolomite springs occur where the dolomite water discharges as surface flow.
    - § Groundwater gradients are highly variable, typical of dolomite aquifers. Within dolomite compartments bounded by dykes, groundwater gradients are generally very low indicating high aquifer transmissivity. Pending the topographic relief and the hydraulic conductivity of dykes very steep groundwater gradients (or steps) are observed across dyke boundaries. Groundwater steps across dykes range from less than 2 to 50 meters. In areas with low topographic relief, the potential boundary effect of some dykes may presently not be evident from groundwater piezometric levels.
- Fractured Karoo Super Group and Waterberg Group aquifers (Predominately)
    - § The Waterberg aquifer is predominantly of a fractured and weathered type potentially connected to alluvial deposits occurring along the Mokolo River. The main groundwater targets are associated with fractured dyke contacts and fault zones. The Waterberg formation is associated with steep topography and shows generally poor capability to produce huge amounts of groundwater. Recharge to the aquifer, often discharged on the steep slopes, provides baseflow to the rivers. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer.

§ The Karoo aquifer shows similar aquifer properties as the Waterberg aquifer comprising of fractured rocks with a porous matrix. However, groundwater resources and especially the development thereof, are limited due to the low recharge to these aquifers.

- Intergranular Alluvial aquifers (Limited to the main river stems)

§ Alluvial aquifers are recharged during periods of high stream-flows and discharge events (from the Mokolo dam) as well as during the rainfall season. It is an important local, major aquifer and exists in equilibrium with surface water, adjacent groundwater systems and ecosystems along the rivers.

- Intergranular and fractured (near the confluence of the Limpopo River)

§ The northern region of the Mokolo drainage area is underlain by basement aquifers that comprise of deeper fractured (i.e. secondary) aquifers overlain by a weathered horizon of variable thickness. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. The existence of diabase and dolerite dykes forms poor groundwater targets due to the lack of weathering on the margins of these dykes with the basement rocks (gneiss), especially below the static water level. The most noticeable aquifer within the basement rocks are the ENE trending zones of shearing, faulting and brecciation and are usually covered with Quaternary deposits contributing to the aquifer's storage potential

4.2 Borehole Yield Class and Aquifer Rating

The DWA has published hydrogeological maps which indicate median borehole yield (excluding dry boreholes) in l/s from 0 to > 5l/s for various aquifer types. The borehole yield class was grouped together for various aquifer types in four yield categories with an aquifer rating as follows:

Borehole Yield Class (l/s)	Aquifer Rating
0 to 0.5 l/s	Insignificant
>0.5 to 2.0 l/s	Minor
>2.0 to 5.0 l/s	Moderate
>5.0 l/s	Significant

The above aquifer rating is presented in Figure 5, which shows that insignificant and minor aquifers are present in large parts of the study area. Moderate aquifer zones are associated with river courses. Significant aquifers are associated with the Malmanie dolomite formations in the south of the study area and the Letaba basalt formations in the eastern central part in IUA 14.

4.3 Delineation of Major Dolomite Resources

The delineation of dolomite resources requires the identification and mapping of small and larger dolomite compartments, at sub quaternary catchment scale, by considering aspects such as geological lithology, aquifer recharge, hydraulic gradients, water level (piezometric) information, water quality data, location of springs, discharge areas and quaternary catchment boundaries.

4.3.1 Centurion, Pretoria, Rietvlei-Kempton Park Dolomite Area

The delineations of groundwater resources within the Centurion, Pretoria and Rietvlei Dam dolomite areas are presented in Figure 6. Three main dolomite resource units (GMA's) are shown. The boundary of two GMA's, numbered A21A and A21B, correspond to a large extent with the quaternary drainage boundaries A21A and A21B, especially for areas underlain by the weathered and fractured aquifers of the granites and sedimentary rocks of the Pretoria Group.

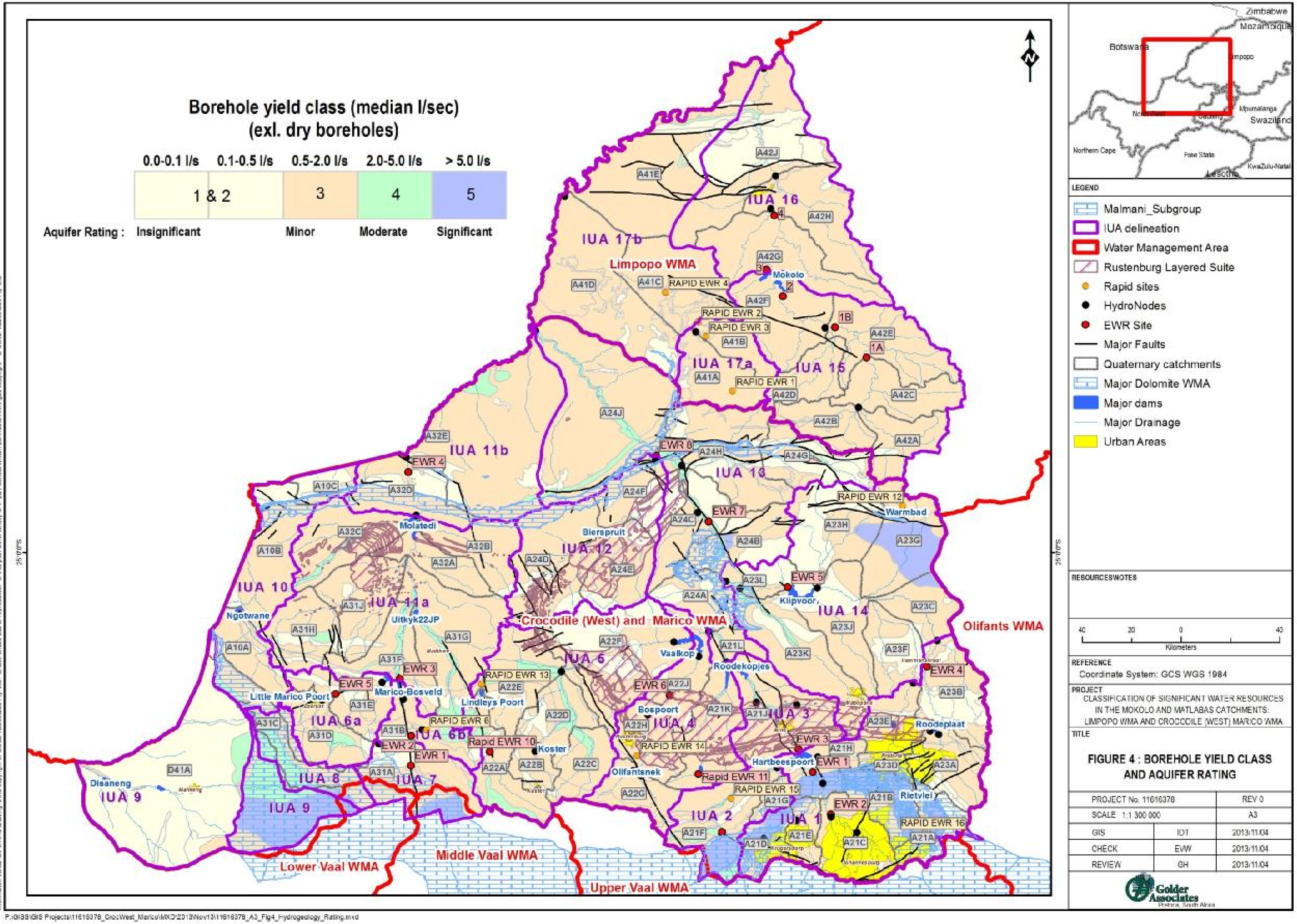


Figure 5: Borehole yield class and aquifer rating

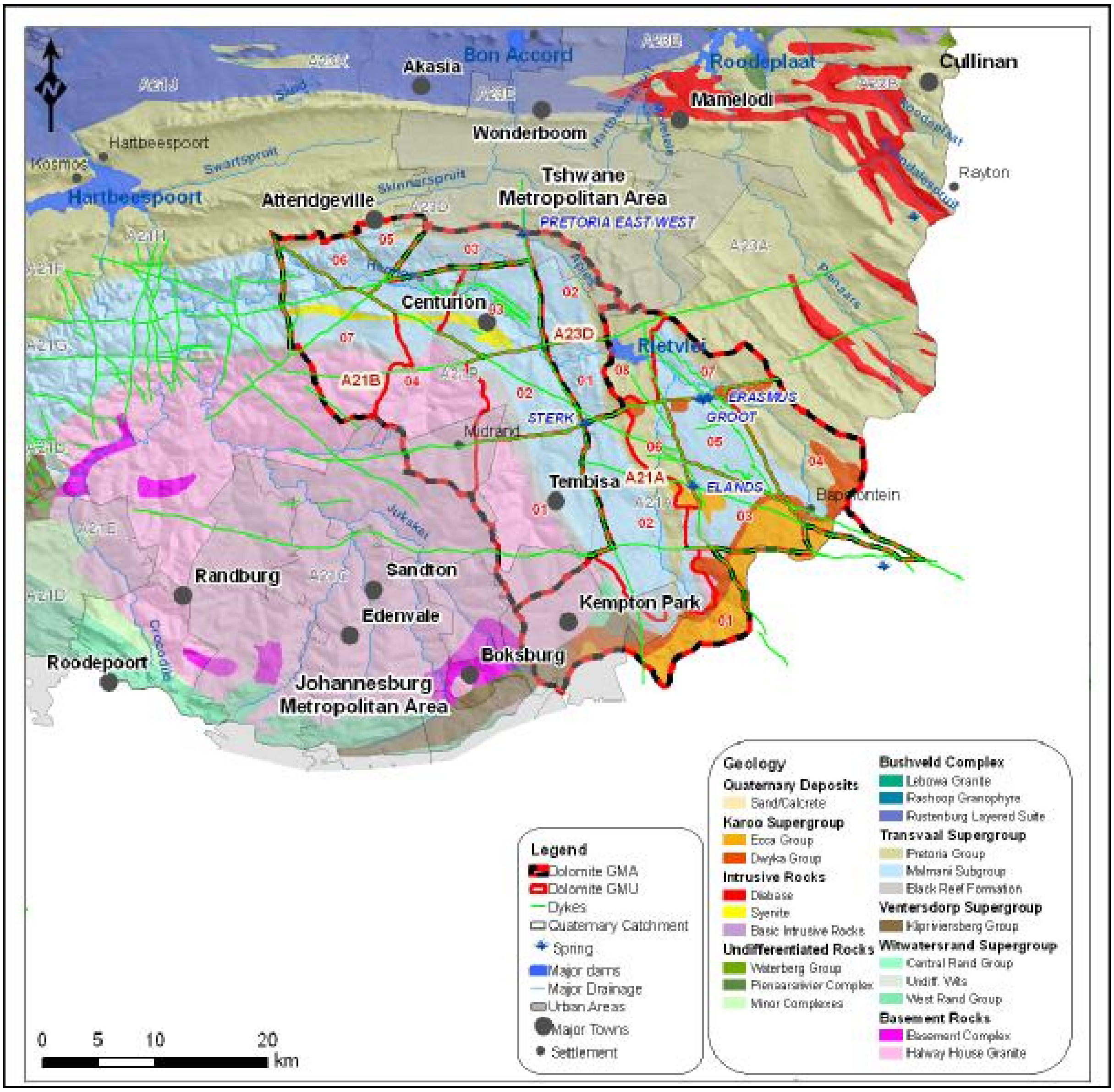


Figure 6: Delineation of the Centurion, Pretoria and Rietvlei-Kempton Park dolomite resources

Eight GMU's were delineated within the Rietvlei-Kempton Park dolomite GMA-A21A totalling 499 km^2, slightly larger than the 483 km^2 of the quaternary catchment drainage A21A. The GMU sub-numbers 01 to 08 follow the drainage as in surface catchments. The lowest number is used for the upper catchment area and the largest number in the discharge area. Springs in the area include the Sterkfontein, Elandsfontein, Erasmusfontein and Grootfontein (Figure 6).

In the Centurion dolomite GMA A22B seven GMU's were delineated totalling 464 km^2, less than the 527 km^2 of the quaternary catchment.

The delineation of GMA A23D entailed only the dolomite resource area, excluding the remaining portion of the total surface catchment area. The presence of impermeable dykes resulted in noticeable differences between the resource and surface drainage boundaries. Springs in the GMA include the well-known Pretoria East and West Fountains.

4.3.2 Maloney's Eye Catchment and Tarlton Dolomite Area

Three GMU's were delineated within the Maloney's Eye catchment area GMA-A21F totalling 311 km^2, which includes the Steenkoppies dolomite compartments at 213 km^2. The Maloney's Eye catchment area is a smaller portion of the quaternary catchment A21F at 1000 km^2. The GMU sub-numbers 01 to 03 follow the drainage as in surface catchments, with the Maloney's eye discharging from unit A21F-03 at a natural long term average of 14.7 million m^3/a (Figure 7). In areas where the catchment is underlain by dolomite the boundary of GMA-A21F differs (being larger) from the surface catchment boundary.

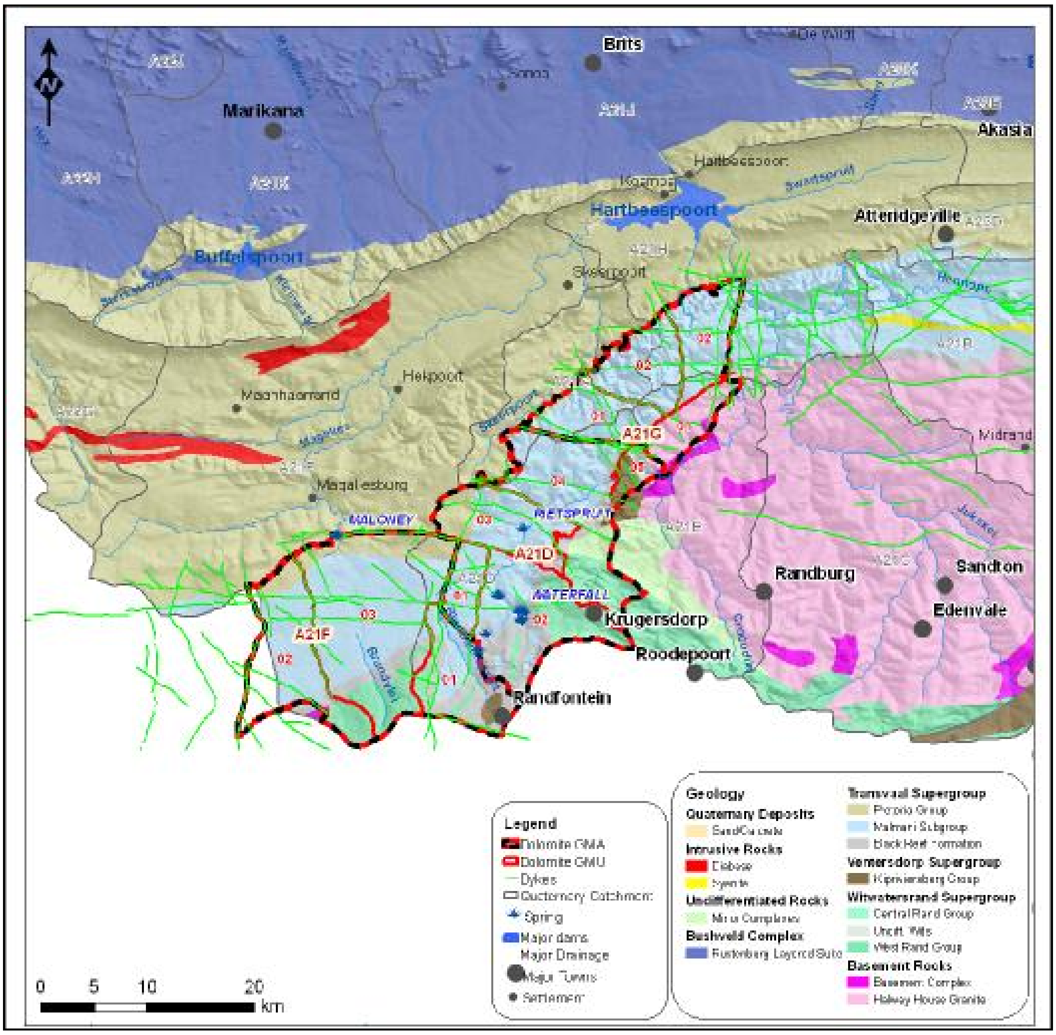


Figure 7: Delineation of the Maloney's Eye Catchment and Tarlton Dolomite resources

Five GMU's were delineated within the Tarlton dolomite catchment area GMA-A21D, which includes the Zwartkranz dolomite compartment, totalling 291 km^2 and smaller than the 372 km^2 of the quaternary catchment drainage A21D. In areas where the catchment is underlain by dolomite the boundary of GMA-A21D differs from the surface catchment boundary The GMU sub-numbers 01 to 05 largely follow the surface drainage (Figure 6). Springs in the area include the Waterfall, Rietspruit (Zwartkranz) and Kromdraai springs. Average annual spring flowsfor the Zwartkranz Springis 8.2 million m^3 and for the Kromdraai Spring is 11.7 million m^3

Decanting of mine water south and near Mogale City (former Krugersdorp) has led to significant pollution, resulting in elevated heavy metal concentrations, high sulphate content, increased electrical conductivity and a lowering of the pH in abandoned mining areas (Holland 2008). The area of decant, is immediately south (GMU unit A21D-02) of the Cradle of Humankind World Heritage Site (COHWHS), which hosts a vast treasure of fossilized remains of past life forms, particular hominids found in over 200 local karst caves.

Surface water drainage (mainly effluent return flows from the Percy Steward WWTW) along the Blougatspruit recharges the underlying karts aquifer (GMU's: A21D-02 and A21D-04) at approximate 5.9 million m^3 /annum (Bredenkamp *et al*.1986). Observed increases in chloride and sulphate content in the groundwater originate from the Percy Steward WWTW. The Zwartkranz dolomite compartment is stressed due to groundwater contamination.

4.3.3 Zeerust and Marico/Holpan Dolomite Area

The delineation of the Zeerust and Marico/Holpan dolomite areas is presented in Figure 8. Three GMU's were delineated within the Marico/Holpan dolomite catchment area GMA-A31A, totalling 531 km^2. The A31A GMA consists predominantly of dolomite formations and is a smaller area than the 632 km^2 of the quaternary catchment A31A. The GMU sub-numbers 01 to 03 follow the general surface drainage, with several springs discharging as surface flows from which the Marico River originates. Springs in the area include Bokkraal, Grootfontein, Rhenosterfontein and Kuilfontein all discharging to the north, towards Kaaloog se Loop.

In the Zeerust dolomite area, GMA A31C, up to 08 GMUs were delineated, most containing one or more springs. The total area of GMA A31C is 693 km^2, 43 per cent larger than the 485 km^2 of the quaternary catchment A31C.

Prominent dolomite springs in the Zeerust dolomite area include Wonderfontein, Malmani, Buffelshoek, Rietpoort, Doornfontein, Paardenvallei, Vergenoegd, Wolvekoppies and Klaarstroom. The latter four springs and Buffelshoek under natural average conditions discharged water from the karst aquifer to surface flows (approximate 9.3 million m^3 /annum - Van Rensburg 2005) in the upper Klein Marico River catchment area. Increased abstraction for municipal water supply and extended drought period has however reduced current spring flows.

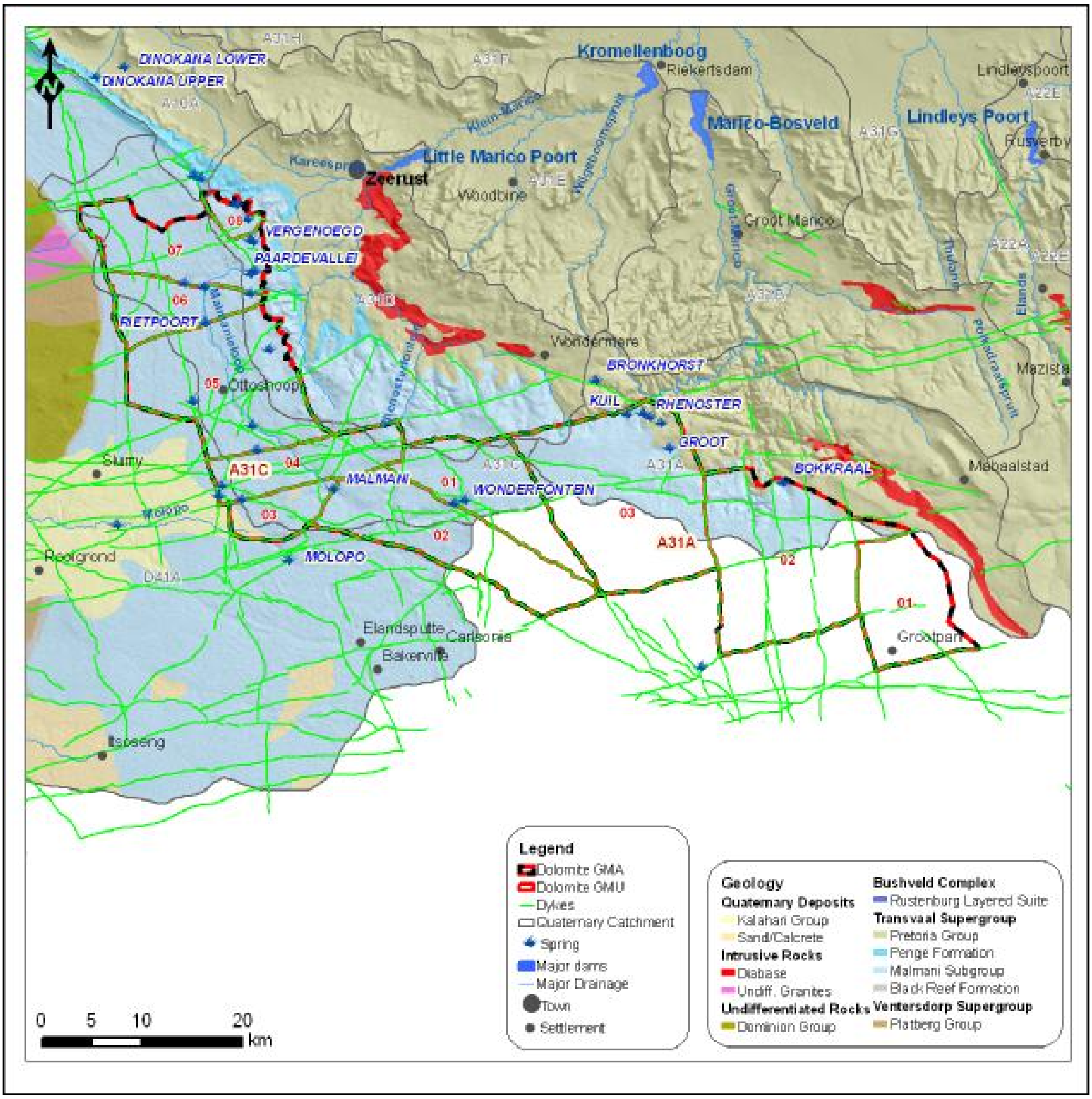


Figure 8: Delineation of the Zeerust and Marico/Holpan dolomite resources

The steady state annual recharge for the Zeerust GMA A31C was simulated by Van Rensburg (2005) at 1330 l/s (approximate 42 million m^3) or 1.9 l/s/km^2. In the Marico/Holpan GMA A31A the average unit recharge is higher and preliminary estimated at 2.5 l/s/km^2 approximate 42 million m^3 /a for the total Marico/Holpan dolomite GMA.

Irrigation use dominates and in the GMA A31A (Marico/Holpan Dolomites) which is mainly located in southern portion of the GMA, to the south and outside the quaternary catchment boundary.

4.4 Present state of groundwater resources in the study area

Table 3 summarises the present state of groundwater resources in the study area based on the methodology and data set out in Appendix B.

Table 3: Summary of present state of groundwater resources in the study area

IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Gwater Compliance Monitoring. [2] Ecological Management Requirements.
IUA15 (A42A & B-F)	27%	II	I	II	[1]_ Sustainability of resources in close proximity of rivers with baseflow requirements reviewed.
	19%	I	I	II	[2]_EWR's: 1A, 1B, 2 & 3: 0.8Mm^3, 1Mm^3, 6Mm^3/a and 5.2Mm^3/a. This reserve needs to be managed (DWA, 2011).
IUA16 (A42G & H, J)	1%	I	I	III	[1]_ Required for management of groundwater resources (Gwater quality is a concern and needs to be monitored prior to developments).
	7%	I	II	III	[2]_ EWR 4: 11.4Mm^3/a. To be managed due to future impacts of mining activities (DWA, 2011).
Mokolo Catchment.					
IUA 17a (A41A & B)	5%	I	I	-	[1]_Sustainability to be confirmed by recharge frequency monitoring; low Gwater use. Assessment of poor Gwater quality required (geological?). Sustainability of resources close to drainage systems reviewed. [2]_No EWR. High ecological requirement in drainages (25% of Gwater recharge) and should be reserved.
IUA 17b (A41C & D & E)	11%	I	I	III	[1]_Expansion of Gwater quality evaluation (hydrocensus) and monitoring required. Gwater potential high, baseline monitoring required to support management of Gwater resources in light of developments of the Lephalale Coalfields. [2]_No EWR. Baseflow in drainages supported by local Gwater resources; ecological requirement to be specified/managed.
Matlabas Catchment.					
IUA 1	34%	II	II	I	[1]_Monitoring programmes for dolomite aquifer systems upgraded and reviewed. Localised pollution impacts on these aquifer systems to be investigated (especially impact from industries). [2]_EWR's 1, 2, 4 & R16: 42, 25, 2.8 & 0.2 Mm^3/a.
IUA 2	49%	II	II	I	[1]_Gwater monitoring programmes operational; needs to be assessed

IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Gwater Compliance Monitoring. [2] Ecological Management Requirements.
					i.t.o. quality. Deterioration of Maloney's Eye needs to be noted (long-term SO_4 impact noted). [2]_EWR's R9 & R15: 46 &0.8Mm^3/a. Ecological requirement in the area immediately below Maloney's Eye to be reviewed; expecting baseflow contribution from aquifer systems.
IUA 3	46%	II	II	I	[1]_Groundwater level monitoring programmes to be reviewed (quarterly interval). [2]_ EWR 3: 22Mm^3/a.
IUA 4	35%	II	II	I	[1]_Groundwater quality monitoring programme to be reviewed and upgraded (quarterly interval) due to high level of mining activities. [2]_EWR's 6, R11 & R14: 1.1, 1.2 & 0.4Mm^3/a .
IUA 5	14%	I	II	I	[1]_ Groundwater quality monitoring programme to be reviewed and upgraded (quarterly interval) due to high level of mining activities. [2]_EWR's R10 & R13: 0.6 & 0.5Mm^3.
IUA 12	14%	I	I	II	[1]_Low impact on Gwater resources. Groundwater use Groundwater monitoring programmes to be reviewed in terms of local uses. [2]_EWR 8: 52.06Mm^3/a.
IUA 13	41%	II	II	II	[1]_Groundwater stress index high (42%); Gwater levels and quality monitoring need to be reviewed. [2]_EWR 7: 31.4Mm^3/a.
IUA 14	24%	II	II	II	[1]_Groundwater (levels and quality) to be reviewed in future (current status sufficient) [2]_EWR 5 & R12: 2.53 & 0.27Mm^3/a.
Crocodile West Catchment.					
IUA 6a	5.0%	I	I	I	[1]_Groundwater level and quality monitoring programme to be reviewed.

IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Gwater Compliance Monitoring. [2] Ecological Management Requirements.
					Local mining and irrigation practices may impact the local resources required for domestic supplies. [2]_ EWR 2 & R6: 9.56Mm^3 & 0.14Mm^3/a; water requirements should be managed.
IUA 6b	16.0%	I	I	I	[1]_Groundwater level and quality monitoring programme to be reviewed. Local mining and irrigation practices may impact the local resources required for domestic supplies. [2]_ EWR 4 & R5: 6.1Mm^3, 0.6Mm^3 & 0.55Mm^3/a; water requirements should be managed.
IUA 7	5.4%	I	I	I	[1]_Groundwater level monitoring programme to be reviewed due to high impact on Grootpan dolomite aquifer system and long-term, sustainable management of resource. [2]_ EWR 1, 5.23Mm^3; water requirement should be managed.
IUA 8	21%	I	II	I	[1]_Groundwater monitoring programmes need to be reviewed; although moderate groundwater usage (SI-21%)' local resources may have breached the long-term sustainability. Sustainable management of resource required. [2]_No EWR. Significant impact on dolomite eyes supporting ecological requirements. Status of contribution to baseflow to be evaluated.
IUA 10	1.7%	I	II	-	[1]_Although SI is low (3.4%), supplies to the Dinokana area depends on the lomg-term sustainability of the Dinokana dolomite aquifer system. [2]_ No EWR. Significant impact on dolomite eyes supporting ecological requirements. Status of contribution to baseflow to be evaluated.
IUA 11a	5%	I	I	II	[1]_Almost natural conditions prevail; local groundwater status should be monitored for new developments. [2]_EWR 3: 6.7Mm^3/a.
IUA 11b	1.8%	I	I	II	[1]_ Almost natural conditions prevail; local groundwater status should be

IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Gwater Compliance Monitoring. [2] Ecological Management Requirements.
					monitored for new developments. [2]_EWR 4: 6.1Mm^3/a.
Marico Catchment					
IUA 9- D41A (Dolomite Aqf.)	105%	III	III	I	[1]_Groundwater monitoring programmes for aquifer system need to be reviewed in the light of localized over abstraction, viz. the Grootfontein dolomite aquifer system. [2]_No EWR; Groundwater contribution to the upper Molopo River from the Molopo Eye needs to be sustained/managed.
IUA 9- D41A (Other Aqf.)	1.2%	I	I	II	[1]_Low groundwater use; limited monitoring required. [2]_No EWR: Groundwater contribution to baseflow not existing due to deep water table status (a result of low groundwater recharge status).
IUA 9 (Summary)	72%	III	III	II	
Upper Molopo Catchment					

5 SIGNIFICANT WETLANDS

In certain of the IUA's, a desktop approach (desktop delineation using wetland signatures observed on available aerial imagery) was used to update the existing coverage and provide better information on the location and types of wetlands within the study area. All areas suspected of being wetlands based on the visual signatures on the digital base maps were mapped using ArcView. While some field verification was done, information collected for the purpose of this study was based predominantly on desktop studies combined with a review of in-house and other reports that were applicable and available.

Available information on wetlands was obtained from the National Spatial Biodiversity Assessment (NSBA), the South African National Biodiversity Institute (SANBI) wetland probability map for South Africa, and the NFEPA wetland coverage of South Africa. In some IUA's the available information was updated, in others this was replaced by the new shapefiles produced as part of the desktop delineation. The NFEPA coverage was also filtered by removing wetlands in some cases where the coverage did not show wetland signatures and/or where the signatures were clearly associated with dam basins. In these cases the areas marked as wetlands could clearly be seen not to be wetlands or to be artificially created wetlands. In order to come up with a final coverage, all filtered shapefiles indicated as artificial in the NFEPA database were removed and the remaining shapefiles were merged with the desktop delineations (with the desktop coverage overriding the NFEPA layer where there was overlap and higher confidence in the information).

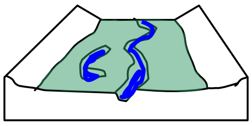
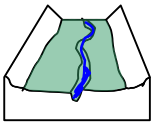
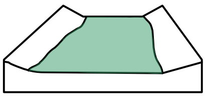
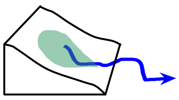
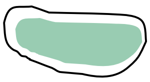
5.1 Wetland Classification

Standard practice is to use the HydroGeomorphic classification which describes wetlands in terms of their hydro-geomorphic setting being their position in the landscape and how water moves in, through and out of the system (Brinson, 1993). The classification inherently also provides a general indication of some of the likely functions the wetland is expected to perform (Table 4). The approach has been modified for use in southern Africa by Marneweck and Batchelor (2002) and Kotze, Marneweck, Batchelor, Lindley and Collins (2009), and has recently been proposed as the basis of inland wetland classifications in South Africa (Ewart-Smith *et al.*, 2006). Due to the scale of the project, budget constraints for extensive site visits and the inability to access private land over much of the area, extensive ground truthing was not possible.

For this reason a detailed classification of the wetlands was not viable and as such no detailed classification maps were produced. Instead the maps simply indicate the presence of wetlands based on the approach described above. Where possible though, the general wetlands types occurring in particular IUA's were described with reference to their HGM classification as were individually prioritized systems for which the classification was already known or which was determined based on the field visits.

Where appropriate, limited field work was undertaken to assist with the classification of the priority wetlands.

Table 4: HGM Wetland Classification system used to describe the main wetlands in the report (taken from Kotze, Marneweck, Batchelor, Lindley, and Collins, 2009)

Hydro-geomorphic types	Description	Source of water maintaining the wetland[1]	
		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 	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from sub-surface flow. Outflow is usually via a well defined stream channel connecting the area directly to a stream channel or through diffuse sub-surface and/or surface flow but with no direct surface water connection to a stream channel.	*	***
Pan (depression) 	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, but overall its drainage is predominantly closed. An outlet is usually absent, and therefore this type is usually isolated from the stream channel network.	*/ ***	*/ ***

[1] Precipitation is an important water source and evapo-transpiration an important output in all of the above settings

Water source: * Contribution usually small

*** Contribution usually large

*/ *** Contribution may be small or important depending on the local circumstances

5.2 Wetland prioritisation

The prioritisation of the wetlands was based predominantly on available information supported by inputs provided during the various task team, steering committee and other consultative meetings held as part of the project. In addition, the desktop mapping results, particularly where new information was collected, were also used to support the prioritisation. Other aspects that were also considered in developing the prioritization were:

- Wetland size;
- Wetland type and rarity;

- Wetlands known to have unique or high biodiversity;
- Wetlands occurring in areas where the vegetation grouping has a high threat status (National Biodiversity Assessment, 2011 - Driver, Sink, Nel, Holness, Van Niekerk, Daniels, Jonas, Majiedt, Harris and Maze, 2012);
- Wetland connectivity in the landscape; and
- Representative wetlands of the area.

A priority list of what are perceived to be the most important identified wetlands in each of the IUA's was compiled. Note that there may still be other wetlands that could rank as important but which were not captured in any of the databases used, or not identified as part of this study.

5.3 Present Ecological State (PES) Assessment

A PES analysis was conducted for the mapped wetlands within each of the IUA's. This was done at a whole wetland scale as opposed to HGM scale and instead of applying either of the two main PES assessment tools, namely WET-Health (Macfarlane, Kotze, Ellery, Walters, Koopman, Goodman and Goge, 2008) and IHI (DWAF, 2007), a surrogate measure was used as an indication of wetland health.

The number of systems mapped as well as extent of the overall study area meant that undertaking individual PES assessment for each wetland was also not possible. While the same PES categories as described in the PES methods of Kleynhans (1996), DWAF (1999), the IHI (DWAF, 2007) and Macfarlane *et al*. (2008) were used (**Table 2**), no scores were derived. Instead PES Values were assigned to individual wetlands using a surrogate indicator of their health, namely surrounding landuse. PES Values were assigned to the dataset based on the intersection of wetland boundaries with various land-cover types which were derived from SANBI's 2009 national land-cover dataset.

The PES score assigned to each landcover type, and hence each wetland as a result of its intersection with a particular landcover type, was as follows:

- Natural: A/B;
- Degraded: C;
- Cultivation: C/D;
- Plantation: C/D;
- Urban: D/E; and
- Mines: E/F.

Table 5: Present state categories used by the various PES assessment methods for describing the integrity of wetlands (derived originally from Kleynhans, 1996)

Impact category	Description	Present state category
None	Unmodified, natural	A
Small	Largely natural with few modifications. A slight change in ecosystem processes is discernable and a small loss of natural habitats and biota may have taken place	B
Moderate	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	C
Largely Modified	A large change in ecosystem processes and loss of natural habitat and biota and has occurred	D
Serious	The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable	E
Critical	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota	F

In the case that a wetland overlapped more than one type of land-cover, the lowest possible PES score was assigned to the individual wetland. In order to avoid an overestimation of the level of degradation from a PES perspective, Mining and Urban/Built up areas smaller than 20 hectares were ignored, as was cultivation, plantation, and degraded areas smaller than 5 hectares.

The PES scores derived for the wetlands are hence very general and subject to further verification. They can only be used as a general indication of the expected integrity/health status of the wetlands in a particular area or region. Detailed PES assessments will therefore always replace any of the categories indicated as these are derived from surrogate indicators. The coverage nevertheless provides a broad indication of the general state of the wetlands within each of the IUA's and for the purposes of this report provides a basic indication of problems or wetland health concerns at that scale.

5.4 Ecological Importance and Sensitivity (EIS) Assessment

The number of systems mapped as well as extent of the overall study area meant that undertaking individual EIS assessment for each wetland was also not possible. As no surrogate information was available for a general assessment of the EIS, it was decided that EIS would only be derived for the priority wetlands. Where information was available for the priority wetlands, this was used. Where no information was available for the priority wetlands, the EIS was derived based on consideration of the vegetation group threat status, a review of available literature and reports, whether or not it was indicated as a WETFEPA, and based on experience of the area or of a particular system.

Again this was done at a whole wetland scale as opposed to HGM scale using the DWAF (1999) method where appropriate. The same EIS categories as indicated in DWAF (1999) and DWA (2011) were used.

5.5 Description of priority wetlands per IUA

5.5.1 IUA 1 Wetlands

IUA 1 is by far the most populous of all IUAs as it includes the Metropolitan Municipalities of Tshwane (full), Johannesburg (part) and Ekurhuleni (part) and the town of Krugersdorp. The IUA is also a major hub for commercial, financial and industrial sectors for South Africa as well as Africa. Much of the area has been subjected to urbanisation, with the remaining sections comprising small holdings, parks and open space. The area includes the Halfway House granites which occur predominantly in the northern areas of Greater Johannesburg. The wetlands which occur here are not always easily discernible, even in the field, due to anomalies in the soil characteristics (complexities in terms of diagnostic hydric soil indicators). Urban development on the granites has resulted in the loss of many of these systems as well as changes in hydrology of many of those that remain. A section of this IUA also occurs on dolomites with the resulting development of wetlands derived from groundwater emergence such as at Rietvlei south-east of Pretoria.

Based on the current conditions, an understanding of the geomorphology, drainage patterns, and soils in the remaining relatively undisturbed open space areas of this IUA, five wetland types are encountered, namely pans, hillslope seepage wetlands, unchannelled valley bottom wetlands, channelled valley bottom wetlands and floodplains. An approximate, *albeit* underestimated, distribution of the wetlands in this IUA is shown in Figure 9. Large parts of this IUA have been converted from grasslands to accommodate industrial and housing estates (see 2007 landuse data). This has taken place at the expense of grasslands and their associated hillslope seepage wetlands and secondarily on previously unchannelled valley bottom wetlands. Many historically unchannelled valley bottom systems have become channelled as a result of post-development changes in hydrology. Increased surface runoff as a result of the development of the catchments of many of these systems has resulted in erosion and the development of headcuts and channelling in most of these systems in the urban environment.

Pans are also fairly well represented in the IUA, mainly towards the south-east with approximately 24 occurring between Midrand and Kempton Park. Pans are recognized as being important for biodiversity support and more recently their links to other wetland systems in relation to landscape hydrology have also been highlighted. Pans are also unique in terms of their individual biogeochemical attributes. The pans in the Midrand and Kempton Park area are considered important, mainly from a biodiversity perspective as they support related bird and amphibian populations. Those that still have some of their catchments intact or that still have associated hillslope seepage wetlands such as Bullfrog pan in Glen Austin are thought to support some of the last remaining populations of the Giant bullfrog (*Pyxicephalus adspersus*) on the Highveld. The remaining pans and their associated hillslope seepage wetlands are thus regarded as critical habitat for these populations. The wetlands including the pans in this area are all threatened by impacts from urbanization. Wetland habitat loss continues as urbanization expands and the hydrology of the related systems and catchments change due largely to stormwater management or lack thereof.

While the pans only occupy less than 1% of the area of wetlands, they have been recognised as being of high conservation value (EIS of all the systems are expected to be High to Very High) and as such the pan basins and their contributing catchment should be excluded from development in order to try to protect the remaining systems.

The Rietvlei wetland system is situated immediately upstream of the Rietvlei Dam within the Rietvlei Dam Nature Reserve. The wetland is a peatland. Peatlands are defined as peat-accumulating fresh water wetlands which develop in areas where there is a net surplus of water with an accreting substrate comprising a high percentage of undecomposed organic plant material (usually with more than 20 - 35% organic matter on a dry weight basis - Mitsch and Gosselink, 1986).

The dam has provided Pretoria with drinking water since 1934, producing approximately 41 million litres per day, or 3% of the city's current requirement. Historically the Rietvlei wetlands were heavily eroded and desiccated, having been drained for cultivation and peat mining before the area was proclaimed a nature reserve. In recent years, the dam has become overloaded with nutrients and other pollutants, as its highly urbanized catchment has received increasing volumes of treated domestic sewage and industrial effluent. Partly in response to this situation, and recognising that the wetlands were degraded, Working for Wetlands (WfW) formed a partnership with the Tshwane municipality in 2000 to rehabilitate the wetlands upstream of the dam. The primary objective was to try to improve their ability to treat the water flowing into the dam. Interventions included gabion, concrete and earthen structures to control erosion, re-wet the organic soils, increase retention time of water and ensure even distribution of flow across the wetland. Monitoring results tend to show that there has been some improvement of the quality of water flowing into the dam since the rehabilitation was implemented (Masupa, Makhado, Coetzee and Marais, WfW Gumboot Newsletter, 2008) and that the rehabilitation interventions have has resulted in the re-establishment of reeds throughout the wetland (WfW website).

Another important wetland that occurs within the urban setting in this IUA is the Colbyn Valley wetland. It is approximately 15 ha in extent and is situated on shales of the Silverton Formation. The key point of the wetland is the quartzite ridge of the Daspoort Formation in the north and the wetland occurs behind this where the Hartbeesspruit flows through the poort. Localised back flooding of the Hartbeesspruit as a result of restricted flow through the poort and flow from seeps upstream above the poort resulted in the formation of the wetland and the accumulation of peat under the associated favourable conditions (WCS, 2000).

The peat in the wetland is a medium fibrous to fine reed-sedge peat and is approximately 1.05 ha in extent representing approximately 7% of the total wetland area. The maximum peat thickness is 2.4 m (Grundling and Marneweck, 1999) and the *in situ* volume is estimated at approximately 15 000 m^3. This wetland with its associated peat is a scarce wetland type in the Pretoria region and as such has an intrinsic conservation value. In terms of species composition, diversity and abundance however, the Colbyn Valley wetland is not unique in the region (Grundling and Marneweck, 1999). The uniqueness value is therefore a result of the peat resource it contains. Since the peat has developed in response to specific physical and biological conditions, it can be argued that factors such as the hydrological regime, slope and low energy environment which have created conditions favourable for the accumulation of peat are in their own right rare features in the area. Peat therefore is the product of the features which make this type of wetland scarce or rare in the region. The system has been impacted as a result of adjacent land-use and hydrological changes and is considered to be largely modified with a PES of D. The EIS on the other hand is regarded as High to Very High due to the uniqueness of the system in the region.

A number of floodplain wetlands also occur in the region, including the Apies River floodplain which has been canalised and straightened in the urban areas. This has resulted in higher flows which in turn have also altered channel and bed shape in the floodplain area lower down in the system. Urban runoff, sewage spills and litter from settlements impact heavily on water quality and the functional integrity of the river. Most of the riparian vegetation has been cleared due to high levels of development and where this remains, it is generally associated with steep banks and terraces that are scoured. Alien vegetation encroachment is high in some areas with mulberries, jacaranda, seringa and sesbania being some of the more common species. Across much of this area, watercourses are not afforded the opportunity of self-adjustment to accommodate changes to the imposed hydrology because of encroachment of buildings and other infrastructure such as parking lots and roads. This severely limits opportunities to effectively manage the wetlands.

Figure 9: Photograph of typical changes such as the development of erosion gullies or channelization in the wetland systems in this IUA as a result of changed hydrology due to urban development upstream.

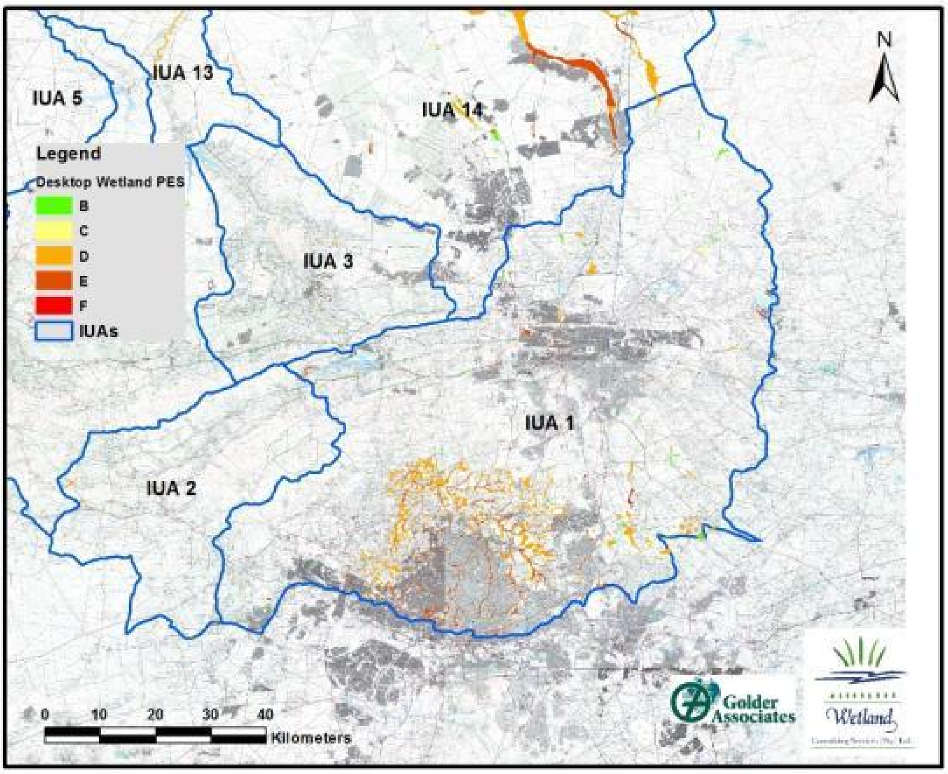


Figure 10: Map showing the main wetlands according to the desktop derived PES for IUA 1

Table 6 sets out a preliminary list of priority wetlands in IUA 1 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 6: Priority wetlands in IUA 1

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Pans	C/D to E	Very High	Mesic Highveld Grassland Group 4 - **CR**	Some Notably Glen Austin Pan and pans associated with Rietvlei River Highveld Grassland - **CR**	Some	Endorheic seasonal grass-sedge depressions
-	Valley bottom wetlands	A/B to D/E	Moderate	Mesic Highveld Grassland Group 4 – **CR** Dry Highveld Grassland Group 5 - **LT**	Many occur in the Egoli Granite Grassland - **EN**	Mainly those associated with the Rietvlei River	-
-	Hillslope seepage wetlands	C/D to E/F	High	Mesic Highveld Grassland Group 4 – **CR** Dry Highveld Grassland Group 5 - **LT**	Many occur in the Egoli Granite Grassland - **EN**	None	High botanical diversity

Rietvlei wetland complex	Peatland	C/D to D/E	High to Very High	Mesic Highveld Grassland Group 4 – **CR** Central Bushveld Group 2 - **VU**	Rietvlei River Highveld Grassland - **CR**	Yes	Peatlands
Colbyn Valley wetland	Peatland	D	High to Very High	Mesic Highveld Grassland Group 4 – **CR** Central Bushveld Group 2 - **VU**	Marikana Thornveld - **VU**	No	Peatlands

5.5.2 Wetlands in IUA 2

This IUA includes the upper reaches of the Magalies River. The present state of the Magalies River is in a B category, especially with Maloney's Eye situated in the upper reaches (see DWA, 2012). The EIS is very high due to the presence of the rare *Barbus motebensis* in the system. The Magalies River is an important provincial conservation area and has been identified as a sensitive catchment in the Gauteng conservation plan. Agriculture and conservation to some extent are the dominant land-uses in this IUA. The lower reaches of the Magalies and Skeerpoort Rivers are impacted by water abstraction for irrigation.

Maloney's Eye, the source of the Magalies River, a tributary of the Skeerpoort River upstream of Hartebeespoort Dam, is a unique dolomitic eye in the upper Crocodile West system and should be regarded as a priority system (DWA, 2012). The Gauteng Department of Agriculture and Rural Development's Conservation Plan Version 3.3 has indicated that major areas associated with Maloney's Eye are defined as Irreplacable and the area is defined in terms of Mogale City Local Municipality Spatial Development Plan (SDF) as being important for tourism. Any forms of mining activities or other developments which could negatively impact the upper reaches of Maloney's Eye are considered incompatible with the SDF and would potentially threaten the Class B status of the river and the EIS of the associated eye and wetlands along its course. Wetlands are mostly confined to the banks of the Magalies River and hillslopes adjacent to the river.

The general water quality in the wetland systems is very good and can be considered to be close to natural in most areas, particularly in the upper watershed. In the upper reaches of the Magalies River, water is predominantly alkaline due to the local geological and biological processes and the overall integrity of many of the systems in the watershed can be considered to have a PES that is unmodified or natural (A) or largely natural (B). The EIS of the wetlands associated with the river and around the eye would be regarded as High to Very High. The surrogate PES analysis of the mapped wetlands shows PES categories of D for many of the larger systems in the IUA mainly due to agricultural impacts associated with cultivation.

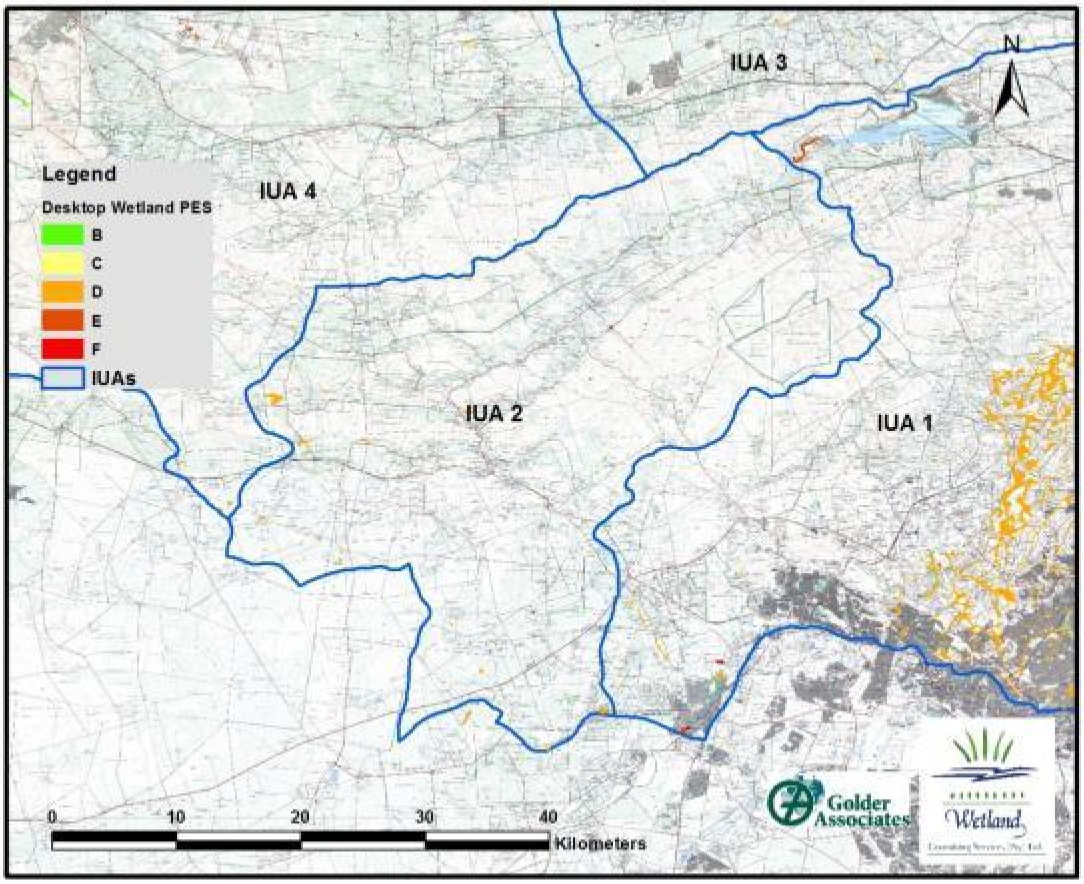


Figure 11: Map showing the main wetlands according to the desktop derived PES for IUA 2

Table 7 sets out a preliminary list of priority wetlands in IUA 2 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 7: Priority wetlands in IUA 2

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Pans	-	High	Dry Highveld Grassland Group 5 - **LT**	Some occur on the Soweto Highveld Grassland - **VU**	One	Endorheic seasonal grass-sedge depressions
-	Valley bottom wetlands	-	Moderate	Central Bushveld Group 5 - **VU**	Some occur in the Witwatersberg Skeerpoort Mountain Bushveld – **EN** Others on the Soweto Highveld Grassland - **VU**	None	-

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Hillslope seepage wetlands	-	High	Central Bushveld Group 5 - **VU**	Some occur in the Witwatersberg Skeerpoort Mountain Bushveld – **EN** Others on the Soweto Highveld Grassland - **VU**	None	High botanical diversity
Maloney's eye	Dolomitic eye and peatland	B	Very High	Central Bushveld Group 5 - **VU**	No	No	Dolomitic eye

5.5.3 Wetlands in IUA 3

IUA 3 which includes Brits and surrounding areas is characterised by extensive agriculture. Apart from the Langberg, the topography is relatively flat, and in places the heavy vertic soils preclude subsurface seepage which is generally integral to wetland formation. Wetlands are therefore mostly associated with incised drainage lines and streams and low lying depressions, and are widely dispersed (**Figure 12**). Due to the topography and soil type, the entire landscape tends to take on the hydrological function associated with wetland habitat. During the dry season the smectitic clays shrink as they desiccate, resulting in deep cracks in the soil surface. Once the clays are saturated and seal following rainfall, water flow becomes surface driven. The flat topography, however, means that water sits on the surface and is stationary within the landscape with the dominant water losses being to evaporation and evapotranspiration. Water does not have the opportunity to infiltrate the soil and accumulate for long enough periods to impart hydromorphic characteristics to the soil profile. It is also likely that any hydromorphy is masked by magnesium oxides and organic matter in the dark soils. This explains the relative scarcity of wetlands in this landscape. It is likely that there is subsurface movement of water laterally across the landscape at depth through the interface between the soil and parent material.

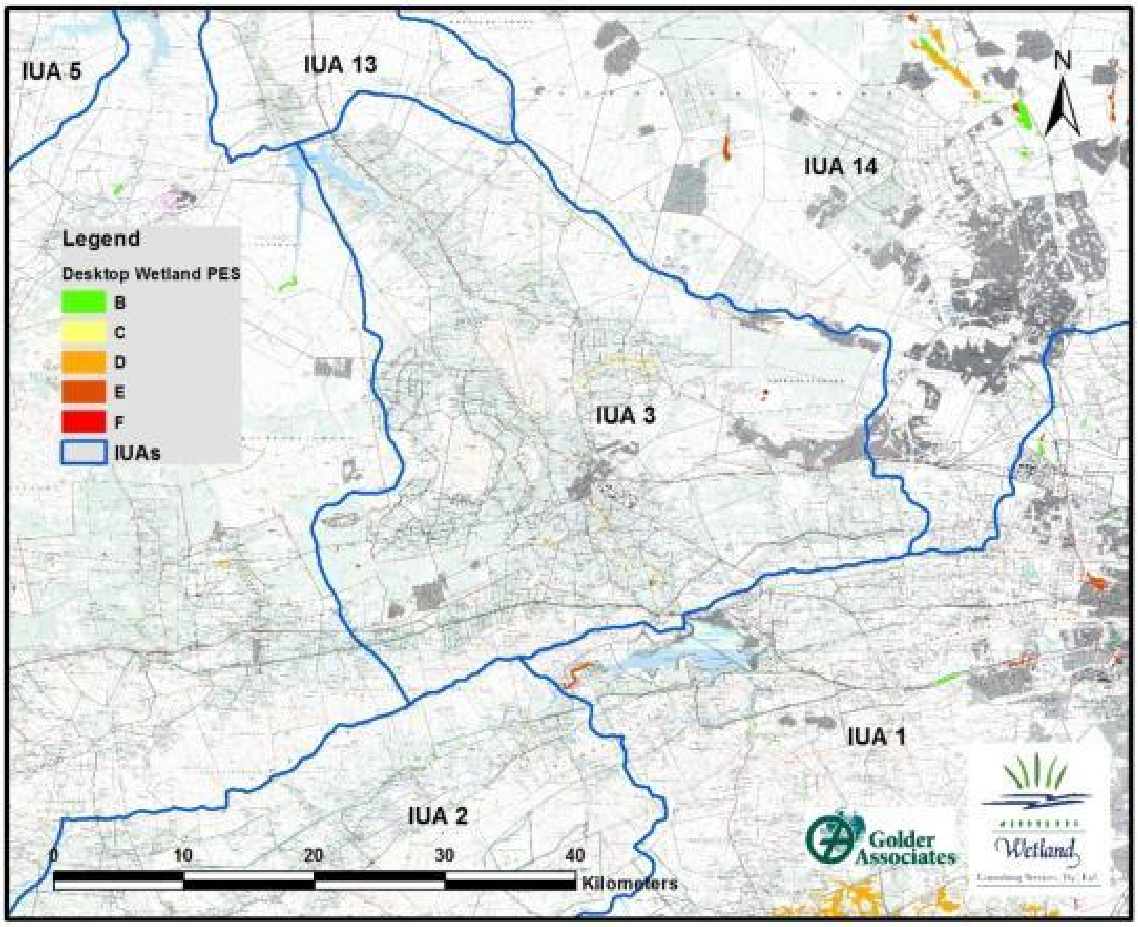


Figure 12: Map showing the main wetlands according to the desktop derived PES for IUA 3

5.5.4 IUA 4

Mining in the study area is largely centred on IUA 4, which contains the town of Rustenburg and is dominated by PGM mining. Granite mining is found in IUA 4. In places the topography is steep and characterised by numerous granite outcrops. This has a major impact on the movement of water through the landscape creating zones where water accumulates and hence a mosaic of areas of differing saturation. However, importantly, because the soils are so high in clay content and have consequently a high moisture holding capacity across terrestrial and wetland habitat, the vegetation composition is essentially the same across the range of herbaceous habitats, with the exception of permanent wetlands which tend to be dominated by *Typha capensis*.

A number of wetland types occur in this IUA, with most containing clear wetland hydromorphic characteristics. In particular depression wetlands and channelled and unchannelled valley bottom systems are quite common. Many of the unchannelled wetlands, driven mostly by diffuse inputs from relatively flat, large, inward-draining catchments, are undergoing channel incision, often as a result of road crossings or other impacts that result in the concentration of flow. In parts of this IUA there are coarse-grained, sandy, shallow soils within a gently undulating topography, attributes which are conducive to the formation of valley bottom and seepage wetland systems. Unchannelled valley bottom wetlands in these areas are mostly dominated by temporary and seasonal wetland zones, and driven predominantly by subsurface seepage of water through the shallow, sandy catchment soils. Channelled valley bottom wetlands generally incorporate a central channel with adjacent seepage zones on either side, mostly consisting of temporary wetland with a patchy mosaic of seasonal wetland. These are driven predominantly by longitudinal and lateral surface flow and lateral subsurface seepage.

Typical unchannelled systems with perennial watercourses dominated by *Phragmites australis* and a well-established riparian fringe are also found in this IUA (Figure 13). Seepage wetlands are usually situated on slopes or at the head of larger drainage systems and are mostly temporary zone wetlands, with patches of seasonal wetland forming if the surrounding catchment is large enough (Figure 13). These are driven almost exclusively by subsurface lateral seepage.

Figure 13: Photographs showing a typical hillslope seepage wetland (left) and a riparian C-channel with a perennial watercourse dominated by *Phragmites australis* and a well-established riparian fringe (right)

An important wetland in this IUA is the Waterval Valley mire (peatland) in the Kgaswane Nature Reserve (Figure 14). This has been subject to rehabilitation as part of WfW programme.

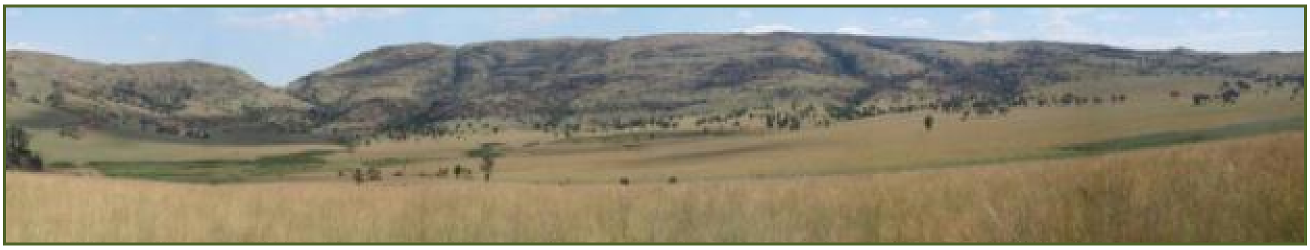


Figure 14: Photograph of the Waterval Valley peatland in Kgaswane Nature Reserve outside Rustenberg

A map of the wetlands in this IUA is shown in Figure 15. sets out preliminary list of priority wetlands in IUA 4 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 8: Priority wetlands in IUA 4

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Waterval Valley Bottom Mire (peatland)	Unchannelled valley bottom	-	Very High	Central Bushveld Group 1 - **CR**	No	Yes	Peatland

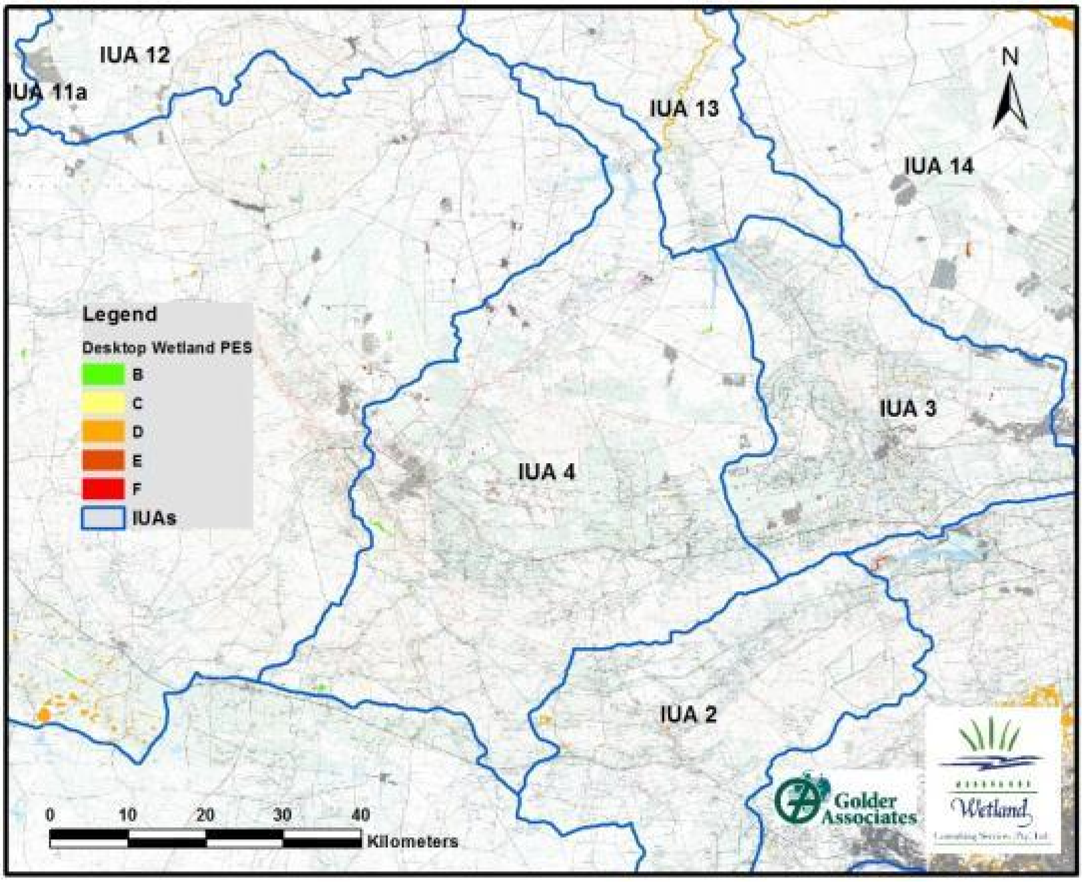


Figure 15: Map showing the main wetlands according to the desktop derived PES for IUA 4

5.5.5 Wetlands in IUA 5

This IUA includes a number of ecoregions from the Highveld to the Bushveld Basin. Agriculture is an important sector in this IUA with granite mining also occurring. Based on an understanding of the geomorphology, drainage patterns, and soils in this IUA, four wetland types occur, namely pans, hillslope seepage wetlands, unchannelled valley bottom wetlands and channelled valley bottom wetlands.

A large pan complex (groups of pans) occurs to the south of Koster (a complex of approximately 24 pans). A number of hillslope seepage and valley-bottom wetlands are also associated with these pans. Pans are recognized as being important for biodiversity support and more recently their links to other wetland systems in relation to landscape hydrology have also been highlighted. Pans are also unique in terms of their individual biogeochemical attributes. This combination of an extensive network of pans, hillslope seepages and valley-bottom systems, and also that they are unaffected by urbanization and not found elsewhere in any of the other IUA's in such a cluster in this study, renders this an important water resource in the study area. It is likely that populations of the Giant bullfrog may occur or be found in the pans in this IUA.

The pans appear to be mainly fresh (low salinity systems) and dominated by grasses and sedges (Figure 16). These pans are all associated with hillslope seepage wetlands and probably receive water from both surface runoff and lateral seepage via a perched aquifer. The possibility exists that these pans could contribute towards the local aquifer that supports other wetland systems, particularly the valley bottom systems in the area (Figure 16). These pans and their associated hillslope seepage wetlands represent good examples of specific types of wetlands which occur in the Highveld region, an area not well represented outside of IUA1 in this study area. They are therefore an important feature contributing towards the maintenance of the the ecological diversity of the region. Threats are mainly from agricultural activities including agricultural pollutants such as fertilizers, pesticides and herbicides. Road crossings also intersect the pans and disrupt the movement of water. Runoff water from roads also contributes towards the silt load that is built up in these pans. Current potential effects on the integrity of pans and associated hillsope seepage wetlands include cultivation, accumulation of pesticide residues, direct impacts from ploughing, and road related impacts. While the pans in particular have a High to Very High EIS, the PES categories are mostly D due to the related agricultural impacts.

Figure 16: Photographs of a pan (left) and channelled valley bottom wetland (right) from IUA 5

An approximate, *albeit* underestimated, distribution of the wetlands in this IUA is shown in Figure 17.

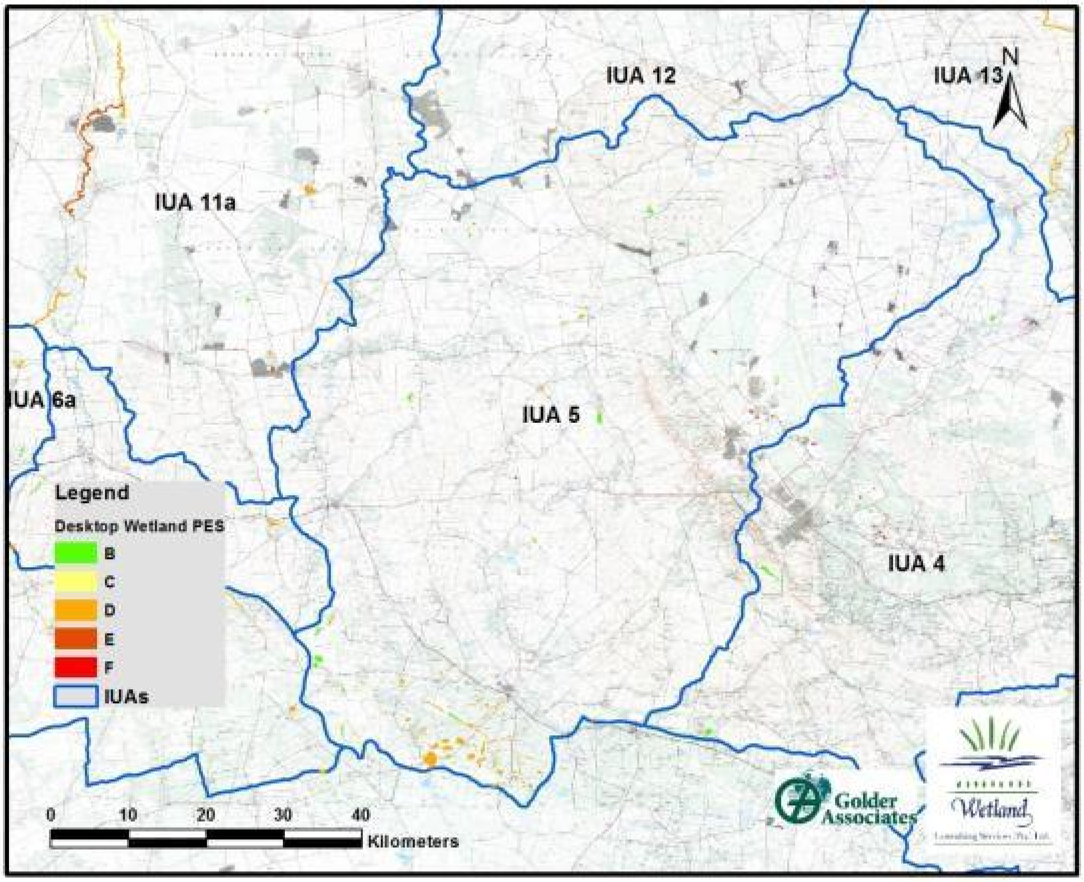


Figure 17: Map showing the main wetlands according to the desktop derived PES for IUA 5

Table 9Preliminary list of priority wetlands in IUA 5 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 9: Priority wetlands in IUA 5

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Pans	-	Very High	Mesic Highveld Grassland Group 4 - **CR**	Rand Highveld Grassland - **VU**	None	Endorheic seasonal grass-sedge depressions
-	Valley bottom wetlands	-	Moderate	Mesic Highveld Grassland Group 4 - **CR**	Rand Highveld Grassland - **VU**	None	-
-	Hillslope seepage wetlands	-	High	Mesic Highveld Grassland Group 4 - **CR**	Rand Highveld Grassland - **VU**	None	High botanical diversity

5.5.6 Wetlands in IUAs 6a and 6b

Given the available information and due to the topography and soil type, there do not appear to be many wetlands in this IUA. Where wetlands occur, they are mostly associated with drainage lines and streams and low lying depressions and are widely dispersed (Figure 18). Based on examination of the aerial imagery, it appears that the SANBI probability map and NFEPA wetland coverage exaggerates the wetland extent and distribution in the south central section of this IUA and as such this representation is probably not accurate. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

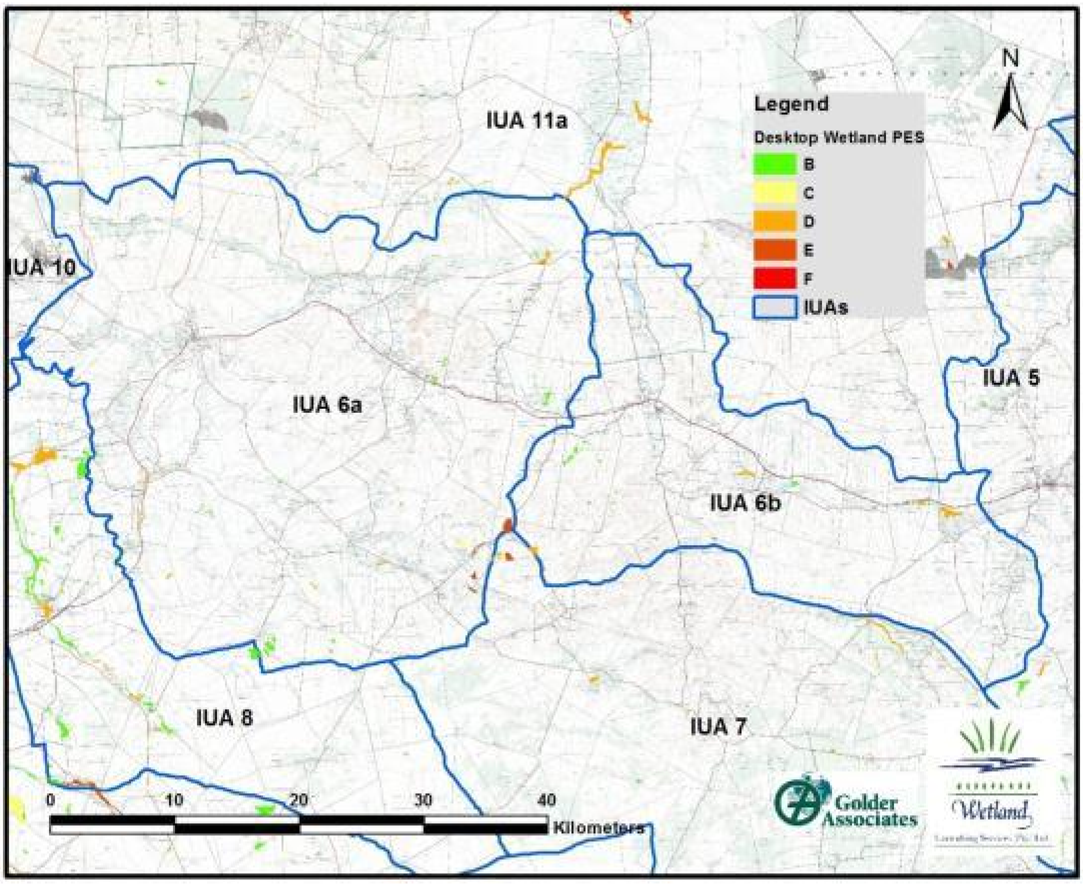


Figure 18: Map showing the main wetlands according to the desktop derived PES for IUAs 6a and 6b

5.5.7 Wetlands in IUA 7

This IUA includes two ecoregions, namely Highveld and Western Bankenveld. Agriculture is an important sector in this IUA with conservation in the form of game farming also occurring. Five wetland types occur, namely hillslope seepage wetlands, unchannelled and channelled valley bottom wetlands, dolomitic eyes and a tufa waterfall. Seepage wetlands are common in the upper reaches of the Bokkraal and the Ribbokfontein se loop. Channelled valley bottom wetlands are the most common system in this IUA and in the upper reaches of the Marico River these form broad wetlands in some reaches (Figure 19). Impacts on these wetlands occur mainly in the form of invading exotic vegetation (Grey poplar, Seringa, Wild Senna, Wattle, and Giant Reed), agricultural activities, road crossings and small farm dams.

Figure 19: Photograph of a channelled valley bottom wetland in the upper reaches of the Marico River in IUA 7. Note the poplar trees along the edge of the channel to the left of the photograph

Unchannelled valley bottom wetlands also occur in this IUA with a good example being the upper reaches of the Rietspruit (**Figure 12**).

Figure 20: Photograph of an unchannelled valley bottom wetland associated with the Rietspruit in IUA 7

A special feature of this IUA is the tufa waterfall at Bokkraal (Figure 21). This is a waterfall composed of limestone or calcium carbonate formed by the precipitation of carbonate minerals. It is a very rare type of waterfall in South Africa and as such can be considered as having a Very High EIS.

Figure 21: Photographs of the tufa waterfall at Bokkraal in IUA 7

Also found in this IUA is the dolomitic eye (Kaaloog or Marico eye) at the source of the Kaaloog-se-loop (headwaters of the Marico River). As with the other eyes in the region, it comprises a peat wetland system fed by groundwater (Figure 22) originating from fractures in the underlying dolomite. The system has a PES of B/C as a result of surrounding agricultural influences but the EIS is

Figure 22: Photographs of the eye of the Kaaloog-se-loop (Marico eye)

A map of the wetlands in this IUA is shown in Figure 23 with a list of preliminary priority wetlands in this IUA provided in **Table 5**.

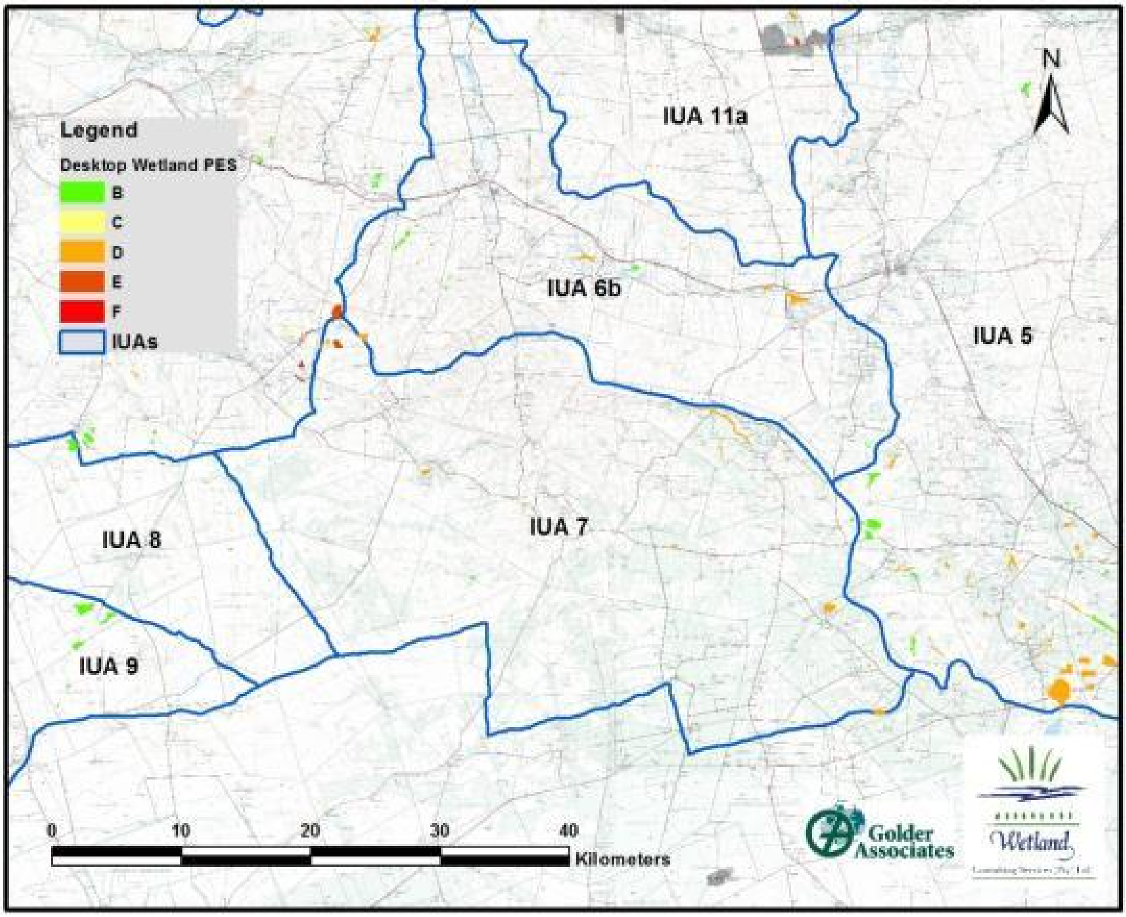


Figure 23: Map showing the main wetlands according to the desktop derived PES for IUA 7

Based on examination of the aerial imagery, it appears that the SANBI probability map and NFEPA wetland coverage exaggerates the wetland extent and distribution in the northwest corner of this IUA and as such this representation is probably not accurate.

Table 10 sets out preliminary list of priority wetlands in IUA 7 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 10: Priority wetlands in IUA 7

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Valley bottom wetlands	C/D	Moderate to High	Mesic Highveld Grassland Group 4 - **CR**	Rand Highveld Grassland - **VU**	No	-
-	Pans	D	High	Mesic Highveld Grassland Group 4 - **CR**	Rand Highveld Grassland - **VU**	No	-

-	Tufa waterfall	B	Very High and very sensitive to water quality changes	Mesic Highveld Grassland Group 4 - **CR**	No	No	Waterfall composed of limestone or calcium carbonate formed by the precipitation of carbonate minerals. Very rare type of waterfall in SA
Marico eye (Kaaloogse Loop)	Valley bottom Peatland	B/C	Very High	Mesic Highveld Grassland Group 4 - **CR**	No	No	Dolomitic eye

5.5.8 Wetlands in IUA 8

This IUA is dominated by one ecoregion, namely Highveld. Agriculture is an important sector in this IUA. An important wetland dominates this IUA, namely the system associated with the Malmanie River which runs south to north across the IUA (Figure 24). Dolomite forms the main watershed of the Malmanie River in the central portion of this IUA. The source of the Malmanie River is the Malmanie eye which comprises a wetland system fed by groundwater originating from fractures in the underlying dolomite. The water from the eye is typically alkaline (pH range from 7.5 to 9.3) having picked up magnesium and calcium carbonates through solution from the parent dolomite. Being perennial, the wetland system associated with, and downstream of, the eye forms peat. This peatland forms part of the Highveld peat ecoregion (Marneweck, Grundling and Muller, 2001).

The peat wetlands that fall within the Highveld Peat ecoregion have developed over long periods ranging between 7000 to 15000 years (depending on peat depth) with peat accumulation rates of between 0.3 to 0.6mm/year (Grundling and Marneweck, 1999; Marneweck *et. al.*, 2001).

Peatlands in general, and more specifically those associated with the dolomitic eyes, are rare in South Africa and southern Africa in general. Those associated with the dolomites in the Malmanie as well as Molopo and Marico Rivers in particular comprise unique ecosystems characterised by a high degree of endemicity (species which are found only there). The results from both morphological and genetic studies of the fish species showed that the indigenous cichlid populations inhabiting these dolomitic wetlands are unique, with a number of populations having differentiated to the extent where they may be considered as separate species (DEA&T, 1995).

Studies on the aquatic invertebrates of these dolomitic wetlands have also produced several new distribution records for South Africa and also 21 new species to science (DEA&T, 1995). For this reason, dolomitic eyes and their associated peatlands are regarded as sensitive systems. Most of these systems are also important water supply sources and thus the associated ecosystems have been impacted by water abstraction. They are also threatened by groundwater contamination from agriculture, industry and mining, habitat transformation and invasions by alien species (particularly exotic plants e.g. poplars and fish species e.g. black bass) and some have been mined for peat.

These groundwater dependent ecosystems are facing increasing pressure from pollution and consumptive uses for agriculture and commercial developments. Collectively, anthropogenic changes in the groundwater regime pose a significant, but largely unknown threat to these important groundwater dependent ecosystems. Seepage areas can occur along the margin of these wetlands with the presence of both seasonally and temporary wet zones. A characteristic deposit of white sulphur reducing bacteria often also occurs in the substrate of the eyes. Typical riparian species associated with rocky habitat also occur around the eyes with terrestrial habitat immediately adjacent to the wetland area.

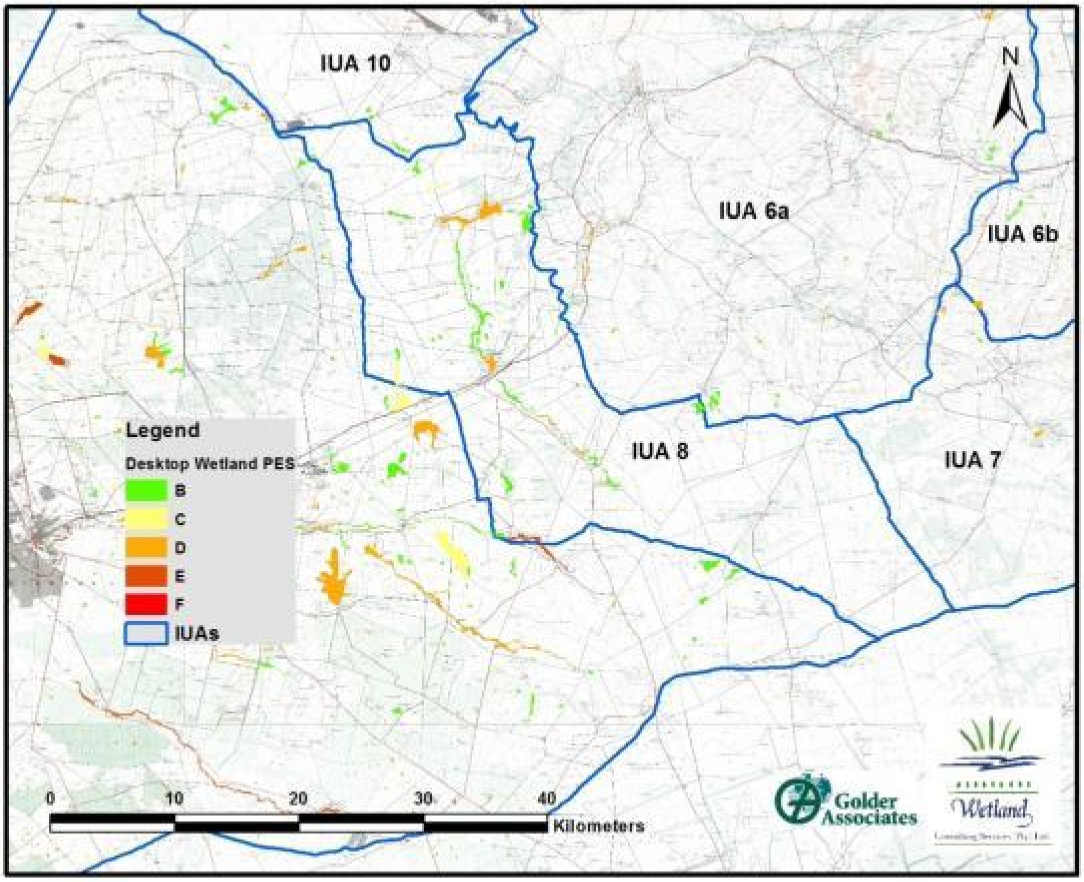


Figure 24: Map showing the main wetlands according to the desktop derived PES for IUA 8

Table 11 sets out preliminary list of priority wetlands in IUA 8 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 11: Priority wetlands in IUA 8

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Malmanie Loop	Valley bottom mire or peatland	B to C/D	Very High	Dry Highveld Grassland Group 5 - **LT**	No	Yes	Dolomitic eye with a valley bottom peatland downstream. Unique biota associated with the dolomitic eye.

5.5.9 IUA 9

Agriculture is also an important sector in this IUA. This IUA is also dominated by two ecoregions, namely Highveld to the east and Southern Kalahari to the west. Agriculture is an important sector in this IUA. A number of important wetlands occur in this IUA. These include the dolomitic eyes and peatlands associated with the two arms of the upper Molopo River which run east to west across the IUA. Again dolomite forms the main watershed of the Molopo River to the east of this IUA. Each of the arms of the Molopo River has peatlands and eyes at their source. The main Molopo eye feeds the arm to the north (

Figure 25). The southern arm is referred to as the Droë Moloporivier. The PES category of this arm is C/D, mainly due to agricultural impacts whereas that of the main northern arm ranges from A/B to C/D. The EIS of both these arms is considered Very High. This is mainly due to the unique biodiversity associated with these systems as well as the fact that the wetlands represent a rare type of wetland in South Africa which is also unique to this particular region.

One cyprinid species in particular, *Barbus cf. brevipinnis* (a type of ghieliemientjie) is endemic to the Molopo and is currently under high risk of extinction due to loss of habitat as a result of reduced flows to the wetland area. Similarly, the ostracod diversity from the Molopo system showed that of all the species found in the area at the time of the survey, 30% were new to southern Africa and one species was new to science (DEA&T, 1995). The Molopo eye is also an important water supply source and thus the associated ecosystems and downstream wetland have been impacted by water abstraction. As with all the dolomitic peatlands in the region, it too is threatened by groundwater abstraction, contamination from agriculture, industry and mining, habitat transformation and invasions by alien species (particularly exotic plants e.g. poplars and fish species e.g. black bass). Tourism development in the form of clearing of natural habitat for grass lawns, braai areas, slip ways, terraces, etc. has also contributed towards the loss of natural habitat on the periphery of the eye. Working for Wetlands (WfWetlands) started doing rehabilitation work in the Molopo catchment in 2001 including in the headwaters. It has long been recognized that an integrated management strategy is required for conserving or maintaining these unique wetland systems.

The Mareetsane wetland (Figure 26) near Mafeking also provides important ecosystem services for people, livestock and wildlife, including water supply and livelihoods support. It is on the Mareetsane River, which flows into the Molopo River. WfWetlands has been undertaking wetland rehabilitation work on this system. These projects were undertaken in partnership with the Local Municipality and Tribal Authority.

To the south is the Bodibe peatland along what is shown as the Potfonteinspruit on the 1:50000 topographic maps. As a result of a drop in groundwater levels in the dolomite, the peatland at the eye of the Bodibe system has dried and the peat started to burn (

Figure 27). The system has been burning for a few years and this has not only resulted in the loss of the peatland, but also poses a health and safety hazard for people and livestock living adjacent to the peatland. Working for Wetlands (WfW) has done some work at the eye, mainly trying to prevent the fire from spreading west by creating a soil barrier across the system. This has not been successful and the system continues to burn. As a result of the degradation of the system, the PES category is D/E. The system would have had a High to Very High EIS but as a result of the desiccation, its biodiversity value has deteriorated.

Another feature of this IUA is an abundance of small pans. Inundation of these is characteristically ephemeral. Some of the pans can stand dry for years between temporary flooding (DWA, 2010). Water loss from pans is largely due to evaporation. The 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 (DWA, 2010). The relative contributions of these different water sources may vary considerably amongst different depressions. Although the pans are not inundated for long periods at a time, they are still a good example of a specific type of wetland which occurs in this region.

Threats are mainly from agricultural activities including agricultural pollutants such as fertilizers, pesticides and herbicides. Road crossings intersect pans and disrupt hydrological movement of water. Runoff water from roads also contributes towards the silt load built-up in these pans. Pans in general have received little attention and this also applies to the systems associated with this IUA. No information could be found in the literature review relating to these systems and so very little is known about their hydrology or biogeochemistry. Further studies would be required on these systems to get a better understanding of their role and ecological importance in the region.

Figure 25: Photographs of the Molopo eye and associated peatland (top) as well as water abstraction infrastructure (bottom left) and development around the edge of the eye (bottom right)

Figure 26: Photograph of part of the Mareetsane wetland near Mafeking where it forms a distinct unchannelled valley bottom system

Figure 27: Photographs of the Potfontein eye which forms part of the Bodibe peatland showing the eye (top), burning peat and ash (middle row and bottom row left), and the dry channel of the Potfonteinspruit downstream of the eye (bottom centre and right)

A map of the wetlands in this IUA is shown in Figure 20 with a preliminary list of priority wetlands provided in Table 9

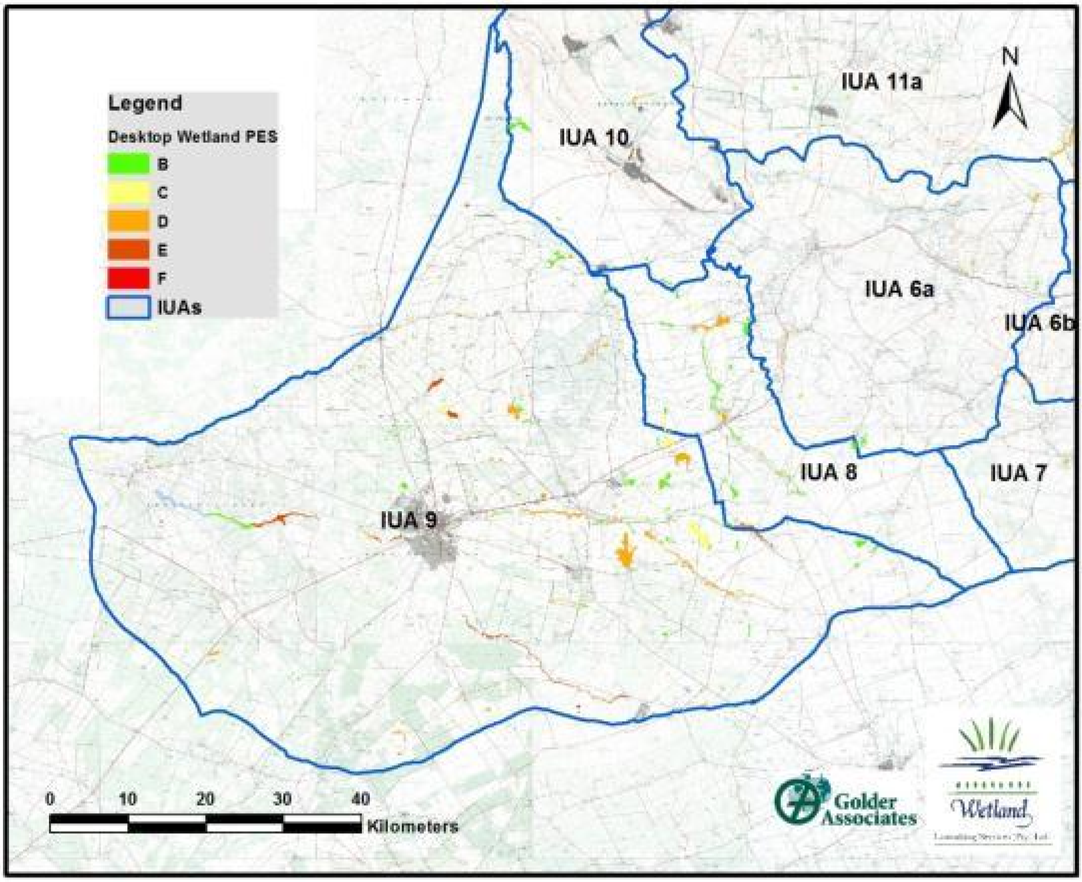


Figure 28: Map showing the main wetlands according to the desktop derived PES for IUA 9

Table 12 sets out preliminary list of priority wetlands in IUA 9 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 12: Priority wetlands in IUA 9

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Pans	-	High	Dry Highveld Grassland Group 5 - LT	Western Highveld Sandy Grassland - CR	None	Endorheic temporary to seasonal depressions
-	Pans	-	High	Eastern Kalahari Bushveld Group 1 - LT	Mafikeng Bushveld – VU	Some	Endorheic seasonal grass-sedge depressions
-	Valley bottom wetlands	-	Moderate	Dry Highveld Grassland Group 5 - LT	No	No	-
-	Valley bottom wetlands	-	Moderate	Eastern Kalahari Bushveld Group 1 - LT	No	No	-
Molopo	Unchannelled valley bottom wetlands and peatlands	B to D	Very High	Dry Highveld Grassland Group 5 - LT	No	Yes	Molopo Eye and peatland. Is important for water supply and

							biodiversity support
Bodibe peatland	Unchannelled valley bottom wetlands	E/F	Very High	Dry Highveld Grassland Group 5 - LT	No	No	Potfontein eye and Bodibe peatland.

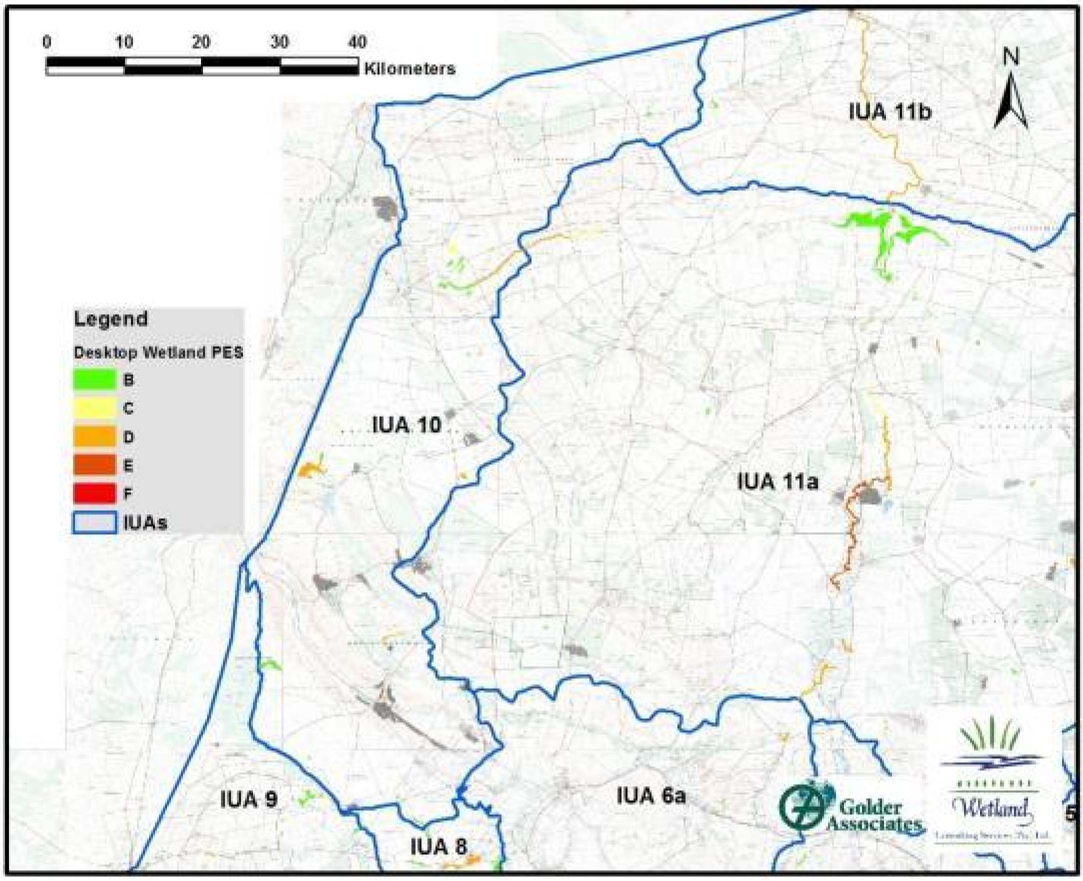
5.5.10 Wetlands in IUA 10

This IUA is also dominated by two ecoregions, namely Western Bankenveld to the north and Highveld to south. The area comprises numerous settlements and livestock farming and subsistence agriculture are important land uses in this IUA. There are not many wetlands in this IUA but two important systems do occur, namely the Dinokana eye and associated wetland (Figure 29) and the Ngotwana wetland (Figure 30). Both these wetlands provide important ecosystem services for people, livestock and wildlife, including water supply and livelihoods support. The PES category of the former D/E, mainly due to the impacts associated with the surrounding settlements and land degradation. The PES category of the latter ranges from A/B to C/D mainly as the area upstream is severely eroded due to overgrazing. The EIS of both these systems is considered to be High to Very High. This is mainly due to the unique biodiversity associated with these systems as well as the fact that the wetlands, *albeit* that they are quite different, each represent a particular type of wetland in which is also unique to this particular region.

Figure 29: Photographs of the Dinokana wetland showing a section of the unchannelled valley bottom system (left) and associated hillslope seepage wetlands (right)

Figure 30: Photographs of the Ngotwana wetland showing the main perennial area of the system (top), effects of grazing (second row), seasonal grass-sedge meadows (third row left), livestock grazing (third row right) and erosion on the sodic soils towards the upper reaches of the system (bottom row)

A map of the wetlands in this IUA is shown in Figure 31.



UA 10

Table 13 sets out preliminary list of priority wetlands in IUA 10 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 13: Priority wetlands in IUA 19

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Ngotwana Wetland	Unchannelled valley bottom wetland and spring	B to D/E	High to Very High	Central Bushveld Group 2 - **VU**	No	No	High biodiversity wetland in semi-arid climate with its source in Botswana. Important grazing and water resource for local community
Dinokana eye and Wetland	Unchannelled valley bottom, spring and hillslope seepage wetlands	C to D/E	High to Very High	Central Bushveld Group 2 - **VU**	No	No	High biodiversity wetland and important for water supply

5.5.11 Wetlands in IUA 11a

IUA 11a is characterised by a large rural population with high unemployment rates. Given the available information and due to the topography and soil type, and apart from pans, there do not appear to be many wetlands in this IUA. Where wetlands occur, they appear to be mostly associated with drainage lines and streams and low lying depressions and are widely dispersed (Figure 32). Based on examination of the aerial imagery, it appears that the SANBI probability map and NFEPA wetland coverage exaggerates the wetland extent and distribution around the dam in the north of the IUA. As such this representation is probably not accurate in this area. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

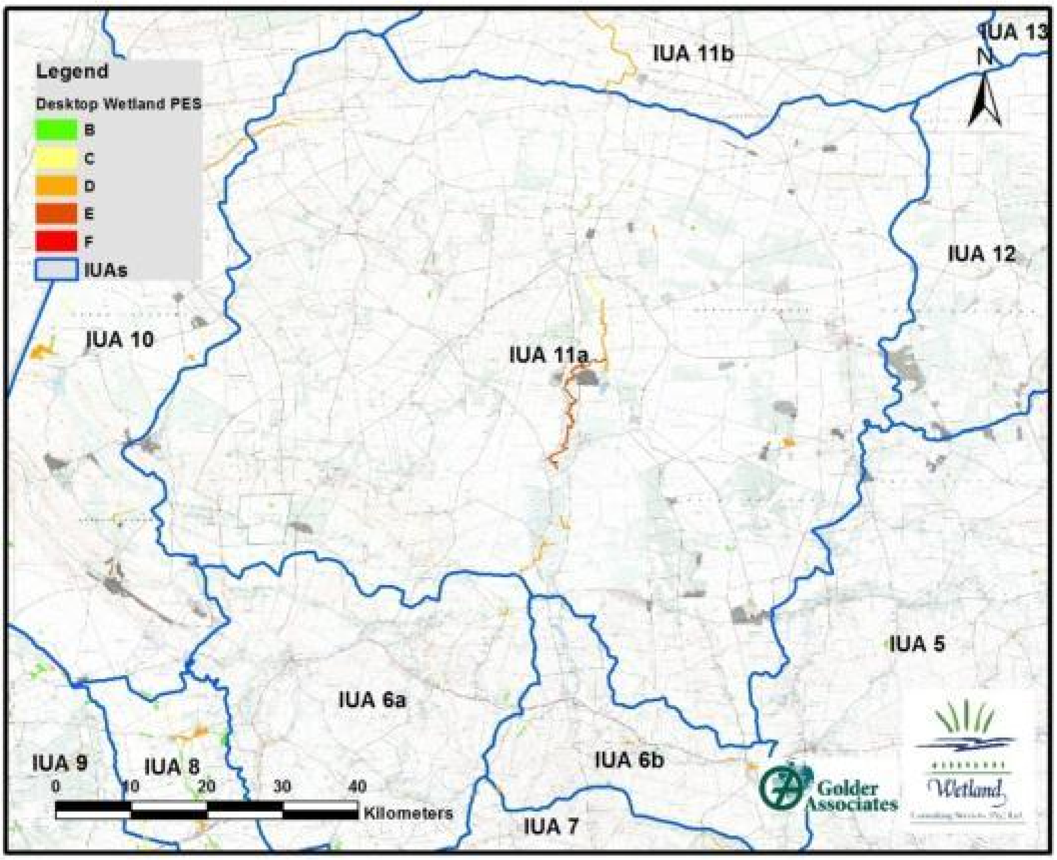


Figure 32: Map showing the main wetlands according to the desktop derived PES for IUA 11a

5.5.12 Wetlands in IUA 11b

As with IUA 11a, IUA 11b is characterised by a large rural population with high unemployment rates. Numerous nature reserves and conservation areas, including the Madikwe Game Reserve that is one of the largest game reserves in South Africa is situated in the Marico catchment. Again, given the available information and due to the topography and soil type, and apart from a few pans and the system along the lower Marico River, not many wetlands are indicated on the available databases for this IUA. Two fairly large wetland systems were however identified from the aerial imagery of the area. These include the lower section of the Lengope la Kgamanyane River just before the confluence with the Marico River and what appears to be an extensive floodplain-type system associated the Lenkwane River at and upstream of the confluence of the Marico River.

Additional work would be required at a more detailed scale to accurately map the extent of these systems.

From consideration of the NFEPA maps as well as available aerial imagery, there is also an extensive riparian zone associated with the Marico River (Figure 33).

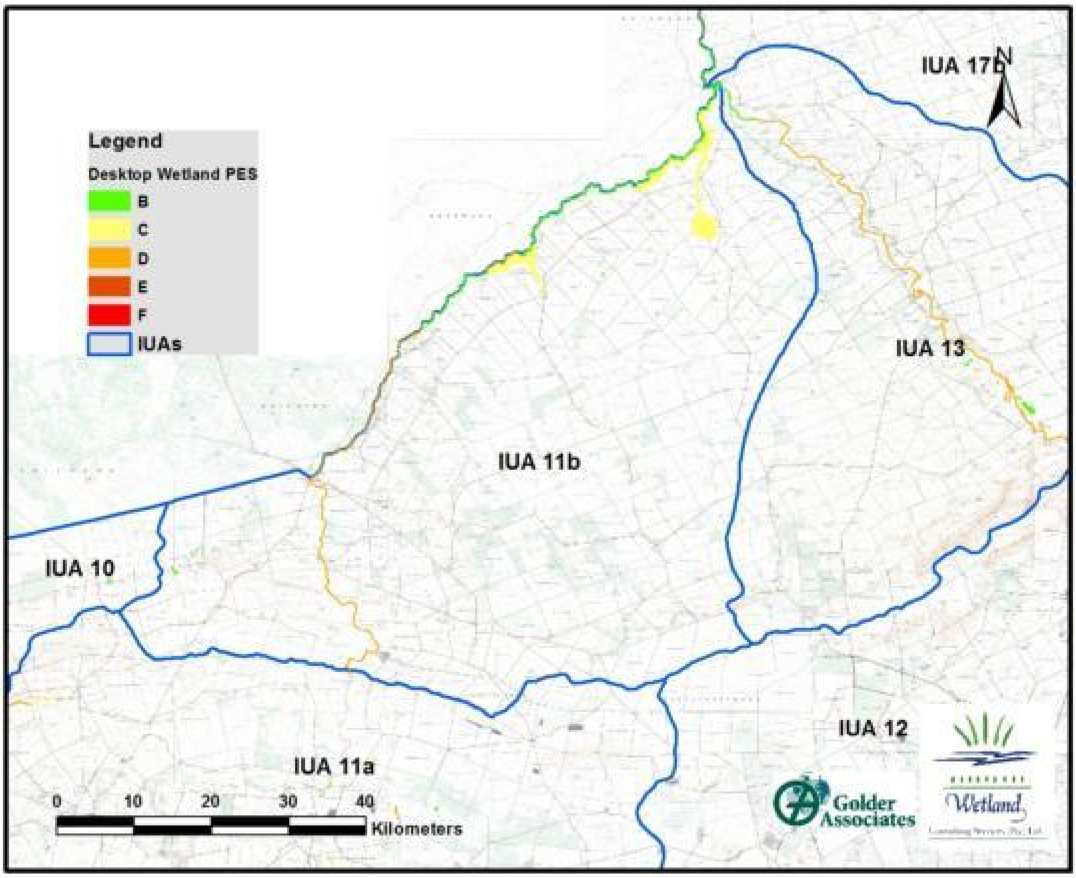


Figure 33: Map showing the main wetlands according to the desktop derived PES for IUA 11b

Floodplain wetland features also occur along the Marico River. Sections of the Marico River and its associated riparian zone as well as well as these wetland features are indicated as a WETFEPA. Pans also occur in this IUA. Some are indicated on the WETFEPA coverage. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

Table 14 sets out a preliminary list of priority wetlands in IUA 11b indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 14: Priority wetlands in IUA 11b

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Lower Marico River	Riparian zone and floodplains	B to D	Very High	Central Bushveld Group 2 - **VU**	No	Yes	Old growth riparian forest assemblages, floodplain features, paleo-channels as well as backwater features
Lengope la Kgamanyane River	Floodplain	C	High	Central Bushveld Group 2 – **VU**	No	No	-
Lenkwane River	Floodplain	C	High	Central Bushveld Group 2 - **VU**	No	No	-
-	Pans	B to D	High to Very High	Central Bushveld Group 2 - **Vu**	No	Some	

5.5.13 Wetlands in IUA 12

Other major mining activities can be found in IUA 12, where there are significant deposits of iron ore and andalusite. Granite mining is found throughout the IUA. Again, given the available information and due to the topography and soil type, there do not appear to be many wetlands in this IUA. It is likely that hillslope seepages would occur on the granites as this would be expected due to the sandy nature of these soils. Shallow groundwater movement would be a key driver of these systems. As these systems are sometimes difficult to detect, even in the field, identifying signatures remotely is even more difficult. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

An approximate, *albeit* probably underestimated, distribution of the wetlands in this IUA is shown in **Figure 25**.

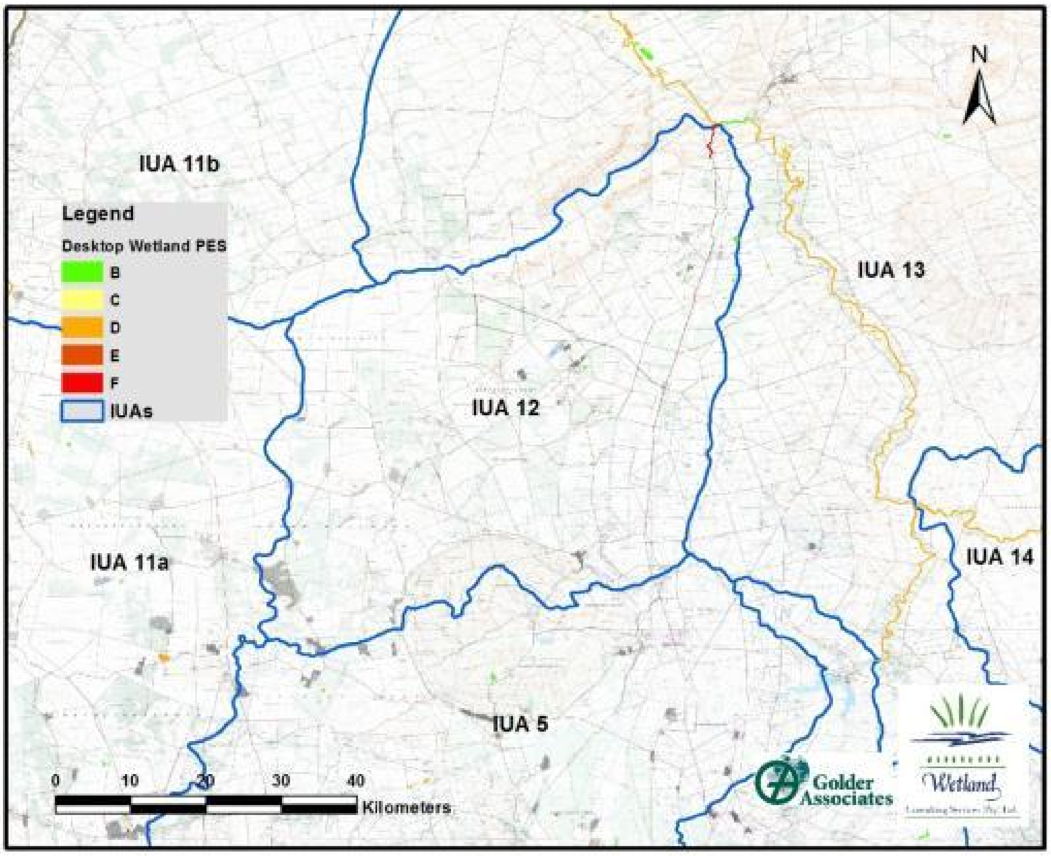


Figure 34: Map showing the main wetlands according to the desktop derived PES for IUA 12

5.5.14 Wetlands in IUA 13

The dominant land use in IUA 13 (which comprises of the lower reaches of the Crocodile River) is largely natural, but irrigation along the Crocodile River main stem is an important contributor to local GDP. Some granite mining is found in IUA 13. Again, given the available information and due to the topography and soil type, and apart from a few pans, there do not appear to be many wetlands in this IUA apart from pans. Where wetlands occur, they appear to be mostly associated with drainage lines and streams and low lying depressions and are widely dispersed (**Figure 26**). As with IUA 12, it is likely that hillslope seepages would occur on the granites as this would be expected due to the sandy nature of these soils. Shallow groundwater movement would be a key driver of these systems. As these systems are sometimes difficult to detect, even in the field, identifying signatures remotely is even more difficult. Sections of the Crocodile River and its associated off-channel wetlands and floodplain are indicated as a WETFEPA. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

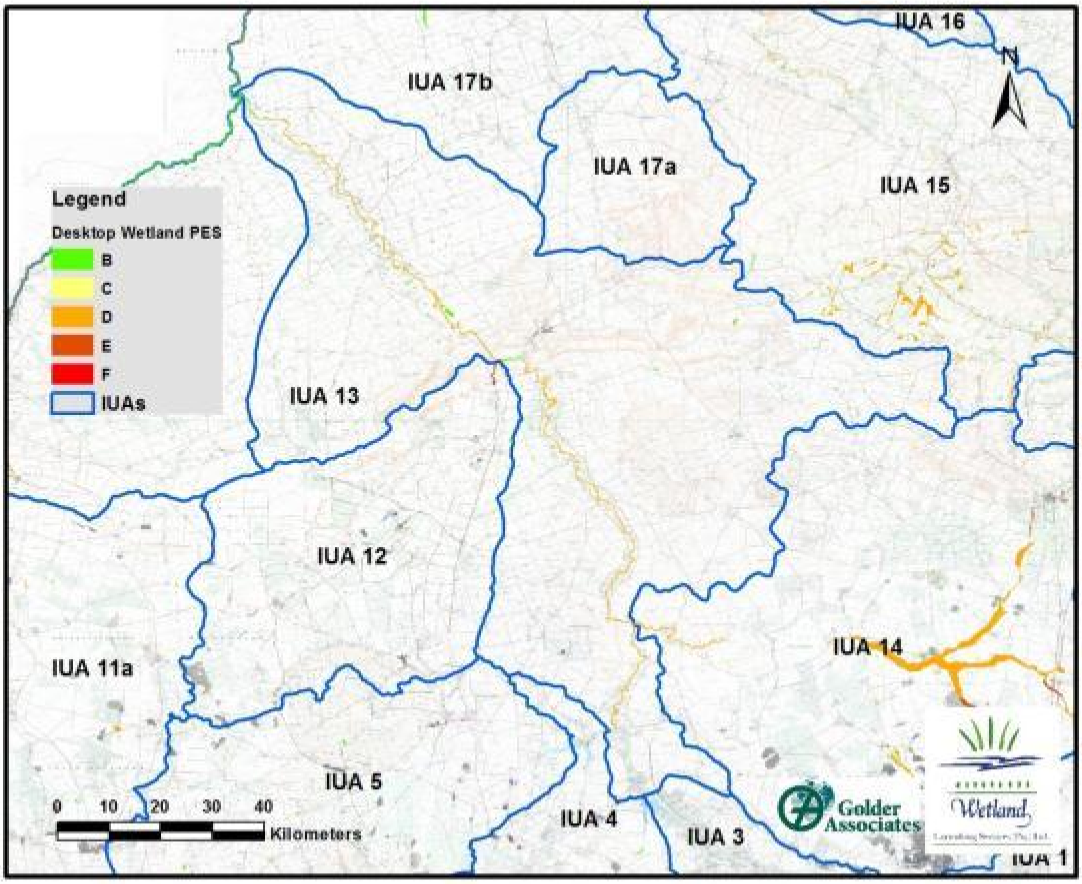


Figure 35: Map showing the main wetlands according to the desktop derived PES for IUA 13

Table 15 sets out a preliminary list of priority wetlands in IUA 13 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 15: Priority wetlands in IUA 13

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Sections of the Crocodile River	Riparian zone, off-channel wetlands, backwaters and floodplains	B to D	High	Central Bushveld Group **2 and 3 – VU to EN**	No	Yes	Riparian zone, floodplain and off-channel features

5.5.15 Wetlands in IUA 14

In terms of population, IUA 14 is the second most populous IUA in the study area and contains the areas of Mabopane, Hammanskraal and Soshanguve. These areas are a mix of rural and urban settlements and are characterised by high unemployment rates. Agriculture is also an important sector in this IUA. Based on the current conditions, an understanding of the geomorphology, drainage patterns, and soils in this IUA, four wetland types have been identified. These are pans or depressions, hillslope seepage wetlands, unchannelled valley bottom wetlands, channelled valley bottom wetlands and floodplains.

The largest and probably one of the most important systems in this IUA is the Moretele or Pienaars River floodplain (Figure 36). Together with the Apies River floodplain which is also in this IUA and which flows into the Moretele, this combined system forms the second largest floodplain in the Bushveld Ecoregion. It also represents the southern-most natural distribution of Wild Rice (*Oryza longistaminata*) in Africa. The floodplain is used extensively by the surrounding communities for fishing and grazing and is also regarded as an important birding area, with the floodplain and surrounding area supporting 362 of the 461 species recorded in the North West Province. The wetland also includes traditionally sacred sites which have high cultural significance.

Based on Noble and Hemens (1978) and Rogers (1995) definition, the floodplain can be classified as a "storage floodplain". This category of riparian wetlands is characterised by the occurrence of a riverine area and a grassy floodplain of varying width on either side and is able to retain standing water in oxbow lakes and backwaters for long periods between floods. The riverine area may be permanently or seasonally inundated while the grassy floodplain is more seasonally to intermittently inundated following flooding events. The PES is indicated as C/D to D/E, mainly due to the changes in the systems as a result of the modification of flow due to urban development upstream and sewage as well as agricultural return flows. The EIS is considered to be Very High.

Figure 36: Photographs of the Moretele floodplain showing some of the distinct floodplain features including a meandering channel with oxbows

The wetlands within the Borakalalo National Park are also considered of high conservation value, despite being heavily degraded. They have also been the focus of WfWetlands work over the past few years. Borakalalo forms the western end of the Moretele floodplain. The Tswaing Crator and its associated pan or depression wetland also fall within this IUA. An approximate, *albeit* underestimated, distribution of the wetlands in this IUA is shown in Figure 37 with a preliminary list of priority wetlands provided in Table 16.

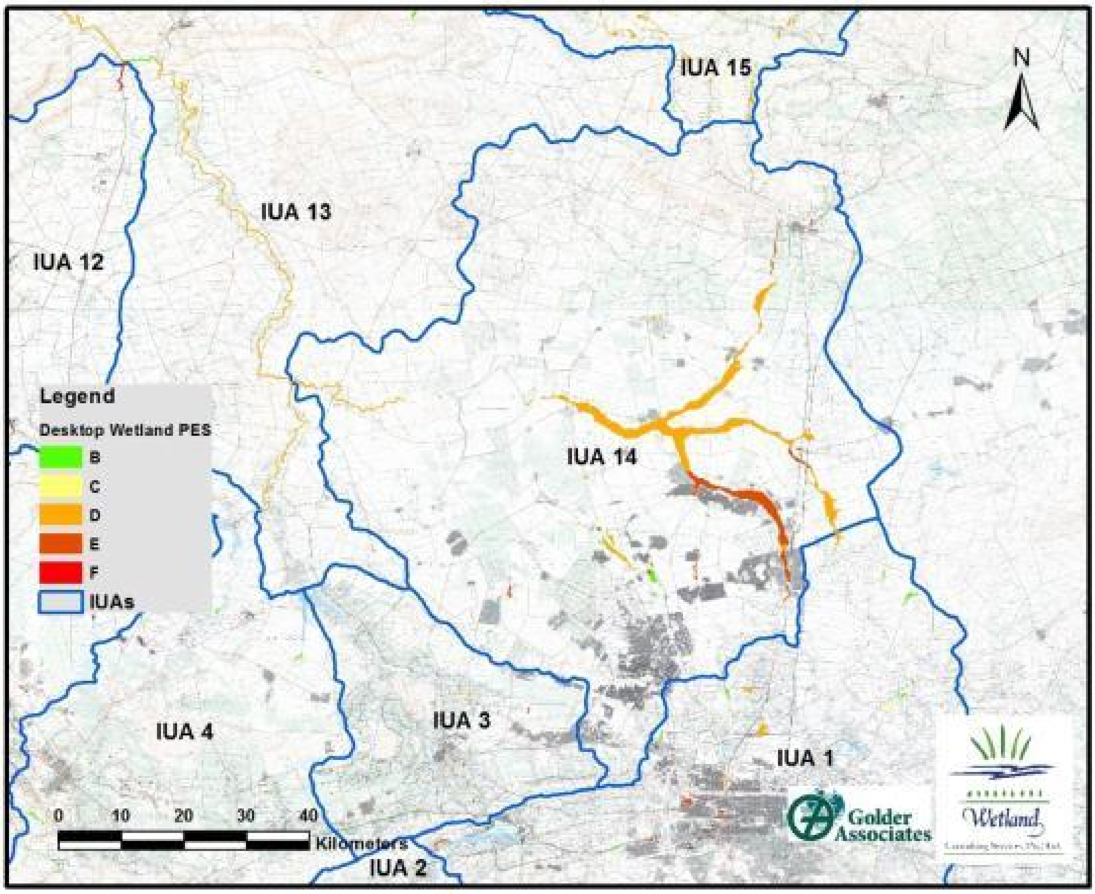


Figure 37: Map showing the main wetlands according to the desktop derived PES for IUA 14

Table 16 set out a preliminary list of priority wetlands in IUA 14 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 16: Priority wetlands in IUA 14

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Moretele River floodplain	Floodplain	D to E	Very High	Central Bushveld Group 2 - **VU**	Springbokvlakte Thornveld - **VU**	Yes	High biodiversity wetland and important bird habitat. Important grazing resource for local community
Apies River floodplain	Floodplain	E to F	Very High	Central Bushveld Group 2 - **VU**	Springbokvlakte Thornveld - **VU**	No	Important grazing resource for local community
Tswaing Crator	Depression	-	Very High	Central Bushveld Group 2 - **VU**	No	Yes	Unique endorheic system

5.5.16 Wetlands in IUA 15

IUAs 15 is found within the Mokolo Catchment and are largely rural in nature with large tracts of land set aside for game farming and hunting. This IUA comprises the watershed and upper catchment of the Mokolo River. This area is characterized by steep mountain slopes of the Waterberg with sandy nutrient poor soils, rocky plateaus and mixed broad leaved savanna bushveld. The wetland systems typically found include hillslope seepage wetlands, sheetrock wetlands and channeled and unchanneled valley-bottom systems, some of which are shown in **Figure 29**. Water quality is typically good, and the streams are flanked by narrow riparian zones with the larger dominant tree typically being the Waterberry (*Syzygium cordatum*) and water pear (*Syzygium guineense)*. Valley-bottom wetlands typically comprise a mixture of tall emergent plants such as the common reed *Phragmites australis* and the grass *Miscanthus junceus* and shorter grass-sedge meadows dominated by *Leersia hexandra* and Red vlei grass (*Ischaemum fasciculatum*). The main ecosystem services supplied by these systems include flood attenuation, water quality enhancement, streamflow augmentation and biodiversity maintenance.

Extensive wetland systems occur in the Sand River catchment (southern-most watershed of the Mokolo River). They form important habitat for Blue cranes and are thus of high importance from a conservation and biodiversity perspective. Land use in the area is mostly agricultural and as a result many of the wetland systems have been degraded. WfWetlands targeted the area for wetland rehabilitation and to date a number of projects have been implemented. The Thaba Metsi wetland was also targeted as part of this work. In addition to these wetlands, the riparian and instream habitats of the Sterkstroom, Taaibosspruit and Rietspruit are also considered important ecologically. These are also some of the remaining rivers in the catchment that still support flow dependent fish species (River Health Programme, 2006). At the catchment scale the wetlands in IUA 15 are expected to provide valuable ecosystem services, most notably streamflow augmentation, but also biodiversity support, and, due to their largely unchannelled, diffuse-flow nature, flood attenuation, sediment trapping and water quality improvement functions (DWA, 2010).

The landuse in the catchment is game farming, and it can be considered to be largely pristine in parts, consisting of mixed broad-leafed woodland. Other parts of the IUA are however heavily impacted by agricultural practices, particularly in the areas where the topography is not so steep. In the agricultural areas, the PES of the wetlands is usually in a category C/D while in the nature reserves and game farms this improves to A/B. Extensive desktop mapping was undertaken in this IUA and the wetland map derived is considered to be reasonable accurate at that level. An approximate and reasonably accurate distribution of the wetlands in this IUA is shown in **Figure 30** with a preliminary list of priority wetlands provided in **Table 14**.

Figure 38: Photographs of typical channelled and unchannelled valley bottom wetlands found in IUA 15

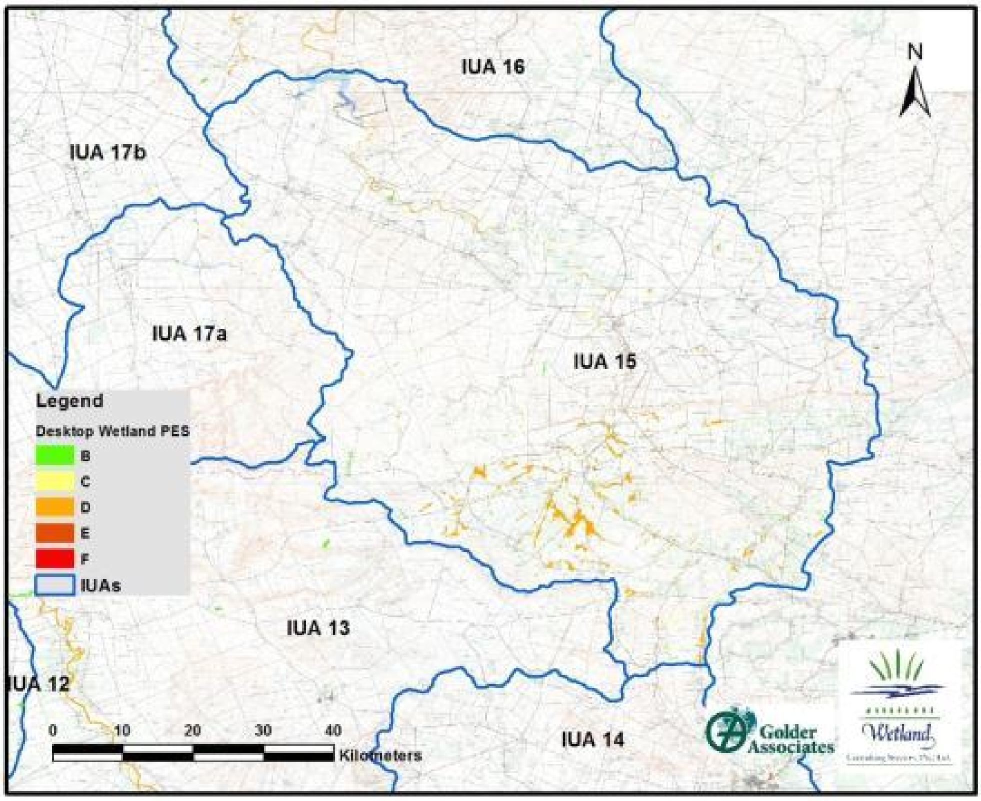


Figure 39: Map showing the main wetlands according to the desktop derived PES for IUA 15

Table 17 sets out a preliminary list of priority wetlands in IUA 15 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 17: Priority wetlands in IUA 15

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Valley bottom wetlands	A/B to C/D	High	Central Bushveld Group 3 - **EN**	No	Yes	Part of the Waterberg system with a unique combination of flora and faunal associations
-	Valley bottom wetlands	A/B to C/D	High	Central Bushveld Group 1 - **EN**	No	No	Part of the Waterberg system with a unique combination of flora and faunal associations. I
-	Hillslope seepage wetlands	A/B to C/D	High	Central Bushveld Group 3 - **EN**	No	No	Part of the Waterberg system with a unique combination of flora and faunal associations
-	Hillslope seepage wetlands	A/B to C/D	High	Central Bushveld Group 1 - **EN**	No	No	Part of the Waterberg system with a unique combination of flora and faunal associations

5.5.17 Wetlands in IUA 16

IUA 16 is found within the lower Mokolo Catchment and is largely rural in nature with large tracts of land set aside for game farming and hunting. This IUA also contains the Matimba coal fired power station and the Medupi power station (under construction). Downstream of the Mokolo Dam the Mokolo River enters the Limpopo plain. Here colluvial processes dominate and the river and associated riparian and wetland habitats are controlled by the deposition, transport and erosion of sediment (Figure 40). Here the alluvial (river process driven) aquifer supports an extensive riparian forest fringe and instream biota. The riparian zone in particular, which includes large specimens of the Nyala berry (*Xanthocercis zambesiaca*), Waterberry (*Syzygium cordatum*) and the Tamboti (*Spirostachys africana*), is dependent on this shallow alluvial aquifer system. The lower reaches also support Leadwood trees (*Combretum imberbe*). The pools and backwater floodplains associated with the lower Mokolo River provide valuable refugia for river and wetland biota during dry periods and thus play a valuable biodiversity support role. The floodplains also provide high quality grazing for the farms located along these areas and sediment trapping and flood attenuation during high flow periods (DWA, 2010)

In the vicinity of Lephalale, the river is extensively used for sand mining. This together with the regulated flows from the Mokolo Dam upstream has affected the structure of the river along this reach with resulting alterations to the flow regime and pattern. There is also evidence suggesting that the resulting changes have not only affected the distribution and abundance of reedbeds in the system, but also the alluvial aquifer which in turn is impacting on the instream and riparian ecosystem. The reduction in flows and large floods due to upstream dams and abstraction is expected to have reduced the recharge of the river-associated wetlands (ox-bows and backwater pools) along the lower section of the Mokolo River (DWA, 2010).

The Tambotie River which flows through D'Nyala Nature Reserve and joins the Mokolo River near to Lephalale, is also regarded as an important system. The floodplain of the Tambotie River supports an extensive population of Tamboti (*Spirostachys Africana*) and Leadwood trees (*Combretum imberbe*). Water abstraction and the droughts experienced in the 1980's and early 1990's impacted on the system and with the drying out of the alluvial aquifer during this time, many of the Leadwood trees died. This floodplain system is nevertheless considered to have high ecological importance and sensitivity and is a key wetland in the region.

Figure 40: Photographs of the Mokolo River downstream of the Mokolo Dam

An approximate distribution of the wetlands in this IUA is shown in Figure 41.

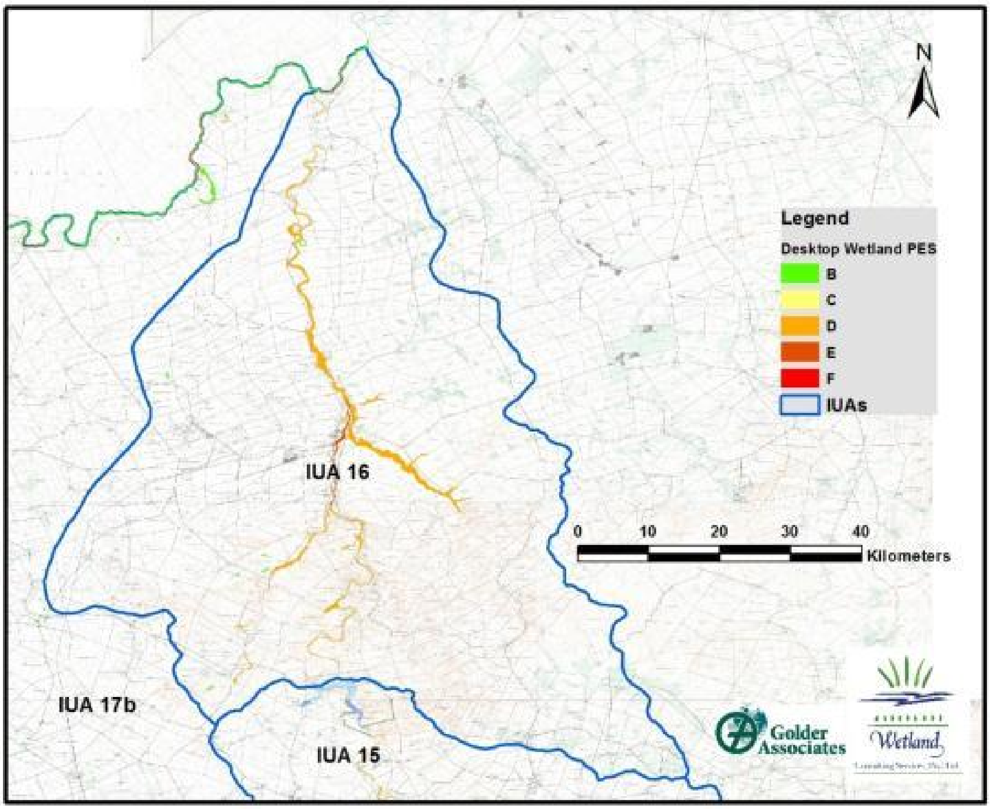


Figure 41: Map showing the main wetlands according to the desktop derived PES for IUA 16

Table 18 sets out a preliminary list of priority wetlands in IUA 16 indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 18: Priority wetlands in IUA 16

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
-	Valley bottom wetlands	-	High	Central Bushveld Group 4 – **VU** to **EN**	No	No	-
-	Hillslope seepage wetlands	-	High	Central Bushveld Group 4 - **VU**	No	No	-
Mokolo River and floodplain	Floodplain	C/D to D/E	High	Central Bushveld Group 4 - **VU**	No	Yes	Old growth riparian forest assemblages, alluvial aquifer and floodplain as well as backwater features
Tambotie River floodplain	Floodplain	C/D to D/E	High to Very High	Central Bushveld Group 4 - **VU**	No	No	Old growth riparian forest assemblages, alluvial aquifer and floodplain features

5.5.18 Wetlands in IUA 17a

IUA 17a is found within the Matlabas catchment, and the dominant landuse is conservation and game farming. The Matlabas River flows through the Marakele Nature Reserve. The park is characterized by the Waterberg Moist Bushveld vegetation type (veld type 12), mixed Bushveld (veld type 18) and the Sweet Bushveld (veld type 17). The Sweet Bushveld is mostly found along the banks of the Matlabas River and forms an important winter refuge area for game particularly during limiting periods at the end of the dry season.

Given the available information not many wetlands have been mapped in this IUA. While there are expected to be many smaller wetlands associated with the drainage lines in the Waterberg in particular, these cannot easily be identified using remote mapping techniques. There however do not appear to be many large wetlands in this IUA. Where wetlands occur, they appear to be mostly associated with drainage lines and streams and are widely dispersed (Figure 42). Some riparian wetlands can be seen on the aerial imagery in sections of the Motlhabatsi and Mamba Rivers. Further work would be required at a more detailed scale to more accurately map the extent of wetlands in the IUA.

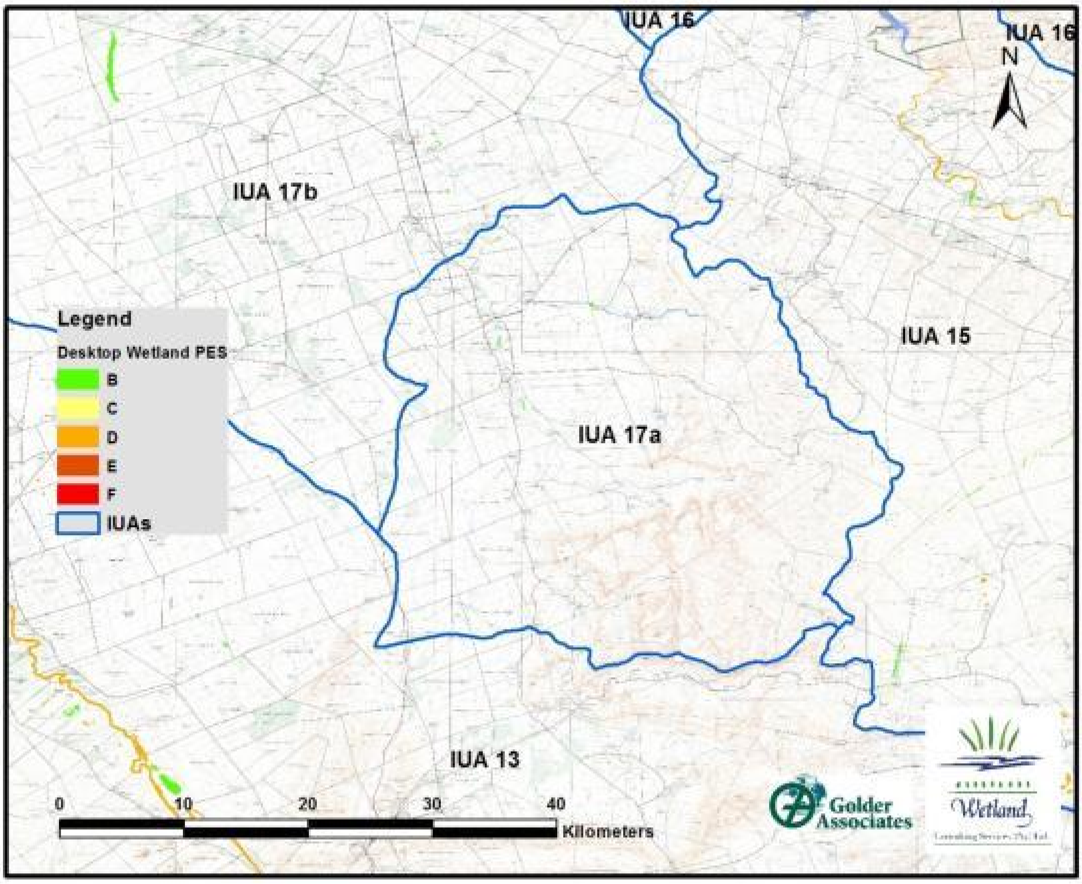


Figure 42: Map showing the main wetlands according to the desktop derived PES for IUA 17a

5.5.19 Wetlands in IUA 17b

IUA 17b is found within the Matlabas catchment, and the dominant land use is conservation and game farming. This IUA has been earmarked for future coal mining developments. Given the available information and due to the topography and soil type, and apart from a fairly large number of pans, there do not appear to be many other wetlands in this IUA. Where wetlands occur, they appear to be mostly associated with drainage lines and streams and low lying depressions and are widely dispersed (Figure 43).

A fairly large wetland system is indicated on the 1:50 000 topographic maps associated with the lower Matlabas River. There is also an extensive wetland system associated with a section of the Aslaagte River which is a tributary of the Matlabas River. From consideration of the NFEPA maps as well as available aerial imagery, there is also an extensive riparian zone associated with the Limpopo River. Floodplain wetland features such as cut-off meanders associated with the paleo-channel of the Limpopo River also occur. The Limpopo River and its associated Riparian zone as well as well as these wetland features are regarded as important systems (WETFEPA) and further work is recommended to more accurately map and assess these systems and features, particularly considering the proposed future coal mining activities in this IUA and the potential impact thereof on this system and these wetland features which lie at the lower-end of the catchment. Similarly, and in addition to considering the wetlands and riparian features along the Limpopo River, additional work would be required at a more detailed scale to accurately map the extent of the wetlands in this IUA.

There is also very little information available on the pans in this IUA and further work on these systems is also recommended, particularly given that many are indicated as WETFEPAS. Pans in general are recognised as being important for biodiversity support. Understanding how they may be linked to other drainage features will also be important, particularly considering the proposed future coal mining activities in this IUA and the potential impact thereof on these systems as well.

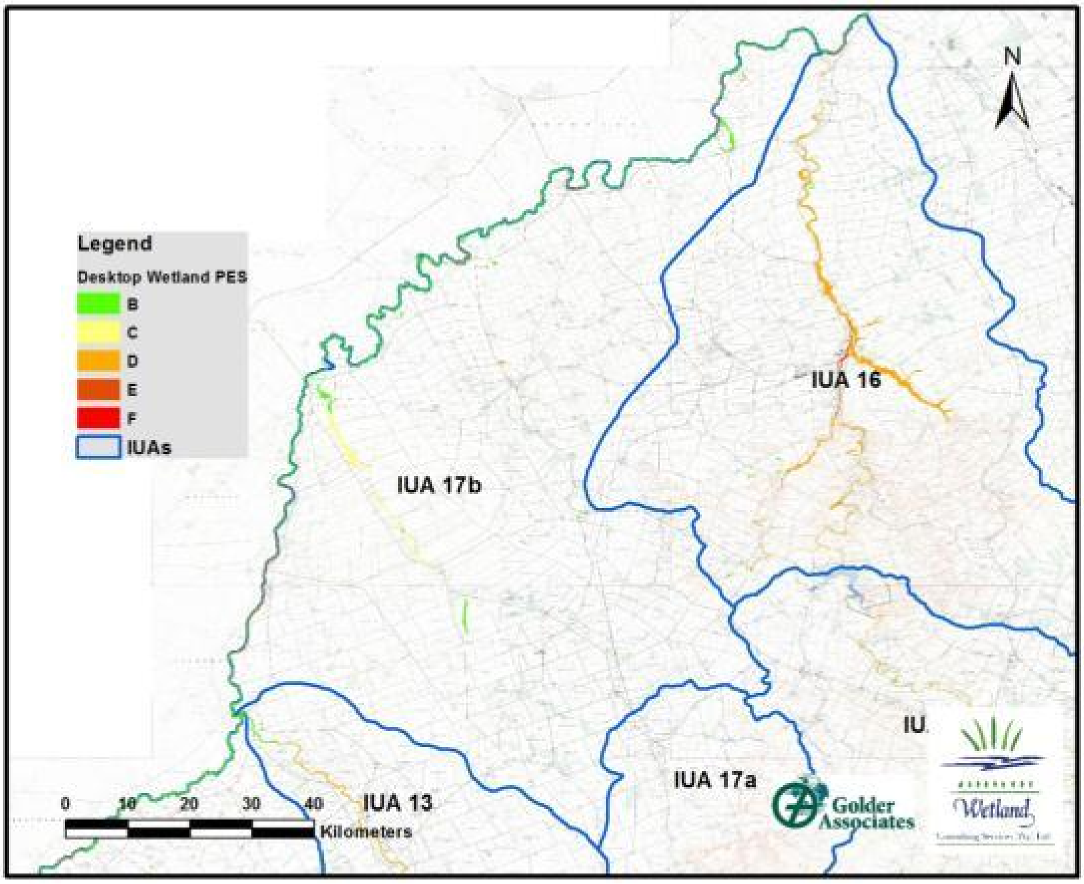


Figure 43: Map showing the main wetlands according to the desktop derived PES for IUA 17b.

Table 19 sets out a preliminary list of priority wetlands in IUA 17b indicating the type of system, range of PES and EIS categories that were identified, the NFEPA Vegetation Group and Threat Status, whether the system forms part of a Threatened Ecosystem (according to GN 1002, National List of Ecosystems that are Threatened and in need of Protection), whether the system is identified as a WETFEPA, and a brief description of any unique features associated with the wetland systems.

Table 19: Priority wetlands in IUA 17b

Wetland	Type	PES	EIS	NFEPA Wetland Vegetation Group and Threat Status	Part of a Threatened Ecosystem	Identified as a WETFEPA	Unique features
Lower Matlabas River	Valley bottom wetland	B/C	High	Central Bushveld Group 4 – **EN**	No	Parts of the system	-
Aslaagte	Valley bottom wetland	B	High	Central Bushveld Group 4 – **EN**	No	No	-
Limpopo River and associated riparian zone and	Riparian zone and floodplains	B to D	Very High	Central Bushveld Group 4 - **VU**	No	Yes	Old growth riparian forest assemblages, floodplain features, paleo-channels as well as backwater features

floodplain features							
-	Pans	B to D	High to Very High	Central Bushveld Group 4 - **EN**	No	No	Old growth riparian forest assemblages, alluvial aquifer and floodplain features

6 ESTABLISHMENT OF THE ECOLOGICAL SUSTAINABLE BASE CONFIGURATION SCENARIO

Determining the management class of a water resource in terms of the process, involves taking into account the social, economic and ecological landscape in a catchment in order to assess the costs and benefits associated with utilisation versus protection of a water resource. As such, classification is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use and the broader goals of the IUA and WMA. The basis for determining the MC is the determination of the ecological sustainable level of protection that is required for water resources and integrating this with the economic and social goals. It is therefore important that an appropriate ecological protection base level (base condition) is established for the water resources; and from this determine what is feasible by understanding the economic and social implications of attaining the minimal (sustainable) level of ecological protection. Once this sustainable ecological protection level is understood, various levels of resource directed protection can be assessed in terms of the overall implications to the IUA and WMA.

The ecologically sustainable base configuration scenario (ESBC) defines this lowest theoretical level of protection required for the sustainable use of the water resources of a catchment. It is not the target scenario but informs the minimal protection level required as a starting point for the hydrological analysis of the water resource system.

This task has been undertaken in compliance with the requirements of the study terms of reference that specify that the classification process is required to build from existing and current initiatives undertaken in support of integrated water resource management.

6.1 Objectives of step 4 of the WRCS

The objective of step 4 of the WRCS is to determine the ESBC and to establish starter catchment configuration scenarios. The ESBC defines the base ecological condition for each water resource (and the EWRs required for maintaining that condition), and the resulting yield.

The establishment of the ESBC requires the running of a hydrological model using the base condition ecological water requirements (EWRs) to test whether these EWRs for all nodes can be met.

The following activities have been undertaken as part of Step 4 of the WRCS, the:

- Determination of an ESBC scenario that meets feasibility criteria for water quantity, water quality, and ecological needs;
- Consideration of the planning or reconciliation scenarios as detailed in the various reports available for the Crocodile (West), Marico, Upper Molopo, Ngotwane, Mokolo and Matlabas catchments; and

- Establishment of alternate catchment configuration starter scenarios.

The process followed is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, 2007a and 2007b).

6.2 Purpose of step 4

In terms of the WRCS 7 step process applied to the determination of a MC, the study process is now at step 4 (

Figure 2), 'the determination of the ecologically sustainable base configuration (ESBC) scenario'.

In respect of step 4 of the process, the purpose is:

- To describe the process undertaken to establish the ESBC scenario;
- To define the ESBC scenario for each IUA (and identified sub-nodes); and
- To describe the alternate catchment configuration scenarios that will be tested in step 5 of the WRCS process.

7 THE APPROACH FOLLOWED

The approach followed to determine the ESBC scenario for the Crocdile (West) Marico WMA and Matlabas and Mokolo catchments of the Limpopo WMA includes the following steps:

- Assessment of the present ecological state for the protection of the water resources within these WMAs at the identified nodes;
- Establishment of the ESBC per IUA, and at relevant sub-nodes;
- Consideration of planning/reconciliation options;
- Description of alternate catchment configuration starter scenarios to be assessed as part of Step 5 of the WRCS process.

The approach is discussed in more detail in sections 6.1 to 6.4to follow.

7.1 Base condition of water resources: Present Ecological Status (PES)

An ESBC scenario is established in order to understand what the result would be in terms of system yield of implementing the present level of ecological protection required to ensure sustainable use of the catchment water resources (consideration of ecological, water quality and quantity needs). This involves the linking of the flow and resource condition using the present ecological category as a starting point, ensuring that the river reaches are maintained in their sustainable condition.

In terms of the WRCS, the base condition for each water resource is set at a minimum which is either a D ecological category or as whichever higher category is required to maintain all downstream nodes in at least a D category. However where the ecological condition requires it, a higher ecological category needs to be set.

After consultation with the Client, in the Crocodile (West) Marico WMA and Mokolo and Matlabas catchments of the Limpopo WMA, the D ecological category (EC) was not selected as the default for the ESBC. Rather, the selected EC was based on the assessment of the present ecological state (PES) and ecological/conservation importance of water resources within the IUAs. The PES of the water resources is thus being used as the base ecological condition for the yield analysis.

The ecological condition of the water resources being used in the yield modelling include the PES at the various EWR sites from the intermediate and rapid Reserve determination studies that were undertaken for the WMAs. The PES per EWR site are summarised in Table 20 and further detail on the EWRs per EWR site is set out in Appendix A. In this respect the drought low flow EWR listed in Appendix A represents the groundwater contribution to base flow (surface groundwater interaction). The groundwater ecological water requirement expressed as % of MAR (Mean Annual Runoff) for the sub-catchments is then as follows:

- Crocodile Catchment: 3 to 16 %, excluding the 46 % for the EWR Site 9 -Maloney's Eye;
- Marico Catchment: 1 to 22 %, excluding the 50 % for the EWR Site 1 – Kaaloog se Loop;
- Mokolo Catchment: 1 to 5%

The PES per identified river node as determined during the rapid and intermediate Reserve studies and the desktop assessment is being used for the ESBC ecological category as listed in Table 20. Where the PES was lower than a D category, a D category was used to determine the EWRs and will be used during the yield modelling. Extrapolation/estimation techniques were used to determine the EWRs per node where no Reserve information was available.

Table 20: Summary of PES, EIS and REC for EWR sites per IUA

EWR site	River	Quaternary catchment	PES	EIS	REC	nMAR [1)] ($10^6 m^3$)	%EWR	Level
				CROCODILE WEST				
CROC_1	Crocodile	A21H	D	Moderate	D	87.8	24.07	Intermediate
CROC_2	Jukskei	A21C	E	Moderate	D	34.4	29.19	Intermediate
CROC_3	Crocodile	A21J	C/D	High	C/D	153.6	25.02	Intermediate
CROC_4	Pienaars	A23B	C	High	C	28.2	20.98	Intermediate
CROC_5	Pienaars/ Moretele	A23J	D	High	C	113.0	11.82	Intermediate
CROC_6	Hex	A22J	D	Moderate	D	26.9	14.96	Intermediate
CROC_7	Crocodile	A24C	D	Moderate	D	463.4	9.14	Intermediate
CROC_8	Crocodile	A24H	C	Moderate	C	559.9	14.22	Intermediate
CROC_9	Magalies	A21F	B	Very high	B	14.7	45.58	Rapid 3

EWR site	River	Quaternary catchment	PES	EIS	REC	nMAR [1)] (10^6m^3)	%EWR	Level
CROC_10	Elands	A22A	C	High	B/C	10.1	30.48	Rapid 3
CROC_11	Sterkstroom	A21K	C	High	C	14.0	28.41	Rapid 3
CROC_12	Buffelspruit	A23G	B/C	Mode rate	B/C	3.144	35.85	Rapid 3
CROC_13	Elands	A22E	C	Low	C	18.77	21.90	Rapid 3
CROC_14	Waterkloofspruit	A22H	B/C	Low	B/C	5.469	28.27	Rapid 3
CROC_15	Magalies	A21H	C/D	Low	C/D	21.89	21.18	Rapid 3
CROC_16	Rietvlei	A21A	C	Low	C	4.788	27.83	Rapid 3
MARICO								
MAR_1	Kaaloog-se-Loop	A31A	B	Very high	B	10.539	76.32	Intermediate
MAR_2	Groot Marico	A31B	B	Very high	B	42.08	50.26	Intermediate
MAR_3	Groot Marico	A31F	C/D	High	C/D	65.083	23.62	Intermediate
MAR_4	Groot Marico	A32D	C	High	C	153.251	7.96	Intermediate
MAR_5	Klein Marico	A31E	C	Mode rate	C	29.42	4.67	Rapid 3
MAR_6	Polkadraaispruit	A31B	B/C	Mode rate	B	9.89	31.87	Rapid 3
MOLOPO								
EFR M8	Molopo: Wetland	D41A	C	High	B	-	-	-
MOKOLO								
MOK_1a	Mokolo	A42C	C/D	High	B/C	84.84	22.6	Intermediate
MOK_1b	Mokolo	A42E	B/C	High	B	135.03	17.6	Intermediate
MOK_2	Mokolo	A42F	B/C	Very high	B	196.2	19.8	Intermediate
MOK_3	Mokolo	A42G	B/C	Very high	B	214.5	12.5	Intermediate
MOK_4	Mokolo	A42G	C	Very high	B	253.3	16.5	Intermediate
MATLABAS								
MAT_1	Matlabas Zyn Kloof	A41A	A	Very High	A	5.23	57.07	Rapid 3
MAT_2	Matlabas	A41B	C	High	B/C	32.80	33.23	Rapid 3

EWR site	River	Quaternary catchment	PES	EIS	REC	nMAR [1)] (10^6m^3)	%EWR	Level
	Haarlem Oos							
MAT_3	Mamba	A41B	B/C	Mode rate	B/C	9.54	35.49	Rapid 3
MAT_4	Matlabas Phofu	A41C	B	Mode rate	B	35.58	33.42	Rapid 1

7.2 The ESBC per IUA

All EWR sites per IUA will be used during the yield modelling to evaluate the implementation of the Reserve and the resulting water balance for the Crocodile (West), Marico, Matlabas and Mokolo catchments. Where the PES is currently in a D/E or lower category, a D category will be used for modelling purposes. The EWR PES to be used for modelling purposes per IUA is provided in Table 21.

Table 21: PES per EWR site (per IUA)

IUA	IUA name	EWR site	River	EWR (PES EC) used in WRYM
1	Upper Crocodile/ Hennops/Hartebeespoort	CROC_1	Crocodile	D
		CROC_2	Jukskei	D (E)
		CROC_4	Pienaars	C/D
		CROC_16	Rietvlei	C
2	Magalies	CROC_9	Magalies	B
		CROC_15	Magalies	C/D
3	Crocodile/Roodekopjes	CROC_3	Crocodile	C/D
4	Hex/Waterkloofspruit/Vaalkop	CROC_6	Hex	D
		CROC_11	Sterkstroom	C
		CROC_14	Waterkloofspruit	B/C
5	Elands/Vaalkop	CROC_10	Elands	C
		CROC_13	Elands	C
6a	Klein Marico/Kromellemboog	MAR_5	Klein Marico	C
6b	Groot Marico	MAR_2	Groot Marico	B
		MAR_6	Polkadraaispruit	B/C
7	Kaaloog-se-Loop	MAR_1	Kaaloog-se-Loop	B
8	Malmaniesloop	Groundwater	Malmaniesloop	-
9	Molopo	Wetland/ groundwater, EFR M8	Molopo	C
10	Dinokeng Eye/Ngotwane Dam	Groundwater	Ngotwane	-

11a	Groot Marico/Molatedi Dam	MAR_3	Groot Marico	C/D
11b	Groot Marico/seasonal tributaries	MAR_4	Groot Marico	C
12	Bierspruit	-	Bierspruit	D*
13	Lower Crocodile	CROC_7	Crocodile	D
		CROC_8	Crocodile	C
14	Tolwane/Kulwane/Moretele/Klipvoor	CROC_5	Moretele	D
		CROC_12	Buffels	B/C
15	Upper Mokolo	MOK_1a	Mokolo	C/D
		MOK_1b	Mokolo	B/C
		MOK_2	Mokolo	B/C
16	Lower Mokolo	MOK_3	Mokolo	B/C
		MOK_4	Mokolo	C
		Floodplain, MOK_5	Mokolo	D
17a	Mothlabatsi/Mamba	MAT_1	Matlabas Zyn Kloof	B
		MAT_3	Mamba	B/C
17b	Matlabas	MAT_2	Matlabas	C
		MAT_4	Matlabas	B

* No EWR site, information from desktop PES/EIS study, 2012

Based on the present ecological condition of water resources within the WMAs, the IUA scale ESBC at the outlets of the IUAs are listed in Table 22 below and indicated in

Figure 44.The proposed management classes (MCs) associated with this ESBC (EC) scenario are also reflected.

Table 22: ECs tested for the ecological sustainable base configuration (per IUA)

IUA	Catchment area	Ecological Category (ESBC)	IUA Management Class associated with scenario
1	Upper Crocodile/Hennops/Hartebeespoort	D	III
2	Magalies	C	II
3	Crocodile/Roodekopjes	C/D	III
4	Hex/Waterkloofspruit/Vaalkop	C	II
5	Elands/Vaalkop	C	II
6a	Klein Marico/Kromellemboog	B/C	II
6b	Groot Marico, Polkadraaispruit upstream Maroicopoort Dam	B	II
7	Kaaloog-se-Loop	B	I
8	Malmaniesloop	-	II*
9	Molopo	C	III*
10	Dinokeng Eye/Ngotwane Dam	-	II*
11a	Groot Marico/Molatedi Dam	C/D	III
11b	Groot Marico/seasonal tributaries	C	II
12	Bierspruit	D	III
13	Lower Crocodile	C/D	III
14	Tolwane/Kulwane/Moretele/Klipvoor	D	III
15	Upper Mokolo	B/C	II
16	Lower Mokolo	B/C	II
17a	Mothlabatsi/Mamba	B	I
17b	Matlabas	B/C	II

*groundwater classes

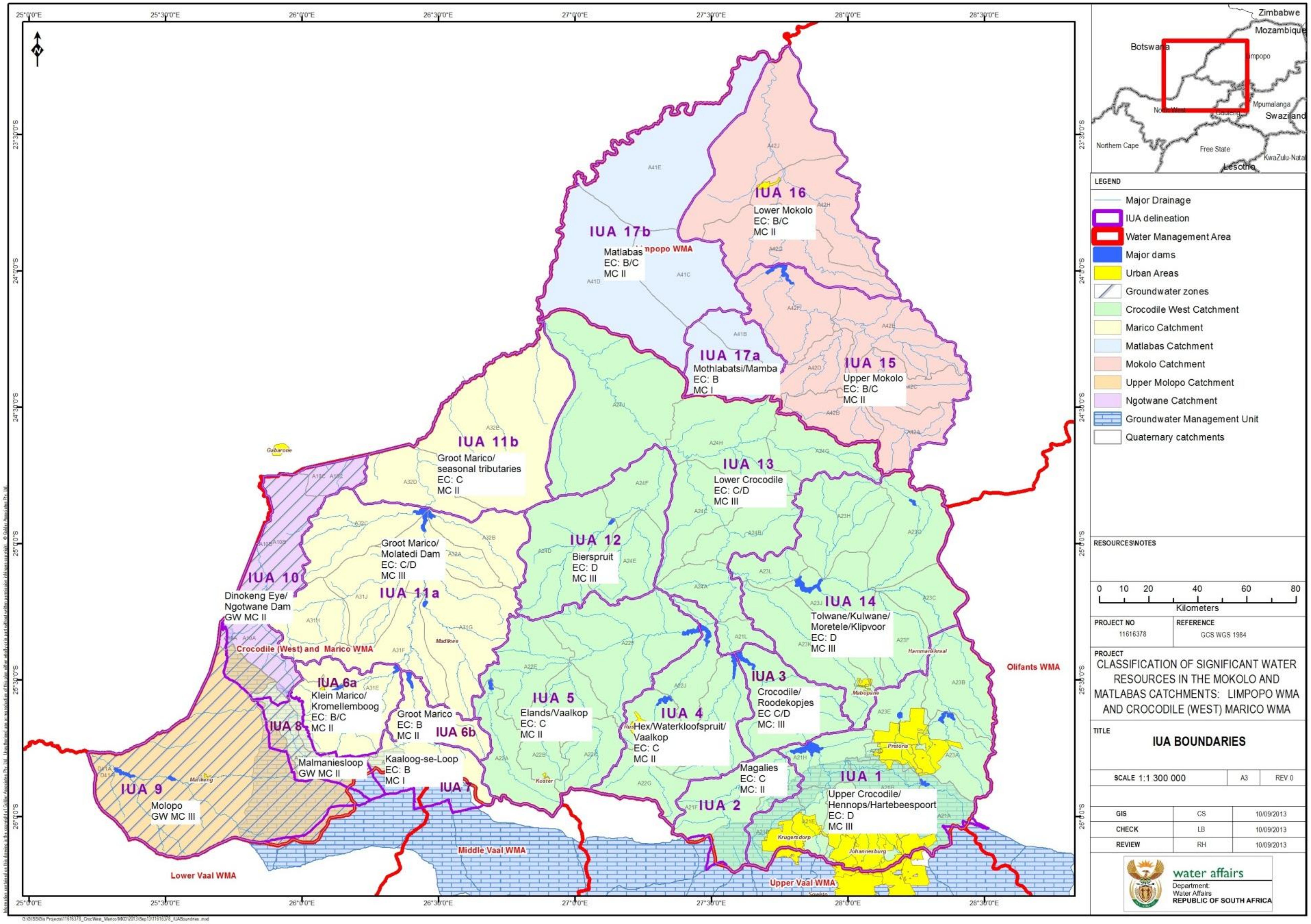


Figure 44: ESBC per IUA for the ESBC scenario

This configuration of ecological categories ensures that a sustainable level of ecosystem functioning is maintained in the water resources of the WMAs. The water resource system will have to provide for the required volume of EWRs needed to maintain this configuration (**Table 23**).

Table 23: EWRs needed at EWR sites to maintain the ESBC

IUA	IUA name	IUA Ecological Category (ESBC)	EWR site	EWR needed to maintain ESBC (10^6m^3)
1	Upper Crocodile/ Hennops/ Hartebeespoort	D	CROC_1 CROC_2 CROC_4 CROC_16	55.60 40.83 8.69 1.33
2	Magalies	C	CROC_9 CROC_15	6.71 4.64
3	Crocodile/Roodekopjes	C/D	CROC_3	35.86
4	Hex/Waterkloofspruit/Vaalkop	C	CROC_6 CROC_11 CROC_14	4.03 3.97 1.55
5	Elands/Vaalkop	C	CROC_10 CROC_13	3.08 4.11
6a	Klein Marico/ Kromellemboog	B/C	MAR_5	1.84
6b	Groot Marico/Polkadraaispruit/upstream Maricopoort Dam	B/C	MAR_2 MAR_6	21.15 2.64
7	Kaaloog-se-Loop	B	MAR_1	8.04
8	Malmaniesloop	-	Groundwater	-
9	Molopo	C	Wetland	-
10	Dinokeng Eye/Ngotwane Dam	-	Groundwater	-
11a	Groot Marico/Marico Bosveld Dam	C/D	MAR_3	15.37
11b	Groot Marico/Molatedi Dam	C	MAR_4	12.20
12	Bierspruit	D	-	-
13	Lower Crocodile	C/D	CROC_7 CROC_8	42.35 79.62
14	Tolwane/Kulwane/Moretele/ Klipvoor	D	CROC_5 CROC_12	13.36 1.13
15	Upper Mokolo	B/C	MOK_1a MOK_1b MOK_2	14.17 18.36 22.96
16	Lower Mokolo	B/C	MOK_3 MOK_4	19.09 31.16
17a	Mothlabatsi/Mamba	B	MAT_1 MAT_3	2.98 3.39
17b	Matlabas	B/C	MAT_2 MAT_4	10.89 11.89

6.2.1 Extrapolation and EWRs for river nodes

The information available from the intermediate and rapid Reserve determinations has been used for extrapolation to all the identified river nodes. Table 24 lists all the river nodes with the EWR sites that were used for extrapolation. The eco-region level 2 information as well as discussions with specialists were used as a guide during this process.

The rule and summary tables and the long term EWR time series as generated with the Desktop Reserve Model in SPATSIM were used during the ESBC scenario establishment and will also be used in Step 5 of the WRCS process.

The PES and REC information from the desktop study (2012), existing EWR sites and the additional rapid studies were used as the basis for extrapolation as indicated.

Table 24: River nodes and associated EWR sites used for extrapolation

IUA	No	Quaternary catchment	Hydro node	EWR sites used for extrapolation
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	CROC_EWR 16
	HN2	A21B	Sesmylspruit with its' tributaries to confluence with Hennops	CROC_EWR 16
	HN3	A21C	Modderfonteinspruit to confluence with Jukskei	CROC_EWR 2
	HN4	A21C	Klein Jukskei at confluence with Jukske	CROC_EWR 2
	HN5	A21C	Jukskei River at CROC_ EWR2	CROC_EWR 2
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Use updated PES with DRM
	HN7	A21A, B, H	Hennops (source) to confluence with Crocodile	CROC_EWR 2
	HN8	A21H	Swartspruit to Hartbeespoort Dam	Use DRM
	HN9	A21E, H	Crocodile (source) to CROC_EWR1	CROC_EWR 1
	HN10	A21H, J	Crocodile at Hartbeespoort Dam, outlet of IUA1	CROC_EWR 3
	HN11	A23A	Pienaars(source) and including Moreletaspruit and Edendalespruit to outlet of Roodeplaat Dam	Use updated PES with DRM
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	CROC_EWR 4
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	Use updated PES with DRM
	HN14	A23D	Skinnerspruit (source) to confluence with Apies	Use updated PES with DRM
	HN15	A23D, E	Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Use updated PES with DRM
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	CROC_EWR 9
	HN17	A21G, F	Magalies (CROC_EWR15)	CROC_EWR 15
	HN18	A21G, F	Skeerpoort at outlet of IUA2	Use updated PES with DRM
3	HN19	A21J	Rosespruit at confluence with Crocodile	Use updated PES with DRM
	HN20	A21J	Crocodile from Hartbeespoort Dam to	CROC_EWR 3

IUA	No	Quaternary catchment	Hydro node	EWR sites used for extrapolation
			upstream Roodekopjes Dam, outlet of IUA3	
4	HN21	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11)	CROC_EWR 11
	HN22	A21K	Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	Use updated PES with DRM
	HN23	A22G	Hex (source) to Olifantsnek Dam	CROC_EWR 11
	HN24	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex	CROC_EWR 14
	HN25	A22H	Hex from Olifantsnek Dam to Bospoort Dam	Use updated PES with DRM
	HN26	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6)	CROC_EWR 6
	HN27	A22J	Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	Use updated PES with DRM
5	HN28	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10)	CROC_EWR 10
	HN29	A22A	Elands from Swartruggens Dam to Lindleypoort Dam	CROC_EWR 10
	HN30	A22B	Koster (source) to Koster Dam	CROC_EWR 10
	HN31	A22C, A22D	Selons to confluence with Elands	CROC_EWR 13
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	CROC_EWR 13
6b	HN33	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6)	MAR_EWR 6
	HN34	A31B	Marico from MAR_EWR2 to N4 road at town	MAR_EWR 2
	HN63	A31B	Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	MAR_EWR 6
6a	HN64	A31D	Malmaniesloop to confluence with Klein Marico	MAR_EWR 5
	HN35	A31D	Klein Marico from Zeerust to Klein Maricopoort Dam	MAR_EWR 5
	HN65	A31E	Klein Mario from Klein Maricopoort Dam to Kromellemboog Dam	MAR_EWR 5
	HN36	A31E	Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	MAR_EWR 5
7	HN37	A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico	MAR_EWR 1
	HN38	A31A	Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	MAR_EWR 1
8	-	A31C	Groundwater	-
9	HN66	D41A	Molopo at outlet of wetland	MAR_EFR M8, Use updated PES with DRM
	HN67	D41A	Molopo at Modimolla	MAR_EFR M8, Use updated PES with DRM
	HN39	D41A	Molopo at outlet of IUA9	MAR_EFR M8, Use updated PES with DRM

IUA	No	Quaternary catchment	Hydro node	EWR sites used for extrapolation
10	HN68	A10A	Ngotwane from Dinokana to Ngotwane Dam	-
	-	A10A, B, C	Ngotwane from Dinokana to outlet of IUA10	-
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	MAR_EWR 3
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	MAR_EWR 3
12	HN42	A24D, E, F	Bierspruit to confluence with Crocodile River, outlet of IUA12	Use updated PES with DRM
13	HN43	A24G, A24H	Sand to confluence with Crocodile	CROC_EWR 7
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	CROC_EWR 8
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	CROC_EWR 8
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	CROC_EWR 12
	-	A23C, A23F	Wetland at Pienaars & Apies confluence and inflow to Klipvoor Dam	-
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	CROC_EWR 12
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	CROC_EWR 5
	HN49	A23K	Tolwane to confluence with Moretele	Use updated PES with DRM
15	HN50	A42A	Sand (source) to confluence with Grootspruit	MOK_EWR 1a
	HN51	A42B	Grootspruit (source) to confluence with Sand	MOK_EWR 1a
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	MOK_EWR 1a
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	MOK_EWR 1b
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	MOK_EWR 1b
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	MOK_EWR 2
16	HN56	A42G	Rietspruit (source) to Mokolo confluence	Use updated PES with DRM
	HN57	A42G	Mokolo below dam (MOK_EWR3) to Rietspruit confluence (MOK_EWR4)	MOK_EWR 3, MOK_EWR 4
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	MOK_EWR 4 and wetland requirements
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	MAT_EWR 1, MAT_EWR 2
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	MAT_EWR 3
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	MAT_EWR 4
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of	MAT_EWR 2

IUA	No	Quaternary catchment	Hydro node	EWR sites used for extrapolation
			IUA17b	

7.3 The Hydrological Modelling – The Water Resources Yield Model (WRYM)

7.3.1 Background and setup

The Water Resources Yield Model (WRYM) that was used during the latest reconciliation strategy and updating of the water resources hydrology studies was obtained and used as the base from which the ESBC was constructed.

Detailed schematic diagrams were obtained from the study teams responsible for the development of the WRYM setups for the various systems. These were used as the basis for changing, checking and evaluation of the ESBC. The following major nodes were included as part of the setup per IUA:

- All major dams as well as combined farm dams and irrigation areas;
- Ecological requirements for all the EWR sites as listed in Table 23; and
- Specific sub-nodes that were identified from a protection/conservation perspective have also been included in the model setup (for example, Waterkloofspruit and Magalies just downstream of Maloney's Eye).

Where no WRYM model setup is available, the information from the 2004 ISP process and the WR2005 study will be used and adapted for the current state. This information was sourced from the Planning directorate in DWA and the WRC.

7.3.2 System schematic – Major nodes/points

Detailed schematic diagrams were obtained from the study teams responsible for the development of the Crocodile West/Marico and Mokolo Water Supply System Reconciliation Strategy and this was used as the basis for changing, checking and evaluation of the ESBC. The following major nodes were included as part of the setup per IUA:

- All major dams as well as combined farm dams and irrigation areas; and
- Ecological requirements for all the EWR sites as listed in Table 23.

In the case of the Matlabas catchment where no schematic was available, the WR2005 model setup was used as the base for configuring the WRYM.

7.3.3 Model Runs

The WRYM will be run with present day water requirements as defined in the various studies and the EWR requirements as determined using the approach described in section 7.2.

This will provide the basis for the evaluation of the impact of the implementation of the ESBC on the resulting water balance for the WMAs and to determine the economic consequences of these.

7.4 The ESBC Scenario – Scenario 1

The ESBC defines this lowest theoretical level of protection required for the sustainable use of the water resources of a catchment. It is not the target scenario but informs the minimal protection level required constructed as a starting point for the hydrological analysis of the water resource system.

A scenario is used to understand different ways that future events might unfold. Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition. Analysis thereof gives the ability to compare the implications of one scenario against another, with the ultimate aim to make a selection of the preferred scenario.

This ESBC scenario (PES scenario) will be tested in the yield model for the various sub-catchments with the following parameters as listed in Table 25.

Table 25: Proposed ESBC for the catchments

Sub-catchment	Present day water requirements	EWR
Crocodile West	2008: Water Requirements as per Reconciliation Strategy (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Marico, Molopo & Ngotwane	2009: Water requirements for the Marico, Ngotwane and Molopo catchments (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Mokolo	2007: Water requirements of the Mokolo River catchment (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Matlabas	2004: ISP documents & WR2005 (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)

The results of the ESBC will be presented at the third PSC meeting in March 2013 and the alternate catchment configuration scenarios will be discussed for consideration. Proposed scenarios are listed in Section 8 of this report. However it should be noted that these are currently just proposals and other alternative scenarios may be considered. For completeness, the ESBC scenario is included.

8 RESULTS OF THE YIELD ANALYSIS

The yield model for the Crocodile West, Marico, Mokolo and Matlabas catchments were setup and run with the ESBC scenarios described in Section 6. The assessment allowed for evaluation of the yield that would result in the catchment with the EWRs required for maintaining the PES ecological category. The output of the yield analysis provided the impact of the EWR at the major dams in the various catchments.

The yield analysis results with the ESBC scenario indicate varying degrees of water surpluses and deficits. The results of the simulation for the ESBC are listed in Table 26.

Table 26: Impact of EWR (PES) at major dams

Major Dams	Catchment	Yield without EWR (million m^3/a)	Yield with EWR (million m^3/a)
Klein Maricopoort	A31D	5.38	3.98
Kromelmboog	A31E	2.61	2.44
Marico Bosveld	A31B	21.54	9.19
Molatedi	A32C	11.37	11.9
Mokolo	A42F	38.7	*3.48
Hartbeespoort	A21H	237.9	231.0
Roodekopjes	A21L	59.0	55.0
Lindleyspoort	A22E	3.4	2.7
Bospoort	A22H	1.3	0.9
Vaalkop	A22J	6.5	3.4
Roodeplaat	A23A	37.5	35.0
Klipvoor	A23J	24.5	28.0

*depending on operating rules;

All other water user requirements (irrigation, domestic, industrial, mining, power generation and forestry) within the catchments were included for both yield with and without EWR.

This configuration of ecological categories ensures that a sustainable level of ecosystem functioning is maintained in the Crocodile West/Marico WMA and the Mokolo and Matlabas catchment of the Limpopo WMA.

The modelling of the various catchments including the EWRs (Present State) resulted in most of the cases a reduction of yield in the major dams. The following can be concluded:

Crocodile West catchment: The modelling of the EWRs in the Crocodile West catchment resulted in a slight decrease of yield with the largest decrease in the Elands River catchment at Vaalkop Dam with a reduction from 6.5 x $10^6 m^3$ to 3.4 x $10^6 m^3$. The yield from Klipvoor Dam increased mainly due to EWR releases.

Marico catchment: The most severe change in yield was in the Marico Bosveld Dam with a reduction in yield from 21.5 x $10^6 m^3$ to 9.2 x $10^6 m^3$. The slight increase in yield in Molatedi Dam is due to the releases for EWR from the upstream dams.

9 THE ALTERNATE CATCHMENT CONFIGURATION SCENARIOS

Having established the ESBC (detailed above), the classification process requires that additional catchment scenarios are configured for the IUAs within the WMAs to assess the resulting yields of alternate ecological protection categories; conservation targets and future use and development to determine what is most feasible and achievable in terms of a MC.

The following additional catchment scenarios are proposed to be evaluated for the WMAs part of the scenario analysis:

- **Scenario 2**: RDM Scenario (Recommended Ecological Categories) with present day water use requirements;
- **Scenario 3**: Maximum Use Scenario (Ecological category of D throughout the system- Class III) with present day water use requirements;
- **Scenario 4**: ESBC scenario (PES scenario) with future water requirements;
- **Scenarios 5**: Scenario 2 with future water requirements; and
- Any specific scenarios identified for parts of a catchment where the water resources are in an unacceptable state.

The catchment configuration scenarios proposed for assessment are listed in Table 27. These may change after stakeholder input and will be further discussed in the Scenarios Report to follow.

Table 27: Alternative catchment configuration scenarios

Scenario	Water Requirements	EWR
2	Present day water requirements	Recommended Ecological Category (REC) Include all flow components (maintenance low and floods/freshets)
3	Present day water requirements	Class III throughout the system (EWR D Category, include all flow components - maintenance low and floods/freshets)
4	Future Water Requirements	PES EC Include all flow components (maintenance low and floods/freshets)

Scenario	Water Requirements	EWR
5	Future Water Requirements	Recommended Ecological Category (REC) Include all flow components (maintenance low and floods/freshets)

The catchment configuration scenarios listed above will be assessed as part the evaluation step (Step 5) of the WRCS process to determine the social, economic and ecological implications of the Crocodile (West) – Marico and Limpopo (Matlabas and Mokolo) WMAs. The results of these scenarios and the consequences will be communicated to stakeholders to facilitate the decision making process on the recommended scenario.

10 CONCLUSIONS

The ESBC scenario (Scenario 1) has been established using the PES of the water resources as the base ecological category. This configuration of ecological categories (PES) ensures that a sustainable level of ecosystem functioning is maintained in the catchments of the Crocodile (West) – Marico and Limpopo (Matlabas and Mokolo) WMAs (current water use scenario). The ESBC does provide a sustainable level of protection, and is adequate to form the basis for the assessment of other scenarios.

Consideration of any lower ecological categories (all D categories) will result in deterioration in the PES of the water resources. The impact of consideration of higher ecological categories (REC) catchment configurations scenarios need to be investigated. It is possible that it will result in increased water deficits in the WMAs. The water resource system would have to provide for the required volume of water needed to maintain the various scenario configurations. The evaluation going forward will therefore require a decision on the interventions required to achieve this reconciliation. The costs of the options will be included in the socio-economic assessment.

Step 5 of the WRCS process will interrogate these aspects as part of the evaluation of the scenarios. The consultation process that follows with stakeholders will then provide direction on the recommended scenario and proposed classes that this configuration will translate into.

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APPENDIX A

DETAILS OF ECOLOGICAL REQUIREMENTS PER EWR SITE IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS

Ecological Water Requirements per EWR Sites in the Study Area

EWR Site	EWR site name	River	Coordinates	Quaternary catchment	Reference MAR Mm^3/a	REC	Units	Total EWR	Maintenance Low flow	Maintenance High flow	Drought Low flow
Crocodile Catchment											
1	Upstream of the Hartbeespoort Dam	Crocodile	E 27.896	A21H	231.047	D	Mm^3/a	55.607	41.687	13.921	41.689
			S 25.8004				%	24.07	18.04	6.02	18.04
2	Heron Bridge School	Jukskei	E 27.9621	A21C	139.9	D	Mm^3/a	40.832	25.288	15.544	25.288
			S 25.9539				%	29.19	18.08	11.11	18.08
3	Downstream of Hartbeespoort Dam in Mount Amanzi	Crocodile	E 27.8431	A21J	143.3	D	Mm^3/a	35.855	21.607	14.248	21.708
			S 25.7168				%	25.02	15.08	9.94	15.15
4	Downstream of Roodeplaat Dam	Pienaars	E 28.312	A23B	28.2	D	Mm^3/a	8.693	4.797	3.869	2.828
			S 25.4155				%	30.81	17	13.81	10.03
5	Downstream of the Klipvoor Dam in Borakalalo National Park	Pienaars	E 27.80457	A23J	113	D	Mm^3/a	13.36	7.28	6.08	7.16
			S 25.12657				%	11.82	6.44	5.38	6.34
6	Upstream of Vaalkop Dam	Hex	E 27.3749	A22J	26.9	D	Mm^3/a	4.029	1.373	2.657	1.117
			S 25.5214				%	14.96	5.1	9.86	4.15
7	Upstream of the confluence with the Bierspruit	Crocodile	E 27.51743	A24C	463.4	D	Mm^3/a	42.351	31.35	11	31.356
			S 24.88661				%	9.14	6.77	2.37	6.77
8	Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	Crocodile	E 27.32569	A24H	559.9	C	Mm^3/a	79.62	67.03	12.58	50.93
			S 24.64476				%	14.22	11.97	2.25	9.09
9 Rapid 3	Upstream of Malony's Eye	Magalies	E 27.56581	A21F	14.7	B	Mm^3/a	6.711	6.703	0.008	6.703
			S 26.01689				%	45.58	45.53	0.06	45.53
10 Rapid 3	Highveld	Upper Elands	E 26.72044	A22A	9.09	B/C	Mm^3/a	3.084	1.819	1.264	0.552
			S 25.72655				%	30.48	17.98	12.5	5.45
11 Rapid 3	Upstream Buffelspoort Dam	Sterkstroom	E 27.47848	A21K	12.87	C	Mm^3/a	3.965	2.825	1.14	1.197
			S 25.80739				%	28.41	20.24	8.17	8.58
12 Rapid 3	Buffels River	Buffels	E 28.2224	A23G	3.14	B/C	Mm^3/a	1.126	0.863	0.263	0.272
			S 24.8304				%	35.85	27.48	8.37	8.67
13 Rapid 3	Elands River	Elands	E 26.6904		18.77	C	Mm^3/a	4.11	1.984	2.126	0.521
			S 25.4811				%	21.9	10.57	11.33	2.78
14 Rapid	Waterkloofspruit	Waterkloof spruit	E 27.2568		5.469	B/C	Mm^3/a	1.546	1.013	0.533	0.373
			S 25.7414				%	28.27	18.53	9.74	6.81
15 Rapid 3	Magalies River	Magalies	E 27.5982		21.899	C/D	Mm^3/a	4.639	2.516	2.123	0.802
			S 25.8969				%	21.18	11.49	9.69	3.66
16 Rapid 3	Rietvlei River	Rietvlei	E 28.3044		4.788	C	Mm^3/a	1.331	0.835	0.496	0.166
			S 26.0189				%	27.83	17.45	10.38	3.47
Marico Catchment											
1	Site below the gorge area (before confluence with Marico)	Kaaloog se loop	S25.777	A31A	10.54	B	Mm^3/a	8.043	8.037	0.006	5.227
			E26.433				%	76.32	76.26	0.06	49.6
2	Upstream confluence of the Sterkstroom	Groot Marico	S25.659	A31B	42.08	B	Mm^3/a	21.152	18.438	2.713	9.56
			E26.435				%	50.26	43.82	6.45	22.72

EWR Site	EWR site name	River	Coordinates	Quaternary catchment	Reference MAR Mm^3/a	REC	Units	Total EWR	Maintenance Low flow	Maintenance High flow	Drought Low flow
3	Downstream of Marico Bosveld dam	Groot Marico	S25.461	A31F	65.08	C/D	Mm^3/a	15.371	8.506	6.865	6.698
			E26.392				%	23.62	13.07	10.55	10.29
4	Downstream of the Tswasa Weir, in the Madikwe Game Res.	Groot Marico	S24.706	A32D	153.25	C	Mm^3/a	12.198	7.673	4.525	6.131
			E26.424				%	7.96	5.01	2.95	4
5 Rapid 3	Downstream Klein Maricopoort Dam	Klein Marico	S25.516	A31E	29.8	C	Mm^3/a	1.839	0.633	1.206	0.554
			E26.159				%	4.67	1.61	3.06	1.41
6 Rapid 3	Polkadraaispruit	Polkadraaispruit	S25.6469	A31B	9.866	B/C	Mm^3/a	2.64	1.57	1.07	0.14
			E26.4893				%	26.76	15.89	10.87	1.45
Mokolo Catchment											
EWR 1a	Vaalwater	Mokolo	S24 17.362	A42C	84.84	B/C	Mm^3/a	14.17	20.87	3.39	0.76
			E28 05.544				%	16.70	24.60	4.00	0.90
EWR 1b	Tobacco	Mokolo	S24 10.697	A42E	135.03	B	Mm^3/a	23.77	24.58	6.08	0.95
			E27 58.661				%	17.60	18.20	4.50	0.70
EWR 2	Ka'ingo	Mokolo	S24 03.897	A42F	196.2	B	Mm^3/a	38.85	34.53	9.22	5.89
			E27 47.230				%	19.80	17.60	4.70	3.00
EWR 3	Gorge	Mokolo	S23 58.080	A42G	214.5	B	Mm^3/a	26.81	19.95	7.08	5.15
			E27 43.614				%	12.50	9.30	3.30	2.40
EWR 4	Malalatau	Mokolo	S23 46.272	A42G	253.3	B	Mm^3/a	41.79	34.20	11.91	11.40
			E27 45.315				%	16.50	13.50	4.70	4.50
Matlabas Catchment											
EWR 1	Matlabas Zyn Kloof	Tributary to Matlabas	S 24.4120;	A41A	5.23	A	Mm^3/a	2.98	2.13	0.86	1,00
			E 27.6034				%	57.07	40.67	16.40	16.40
EWR 2	Matlabas Haarlem East (A4H004)	Matlabas	S 24.1601;	A41B	32.80	B/C	Mm^3/a	10.89	1.01	3.83	5.89
			E 27.4797				%	33.23	21.56	11.67	5.89
EWR 3	Mamba River Bridge	Mamba	S 24.2127;	A41B	9.54	B/C	Mm^3/a	3.39	2.18	1.21	0.34
			E 27.5072				%	35.49	22.79	12.70	3.52
EWR 4	Matlabas Phofu	Matlabas	S 24.0515;	A41C	35.58	B	Mm^3/a	11.89	7.16	4.73	1.83
			E 27.3592				%	33.42	20.13	13.29	5.14

APPENDIX B

DETAILS OF THE GROUNDWATER RECHARGE, USE AND QUALITY

1 REGISTERED GROUNDWATER USE

The main water user sectors of groundwater in the catchments are:

- Mokolo: Mining (dewatering), municipal water supply (Vaalwater), rural domestic, livestock farming/nature reserves and commercial irrigation farming;
- Matlabas: Local, village water supply (Steenbokpan), rural domestic, small scale irrigation and livestock farming;
- Crocodile West: Urban domestic (Pretoria/Centurion: extensive groundwater abstractions, part of Sw-Gw conjunctive use), non-urban/rural domestic (conjunctive supplies: Thabazimbi, Bela Bela and Rustenburg rural sectors, most other rural villages and communities supply augmented from piped surface water supplies), mining related (limited mine dewatering on platinum mines), irrigation (significant uses along the lower stem of the WMA, viz. A24J QC, the Springbok Flats and the Maloney's Eye-Skeerpoort River), extensive irrigation from dolomite aquifer systems (Tarlton, Maloney's Eye catchment, Bapsfontein-upper Rietvlei system) livestock/dry land farming;
- Marico: non-urban/rural domestic (sole supplies: Dinokana and Zeerust, conjunctive supplies: Swartruggens, Groot Marico, Pella, Madikwe and Koster supported by piped surface water supplies), extensive groundwater irrigation schemes (Groot Pan area), recreational (Molopo Oog), mining related (local mine dewatering on alluvial diamond and limestone mines) and extensive livestock/dry land farming; and
- Upper Molopo: Urban domestic (Mafikeng and Itsoseng), extensive irrigation schemes from dolomite aquifer systems (Rooigrond-Grootfontein area) and extensive livestock/dry land farming.

WARMS

The NWA makes registration with the National Register of Water Users mandatory. All water users, who do not receive their water from a service provider, local authority, water board, irrigation board, government water scheme or other bulk supplier need to register. This is with the exception of Schedule 1 users. It is important to note that the lawfulness of the registered water use still needs to be determined by the Department of Water Affairs. The Water Use Authorisation & Registration Management System (WARMS) is one of the only sources of data available that is based on actual current reporting. There are issues with under and over registration, but when these have been corrected it will be a fundamental functional dataset for the DWAF with a potentially long lifetime.

The approach adopted for this study was to compare WARMS 2008 data generally used in existing/previous reports with WARMS 2013 (January) data. The 2013 is used to determine the stress index.

The WARMS 2013 water use distribution is indicated in Figure 1, and differentiates between water use from boreholes and springs. High density water use registration corresponds with higher aquifer yield prospects and also with presence of alluvium along river reaches. The utilization of spring water is prominent for dolomite areas as well as sedimentary formations within the Pretoria Group and Nylstroom sub-Group.

The registered coordinates of the WARMS 2013 data was used, after correcting for obvious coordinate errors, to determine the groundwater use per quaternary catchment as listed in relevant tables in following sections.

2 WATER RESOURCE CLASSIFICATION CRITERIA

Water resources must be classified into one of the following classes –

a) **Class I water resource**: This is one –
   (i) which is minimally utilised; and
   (ii) in which the configuration of the ecological categories of the water resources within a catchment results in an overall condition of that water resource that is minimally altered from its pre-development condition.

b) **Class II water resource**: This is one –
   (i) which is moderately utilised; and
   (ii) in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is moderately altered from its pre-development condition.

c) **Class III water resource**: This is one –
   (i) which is heavily utilised; and
   (ii) in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is significantly altered from its pre-development condition.

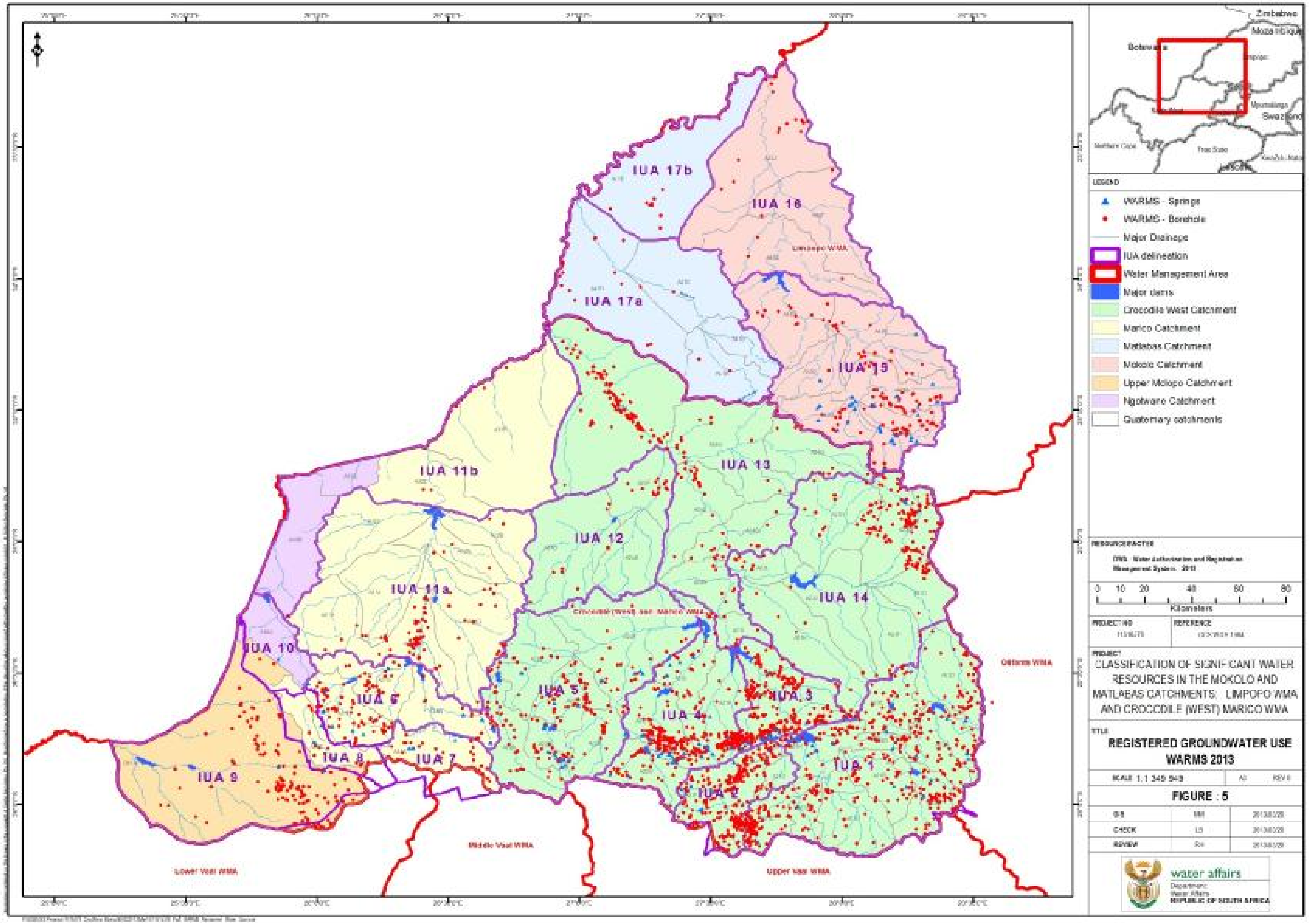


Figure 1: Registered groundwater use – WARMS 2013

The procedure to determine the different classes of water resources comprise of the following seven steps:

a) **Step 1**: Delineate the units of analysis and describe the *status quo* of the water resource or water resources.

Groundwater management units were established and incorporated into units of analysis. The initial boundary of the units of analysis for these cases was altered to fit the flow regime of a group of groundwater resource units (GRU's). A GRU is regarded as a groundwater body having unique hydrogeological characteristics such as a dolomitic compartment. A group of GRU's represents a groundwater management unit (GMU). The next category of grouping represents a groundwater management area (GMA) and generally coincides with surface catchments (e.g. quaternary catchments, QC) or dolomite compartment boundaries formed by impermeable dykes. A GMA generally includes more than one GMU. The dolomite aquifers (all grouped as groundwater management units) were treated as special cases due to their unique boundary conditions and flow patterns. A GMA based on dolomite compartment boundaries may therefore not coincides with the QC as is the case in Crocodile West – Marico WMA. This dolomite based GMA's were grouped with other significant non-dolomitic aquifer systems (demarcated by QC boundaries) and represents the integrated groundwater units in the IUA. For the non-dolomite aquifer systems, it was decided to group the aquifer systems into the surface water catchment (viz. quaternary catchments) as all the water resources needs to fit into an established geometrical context (viz. the IUA which has its own level of delineation).

b) **Step 2**: Link the socio-economic and ecological value and condition of the water resource or water resources.

This category refers to the spectrum of groundwater users and their dependence on the water resource. Several categories of significant water users exist (viz. in terms of volumes) have been noted of which: (i) bulk domestic water supplies to communities and villages, (ii) water supply to irrigation schemes, and (iii) mining/industrial applications (e.g. dewatering and use) represents the larger bulk water use components. Schedule 1 (S1) users represents the remaining component of the water use component of each IUA. Two aquifer systems in terms of the potential are present in the study area and provide substantial volumes of water to sustain the socio-economic values brought about due to their sustainable yields, i.e. the dolomite aquifer systems and alluvial aquifer systems along the major river systems (viz. the so-called intergranular alluvial aquifer systems; limited to the main river stems: the related the dolomite aquifer systems probably represent the most important component of the water resources classification requirement in this regard. The conditions of dolomite aquifer systems are naturally of a good quality and due to their high level of flushing during wet climate cycles (i.e. high recharge rates) they tend to remain in this state. Being the sole water source for many dolomite eyes in the Crocodile West and Marico WMA, the socio-economic and ecological value will be high compared to the non-dolomite resources in the region. The water supplies from these systems are high in demand and sustainable quality is a concern since they form part of many headwater reaches of the large surface watercourses such as the Marico and Crocodile West Rivers. In terms of Step 2, the dolomite aquifer systems have been categorised as significant aquifer systems and their importance have been incorporated into the management class classification by empirical interpretation.

In terms of the condition (water quality and quantity) of the remaining non-dolomite groundwater resources in the CWMMM, and especially the Crocodile West and Marico catchments, many local aquifers are supplying water for domestic requirements.

Special management protocols will have to be part of the proposed management classification scenarios.

c) **Step 3**: Quantify the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes.

The headwater regions of the dolomite aquifer systems are particularly important to drive the dolomitic eyes that support and maintain the ecological requirements of surface water systems further downstream. In several cases (e.g. Grootfontein Eyes at Rooigrond) abstraction from the eye via boreholes has dropped the eye's water table and stopped the decanting resulting in a total collapse of the ecology (running dry) further downstream. In the case of the Kaaloog se Loop, the ecological requirements for the drainage has been quantify (MC I). If water from the compartment feeding the eye will be required in future for domestic supplies for example, special arrangements to keep the eye's flow and ecological flow support intact will have to be exercised.

d) **Step 4**: Determine an ecologically sustainable base configuration scenario.

Areas/sections of surface water drainages where groundwater-surface water interaction occurs has been identified.

e) **Step 5**: Evaluate scenarios within the integrated water resource management process.

From a groundwater perspective, the most vulnerable aquifer systems in the CWMMM are the southern dolomitic aquifer systems in terms of annual recharge (sustainable yields during low-rainfall seasons) and long-term water quality (highly vulnerable to pollution). Water supplies to the Mahikeng area (Molopo River) are critical and water table depletion in the Grootfontein Eye region has been noted recently. This has a significant effect on the sustainable yield of the Grootfontein Water Scheme.

In terms of non-dolomitic aquifer systems, the development of coalmines in the lower reaches of the Mokolo and Matlabas Rivers has been addressed as a scenario with possible impacts on the local surface and groundwater resources. The impact(s) however will be localised, but management thereof will be required through dedicated monitoring and auditing.

f) **Step 6**: Evaluate the scenarios with stakeholders.

The groundwater aspects and possible scenarios (droughts and expansion of mining activities) have been addressed during stakeholder meetings. The expansion of the coal and possible iron ore mining in the lower Mokolo/Matlabas has been noted as a concern and pro-active groundwater management protocols need to be developed.

g) **Step 7**: Gazette and implement the class configuration.

Groundwater forms part of the total CWMMM water resource classification process. Certain IUA's are mainly groundwater driven systems and the groundwater classification contribution has been.

Defining stress

The concept of stressed water resources is addressed by the NWA, but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of 'water stress':

- Where demands for water are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist.
- Where water resource quality is under threat.

The groundwater stress index reflects water availability versus water used. Groundwater use should include water utilised by current water users, water required to sustain the Reserve as well as for BHN. The Stress Index for an assessment area is defined as follows:

$$SI(\%) = \frac{gwUse}{Recharge} \times 100$$

Where:

gwUse = Current groundwater use

Recharge = Recharge (as a volume)

In calculating the Stress Index, the variability of annual recharge is taken into account in the sense that not more than 65%[1] of average annual recharge can be allocated on a catchment scale).

PRESENT CATEGORY	DESCRIPTION	COMPLIANCE (SPATIAL/TEMPORAL)
I	Minimally used	≤20%
II	Moderately used	20% – 65%
III	Heavily used	> 65%

A guide for quantifying groundwater use is documented below.

ACTIVITY	PERCENTAGE OF RECHARGE
Small scale utilisation: Schedule 1 water uses, viz. stock watering, farm domestic water supply, rural water supply and irrigation for household food supplies;	Use ranges between 5% and 20% of recharge
Medium scale utilisation: Small-scale commercial irrigation, small scale industries, rural water supply, water supply to villages and small towns; and	Use ranges between 20% and 40% of recharge
Large-scale utilisation: Large scale mining/industries, water supply to cities, water supply for large rural communities, medium to large towns, large-scale commercial irrigation.	Use ranges between 40% and 65% of recharge

[1] 65% of the average annual recharge is available for full abstraction; based on values (66%) used for the Harvest Potential (Baron and Seward, 2000) initially as a norm to sustain base flow support, climate and recharge variability.

Baseline class

Defining the point at which a resource is no longer being used in a sustainable manner is generally very difficult. The level of sustainability probably fluctuates through time, and impacts from over-use could manifest themselves sometime after the impact was caused. The change from sustainable use to over-use is gradual, and not necessarily marked by some distinct change. Indicators of quantitative unsustainable groundwater use include:

- Land subsidence or sinkhole formation.
- Long-term declining water levels on a regional level.
- Long-term declining water quality levels.
- Periodic deterioration of water quality (salinity) and quantity (aquifer saturation levels) during periods of drought impacted by large-scale use on small scale users (viz. Schedule 1 and General Authorizations).

A guide for assessing the status of groundwater units based on **observed impacts** resulting from groundwater abstraction is presented below.

PRESENT CATEGORY	GENERIC DESCRIPTION	AFFECTED ENVIRONMENT
Minimally used (I)	The water resource is minimally altered from its pre-development condition	No sign of significant impacts observed
Moderately used (II)	Localised low level impacts, but no negative effects apparent	Temporal, but not long-term significant impact to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality
Heavily used (III)	The water resource is significantly altered from its pre-development condition	Moderate to significant impacts to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality

3 CLASSIFICATION DETERMINATION

3.1 Mokolo Catchment

a) Groundwater recharge

Groundwater recharge is defined as the addition of water to the zone of saturation. The primary recharge source for groundwater is rainfall that infiltrates into the ground and replenishes aquifer storage. Recharge is a critical and difficult parameter to quantify. The amount of rain water that recharges the aquifer is a function of several factors such as geological lithology, aquifer characteristics, rainfall intensity, water level depth, etc., and is generally expressed as a percentage of the mean annual precipitation (MAP). Recharge was assessed on a national scale during the Groundwater Resource Assessment Phase II project (GRA II, DWAF 2005) and is used in GRDM datasets at quaternary catchment scale.

Usually the method used to quantify recharge is dependent on the data available on which to base the assessment. For this classification existing datasets are used e.g. Vegter's (1995) recharge map and GRA II data (DWAF, 2005), as well as specialists reports.

The characteristics of the catchment indicate that there are three climatic zones. In the upper catchments the MAP varies between 600 and 700 mm per annum. In the middle portion of the catchment the MAP varies between 500 and 600 mm per annum, while in the lower catchment downstream of the Mokolo Dam, the MAP varies between 400 mm and 500 mm per annum. The low and variable rainfall together with evaporation rates considerably exceeding rainfall in the lower Mokolo catchment result in a low expectation of natural recharge to groundwater over most of the area. As a result the recharge vary spatially from as high as 22 mm/a in the higher lying areas to less than 2 mm/a in the lower parts of the catchment.

A review of previous work done on the GRA II project estimates (DWAF, 2005) and Vegter's (1995) recharge estimates based on specialist reports were made. These values are listed for each of the quaternary catchments constituting the IUA's and are summarised as Table 1.

Table 1: Recharge (Re) estimation (Mokolo Catchment)

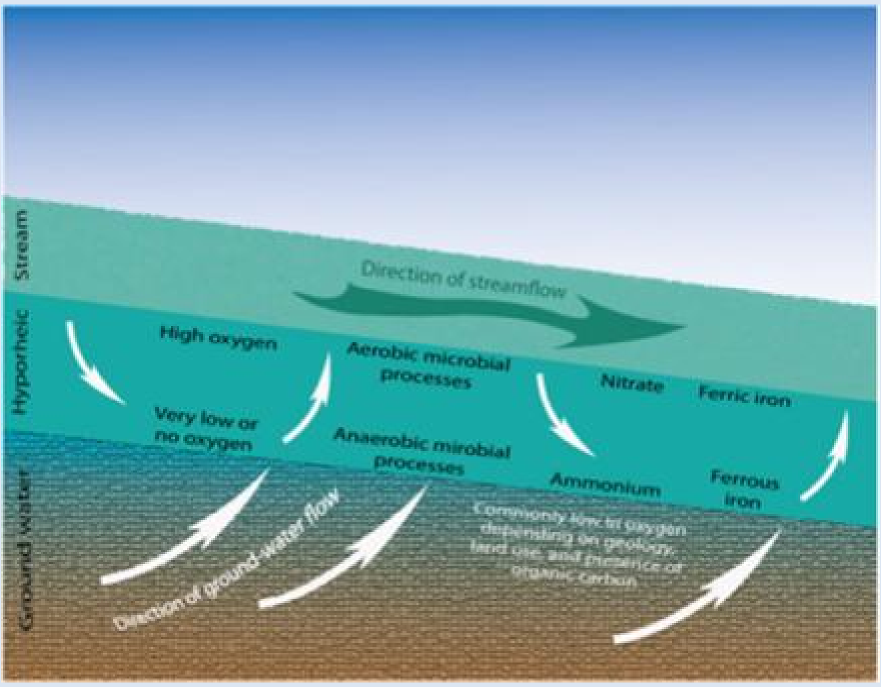
IUA Catchment	QC	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)	Re Specialist report Mm^3	Re value used Mm^3	Recharge %
				(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3			
IUA15 **Upper Mokolo**	A42A	639.9	573	15.96	11.60	27.00		18.19	**5.0**
	A42B	659.9	522	16.58	12.11	18.63		15.77	**4.6**
	A42C	655.5	698	21.91	15.99	43.18		27.02	**5.9**
	A42D	667.3	497	19.57	14.35	16.67		16.86	**5.1**
	A42E	604.7	1007	30.11	21.62	47.22		32.98	**5.4**
	A42F	577.0	1022	22.87	16.29	28.21		22.46	**3.8**
IUA16 **Lower**	A42G	550.8	1207	25.80	18.25	35.15		26.40	**4.0**
	A42H	517.6	1057	15.85	11.05	27.53		18.15	**3.3**

Mokolo	A42J	428.3	1812	13.53	9.18	16.18	12.34	12.81	**1.7**

b) Groundwater Quality.

Groundwater quality

Domestic use (human consumption) is considered by the authors as the highest beneficial use, with the supposedly most stringent quality requirements. It is assumed that any water resource, which is deemed fit for human consumption, also meets the requirements of aquatic ecosystems. While the water quality requirements of aquatic ecosystems might differ and are in fact for several elements even more stringent than for domestic use (e.g. Cd), the chosen approach avoids the pitfall of equating groundwater quality in the sub-surface to water quality discharging into a surface water body. In other words, the methodology recognizes the processes occurring in discharge areas in general (e.g. evapotranspiration) and the enhanced microbiological and chemical reactions (e.g. Redox or cation exchange reactions) in the hyporheic zone specifically (Figure below), without trying to quantify them by setting only domestic use requirements for the groundwater resource itself.



It is therefore recommended to use the South African Water Quality Guidelines Vol. 1 – Domestic use (DWAF, 1996), or the national drinking water standard (SANS 241, 2006) for the present status category assessment of a water resource.

PRESENT CATEGORY	DESCRIPTION	COMPLIANCE (SPATIAL/TEMPORAL)
I	DWA class 0 or 1 or natural background	95 %
II	DWA class 2 (95 % compliance) or natural background (75 % compliance)	75 %
III	DWA class 3 or 4 or natural background (<75 % compliance)	<75 %

Groundwater quality in the IUA 15 (Upper Mokolo A42A and A42B QC's) is considered to be marginal with more than 75 % of samples within the recommended drinking limit as specified by SANS (2006). However, in the remainder of the IUA 15 (A42C-F, Middle Mokolo) and IUA 16 (A42G-J, Lower Mokolo) less than 30 % comply with the specified drinking water quality standard. The most notable elements of concern include NO_3 as N and F with average concentrations above the recommended drinking limit (Table 2). In addition, several samples show major ion concentrations (e.g. Mg, and Cl) and subsequently electric conductivities (EC) beyond acceptable limits. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples. Elevated SO_4 concentrations may be attributed directly to the mining activities in the IUA 16.

The impact of certain geological formations on the groundwater quality may be responsible for certain elevated hydrochemical signatures.

Table 2: Groundwater quality for the Mokolo Catchment (All units in mg/l, EC in mS/m)

IUA (QC's)	Para-meter	pH	EC	Ca	Mg	Na	K	SO_4	Cl	NO_3as N	F	Compliance (% of samples within Class I)	Present Category
IUA 15 (A42A-B)	Nr	8	8	8	8	8	7	8	8	1	8	65 %	*II*
	Mean	7.6	16.9	14.0	3.3	18.3	1.7	6.5	10.4	1.0	0.8		
IUA 15 (A42C-F)	Nr	55	55	50	51	51	43	51	54	36	55	87 %	*II*
	Mean	7.5	39.1	25.7	16.5	35.4	1.9	14.3	29.4	3.4	0.4		
IUA 16 (A42G)	Nr	6	6	6	6	6	6	6	6	4	6	33 %	*III*
	Mean	7.8	121.7	52.0	32.0	159.0	3.6	126.4	195.9	1.6	1.0		
IUA 16 (A42G-J)	Nr	222	216	206	203	206	195	205	204	98	204	20 %	*III*
	Mean	7.4	266.2	134.5	78.2	190.7	10.2	411.8	301.9	15.6	1.8		

Class I

Class II

Exceed Class II

c) Groundwater use

Borehole yields generally range between 0.1 – 2 l/s. However, recent groundwater exploration investigations in the Lephalale area yielded boreholes of more than 20 l/s within the confined Waterberg Group (underlying the Karoo aquifer) and more than 10 l/s within the alluvium aquifer.

Groundwater use estimates vary significantly between the WARMS 2008 dataset and the recently updated WARMS 2013 dataset (see Table 9). Despite the extensive use of groundwater especially in the upper Mokolo it appears that groundwater is underutilised in the region. Significant increases in the stress index (SI), between 2008 and 2013, are probably due to the updating of water use registrations between these two periods.

Table 3: Groundwater availability and stress index (Mokolo Catchment)

IUA Catchment	QC	RE Mm^3	Groundwater Use Mm^3/a			Stress Index '08 (GW Use as % of Recharge)	Stress Index '13 (GW Use as % of Recharge)
			GRA II (2005)	[1]WARMS (2008)	WARMS (2013)		
IUA15 **Upper Mokolo**	A42A	18.19	0.03	1.33	**6.332**	7%	**35%**
	A42B	15.77	0.03	2.47	**7.577**	16%	**48%**
	A42C	27.02	0.07	3.27	**7.888**	12%	**29%**
	A42D	16.86	0.01	0.11	**0.605**	<1%	**4%**
	A42E	32.98	0.07	1.51	**2.555**	5%	**8%**
	A42F	22.46	0.03	0.86	**1.798**	4%	**8%**
		133	**0.234**	9.6	**26.76**		
IUA16 **Middle Mokolo**	A42G	26.40	0.07	0.13	**0.669**	<1%	**3%**
	A42H	18.15	0.06	0.09	**0.119**	< 1%	**1%**
	A42J	12.81	0.22	2.12	**5.172**	17%	**40%**
		57	**0.35**	2.3	**5.96**		

d) Proposed classification

A summary of the groundwater classification categorisation for the Mokolo Catchment is shown in Table 4.

Table 4: Final groundwater categorisation for each IUA (Mokolo Catchment)

IUA Catchment	QC	Area (Km^2)	Recharge Mm^3	Groundwater Use Mm^3/a	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)
IUA15 **Upper Mokolo**	A42A	1095	33.96	9.02	27%	**II**	**I**	**II**
	A42B-F	3224	99.33	19.20	19%	**I**	**I**	**II**
IUA16 **Lower Mokolo**	A42G	1207	26.40	0.13	1%	**I**	**I**	**III**
	A42H-J	2869	30.95	2.21	7%	**I**	**II**	**III**

3.2 Matlabas Catchment

a) Groundwater recharge

Mean annual precipitation is approximately 400 to 500 mm per annum over most of the Matlabas drainage region. The low and variable rainfall together with evaporation rates considerably exceeding rainfall result in a low expectation of natural recharge to groundwater over most of the area. Recharge vary spatially from as high as 18 mm/a in the higher lying areas to less than 2 mm/a in the lower parts of the catchment.

A review of previous work done on the GRA II project (DWA, 2005) estimates and Vegter's (1995) recharge estimates based on specialist reports were made. These values are listed for each of the quaternary catchments constituting the unit of analysis and are summarised in Table 5.

Table 5: Recharge estimation (Matlabas Catchment)

IUA Catchment	QC's	MAP (mm)	Area (km^2)	GRA II (Wet) Mm3	GRA II (Dry) Mm^3	Vegter (1995) Mean Mm^3	Specialist report Mm^3	Used Mm^3	Recharge %
IUA 17a **Upper Matlabas**	A41A	625.3	692	19.85	14.33	18.81	-	17.66	4.1
	A41B	586.6	358	8.60	6.14	8.85	-	7.86	3.7
		606	**1050**	**28.5**	**20.5**	**27.7**		**25.5**	**4.0**
IUA 17b **Lower Matlabas incl Steenbokpan**	A41C	511.7	1111	16.41	11.44	11.84	-	13.23	2.3
	A41D	491.6	1913	20.51	14.12	15.51	-	16.71	1.8
	A41E	438.2	1940	14.99	9.96	12.80	11.9	12.41	1.5
		481	**4964**	**51.9**	**35.5**	**40.2**		**42.35**	**1.8**

b) Groundwater Quality

Overall groundwater quality in the Matlabas region is considered to be marginal to poor with only a third of groundwater samples being within the recommended drinking limit as specified by SANS (2006). The most notable elements of concern include NO_3 as N and F with average concentrations above the recommended drinking limit (Table 6). In addition, several samples show major ion concentrations (e.g. Mg, Na, Cl) and subsequently electric conductivities (EC) beyond acceptable limits. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples (DWA, 2011).

Table 6: Groundwater quality for the Matlabas Catchment (All units in mg/l, EC in mS/m)

IUA	Para-meter	pH	EC	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F	Compliance (% of samples within Class I)	Present Category
IUA 17a	Nr	190	190	189	189	189	189	189	189	187	189	31 %	***III***
	Mean	7.5	214.5	125.9	79.5	202.7	7.4	126.7	439.4	10.5	1.6		
IUA 17b	Nr	81	82	78	78	78	69	78	78	54	78	32 %	***II****
	Mean	7.6	221.9	91.6	52.6	200.7	13.0	150.8	298.9	9.0	1.2		

Class I

Class II

Exceed Class II

* - Natural high sodium and chloride concentrations (reduced to Present Category II).

c) Groundwater use.

Groundwater use estimates vary between the WARMS 2008 dataset and the recently updated WARMS 2013 dataset (see Table 1), probably due to the update of water use registrations between these two periods. However, even with the utilisation of the upper limit for the assessment it appears that groundwater is underutilised in the Matlabas Catchment.

Table 7: Groundwater availability and stress index (Matlabas Catchment)

IUA (Catchment)	QC's	RE Mm^3	Groundwater Use Mm^3/a			Stress Index (GW Use as % of Recharge 2008)	Stress Index (GW Use as % of Recharge)
			GRA II	WARMS 2008	**WARMS 2013**		
IUA 17a **Upper Matlabas**	A41A	17.66	1.22	0.21	**0.32**	1%	**2%**
	A41B	7.86	0.01	0.15	**0.15**	2%	**2%**
IUA 17a	**A41A-B**	**25.5**	**1.2**	**0.36**	**0.47**	**1%**	**2%**
IUA 17b **Lower Matlabas (incl Steenbokpan)**	A41C	13.23	0.25	0.11	**0.11**	2%	**1%**
	A41D	16.71	2.76	0.89	**1.52**	16%	**9%**
	A41E	12.41	1.79	0.30	**2.92**	14%	**24%**
IUA 17b	**A41C-E**	**42.4**	**4.8**	**1.3**	**4.6**	**8%**	**4%**

d) Proposed classification

A summary of the groundwater classification for the Matlabas Catchment is shown in Table 8.

Table 8. Final groundwater categorisation for each IUA (Matlabas Catchment)

IUA (	QC's	Area (Km^2)	Recharge Mm^3	[1]Groundwater Use Mm^3/a	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)
IUA 17a **Upper Matlabas**	A41A	692	17.66	0.32	2%	**I**	**I**	_[2]
	A41B	358	7.86	0.15	2%	**I**	**I**	_[2]
IUA 17a (Tot)		**1050**	**25.5**	**0.47**	**2%**	**I**	**I**	_[2]
IUA 17b **Lower Matlabas (incl Steenbokpan)**	A41C A41D	3024	29.95	1.64	6%	**I**	**I**	**III**
	A41E	1940	12.41	2.923	23%	**I**	**I**	**II**
IUA 17b (Tot)		**4964**	**42.36**	**4.56**	**11%**	**I**	**I**	**III**

[1]WARMS

[2]No data available.

[1]WARMS 2013

4 CLASSIFICATION DETERMINATION: CROCODILE (WEST) MARICO WMA

4.1 Crocodile West Catchment

The catchment area of the Crocodile (West) River is one of the most developed in the country. It is characterized by the sprawling urban and industrial areas of northern Johannesburg and Pretoria, extensive irrigation downstream of Hartbeespoort Dam and large mining developments north of the Magaliesberg. The Crocodile River is thus one of the rivers in the country that has been most influenced by human activities.

The Crocodile (West) River catchment area includes the tertiary drainage regions A21, A22, A23 and A24. The catchment covers a total catchment area of approximately 29 900 km^2. The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 secondary drainage catchment.

The catchment area includes four major sub-catchments as listed in Table 9.

Table 9: Sub-catchments within the Crocodile (West) River catchment area

Sub-catchment	Catchment Area (km^2)
Lower Crocodile	9204
Elands	6221
Upper Crocodile	6336
Apies/Pienaar	7588

The northern suburbs of Johannesburg, as well as Ekurhuleni and Krugersdorp, are situated in the Upper Crocodile sub-catchment (A21). Rustenburg is located in the Elands sub-catchment (A22), while Tshwane and Bela Bela are situated in the Pienaars sub-catchment (A23). These three sub-catchments feed into the Lower Crocodile sub-catchment (A24), within which Thabazimbi is located.

Extensive developments and level of human activity in the catchment led to water use in the catchment far exceeding the water available from the local sources. Most of the water used in the catchment is therefore supplied from the Vaal River system via Rand Water, mainly to serve the metropolitan areas and some mining developments. This in turn results in large quantities of effluent from the urban and industrial users, most of which is discharged to the river system after treatment, for re-use downstream. In many of the streams and impoundments, water quality is severely compromised by the proportionate large return flows.

Most of the total water used in the catchment is for urban and industrial purposes (representing 50% of the total), followed by irrigation (33%) and mining (8%). Various Game and Nature Reserves are present in the catchment. The strongest growth in requirements is experienced in the urban/industrial and mining sectors.

The Sterkfontein Caves and surrounding area, north of Mogale City, in the Upper Crocodile sub-catchment has been declared a World Heritage Site as a result of its paleontological significance.

a) Groundwater recharge.

The primary recharge source for groundwater is rainfall that infiltrates into the ground and replenishes aquifer storage. Recharge is a critical and difficult parameter to quantify. The amount of rain water that recharges the aquifer is a function of several factors such as geological lithology, aquifer characteristics, rainfall intensity and water level depth, and is generally expressed as a percentage of MAP. Recharge was assessed on a national scale during the GRA II project (DWAF 2005) and is used in GRDM datasets at quaternary catchment scale.

The GRDM recharge values at quaternary scale were used as initial value and in some instances updated based on estimates by other more detailed studies and the use of median chloride values in Technical Report RDM/ A000WMA3/00/CON/0208A, 2010. In view of the cautionary principle a conservative approach was followed in compiling Table 10 for areas where the chloride values indicated higher recharge percentages.

Preliminary groundwater recharge estimates for the Crocodile (West) River catchment are listed in Table 10. The long term annual recharge for the Crocodile (West) River catchment area of 29 900 km^2, amounts to 776 million m^3. The sustainable resource potential with limited impact on the ecology and lowering of water level depths is preliminary estimated at 40 %, which amounts to 310 million m^3 /annum.

Table 10 Groundwater recharge estimates per IUA (Crocodile (West) Catchment)

Quaternary Catchment Drainage	Area km^2	MAP mm	Preliminary Groundwater Recharge Estimates			
			% of MAP	Unit value mm/a	Volume million m3	Information Source
IUA1_A21A	483	684	8.37	57.3	27.641	Hobbs
IUA1_A21B	527	672	8.54	57.4	30.215	Hobbs
IUA1_A21C	761	682	3.60	24.6	18.684	Study
IUA1_A21D Total Area	372	714	7.41	52.9	19.655	Study
IUA1_A21D Swartkranz Comp!	147	710	16.00	113.6	16.699	Holland
IUA1_A21E	290	706	4.50	31.8	9.207	Study
IUA1_A21H	514	668	6.09	40.7	20.892	GRDM
IUA1_A23A	682	698	7.2	50.3	34.295	CMB
IUA1_A23B	814	645	2.0	12.9	10.502	CMB
IUA1_A23D - Pretoria Fountains Area Incl.	252	706	10.5	74.1	18.666	Study
IUA1_A23E	490	674	1.9	12.8	6.280	Vivier
IUA1_A21G (from IUA2)						
IUA 1	**5332**				**212.736**	
IUA2_A21F Total Area	1000	677	7.00	47.4	47.399	GRDM
IUA2_A21F Maloneys Eye GMA!	311	670	12.30	82.4	25.630	Holland
IUA2_A21G	161	694	5.60	38.9	6.238	GRDM
IUA2_Tarlton DWA						
IUA 2	**1472**				**79.267**	
IUA3_A21J	1150	637	4.08	26.0	29.893	GRDM
IUA 3	**1150**				**29.893**	
IUA4_A21K	864	718	3.75	26.9	23.279	GRDM

Quaternary Catchment Drainage	Area km^2	MAP mm	Preliminary Groundwater Recharge Estimates			
			% of MAP	Unit value mm/a	Volume million m3	Information Source
IUA4_A22G	499	656	5.5	36.1	17.989	Study
IUA4_A22H	579	658	4.1	27.0	15.612	GRDM
IUA4_A22J	592	600	2.4	14.4	8.518	CMB
IUA 4	**2534**				**65.398**	
IUA5_A22A	706	604	5.0	30.2	21.318	Study
IUA5_A22C	515	611	5.5	33.6	17.303	Study
IUA5_A22B	284	608	5.4	32.8	9.365	Study
IUA5_A22D	541	582	4.5	26.2	14.177	Study
IUA5_A22E	812	597	4.0	23.9	19.386	Study
IUA5_A22F	1688	604	3.5	21.1	35.691	Study
IUA 5	**4546**				**117.239**	
IUA12_A24D	1327	600	2.6	15.5	20.547	GRDM
IUA12_A24E	688	592	2.6	15.4	10.585	Vivier
IUA12_A24F	591	602	3.4	20.5	12.090	Vivier
IUA 12	**2606**				**43.222**	
IUA13_A21L	213	587	3.60	21.1	4.497	Study
IUA13_A24A	493	599	1.9	11.6	5.730	CMB
IUA13_A24B *	709	617	4.3	26.2	18.594	Vivier
IUA13_A24C *	801	589	4.3	25.3	20.297	Vivier
IUA13_A24G	735	645	5.2	33.5	24.662	Vivier
IUA13_A24H *	1338	639	4.4	27.9	37.309	GRDM
IUA13_A24J *	2516	538	2.6	14.0	35.192	GRDM
IUA 13	**6805**				**146.281**	
IUA14_A23C	491	574	2.2	12.6	6.200	CMB
IUA14_A23F	565	596	1.9	11.5	6.476	GRDM
IUA14_A23G	951	627	3.5	21.6	20.580	GRDM
IUA14_A23H	1058	600	4.4	26.6	28.124	Vivier
IUA14_A23J	930	585	1.2	7.3	6.782	GRDM
IUA14_A23K	1131	606	1.6	9.7	10.964	CMB
IUA14_A23L	329	604	1.5	9.4	3.074	GRDM
IUA 14	**5455**				**82.200**	
Total for Crocodile West-Marico.	**29900**				**776.237**	
Note : * Groundwater recharge estimate includes inflows from surface sources						

b) Groundwater Quality

The median groundwater quality major ions in the Crocodile West Catchment is summarised in Table 11. Groundwater qualities in IUA's 1, 2, 3, 4 and 5 have single, slightly elevated concentrations of Ca (IUA 1), NO_2 (IUA 2) and F (IUA's 3, 4 & 5) which could be related to minor pollution incidences and in the case of F, probably related to the geological processes (presence of granitic formations).

Groundwater quality in IUA's 12 (Ca, Mg and F), 13 (Ca, Mg, Cl and F) and 14 (Na, Cl and F) reports elevated levels due to local pollution and/or due to the geological processes.

Table 11 Median water quality of major ions (Crocodile (West) Catchment)

Quaternary Catchment	Quaternary Catchment	**No of Samples**	**EC mS/m**	**Ca mg/l**	**Mg mg/l**	**Na mg/l**	**Cl mg/l**	**F mg/l**	**NO^3 as N**	**SO_4 mg/l**
IUA 1	A21A	120	27.0	22.3	14.4	4.9	2.5	0.1	0.3	5.5
	A21B	204	53.6	47.6	31.8	10.7	13.8	0.1	2.3	12.9
	A21C	11	32.5	24.0	8.3	26.0	23.2	0.2	3.7	19.7
	A21D	267	26.9	21.5	14.9	6.6	12.3	0.1	0.1	14.5
	A21E	-	-	-	-	-	-	-	-	-
	A21H	4	40.9	27.7	22.1	28.8	12.9	0.3	0.4	12.2
	A23A	158	45.6	40.1	23.4	16.3	8.4	0.2	2.7	5.1
	A23B	12	42.4	57.7	23.0	37.2	30.3	0.2	1.5	21.6
	A23D	24	39.8	31.9	24.5	7.4	12.1	0.1	0.3	12.0
	A23E	266	**91.1**	**80.7**	53.7	29.7	74.4	0.1	5.4	104.8
IUA 2	A21F	138	21.1	19.5	12.3	2.5	1.5	0.1	0.1	6.2
	A21G	4	20.6	16.2	14.1	2.6	1.7	0.2	0.1	5.1
IUA 3	A21J	85	**90.9**	50.0	45.0	41.5	49.8	0.3	**6.3**	53.0
IUA 4	A21K	42	46.5	47.0	18.5	39.1	29.0	0.5	1.6	20.5
	A22H	11	44.0	34.0	44.0	8.0	9.0	0.1	1.6	7.0
	A22J	48	**75.0**	58.5	32.5	36.0	25.0	0.4	2.5	20.0
	A22G	2	49.3	13.6	31.8	44.3	56.2	**0.9**	4.3	3.7
IUA 12	A24D	149	**83.0**	29.0	**70.3**	16.0	13.0	0.3	2.1	12.3
	A24E	16	60.9	49.0	27.5	35.0	26.7	0.3	4.7	12.0
	A24F	1	**77.5**	**88.1**	62.1	4.0	5.4	**0.8**	1.1	6.4
IUA 5	A22A	66	30.4	24.7	12.7	10.9	5.0	0.4	2.4	4.6
	A22B	17	20.0	11.5	5.8	4.8	2.0	0.1	0.6	4.2
	A22C	7	51.3	50.6	12.3	18.5	3.9	0.5	0.5	6.4
	A22D	21	58.2	38.0	29.0	16.0	5.0	0.3	0.3	24.2
	A22E	54	46.0	19.0	43.0	10.0	5.1	0.2	1.1	4.0
	A22F	97	47.0	30.5	14.5	34.0	10.0	**1.0**	0.9	5.3

Quaternary Catchment	Quaternary Catchment	**No of Samples**	**EC mS/m**	**Ca mg/l**	**Mg mg/l**	**Na mg/l**	**Cl mg/l**	**F mg/l**	**NO^3 as N**	**SO_4 mg/l**
IUA 13	A21L	1	30.5	32.7	6.0	22.5	4.9	0.3	3.9	2.0
	A24A	75	**83.0**	66.2	38.0	40.3	31.0	**0.7**	2.3	25.0
	A24B	36	**127.5**	**115.5**	**76.3**	77.4	**139.3**	**0.8**	5.1	63.7
	A24C	130	**129.0**	79.5	57.4	95.0	**141.1**	**0.9**	3.9	66.4
	A24G	8	44.7	40.9	3.7	33.5	9.6	**2.7**	0.1	18.3
	A24H	26	62.9	48.3	32.3	30.1	29.5	0.7	0.9	9.9
	A24J	253	**106.0**	62.8	63.5	69.6	87.6	0.7	4.2	46.1
IUA 14	A23C	54	60.6	42.5	25.0	30.0	27.5	0.2	4.6	18.0
	A23F	171	**96.0**	59.0	29.0	**136.5**	**110.0**	**1.7**	1.7	24.4
	A23G	186	66.7	36.2	14.4	31.9	27.0	0.3	3.0	8.2
	A23H	131	27.7	22.0	4.6	21.2	9.7	0.7	1.0	5.0
	A23J	181	**78.1**	41.7	12.1	84.0	69.0	**2.0**	1.0	18.9
	A23K	201	69.0	56.0	12.0	54.0	38.0	**1.1**	2.0	13.0
	A23L	30	39.0	36.5	8.5	31.0	12.0	**3.4**	0.2	5.0

c) Groundwater use

The registered groundwater use from boreholes and springs, for the period ending August 2008 and January 2013 is listed in Table 12. The total water use for the Crocodile (West) WMA in 40 quaternary catchments at 242 million m^3 and 250 million m^3 respectively, an adjustment/increase of ±8 million m^3.

The Integrated Unit of Analysis percentage groundwater used in relation to the total for the Crocodile (West) is:

- IUA 1 31%
- IUA 2 16 %
- IUA 3 5 %
- IUA 4 9 %
- IUA 5 6 %
- IUA 12 2 %
- IUA 13 24 % and
- IUA 14 7 %.

Table 12 Groundwater Use per IUA (Crocodile West Catchment)

IUA – Quaternary Catchment.	GRA II (2005)	Warms (2008)	Warms (2013)
IUA 1- A21A	1.56	20.345	22.990
IUA 1- A21B	0.83	11.575	12.475
IUA 1- A21C	1.52	1.166	0.923
IUA 1- A21D	1.93	11.533	11.860
IUA 1- A21E	5.27	0.774	0.872
IUA 1- A21H	3.95	3.226	3.387
IUA 1- A23A	12.77	5.094	4.982
IUA 1- A23B	1.56	1.448	1.399
IUA 1- A23D	0.00	13.731	13.774
IUA 1- A23E	3.62	3.098	2.639
IUA 1	**33.01**	**71.990**	**75.300**
IUA 2- A21F	7.90	33.618	39.419
IUA 2- A21G	1.82	0.485	0.498
IUA 2	**9.72**	**34.103**	**39.917**
IUA 3- A21J	4.580	14.103	13.700
IUA 3	**4.580**	**14.103**	**13.700**
IUA 4- A21K	0.59	13.535	13.081
IUA 4- A22G	0.09	1.464	1.489
IUA 4- A22H	1.03	6.156	6.471
IUA 4- A22J	0.67	2.199	1.731
IUA 4	**2.378**	**23.354**	**22.772**
IUA 5- A22A	1.22	1.868	1.680
IUA 5- A22B	0.14	1.800	2.195
IUA 5- A22C	0.61	1.027	1.580
IUA 5- A22D	1.01	4.017	5.102
IUA 5- A22E	0.39	1.903	1.205
IUA 5- A22F	0.53	4.022	3.412
IUA 5	**3.896**	**14.637**	**15.174**
IUA 12- A24D	0.88	1.456	1.510
IUA 12- A24E	0.03	0.013	0.013
IUA 12- A24F	0.08	6.041	6.077
IUA 12	**0.96**	**7.510**	**6.077**
IUA 13- A21L	1.20	0.612	0.389
IUA 13- A24A	1.29	2.912	2.631
IUA 13- A24B	7.51	1.046	0.929
IUA 13- A24C	13.35	11.181	10.496

IUA – Quaternary Catchment.	GRA II (2005)	Warms (2008)	Warms (2013)
IUA 13- A24G	0.11	0.360	0.590
IUA 13- A24H	2.07	4.209	4.532
IUA 13- A24J	4.24	39.497	35.299
IUA 13	**29.780**	**59.817**	**59.866**
IUA 14- A23C	0.68	0.791	1.131
IUA 14- A23F	0.45	0.737	0.074
IUA 14- A23G	2.50	10.888	12.076
IUA 14- A23H	0.82	2.587	3.636
IUA 14- A23J	0.80	0.430	0.051
IUA 14- A23K	0.42	0.495	0.525
IUA 14- A23L	0.15	0.619	0.619
IUA 14	**5.81**	**16.547**	**18.112**
TOTAL WMA	**90.13**	**242.061**	**250.918**

d) Proposed classification

A summary of the groundwater classification for the Crocodile West Catchment is shown in Table 13.

Table 13 Final groundwater categorisation for each IUA (Crocodile West WMA)

IUA	Area (Km^2)	Recharge Mm^3	[1]Groundwater Use Mm^3/a	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)
IUA 1	5823	212.736	75.300	35%	II	II	I
IUA 2	1472	79.267	39.917	50%	II	II	I
IUA 3	1150	29.893	13.700	46%	II	II	I
IUA 4	2534	65.398	22.772	35%	II	II	I
IUA 5	4546	117.239	15.174	13%	I	II	I
IUA 12	2606	43.222	6.077	14%	I	I	II
IUA 13	6805	146.281	59.866	41%	II	II	II
IUA 14	4964	82.20	18.112	22%	II	II	II

4.2 Marico Catchment

a) Groundwater recharge

Preliminary groundwater recharge estimates for the Marico River catchment are listed in Table 14. The long-term annual recharge for the Marico River catchment area of 14676 km^2, amounts to 314.888 million m^3. The sustainable resource potential with limited impact on the ecology and lowering of water level depths is preliminary estimated at 40%, which amounts to 126 million m^3 /annum.

b) Groundwater Quality

Groundwater quality in IUA 6a & 6b, 7 and 8 can be classified as "good" i.t.o. the DWA Water Quality Criteria Class 1 - see Table 15. IUA 11a and IUA 11b have been classified into the "fair" category due to elevated magnesium values which could either be a natural phenomenon due to the geology, and/or some local mining activities.

c) Groundwater use

Groundwater use estimates vary between the WARMS 2008 dataset and the recently updated 2013 WARMS dataset – see Table 16. The groundwater use for the Dinokana Eye is included in the A10A values. The following water uses have been noted:

- Agriculture – Aquatic, irrigation, and stock farming
- Industry – Urban and Non-urban as well as Recreational
- Water Supply Services (WSS), Schedule 1
- Mining

Table 14 Groundwater recharge estimates for the Marico Catchment

Quaternary	Area	MAP	Preliminary Groundwater Recharge Estimates			
Catchment Drainage	km^2	mm	% of MAP	Unit value mm/a	Volume million m3	Information Source
IUA 6a- A31B	596	607	4.4	27	15.928	GRDM
IUA 6a	**596**				**15.928**	
IUA 6b- A31D	704	566	5.2	30	20.906	GRDM
IUA 6b- A31E	601	597	4.8	29	17.336	GRDM
IUA 6b	**1 305**				**38.240**	
IUA 7- A31A	632	602	4.4	27	16.878	GRDM
IUA 7- Incl. Southern DLMT's	530	602	12	72	38.287	
IUA 7	**1 162**				**55.165**	
IUA 8- A31C	485	546	5.7	31	15.045	GRDM
IUA 8	**485**				**15.045**	
IUA 10- A10A	558	558	4.0	22	12.300	GRAII
IUA 10- Dinokana DLMT	274	558	5.0	28	7.645	Study
IUA11b- A10B	1013	529	3.3	17	17.51	GRAII
IUA11b- A10C	271	537	3.5	19	5.11	GRAII
IUA 10	**2 116**				**42.565**	
IUA11a- A31F	702	591	5.4	32	22.388	CMB
IUA11a - A31G	1425	583	2.9	17	24.094	CMB
IUA11a - A31H	684	579	3.9	22	15.299	GRDM
IUA11a - A31J	844	552	4.0	22	18.520	GRDM
IUA11a - A32A	472	547	2.1	12	5.425	CMB

Quaternary	Area	MAP	Preliminary Groundwater Recharge Estimates			
Catchment			% of	Unit value	Volume	Information
Drainage	km^2	mm	MAP	mm/a	million m3	Source
IUA11a - A32B	641	569	4.0	23	14.487	CMB
IUA11a - A32C	902	527	3.7	20	17.582	CMB
IUA 11a	**5 670**				**117.795**	
IUA11b- A32D	843	533	3.2	17	14.373	CMB
IUA11b- A32E	2499	526	1.2	6	15.775	CMB
IUA 11b	**3 342**				**30.148**	
TOTAL MARICO	**14676**				**314.886**	

Table 15 Median water quality of major ions (Marico Catchment)

IUA	Quaternary Catchment	No of Samples	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	Cl mg/l	F mg/l	NO^3 as N	SO_4 mg/l
IUA 6a	A31B	18	9.3	5.0	3.8	4.4	5.0	0.2	0.4	2.0
IUA 6b	A31D	159	52.7	47.1	37.0	5.7	6.3	0.5	0.1	14.7
	A31E	7	17.7	14.2	10.0	5.8	3.3	0.3	0.4	2.0
IUA 7	A31A	79	30.5	30.2	18.2	3.5	5.7	0.1	0.2	3.0
IUA 8	A31C	150	46.2	40.6	32.3	3.0	5.0	0.2	0.6	4.4
IUA 11a	A31F	49	64.0	23.0	37.0	20.9	11.0	0.2	0.7	11.0
	A31G	142	**86.8**	34.0	**82.0**	30.0	21.0	0.2	2.3	16.0
	A31H	55	47.4	44.0	23.0	12.0	5.3	0.2	0.4	11.0
	A31J	20	**81.0**	20.0	**97.3**	13.0	11.0	0.2	1.9	10.6
	A32A	49	**98.6**	33.0	**95.0**	36.0	29.0	0.2	2.9	25.0
	A32B	60	**80.0**	36.0	51.5	26.5	14.9	0.3	0.9	7.0
	A32C	6	**88.1**	**92.5**	60.0	8.0	16.0	0.4	1.6	12.1
IUA 11b	A32D	9	**84.0**	**83.0**	59.0	12.0	18.5	0.3	0.5	1.0
	A32E	42	**114.0**	69.2	**92.5**	64.6	53.0	0.5	4.0	19.3

Table 16 lists the total groundwater use registered on WARMS (the August 2008 compared with an updated version for January 2013) for the Marico WMA in 17 Quaternary Catchments at approximately 19.23 million m^3. Irrigation use is the largest at 78 % flowed by domestic use at 14 % and mining at 5 %.

Table 16: Groundwater Use per IUA (Marico Catchment)

IUA – Quaternary Catchment.	GRA II (2005)	Warms (2008)	Warms (2013)
IUA 6- A31B	0.33	2.675	0.779
IUA 6a	**0.33**	**2.68**	**0.78**
IUA 6- A31D	1.53	3.416	5.177
IUA 6- A31E	0.16	0.811	0.901
IUA 6b	**1.69**	**4.23**	**6.08**
IUA 7- A31A	1.262	3.637	2.986
IUA 7	**1.26**	**3.64**	**2.99**
IUA 8- A31C	0.423	3.771	3.089
IUA 8	**0.42**	**3.77**	**3.09**
IUA 10 – A10A	1.370	1.306	0.672
UIA 10 -Dino			
IUA 11a- A10B	1.32	0.380	0.042
IUA 11a- A10C	0.19	0.001	0.001
IUA 10	**2.88**	**1.69**	**0.72**
IUA 11a- A31F	0.46	2.133	4.658
IUA 11a- A31G	1.49	0.671	0.331
IUA 11a- A31H	1.30	0.451	0.445
IUA 11a- A31J	0.35	0.269	0.266
IUA 11a- A32A	0.39	0.042	0.049
IUA 11a- A32B	1.05	0.047	0.025
IUA 11a- A32C	0.36	0.000	0.000
IUA 11a	**5.41**	**3.23**	**5.73**
IUA 11b- A32D	0.93	0.128	0.006
IUA 11b- A32E	0.37	0.597	0.527
IUA 11b	**1.30**	**0.73**	**0.53**
TOTAL MARICO	**13.30**	**19.95**	**19.92**

The IUA's percentage groundwater used (based on 2103 WARMS dataset) in relation to the total water use for the Marico Catchment is as follows:

- IUA 6a 4 %
- IUA 6b 30 %
- IUA 7 15 %
- IUA 8 15 %

- IUA 10 4 %
- IUA 11a 29 % and
- IUA 11b 3 %

d) Proposed classification

A summary of the groundwater classification for the Marico Catchment is shown in Table 17.

Table 17 Final groundwater categorisation for IUA's (Marico Catchment)

IUA	QC's	Area (Km^2)	Recharge Mm^3	Groundwater Use Mm^3/a	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)
IUA 6a		596	15.93	0.78	5.0%	I	I	I
IUA 6b		1305	38.24	6.08	16.0%	I	I	I
IUA 7		1162	55.165	2.986	5.4%	I	I	I
IUA 8		485	15.045	3.089	21.0%	I	II	I
IUA 10		2116	42.565	0.72	1.7%	I	II	-
IUA 11a		5670	117.795	5.731	5.0%	I	I	II
IUA 11b		3342	30.148	0.53	1.8%	I	I	II

4.3 Eastern Kalahari Catchment (Upper Molopo)

The Upper Molopo Catchment consists of the D41A and the C31A Quaternary Catchments; the latter QC forms part of the Lower Vaal WMA and include a portion of the Lichtenburg dolomite aquifer system. The upper part of this dolomite aquifer system has been grouped together with the head waters of the Marico Catchment and included into IUA 7 (see Section 9.2 above). The eastern part of QC D41A includes a significant dolomite aquifer system, viz, Grootfontein, Molopo Eye and Itsoseng aquifer systems, supplying water to towns, communities and mines, such as Mahikeng, Itsoseng, Rooigrond and Slurry. The D41A dolomite aquifer system is also highly impacted by irrigation schemes in the Grootfontein sub-compartment.

The Molopo Eye is probably the only one of the original pre-1960 flowing dolomite eyes' discharging into the Upper Molopo Catchment and still in a natural condition. Flow from the Molopo Eye is diverted between an ecological supporting yield and water discharged into a pipe line supplying water to Mahikeng. The hydrostatic elevation of the Grootfontein Eye has been lowered significantly due to multiple borehole abstraction from the eye and lies currently at a level of between 30 and 38m below ground elevation. Water supply shortages for Mahikeng has occurred occasionally during 2010-2011 due to several borehole pump failures and a depleted aquifer saturation situation at Grootfontein – a over-abstraction condition! The water balance status in this portion of the Grootfontein Dolomite Aquifer System is a concern and will probably deteriorate in future if the historical annual average recharge rate is not met from now on.

a) Groundwater recharge

The groundwater recharge estimates are listed in Table 18.

The D41A catchment consists of two different aquifers systems, viz. on the eastern side, almost flat lying dolomites of the Chuniespoort Group occurs, whilst the western side is underlain by collection of Basement Formations (Granites) and Ventersdorp Supergroup (Lavas and sedimentary rocks), covered in places with Kalahari Group sediments (windblown sands and calcrete horizons).

Table 18 Groundwater recharge estimates (Upper Molopo Catchment (QC D41A))

IUA- Quaternary Catchment (Aquifer System).	Area	MAP	Preliminary Groundwater Recharge Estimates			
	km^2	mm	% of MAP	Unit value mm/a	Volume million m3	Information Source
IUA 9- D41A (Dolomite Aqf.)	973	580	9	53	50.79	GRDM
IUA 9- D41A (Other Aqf.)	2987	530	1.5	8	23.75	GRDM
IUA 9	**3960**				**74.54**	

b) Groundwater Quality

Groundwater quality in the dolomite aquifer systems (IUA 9- D41A (Dolomite Aqf.) can be classified as still within a natural status (reference to the level of treatment performed at the Mahikeng Water Treatment Plant). The discharges from the Mahikeng Waste Water Treatment Plant flow into a reservoir (a dam a few kilometres downstream from the WWTP, downstream from Mahikeng). The water quality of the western part of the IUA (viz. IUA 9- D41A (Other Aqf.)) is not known extensively, but the quality is probably already impacted due to intensive land use and low rainfall recharge (1.5% of MAP). Several small holdings in addition to the presence of igneous formations in this area could be responsible for elevated nitrate and fluoride (NO_3 and F) levels.

c) Groundwater use

The western portion of Upper Molopo catchment is underlain by Basement granite. This is covered with an increasing thickness of Kalahari sand/calcretes to the west. A mostly intrusive volcanic rock assemblage (Allanridge lava) lies to the east of Mahikeng. Significant aquifers are present locally north of Slurry (open cast lime producing, northeast of Mahikeng). Several smaller, open cast (alluvial) diamond mining activities occurs in the Bakerville area. The aquifers tend to be relatively shallow. Groundwater is the only source of water supply for the rural population.

The WARMS registered groundwater use for January 2013 for registered statuses active and complete from boreholes and springs were considered and listed in Table 19. The total registered water use for IUA 9 (D41A) is 53.76 million m^3/a, of which 11 million m^3/a is for water supply to Mahikeng. The remaining 43 million m^3/a is used for rural water supplies, mining and irrigation practices.

Table 19 Groundwater Use per IUA (Upper Molopo Catchment (QC D41A))

IUA – Quaternary Catchment.			
	GRA II (2005)	Warms (2008)	Warms (2013)
IUA 9- D41A (Dolomite Aqf.)			53.470
IUA 9- D41A (Other Aqf.)			0.290
IUA 9	**8.232**		**53.760**

d) Proposed classification

A summary of the groundwater classification for the UIA 9 (Upper Molopo Catchment) is shown in Table 20.

Table 20 Final groundwater categorisation for IUA 9 (Upper Molopo Catchment (QC D41A))

IUA	QC's	Area (Km^2)	Recharge Mm^3	Groundwater Use Mm^3/a	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)
IUA 9- D41A (Dolomite Aqf.)	D41A	973	50.79	53.47	105%	III	III	I
IUA 9- D41A (Other Aqf.)	D41A	2987	23.75	0.29	1.2%	I	I	II
IUA 9		3960	74.54	53.76	72%	III	III	II