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DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

RESOURCE UNIT REPORT

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

MARCH 2016

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DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

RESOURCE UNIT REPORT

Approved for RFA by:

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EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries and wetlands) and Groundwater in the Lower Orange Water Management Area (WMA). Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

PURPOSE OF REPORT

The purpose of this report is to:

- Delineate Riverine RUs as well as Groundwater Resource Units (GRUs).
- Delineate estuaries of national importance occurring in the study area; and
- Determine and identify priority wetlands in the study area.

RIVERINE DELINEATION RESULTS

Resource Units (RUs) are required as it may not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. Different sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and require individual specifications of the Reserve appropriate for that reach. The approach adopted was to consider both Natural Resource Units (NRUs) and Management Resource Units (MRUs) and to take account of the following aspects:

- EcoRegion classification of the river system.
- Geomorphological zonation in which channel gradient has been found to be a dominant factor.
- Land cover.
- Management and operation of the river system; and
- Local knowledge.

The MRUs selected are summarised below:

MRU summary table

MRU	Rationale
MRU Orange A	Gariep Dam wall to Vanderkloof Dam: This section is an isolated section with Vanderkloof Dam being a logical operational endpoint, due to the operation and the barrier effect of the Dam. This RU falls outside of the study area.
MRU Orange B	Vanderkloof Dam wall to Prieska: Prieska town forms a logical endpoint as the water level fluctuation is less significant at this point and irrigation decreases downstream. As the Vaal River is operated to not contribute significantly to the Orange River, it was not selected as an endpoint. An EWR site was problematic in this reach due to the constraint of ESKOM operational rules.
MRU Orange C	Prieska to Boegoeberg Dam: The dam forms a logical endpoint to this reach due to the barrier effect, the similar operation upstream of Boegoeberg and the increase in irrigation downstream of the dam. As most of this reach is influenced by backup from Boegoeberg or is inaccessible, an EWR site was not advised.
MRU Orange D	Boegoeberg Dam to Augrabies Falls: Land use is similar upstream of the Augrabies National Park. The Augrabies Falls was selected as the end of the MRU due to its role as a natural barrier. An EWR site was selected downstream of Boegoeberg Dam
MRU Orange E	Augrabies Falls to Vioolsdrift Weir: The same delineation applies as for the natural RU. Irrigation is limited and constrained by accessibility. An EWR site preferably in an undisturbed section, but must be accessible and was selected just downstream of the Augrabies Falls National Park.

MRU	Rationale
MRU Orange F	Vioolsdrift Weir to the Fish River confluence. The Fish River forms a logical endpoint as the only large tributary entering the Orange at this point. An EWR site was selected downstream of Vioolsdrift Weir.
MRU Orange G	Fish confluence to the start of the estuary: Although the landuse is vastly different, the operation is the same for this area i.e. a conduit for water through to the downstream mining areas that include irrigation and towns. It was decided therefore, that one MRU was relevant. However, for EWR determination, this section includes a critical area. This area is within the Transfrontier Park and as it is less disturbed than the downstream reaches, will include a greater variety of indicators for EWR assessment. An EWR site was therefore selected within this section.
MRU Orange H (estuary)	As an estuary often has a different EWR than a river, this fact warrants a separate MRU from the upstream river section. The upstream border was set by the estuarine specialists as the area which, under current conditions is the section that should be managed as the estuary. It is possible that under natural conditions (with a frequently closed mouth), the estuary border could have been further upstream.

EWR SITES

Well established criteria and processes (Louw *et al*., 1999) were adopted to select EWR sites for further analysis. A table with the EWR sites and summarised criteria is provided below.

EWR site number	EWR site name	River	Decimal degrees S	Decimal degrees E	EcoRegion (Level II)	Geozone	Altitude (m)	MRU	Quat	Gauge
EWR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EWR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland	433	MRU Orange E	D81B	D7H014
EWR O4	Vioolsdrift	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EWR O5	Sendelingsdrift	Orange	-28.0718	16.95951		Lowland	47	MRU Orange G	D82L	D8H015

ESTUARINE DELINEATION RESULTS

The Lower Orange WMA include six estuaries of national importance namely the Orange, Buffels, Sout, Swartlintjies, Spoeg and Groen. These estuaries each represent a RU and were delineated according to the accepted approach. The geographical boundaries of the estuaries are defined as follows:

Orange Estuary	
Downstream boundary	28°37'58.91"S; 16°27'16.02"E (Estuary mouth)
Upstream boundary	28°33'43.63"S; 16°31'23.02"E
Lateral boundaries	5 m contour above Mean Sea Level (MSL)along each bank
Buffels Estuary	
Downstream boundary	29°40'37.01"S; 17° 3'4.41"E (Estuary mouth)
Upstream boundary	29°40'18.21"S; 17° 4'3.30"E
Lateral boundaries	5 m contour above MSL along each bank
Swartlintjies Estuary	
Downstream boundary	30°15'44.33"; S 17°15'36.39"E (Estuary mouth)
Upstream boundary	30°15'45.73"; S 17°17'8.36"E
Lateral boundaries	5 m contour above MSL along each bank
Spoeg Estuary	
Downstream boundary	30°28'20.54"S; 17°21'34.07"E (Estuary mouth)
Upstream boundary	30°28'17.92"; S 17°22'32.83"E
Lateral boundaries	5 m contour above MSL along each bank
Groen Estuary	
Downstream boundary	30°50'49.05"S; 17°34'35.72"E (Estuary mouth)
Upstream boundary	30°49'38.26"S; 17°34'40.18"E
Lateral boundaries	5 m contour above MSL along each bank
Sout Estuary	
Downstream boundary	31°14'37.66"S; 17°50'52.55"E (Estuary mouth)
Upstream boundary	31°12'38.88"S; 17°53'24.41"E
Lateral boundaries	5 m contour above MSL along each bank

PRIORITY WETLAND IDENTIFICATION

The approach taken in prioritising wetlands in the lower Orange River catchment comprised two steps: First, the spatial distribution and extent of wetlands was explored in order to define and delineate wetland RUs. Secondly, wetlands were prioritised within each wetland RU based on a matrix of various wetland characteristics and properties, which facilitated the ranking of wetlands in order to produce a list of high priority wetlands. A combination of wetland and EcoRegion spatial data were used (Nel *et al.*, 2011 and Kleynhans *et al.*, 2005 respectively) to determine distribution patterns of different types of wetlands in different EcoRegions. A combination of wetland types (Figure 4.3) and Level I EcoRegions resulted in the following broad wetland RUs (each discussed in detail above):

1. Seeps and depressions in the northern part of the southern Kalahari; quaternary catchment D42A.
2. Depressions in the southern part of the southern Kalahari (includes some flats, seeps and unchannelled valley bottom wetlands); quaternary catchments D42B, D42D, D42E, D73E and D81C.
3. Depressions in the southern Kalahari and Ghaap Plateau; quaternary catchments D71A, D71B, D71C, C92B and C92C.

4. Depressions and unchannelled valley bottom wetlands in the eastern Nama Karoo (includes some seeps and channelled valley bottom wetlands); quaternary catchments D62A, D62B, D62C, D62D, D62E, D62F, D62G, D62H and D62J.
5. Depressions in the western Nama Karoo (includes seeps, flats and unchannelled valley bottom wetlands); quaternary catchments D53D, D53F, D53G, D54C, D54D, D54E, D54F, D55M, D57A, D57B, D57C, D57D, D57E, D58B and D58C.
6. Seep and channelled valley bottom wetlands in the southern Namaqua Highlands and southern Western Coastal Belt (includes some flats and floodplain wetlands); quaternary catchments F30A, F30B, F30C, F40B-H, F50A-G and F60A.
7. Floodplain wetlands along the Nossob, Auob, Molopo and Orange rivers.
8. Wetlands associated with the Orange River mouth (which is a RAMSAR site).

A list of quaternary and SQ catchments with priority wetlands is shown in Table 4.3, and relates to defined wetland RUs.

GROUNDWATER RESOURCE UNITS

The objective of this task is to delineate groundwater resource units (GRU) based on quaternary catchment boundaries, aquifer type, and other physical, management and/or functional criteria. Quaternary catchments form the basic unit of delineation. These are can be grouped if geohydrological properties are similar, or further subdivided where significant geohydrological features cut through catchments.

The approach followed in this study for grouping and delineation in hierarchical order is:

- An original primary delineation by quaternary catchment boundary as demarcated in Water Resources South Africa 2012 (WR2012).
- Geological age and lithology based on (GSSA, 2006).
- Identification of ground water regions based on geological considerations.
- Identification of catchments with baseflow to surface water bodies, as listed in Groundwater Resource Assessment Phase II (GRAII) (DWAF, 2006).
- Climate, recharge, and Harvest Potential (DWAF 2006).
- Groundwater levels from the DWS National groundwater monitoring network.
- Groundwater quality from the DWS National water quality monitoring network.
- Groundwater dependent ecosystems and or wetlands based on Nel *et al*. (2011).
- Groundwater use and stress from the WARMs[1] database.

Nineteen GRUs (Figure 5.12) are described:

Bushmanland west: The Bushmanland west GRU is underlain by rocks of the Namaqua-Natal metamorphic Province, which are largely covered by Tertiary cover. Extensive outcrop exists only in the central region from Augrabies to Kenhardt. Recharge is less than 1 mm/a. Mean groundwater depth increases from less than 20 m near Kenhardt to over 50 m to the west near Aggeneys. Water quality is generally poor and of Class 3 or 4 due to high salinity, with the worst quality water being located in the north from Concordia to Augrabies.

Bushmanland east: The Bushmanland east GRU is underlain by rocks of the Kaaien and Areachap Terranes of the Namaqua-Natal metamorphic Province. Tertiary cover is less extensive than to the west. Recharge is from less than 1 mm to over 3 mm/a increasing south-eastward with

[1] Water Resources Simulation Model 2000. The Pitman Model with Sami Model Groundwater interactions.

rainfall. Groundwater levels average 20 - 25 metres below ground level (mbgl). Groundwater quality is less saline than in the western area and is generally of class 2.

Dwyka Tillite: The Dwyka Tillite GRU is underlain by tillites and largely devoid of sediment cover. Recharge is less than 1 mm/a, except in the eastern pocket where rainfall is higher. Groundwater levels are from 18 - 25 mbgl, but above 15 mbgl in the eastern portion. Groundwater is of unacceptable quality due to salinity of class 4.

Ecca Carbonaceous shale: The Ecca carbonaceous shales overlie Dwyka Tillites and are extensively intruded by dolerite sheets. Recharge is less than 1 mm/a, except in the eastern portion where rainfall is higher. Groundwater levels are from 15 - 25 mbgl. Groundwater quality is poor and of class 3.

Ecca sandstone and shale west: The Ecca sandstones and shales overlie the carbonaceous shales and have a recharge of 0.5 - 1 mm/a. Groundwater levels are shallow and are 10 - 15 mbgl. Groundwater quality is good to marginal and of class 1 - 2.

Ecca sandstone and shale central and south west: The Ecca sandstones and shales overlie the carbonaceous shales and have a recharge from 1 - 3.5 mm/a, increasing towards the east. Groundwater levels are shallow and 10 - 15 mbgl. Groundwater quality is highly variable but generally of class 1 - 2.

Ecca sandstone and shale east: The Ecca sandstones and shales overlie the carbonaceous shales. They have a recharge from 4 - 11 mm/a, increasing from Carnarvon to east of Britstown due to increasing rainfall. Groundwater levels are shallow and 7 - 15 mbgl. Groundwater quality is good and of class 1.

Far northern Coastal Hinterland: The Gariep belt, extensively covered by Tertiary and Quaternary sediments, underlies the Far Northern Coastal Hinterland. It has recharge of less than 1 mm/a. Groundwater levels are from 25 - 45 mbgl. Groundwater is of poor to unacceptable quality, class 3 - 4.

Ghaap Plateau: The Ghaap Plateau GRU is underlain by Ghaap Plateau dolomites, which are covered by Kalahari and Tertiary sediments in some. It is the most significant aquifer in the WMA. Recharge is from 7 - 10 mm/a. Groundwater levels are 15 - 20 mbgl. Groundwater quality is of class 1.

Karoo sandstone and shale west: The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Recharge increases from 1 - 3 mm/a from north to south, being highest in the vicinity of Sutherland. Groundwater levels are from 5 - 15 mbgl. Groundwater quality is of class 1 - 2.

Karoo sandstone and shale east: The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Recharge increases from 3 mm/a near Loxton, to nearly 12 mm/a around De Aar. Groundwater levels are from 5 - 15 mbgl. Groundwater quality is good to marginal, of class 1 - 2, with the marginal groundwater found in the South east between Richmond and De Aar.

Namaqualand west: The Namaqualand west GRU is underlain by rocks of the Nama and Vanrhynsdorp groups. Along the coast, they are covered by Tertiary and Quaternary sediments.

Recharge is less than 1 mm but can range to over 3 mm in the vicinity of Garies due to higher rainfall (Figure 5.13). Groundwater levels are from 12 to 50 mbgl, being deeper near the coast. Groundwater is of poor to unacceptable quality, class 3 - 4.

Namaqualand east: The Namaqualand east GRU is underlain by rocks of the Nama and Vanrhynsdorp groups. Recharge is from less than 1 mm to 2 mm. Groundwater levels are from 12 - 30 mbgl. This GRU was delineated due to a higher water class than the rest of Namaqualand and water quality is of class 2 - 3 for domestic purposes.

Taung-Prieska belt: The Taung-Prieska Belt is underlain by Dwyka tillite and, Ventersdorp Supergroup rocks, with extensive Tertiary cover. Recharge is from 3.5 mm/a near Prieska up to 9.5 mm/a near Douglas. Groundwater levels are 15 - 20 mbgl. Groundwater quality is of class 1 - 2.

West Griqualand: The West Griqualand GRU is underlain by the Olifantshoek Supergroup, the Ventersdorp Super Group, some dolomites, and Transvaal Group ironstones. Recharge is from 2 - 6 mm/a and increases to the east. Groundwater levels are 20 - 35 mbgl. Groundwater quality is of class 1 - 2.

Western Kalahari: The Western Kalahari GRU consists of Quaternary sand cover overlying largely Dwyka Tillite, Koras Group sandstone, or metamorphics of the Kaaien Terrane. Recharge is less than 1 mm. Groundwater levels are from 25 to 90 mbgl. Groundwater quality is of class 4 and only improves in the SE around Karos and Grootdrink, where it is of class 2.

Richtersveld: The Richtersveld is underlain by rocks of the Richtersveld Subprovince. Recharge is less than 1 mm. Groundwater levels are from 30 - 50 mbgl, being deeper to the east. Groundwater is of marginal to unacceptable quality, class 2 - 3.

Namaqualand coastal: The Namaqualand west GRU is underlain by rocks of the Nama and Vanrhynsdorp groups, which are covered by Tertiary and Quaternary sediments. Recharge is from less than 1 mm to 2 mm. Groundwater levels are from 40 - 50 mbgl. Groundwater is of poor to unacceptable quality, class 3 - 4.

Karoo sandstone and shale southwest: The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Small volumes of baseflow potentially exist in the vicinity of Sutherland due to higher rainfall (Figure 5.13). Recharge increases from 3 - 8 mm/a from north to south, being highest in the vicinity of Sutherland. Groundwater levels are from 5 - 13 mbgl. Groundwater quality is of class 1 - 2.

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ABBREVIATIONS

BHN	Basic Human Needs
CD: WE	Chief Directorate: Water Ecosystems
CERM	Consortium for Estuarine Research and Management
DWA	Department Water and Sanitation (Name change applicable after April 2009)
DWAF	Department Water and Sanitation and Forestry
DWS	Department of Water and Sanitation (Name change applicable after March 2014)
EFZ	Estuarine Functional Zone
EI	Ecological Importance
EIA	Environmental Impact Assessment
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Area
GIS	Geographic Information System
GRAII	Groundwater Resources Information
GRU	Groundwater Resource Unit
HF	Hydraulic fracturing
HGM	Hydrogeomorphic Wetland
MAP	Mean Annual Precipitation
mbgl	metres below ground level
MRU	Management Resource Unit
MSL	Mean Sea Level
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Area
NRU	Natural Resource Unit
PES	Present Ecological State
PSP	Professional Service Provider
RAU	Reserve Assessment Unit
RQO	Resource Quality Objectives
RSA	Republic of South Africa
RU	Resource Unit
SQ	Sub Quaternary
TOR	Terms of Reference
VB	Valley-bottom wetlands
WARMS	Water Use Authorisation and Registration Management System
WMA	Water Management Area
WR2012	Water Resources of South Africa, 2012

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA'. Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

As per the Terms of Reference (TOR), there is a need to undertake detailed Ecological Water Requirement (EWR) and Basic Human Needs (BHN) studies for various water resource components due to mainly:

- Hydraulic fracturing (HF) that will be undertaken in the Water Management Area (WMA).
- Various water use licence applications.
- The conservation status of various Resources in this catchment; and
- The associated impacts of proposed developments will have on the availability of water.

1.2 STUDY AREA

As indicated in the TOR, the study area is the Lower Orange River WMA (the old WMA 14). It is the largest WMA in the country, and covers almost the entire Northern Cape Province. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north-eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa. The focus area of the study comprises only the South African portion of the Lower Orange River Catchment. The Eastern Boundary starts where the Vaal River Tributary enters the Orange River, and the Western Boundary is the Atlantic Ocean. The study area is downstream of the Upper Orange, Senqu and the Integrated Vaal River System and as such, is affected by the upstream activities in the highly developed river basin. The Orange River forms the border between the Republic of South Africa (RSA) and Namibia to the west of the 20 degrees longitude over a distance of approximately 550 km.

1.3 PURPOSE OF THIS REPORT

The approach to this study was based on the generic 8-step Reserve process (DWAF, 1999). Step 2 of the Reserve process entails the delineation of Resource Units (RUs) applicable to rivers, estuaries, wetlands and groundwater.

The purpose of this report is to:

- Delineate Riverine RUs as well as Groundwater Resource Units (GRUs).
- Delineate estuaries of national importance occurring in the study area; and
- Determine and identify priority wetlands in the study area.

RUs were originally defined in DWAF (1999) specifically for rivers. This definition is not applicable for the other ecosystem components (groundwater, wetlands, and estuaries) and the terminology is explained in Table 1.1.

Table 1.1 RU definition per component

Component	Definition
Rivers	RUs are significantly different from each other and therefore warrant their own specification of the Ecological Water Requirements. If an EWR is therefore set in a RU at the EWR site, it can be hydrological extrapolated to any point in the RU.
Estuaries	Every estuary requires its own EWR and every estuary is therefore an RU based on the space within which estuaries function referred to as the estuarine functional zone (estuarine ecosystem area). Included in the definition of the RUs for estuaries is the delineation of the estuarine boundaries.
Wetlands	Wetlands are classified into different types termed hydro-geomorphic units, i.e. according to its hydrological and geomorphological context within the landscape. Each wetland type will have generic functionality, hydrological requirements and management strategies. RUs therefore represent similar wetland types in the geographic area (catchment).
Groundwater	Units of similar geological, hydrogeological, groundwater quality and surface-groundwater interaction properties.

1.4 OUTLINE OF THIS REPORT

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides general background to the project, study area and purpose of the report.

Chapter 2: River Delineation Results
The approach to determining RUs and EWR site selection are provided in this chapter. The Natural and Management Resource Units are also described and detailed information is provided for the EWR sites.

Chapter 3: Estuarine Delineation Results
Six estuaries were delineated from the estuary mouth (downstream boundary) to the upstream boundary, and the lateral boundary (5 m contour above Mean Sea Level along each bank). The results are provided in map format.

Chapter 4: Priority Wetland Identification
This Chapter provides a description of the types of wetlands within the study area, which were prioritised and grouped into eight Wetland RUs.

Chapter 5: Groundwater Resource Units
The GRUs are provided and described and summary results are provided in map and table format.

Chapter 6: References

2 RIVER DELINEATION RESULTS

The Orange River was delineated into Management Resource Units (MRU) following the standard DWS process (DWAF, 1999; DWAF, 2008a) during two studies undertaken for ORASECOM (Louw *et al*, 2010a; Louw and Van Niekerk, 2012). The results of these studies are summarised in this chapter.

The applicable river reach delineation is the Orange River from the Vaal River confluence to the estuary.

2.1 APPROACH

If an EWR determination is required for a whole catchment, it is necessary to delineate the catchment into RUs. These are each significantly different and therefore warrant their own specification of the EWRs. The geographic boundaries of each must also be clearly delineated (DWAF, 1999, Volume 3).

RUs are required as it would not be appropriate to set the same numerical EWR for the headwaters of a river, as for the lowland reaches. These sections of a river frequently have different natural flow patterns, react differently to stress (according to their sensitivity) and therefore require individual specifications of the EWR appropriate for that reach. The breakdown of a catchment into RUs, for the purpose of determining the EWR for rivers, is done primarily on a biophysical basis within the catchment and termed Natural Resource Units (NRU).

Management requirements (DWAF, 1999, Volume 3) also play a role in the delineation. An example would be where large dams and/or transfer schemes occur. Furthermore, the type of disturbance/impact on the river under the present circumstances would also play a role in selecting homogenous river reaches (from a biophysical basis). These reaches are termed Management Resource Units (MRU).

The delineation process considers all of the above aspects. Overlaying all the data does not necessarily result in a logical and clear delineation. Expert judgement, a consultative process and local knowledge are required for the final delineation. The practicalities of dealing with numerous reaches within one study must also be considered in order to determine a logical and practical suite of MRUs.

MRUs can further be delineated into even smaller assessment units termed Reserve Assessment Units (RAUs). These shorter areas are critical areas within the large MRU and one would normally aim to include an EWR site in these units where possible.

The EWRs are determined for each MRU by means of either of the following (Louw and Hughes, 2002):

- An EWR site is selected within the MRU and represents a critical site within the relevant river section. Results generated at the EWR site will then be relevant for the MRU as a whole.
- NoEWR site is selected within the MRU and derived results from adjacent MRUs with EWR sites are used. The reasons for an EWR site not being selected within the MRU can be the following:
  - The characteristics of the river within the MRU do not meet the criteria for EWR sites.

- o Due to the number of MRUs within the study area, it is not practical and/or cost-effective to address an EWR site within each MRU.

2.2 RESOURCE UNIT CONSIDERATIONS

2.2.1 EcoRegions (Level II)

The EcoRegion typing approach developed in the USA (Omernik, 1987) was tested and applied at a preliminary level in South Africa. EcoRegional classification, or typing, will allow the grouping of rivers according to similarities based on a top-down approach. The purpose of this approach is to simplify and contextualise assessments and statements on EWRs. One of the advantages of such a system is the extrapolation of information from data rich rivers, to data poor rivers within the same hierarchical typing context.

The first phase (Level I) used available information to delineate EcoRegion boundaries at a very broad scale for South Africa. Attributes such as physiography, climate, rainfall, geology and potential natural vegetation were evaluated in this process and 18 Level I EcoRegions were identified (Kleynhans *et al*., 2005). The next Level II (Kleynhans *et al*., 2007), used the same attributes but in more detail. For example, physiography can be explored in more detail by considering terrain morphological classes, slopes, relief, altitude, etc.

2.2.2 Geomorphological zonation

Rountree and Wadeson (1999) have developed a zonal classification system for Southern African Rivers, modified from Noble and Hemens (1978). In their classification, an attempt was made to give each zone a geomorphological definition in terms of distinctive channel morphological units and reach types. After working in a number of different rivers around the country, it has become clear that channel gradient is an accurate indicator of channel characteristics and that probable or expected difference can be identified from an analysis of gradients (Table 2.1).

Table 2.1 Geomorphological Zonation of River Channels (adapted Rountree and Wadeson, 1999)

Longitudinal zone	Characteristic channel features	
	Zone class	Description
Mountain stream	B	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool. Approximate equal distribution of ‘vertical’ and ‘horizontal’ flow components.
Transitional	C	Moderately steep stream dominated by bedrock or boulder. Reach types include plain-bed, pool-rapid or pool riffle. Confined or semi-confined valley floor with limited flood plain development.
Upper Foothills	D	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present.
Lower Foothills	E	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
Lowland river	F	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.

2.2.3 Land cover

The land cover per 500m strip on both sides of the river maps, as well as associated Excel spreadsheets were generated by Geographic Information System (GIS) consultants on the team(ftp://uranus.esrin.esa.int/pub/globcover_v2). These spreadsheets provide a total summary of the hectares (ha) per quaternary catchments. This information was used to determine homogeneity of impacts and considered during the decision-making regarding the MRUs. Emphasis was also placed on a Google Earth evaluation, personal observations and local knowledge.

2.2.4 System operation

A qualitative systems operation description was provided, with specific emphasis of the locality and type of infrastructure (formal and informal) that could have an impact on the hydrological characteristics of the river:

- Orange River: Vanderkloof Dam to Prieska
  This section is still dominated by hydro-electric releases, abstractions and return flows.
- Orange River: Prieska to Boegoeberg Dam
  Mostly an inaccessible reach with little irrigation and developments.
- Orange River: Boegoeberg Dam to Upington
  Canal system, extensive irrigation for crops (such as grapes).
- Orange River: Upington to Vioolsdrift
  Extensive irrigation is present in the reach up to the Augrabies National Park.Extensive irrigation occurs at Blouputs, in a riparian section ‘within’ the Augrabies National Park. Downstream of Augrabies National Park, the irrigation areas are less, due to the river being inaccessible. Irrigation occurs again at Onseepkans. Between Onseepkans and Vioolsdrift, there is very little, to no irrigation.
- Orange River: Vioolsdrift to the Orange River Mouth
  Canal system and extensive irrigation occurs up to ‘Piece of Paradise’. From here, no irrigation on the South African side, to downstream of the Richtersveld National Park is present. On the Namibian side, outside of the cross-border Park, there are sections of mines and irrigation.

2.3 DELINEATION RESULTS: ORANGE RIVER

2.3.1 Natural Resource Units

The NRUs are derived from the EcoRegions and the geomorphological zones or geozones. The rationale for the delineation is provided in Table 2.2.

Table 2.2 Description and rationale for the Orange River NRUs

EcoRegion Level 2	Geozone	Rationale	Delineation
NRU Orange A			
26.03 (65%) 26.01 (32%) 26.02 (3%)	Lowland (80%) Lower Foothills (20%)	The Vaal River forms a major natural hydrological break. Mostly consists of Lowland and all within one Level 1 EcoRegion, i.e. 26.	Gariep Dam wall to the Vaal River confluence: -30.6248; 25.5058 -28.991; 23.8864
NRU Orange B			
26.01 (90%) 26.02 (10%)	Lowland (100%)	As it all falls within one geozone the EcoRegion provides a logical break (26.01).	Vaal River confluence to end of 26.01: -28.991; 23.8864 -29.6658; 22.7861

EcoRegion Level 2	Geozone	Rationale	Delineation
NRU Orange C			
26.05 (90%) 26.02 (10%)	Lowland (100%)	As it all falls within one geozone the EcoRegion provides a logical break (26.05).	End of 26.01 to end of 26.05: -29.6658; 22.7861 -288574; 22.0857
NRU Orange D			
26.05 (75%) 26.02 (23%) 29.01 (2%)	Lowland (80%) Lower foothills (17%) Upper foothills (3%)	Mostly falls within Lowland and EcoRegion 26.05. The Augrabies Falls form a natural barrier and therefore a logical break for the NRU.	End of 26.01 to Augrabies Falls: -288574; 22.0857 -28.5974; 20.3369
NRU Orange E			
28.01 (99%) 26.02 (1%)	Lowland (75%) Lower foothills (23%) Upper foothills (2%)	The EcoRegion 28.01 provides the logical break for this NRU and coincides with the change from river to estuary.	Augrabies Falls to end of 28.01 (estuary): -28.5974; 20.3369 -28.3904; 16.7772
NRU Orange F			
25.03 (100%)	Lowland (100%)	Consists of the estuary.	End of 28.01 (estuary) to sea: -28.3904; 16.7772 -28.6324; 16.4572
NRU Orange E			
28.01 (99%) 26.02 (1%)	Lowland (75%) Lower foothills (23%) Upper foothills (2%)	The EcoRegion 28.01 provides the logical break for this NRU and coincides with the Augrabies Falls (upstream border) and the change from river to estuary (i.e. downstream border).	Augrabies Falls to end of 28.01 (estuary): -28.5974; 20.3369 -28.3904; 16.7772
NRU Orange F			
25.03 (100%)	Lowland (100%)	Consists of the estuary and river where tidal fluctuations might still occur.	End of 28.01 (estuary) to sea: -28.3904; 16.7772

2.3.2 Management Resource Units

The MRUs are illustrated in Figure 2.1 while a description of the rationale for MRU selection is provided in Table 2.3.

Table 2.3 Description and rationale of the Orange River MRUs

EcoRegion Level 2	Geozone	Land cover / use	Delineation	Quat
MRU Orange A				
26.03 (100%)	Lowland (90%) Lower Foothills (10%)	Dominated by hydro-electric releases.	Gariep Dam wall to Vanderkloof Dam: -30.6248; 25.5058 -30.2898; 25.0075	D34A D34E D34G
Rationale: The section between the two dams is an isolated section. Vanderkloof Dam is a logical operational endpoint, due to the operation and the barrier effect of the Dam. An EWR site was problematic in this reach due to the constraint of ESKOM operational rules.				
MRU Orange B				

EcoRegion Level 2	Geozone	Land cover / use	Delineation	Quat
26.01 (90%) 26.02 (8%) 26.03 (2%)	Lowland (90%) Lower Foothills (10%)	Influenced by the hydro-electric releases from the dam and irrigation.	Vanderkloof Dam wall to Prieska (end of 26.01): -29.9983; 24.7917 -29.6658; 22.7861	D33A, D-H, K D71A, C-D D72A
Rationale: Prieska town forms a logical endpoint as the water level fluctuation is less significant at this point and irrigation decreases downstream. As the Vaal River is operated to not contribute significantly to the Orange River, it was not selected as an endpoint as it was for NRU B. An EWR site was problematic in this reach due to the constraint of ESKOM operational rules.				
MRU Orange C				
26.05 (96%) 26.02 (2%) 29.01 (2%)	Lowland (100%)	Mostly an inaccessible gorge with limited farming activities present.	Prieska (end of 26.01) to Boegoeberg Dam: -29.6658; 22.7861 -29.0426; 22.2008	D72A-C
Rationale: Boegoeberg Dam forms a logical endpoint to this reach due to the barrier effect, the similar operation upstream of Boegoeberg and the increase in irrigation downstream of the dam. As most of this reach is influenced by backup from Boegoeberg or is inaccessible, an EWR site was not advised.				
MRU Orange D				
26.05 (80%) 26.02 (18%) 29.01 (2%)	Lowland (80%) Lower foothills (18%) Upper foothills (2%)	Two reaches differentiated by the nature of the channel (multi-channel versus single) and Upington. Mostly irrigation, levees in the riparian zone and weirs.	Boegoeberg Dam to Augrabies Falls: -29.6658; 22.7861 -28.5974; 20.3369	D72C D73B-F D81A
Rationale: Land use is similar to the Augrabies National Park. The actual falls was selected as the end of the MRU due to its role as a natural barrier.				
RAU Orange D1				
26.05 (100%)	Lowland (100%)	No farming in riparian zone, only canal on left bank.	Boegoeberg Dam to start of irrigated lands in riparian zone: -29.6658; 22.7861 -28.9680; 22.1742	D72C D73B
Rationale: Selected as a RAU as this short reach is less disturbed than rest of section. An EWR site should be selected in this reach.				
MRU Orange E				
28.01 (98%) 26.02 (2%)	Lowland (80%) Lower foothills (17%) Upper foothills (3%)	Mixture of natural areas, National Park and irrigation.	Augrabies Falls to Vioolsdrift Weir: -28.3904; 16.7772 -28.7606; 17.7292	D81A-B, D-F D82A, D-F
Rationale: The same delineation applies as for the NRU. Irrigation limited and constrained by accessibility. An EWR site preferably in an undisturbed section, but must be accessible.				
MRU Orange F				
25.03 (100%)	Lowland (97%) Lower foothills (3%)	Extensive canals and irrigation in the floodplain zone on the left bank. Section of National Parks (both banks and wilderness areas).	Vioolsdrift Weir to Fish confluence: -28.3904; 16.7772 -28.71001; 17.1753	D82F-H D82J
Rationale: The Fish River is the end of the study area for EWR determination, i.e. the end point of this MRU.				
RAU Orange F.1				

<table>
<tr><th>EcoRegion Level 2</th><th>Geozone</th><th>Land cover / use</th><th>Delineation</th><th>Quat</th></tr>
<tr><td>25.03 (100%)</td><td>Lowland (60%)
Lower foothills (40%)</td><td>National Parks and wilderness area with some limited irrigation on right bank.</td><td>Piece of Paradise (end of irrigation) to Fish confluence:
-28.3904; 16.7772
-28.7041; 17.4681</td><td>D82J</td></tr>
<tr><td colspan="5">Rationale: There is no access on left bank after ‘Piece of Paradise’, therefore inaccessible and in better condition than the rest of the reach. An EWR site should be situated in this section, however due to inaccessibility, this was not an option.</td></tr>
<tr><td colspan="5">MRU Orange G</td></tr>
<tr><td>28.01 (70%)
25.03 (30%)</td><td>Lowland (100%)</td><td>National Parks, mining, and irrigation.</td><td>Fish confluence:
-28.7041; 17.4681
to start of the estuary
-28.56118; 16.5238</td><td>D82K-L</td></tr>
<tr><td colspan="5">Rationale: Although the landuse is vastly different, the operation is the same for this area i.e. a conduit for water through to the downstream mining areas that include irrigation and towns. It was decided therefore, that one MRU was relevant. However, for EWR determination, this section includes a critical area. This area is within the Transfrontier Park and as it is less disturbed than the downstream reaches, will include a greater variety of indicators for EWR assessment. An EWR site should then preferably be situated within this section. This would ensure that all the components of the ecosystem are catered for during EWR assessment.</td></tr>
<tr><td colspan="5">MRU Orange H (estuary)</td></tr>
<tr><td>25.03 (100%)</td><td>Lowland (100%)</td><td>Mining, irrigation, and towns.</td><td>Estuary:
-28.56118; 16.5238
to mouth.</td><td>D82L</td></tr>
<tr><td colspan="5">Rationale: As an estuary often has a different EWR than a river, this fact warrants a separate MRU from the upstream river section. The upstream border was set by the estuarine specialists as the area which, under current conditions is the section that should be managed as the estuary. It is possible that under natural conditions (with a frequently closed mouth), the estuary border could have been further upstream.</td></tr>
</table>

Figure 2.1 Orange River MRU delineation

2.4 EWR SITES

2.4.1 Criteria for site selection

EWR sites are selected through a multi-disciplinary process. This process consists of evaluating an aerial video (if available) or Google Earth images of the river, to identify a range of possible sites, and then a process of ground truthing (site visits) to make a final selection from the various possibilities. An EWR site consists of a length of river, which includes one or more cross-sections for both hydraulic and ecological purposes (modified from Louw *et al*., 1999).
EWR sites are then used for determining EWRs and it is therefore vital that:

- The sites are selected to provide as much information as possible about the variety of conditions in the river reach.
- The specialists that need to use these sites to set flow requirements for their discipline can relate to the habitat represented at the site; and
- The persons involved in selecting the sites, understand and have experience in using sites in EWR studies.

The selection of EWR sites is guided by a number of considerations which include:

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed and existing developments.
- The locality and characteristics of tributaries.
- The habitat integrity, or Present Ecological State (PES), of the different river reaches.
- The boundaries of Level II EcoRegions within the study area.
- The reaches where people depend directly on a healthy river ecosystem.
- The suitability of the sites for follow-up monitoring.
- The locality of geomorphologically representative sites.
- The habitat diversity for aquatic organisms, marginal and riparian vegetation.
- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river. Consequently, the biota dependant on this habitat (and/or perennial flow) will be adversely affected by flow modification. Pools are not considered critical habitats in perennial systems, since they are still able to function, or at least maintain life, during periods of no flow.

2.4.2 Locality and description of sites

The locality of the EWR sites within the MRUs as identified during this study is provided in Table 2.4 and 2.5 and their locality are illustrated in Figure 2.2.

Table 2.4 Locality and characteristics of EWR sites

EWR site number	EWR site name	River	Decimal degrees S	Decimal degrees E	EcoRegion (Level II)	Geozone	Altitude (m)	MRU	Quat	Gauge
EWR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EWR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland	433	MRU Orange E	D81B	D7H014
EWR O4	Vioolsdrift	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EWR O5	Sendelingsdrift	Orange	-28.0718	16.95951		Lowland	47	MRU Orange G	D82L	D8H015

The locality and characteristics of the EWR sites are provided in Table 2.5.

Table 2.5 Locality, characteristics and view of the EWR sites

Site information	EWR sites	Illustration
EWR no & name *River* *Co-ordinates* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EWR O2 Boegoeberg Orange -29.0055, 22.16225 26.05 Lowland 871 MRU Orange D, RAU D.1 D73C Blinkfontein 10 D7H008	
EWR no & name *River* *Co-ordinates* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EWR O3 Augrabies Orange -28.42867, 19.9983 28.01 Lowland 434 MRU Orange E D81B Oranjestroom 386 D7H014	

Site information	EWR sites	Illustration
EWR no & name *River* *Co-ordinates* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EWR O4 Vioolsdrift Orange -28.75525, 17.71696 28.01 Lowland 167 MRU Orange F D82F - D8H013	
EWR no & name *River* *Co-ordinates* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EWR O5Sendelingsdrift Orange -28.07180, 16.95951 Lowland 47 MRU Orange G D82L - D8H015	

The locality of the EWR sites are illustrated in Figure 2.2.

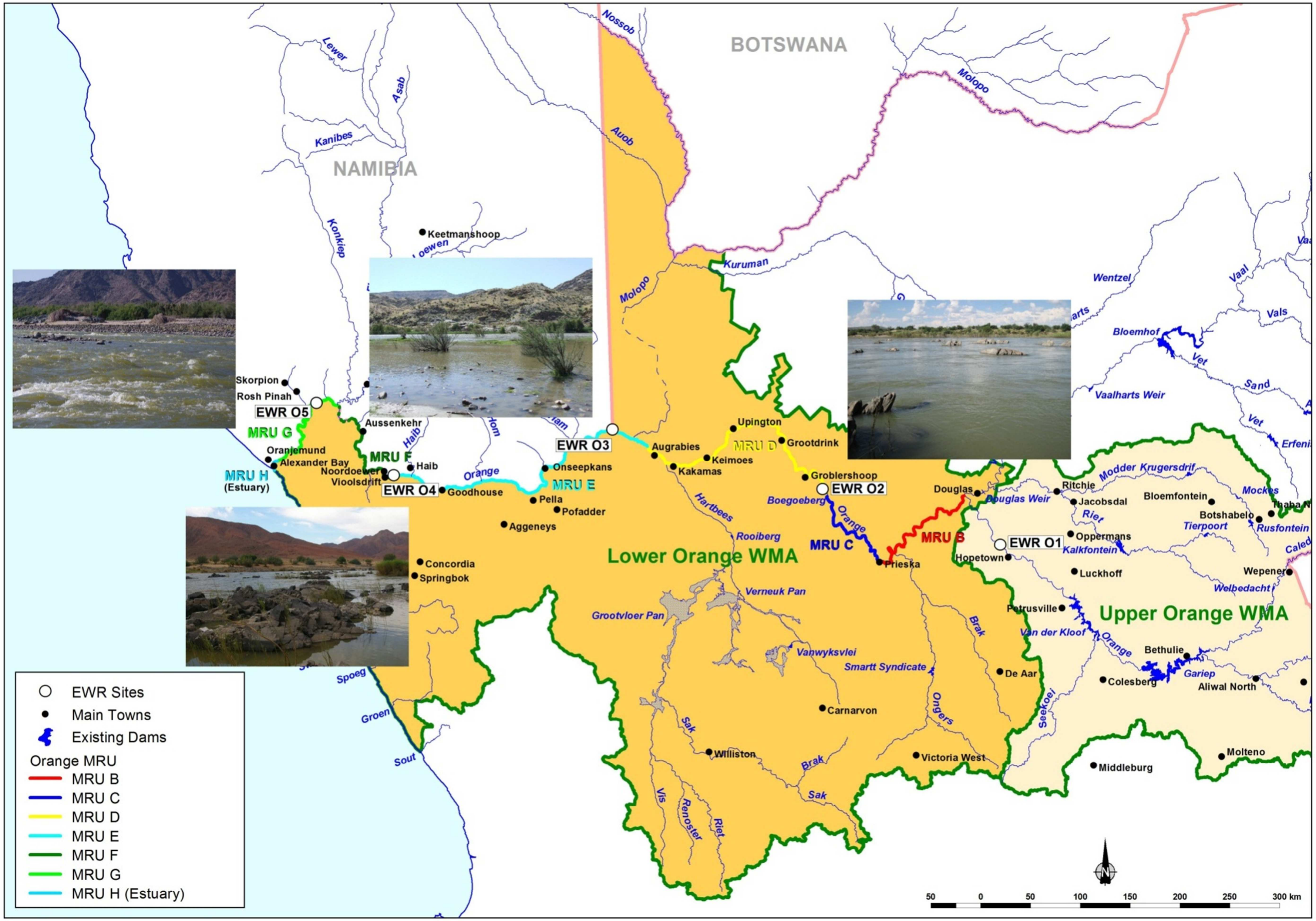


Figure 2.2 Locality and view of EWR sites in context of the RUs

2.4.3 Site suitability

The site suitability of each site was assessed and is provided in Table 2.6. The following ratings were used to describe site suitability:

- Very High suitability:4.1 – 5
- High suitability: 3.1 – 4
- Moderate suitability: 2.1 – 3
- Low suitability: 1.1 – 2
- Very Low suitability: 0 – 1

Table 2.6 Biophysical Site suitability

EWR site	Geomorph	Riparian veg	Fish	Inverts	Average	Median	Max	Min	Comments
EWRO2	3.0	3.5	3.5	4.2	3.6	3.5	4.2	3	High overall suitability with only geomorph at top range of moderate.
EWRO3	3.5	3.5	2.8	3.8	3.4	3.5	3.8	2.8	High overall suitability with only fish at top range of moderate.Fish habitat suitability is however very high and that will override the moderate suitability, which is due to the (natural) lack of good indicator species.
EWRO4	3.1	3.2	2.8	2.9	3.0	3.0	3.2	2.8	Moderate suitability with geomorph and riparian vegetation falling just within the high range.
EWRO5	3.1	3.5	3	3	3.2	3.1	3.5	3	High overall suitability due to variety of habitat, reasonable to good condition of habitat and locality at the lower end of a Transfrontier Park.

Hydraulic site suitability is also evaluated and this provides a possible indication of the expected confidence in hydraulic modelling. For example, a complex three channel site with a steep rapid will most likely result in low suitability and possibly low confidence in the results of the hydraulic modelling (this is of course ultimately dependent on the range of flow and stage measurements that are obtained to calibrate the hydraulic model with). Furthermore, some sites will have different suitability for low and high flows.

As flow requirements are set separately for low and high flows, the integrated suitability evaluation will be different for low and high flows. Geomorphology and vegetation are usually the most crucial components for setting high flows (floods) while fish and invertebrate generally determine low flows (base flows).

The suitability of the sites is therefore evaluated for both low and high flows and is compared to the corresponding suitability for low and high flow hydraulics. Due to the importance of the hydraulics, the hydraulic site suitability usually overrides the biophysical site suitability.

Overall, the EWR sites are suitable for further studies. The driving component at all sites for determining low flows is hydraulics. At all EWR sites the large and irregular nature of the bed substrate (cobbles, boulders and bedrock) and the possibility of pooled water at the cessation of flows can be problematic. However, there are reasonably uniform flow conditions at medium flows and above. There are gauging weirs near each EWR site for determining discharges except at

EWR O5. Although the new gauge constructed at Sendlingsdrif will have a short data record, this data will however improve the overall confidence in hydraulics and hydrology.

3 ESTUARINE DELINEATION RESULTS

The Lower Orange WMA include six estuaries of national importance namely the Orange, Buffels, Sout, Swartlintjies, Spoeg and Groen. These estuaries each represent a RU and were delineated according to the accepted approach outlined below. Figure 3.1 provides the location of the estuaries in the study area.

Figure 3.1 Estuaries of national importance located in the Lower Orange WMA

3.1 APPROACH

In 2010, the Estuarine Functional Zone (EFZ) – encapsulating not only the estuary water body but also supporting physical and biological processes and habitats necessary for that estuarine function and health – was listed as Notice 3 (GN R 546) under the National Environmental Management Act (NEMA), Environmental Impact Assessment (EIA) Regulations (2010). This notice stipulates that estuaries (defined by the spatial delineation of the EFZ) are "sensitive areas" that require environmental authorisation before developments within this zone may proceed. These regulations are meant to curb inappropriate future development in the estuarine functional zone.

Estuaries have little permanent habitat structure; unlike for example a rainforest, as estuarine habitats are constantly forming and eroding at various temporal and spatial scales. However, over longer time scales the total habitat area occupied by the various estuarine habitat types tend to remain more or less constant, while the precise spatial location of the various estuarine habitats is highly likely to change between resetting events (e.g. larger floods).

This relative ephemeral nature of estuarine habitat presents an assessment and planning challenge. Resource protection requires the protection of habitat and ecological and evolutionary processes. In order to do this it is important to define the space within which estuaries function to ensure their present and future health.

In this assessment an estuary is defined as ''a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or when there is little or no fluvial input an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline".

There are over 400 river outlets along the South African coast, but not all of these are deemed functional estuarine systems, i.e. representative of significant biological activity (Van Niekerk and Turpie, 2012). Since South Africa has a very variable climate and high energy coastal conditions, even systems that only open sporadically to the sea (e.g. every 4 – 10 years) are utilised by estuarine associated or dependent biota, e.g. by fish as nursery areas. The National Biodiversity Assessment (NBA) 2011 considered all permanent coastal water bodies (i.e. water bodies that do not dry out) that are sporadically, or permanently, linked to the sea as estuarine systems, e.g. the Groen and Spoeg Estuaries along the arid West coast. In contrast, ephemeral systems such as the Holgat, which dries out, are excluded from the national list (Van Niekerk and Turpie, 2012).

In 2010 mapping was undertaken for nearly 300 functional estuarine systems along the South African coastline and refined in 2015 based on vegetation (van Niekerk and Turpie 2012; Veldkornet, Adams and van Niekerk,2015). For each estuary the EFZ (estuarine ecosystem area) and open water areas were digitized using Spot 5 imagery (2008) and Google Earth. For the most part the images were relatively cloud free, but where cloudy conditions occurred on SPOT 5 images, Google images were used. The lateral boundaries include all the associated wetlands, intertidal mud and sand flats, beaches and foreshore environments that are affected by riverine or tidal flood events. The 5 m topographical contour (obtained from Chief Directorate Surveys and Mapping) was used as the boundary to delineate the EFZ. Where the 5 m contour was not available in digital format, orthophotos (1:10 000) were scanned, georeferenced and the 5 m contour was digitized. Where no orthophotos were available (e.g. Groen and Spoeg Estuaries) floodplains were mapped from Spot 5 imagery using changes in topography and vegetation types as indicators. From the estuarine functional zone delineation, spatial data such as area, length and perimeter (estuary coastline) and distance to the next system can be inferred.

The estuary mouth was taken as the downstream boundary of an estuary or, where the mouth was closed, the middle of the sand berm between the open water and the sea. The upstream boundary was determined as the limits of tidal variation or salinity penetration, whichever penetrates furthest. This is in line with recent scientific studies and the administrative definition of a South African estuary (Van Niekerk and Taljaard, 2007; DWAF, 2008b).

Wherever possible the upstream boundary was derived from the literature, expert judgment or field observations. In a number of systems, no data were available and the upper boundary was taken as the 5 m topographical contour (bearing in mind that the tidal range in South Africa is microtidal (< 2 m) and sand bars at closed estuary mouths can sometimes build up as high as + 4.5 m Mean Sea Level (MSL)). The upper boundaries were also screened against other existing spatial delineations, e.g. the KwaZulu-Natal Estuaries database (Version 1.00.02), with preference given to data from the larger scale studies. Spatially files were converted to Google Earth (KMZ formats) and mailed for review to members of the Consortium for Estuarine Research and Management (CERM) for comment.

3.2 ORANGE ESTUARY

Previous freshwater requirement studies indicated that the Orange Estuary extends from the Sir Ernest Oppenheimer Bridge to the mouth, approximately 11 km upstream (van Niekerk *et al.,* 2013a;b). Tidal variations of a few centimetres are observed during springtide at this bridge. At times the mouth is located at the northern bank and sometimes at the southern bank. In the past the location has been strongly influenced by the managed breachings of the mouth. These mouth breachings were alternatively undertaken on the north and south sides of the river, by Namdeb and Alexcor respectively. The objective was to protect low-lying infrastructure from being flooded. For the purposes of the Orange Estuary EWR study, the geographical boundaries of the systems are estimated as follows (Figure 3.2):

Downstream boundary:	28°37'58.91"S; 16°27'16.02"E (Estuary mouth)
Upstream boundary:	28°33'43.63"S; 16°31'23.02"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 3.2 Geographical boundaries of the Orange Estuary based on the EFZ

3.3 BUFFELS ESTUARY

The geographical boundaries of the Buffels Estuary are defined as follows (Figure 3.3):

Downstream boundary:	29°40'37.01"S; 17°3'4.41"E (Estuary mouth)
Upstream boundary:	29°40'18.21"S; 17°4'3.30"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 3.3 Geographical boundaries of the Buffels Estuary based on the EFZ

3.4 SWARTLINTJIES ESTUARY

The geographical boundaries of the Swartlintjies Estuary are defined as follows (Figure 3.4):

Downstream boundary:	30°15'44.33"; S 17°15'36.39"E (Estuary mouth)
Upstream boundary:	30°15'45.73"; S 17°17'8.36"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 3.4 Geographical boundaries of the Swartlintjies Estuary based on the EFZ

3.5 SPOEG ESTUARY

The geographical boundaries of the Spoeg Estuary are defined as follows (Figure 3.5):

Downstream boundary:	30°28'20.54"S; 17°21'34.07"E (Estuary mouth)
Upstream boundary:	30°28'17.92"; S 17°22'32.83"E
Lateral boundaries:	5 m contour above MSL along each bank

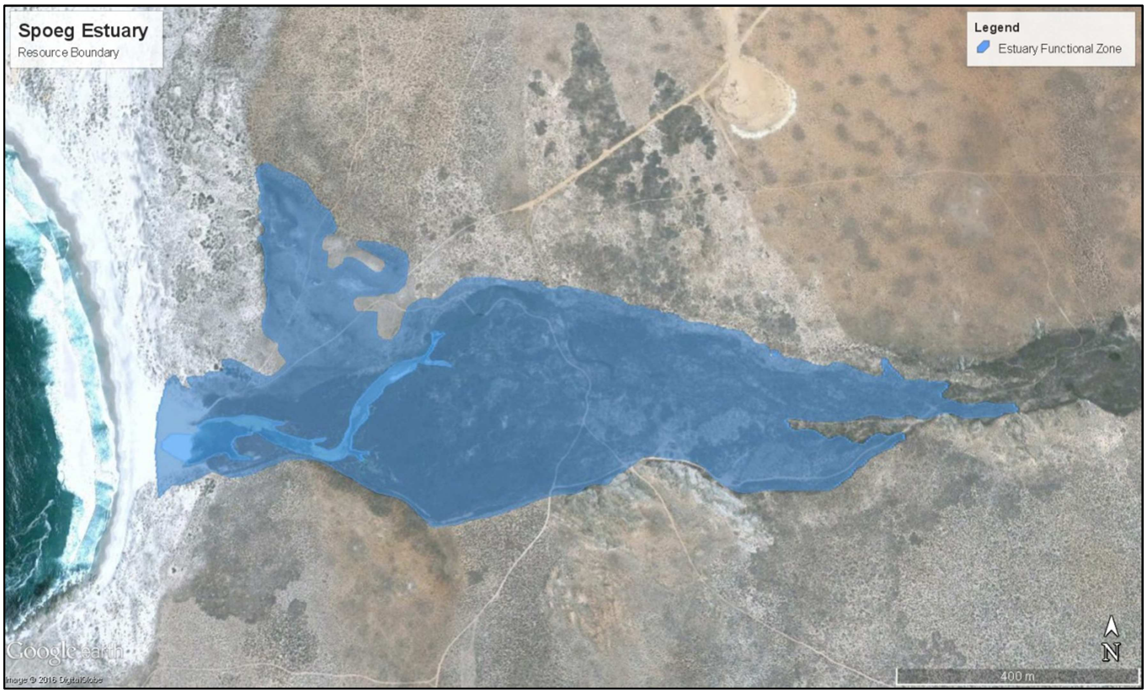


Figure 3.5 Geographical boundaries of the Spoeg Estuary based on the EFZ

3.6 GROEN ESTUARY

The geographical boundaries of the Groen Estuary are defined as follows (Figure 3.6):

Downstream boundary:	30°50'49.05"S; 17°34'35.72"E (Estuary mouth)
Upstream boundary:	30°49'38.26"S; 17°34'40.18"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 3.6 Geographical boundaries of the Groen Estuary based on the EFZ

3.7 SOUT ESTUARY

The geographical boundaries of the Sout Estuary are defined as follows (Figure 3.7):

Downstream boundary:	31°14'37.66"S; 17°50'52.55"E (Estuary mouth)
Upstream boundary:	31°12'38.88"S; 17°53'24.41"E
Lateral boundaries:	5 m contour above MSL along each bank

Figure 3.7 Geographical boundaries of the Sout Estuary based on the EFZ

4 PRIORITY WETLAND IDENTIFICATION

4.1 APPROACH

The approach taken to prioritising wetlands in the lower Orange River catchment comprised two steps: First, the spatial distribution and extent of wetlands was explored in order to define and delineate wetland RUs. Secondly, wetlands were prioritised within each wetland RU based on a matrix of various wetland characteristics and properties, which facilitated the ranking of wetlands in order to produce a list of high priority wetlands. Previous similar assessments of wetlands in a large portion of the lower Orange River catchment (Louw *et al.*, 2010b) were incorporated into the current assessment, and data from the Present Ecological State (PES) and Ecological Importance (EI) - Ecological Sensitivity (ES) (referred to as the PESEIS study) (DWS, 2014) were used to supplement prioritisation even though data were less relevant to wetlands. All assessments, including previous assessments, were at desktop level.

4.1.1 Delineation of Wetlands RUs

A combination of wetland and EcoRegion spatial data were used (Nel *et al.*, 2011; and Kleynhans *et al.*, 2005 respectively) to determine distribution patterns of different types of wetlands in different EcoRegions. Wetland spatial data comprised various datasets within the National Freshwater Ecosystem Priority Area (NFEPA) data and included Hydrogeomorphic (HGM) types based on the national wetland classification system, recognised priority wetlands and recognised wetland clusters of importance. A combination of wetland and EcoRegion spatial data was expected to facilitate the delineation of basic biophysical wetland zones or wetland RUs. Resultant wetland RUs were verified or expanded, to incorporate previous quaternary catchments denoted as highly important (Rountree in Louw *et al.*, 2010b).

4.1.1 Wetland Prioritisation

Wetland prioritisation incorporated the desktop determination and linking of socio-economic and ecological values and condition of the resource (wetlands) within each wetland RU. Wetland biodiversity and functional value, sensitivity, and risk were identified and rated within a matrix (Figure 4.1) in order to facilitate prioritisation. Ratings were done for each wetland RU and wetland unit as far as available desktop data allowed. Data from the PESEIS study (DWS, 2014) were used as a starting point and as a reference guide using Sub Quaternary (SQ) codes. Not all wetlands however, were associated with an SQ code but were nevertheless included in the evaluation. The following criteria were used to filter existing data in order to produce a list of priority wetlands at various scales:

- Quaternary catchments with moderate or high importance (Rountree in Louw *et al*., 2010b).
- Quaternary catchments where wetland integrated ecological importance was high or very high (Rountree in Louw *et al*., 2010b).
- Any wetland denoted as or associated with a RAMSAR site.
- NFEPA wetlands highlighted as important for cranes.
- NFEPA wetlands highlighted as important for amphibians.
- PESEIS data (DWS, 2014): Where EI was high, or ES was high or very high, or the PES was an A or B Category.

For each "wetland RU":	*Explanation*
Identify and rate biodiversity value	Rate specific criteria that define biodiversity value based on desktop information (e.g. RAMSAR status, Heritage sites, wetland condition, habitats for rare and endangered species (e.g. birds, amphibians, plants) for wetlands HGM units.
Identify and rate functional value	Rate specific criteria that evaluate the functional value including socio-economic value, hydrological functioning (flow regulation, maintenance of base flows) and water quality amelioration for wetland HGM units.
Identify and rate wetland sensitivity	Rate sensitivity of each wetland HGM unit using size and type. Include wetlands that undergoing rehabilitation.
Identify and rate risk to wetlands	Rate the risk to wetland HGM units based on landuse and water demand.

Figure 4.1 Explanation of criteria that were identified and rated for wetland prioritisation

4.2 RESULTS

4.2.1 Wetland RUs

NFEPA spatial data facilitated the visual delineation of broad wetland RUs supported by the distribution of wetland HGM units (types), wetland Freshwater Ecosystem Priority Areas(FEPAs) and wetland clusters (Figure 4.2). Six wetland RU areas were discerned (areas indicated in red in Figure 4.2), a seventh (not shown in Figure 4.2) which is associated with major rivers in the catchment (Orange, Molopo, Auob and Nossob), and an eighth (also not shown in Figure 4.2) which comprises wetlands associated with the Orange River mouth; a RAMSAR site. A combination of wetland types (Figure 4.3) and Level IEcoRegions resulted in the following broad wetland RUs:

1. Seeps and depressions in the northern part of the southern Kalahari; quaternary catchment D42A.
2. Depressions in the southern part of the southern Kalahari (includes some flats, seeps and unchannelled valley bottom wetlands); quaternary catchments D42B, D42D, D42E, D73E and D81C.
3. Depressions in the southern Kalahari and Ghaap Plateau; quaternary catchments D71A, D71B, D71C, C92B and C92C.
4. Depressions and unchannelled valley bottom wetlands in the eastern Nama Karoo (includes some seeps and channelled valley bottom wetlands); quaternary catchments D62A, D62B, D62C, D62D, D62E, D62F, D62G, D62H and D62J.
5. Depressions in the western Nama Karoo (includes seeps, flats and unchannelled valley bottom wetlands); quaternary catchments D53D, D53F, D53G, D54C, D54D, D54E, D54F, D55M, D57A, D57B, D57C, D57D, D57E, D58B and D58C.
6. Seep and channelled valley bottom wetlands in the southern Namaqua Highlands and southern Western Coastal Belt (includes some flats and floodplain wetlands); quaternary catchments F30A, F30B, F30C, F40B-H, F50A-G and F60A.
7. Floodplain wetlands along the Nossob, Auob, Molopo and Orange rivers.
8. Wetlands associated with the Orange River mouth (which is a RAMSAR site).

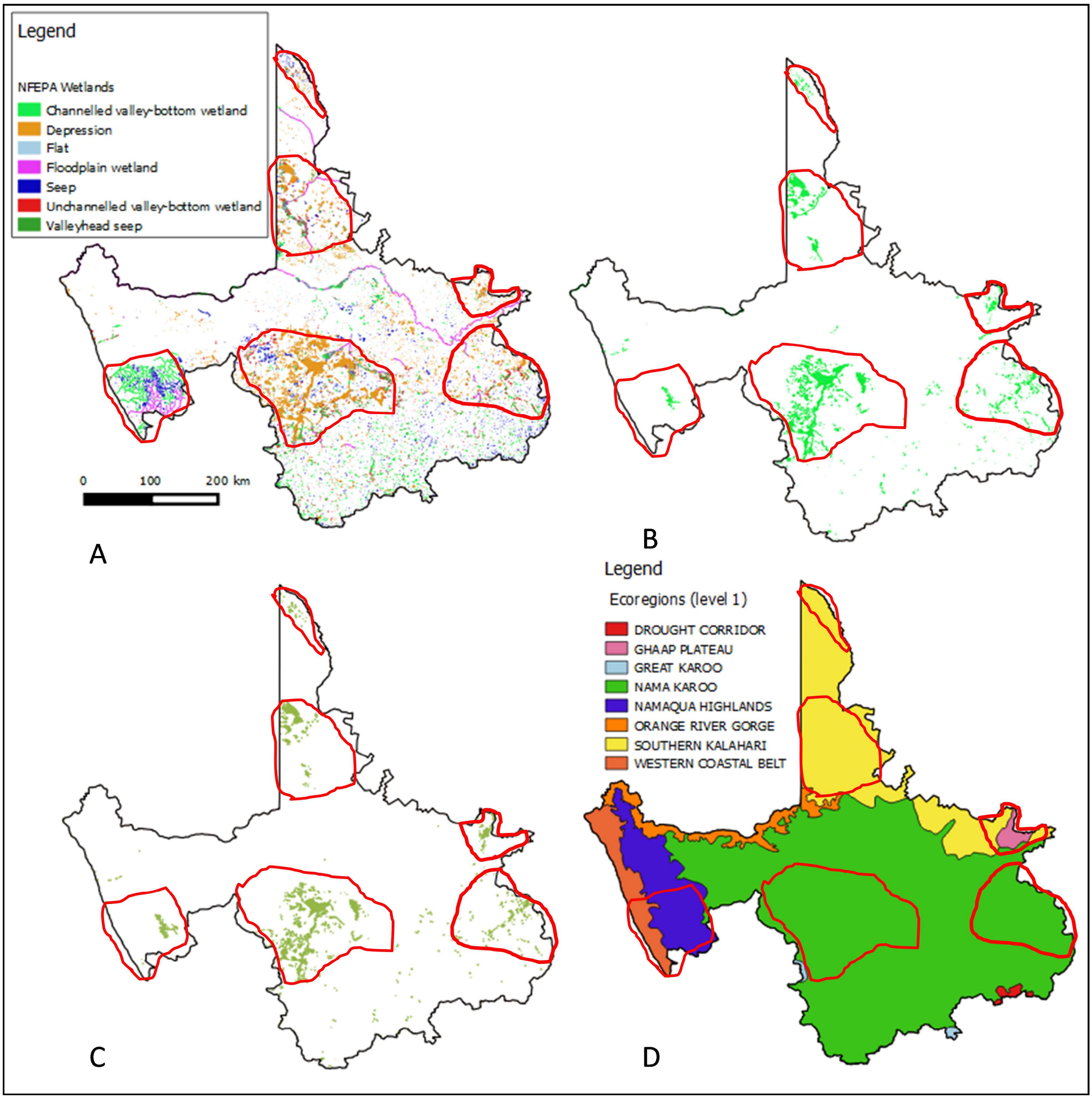


Figure 4.2 NFEPA data shown as wetland types (A), wetland FEPAs (B) and wetland clusters (C), as well as Level I EcoRegion spatial data (D). Areas indicated in red delineate proposed wetland RUs

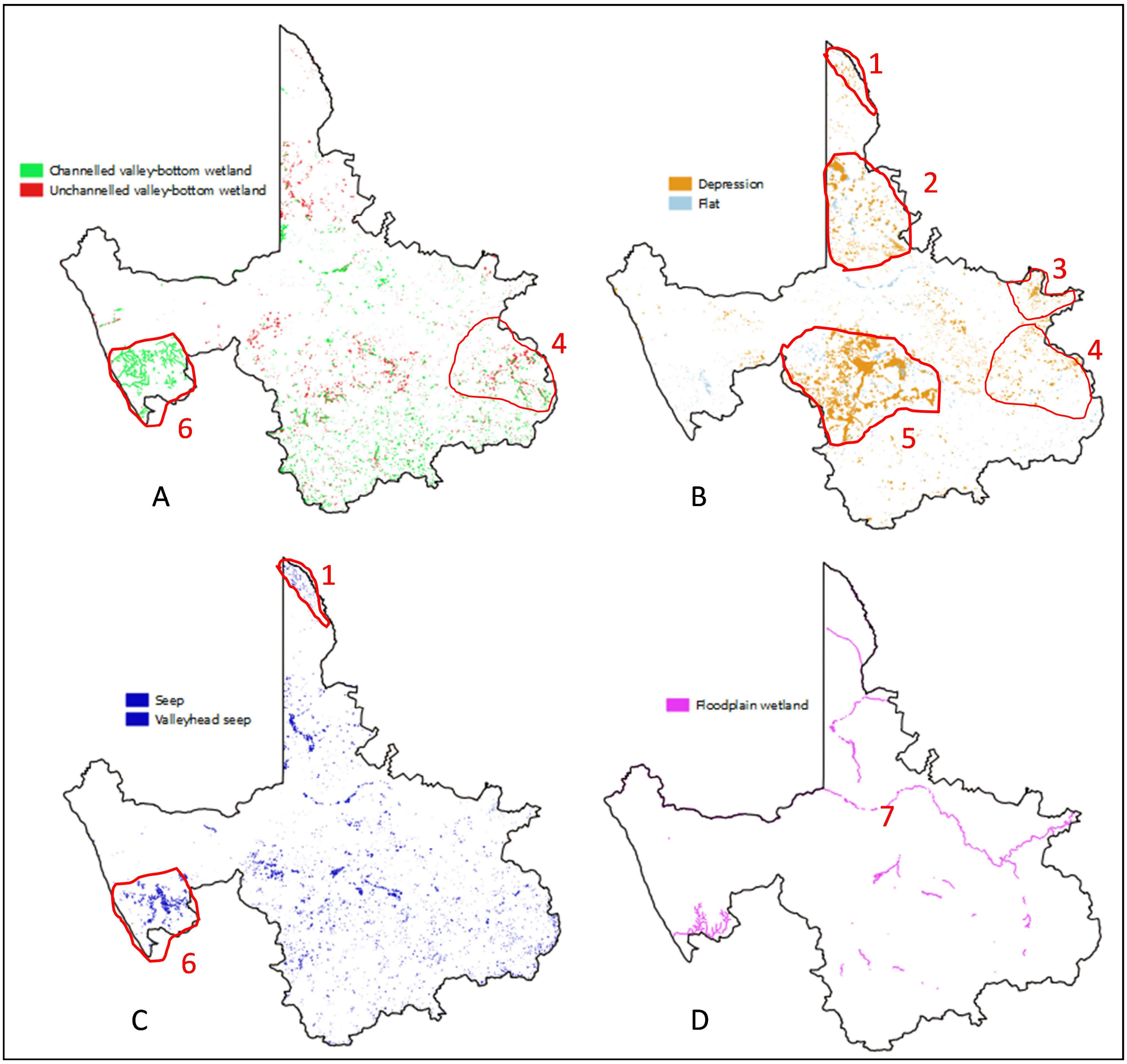


Figure 4.3 NFEPA wetland types (Nel *et al.*, 2011) with broad wetland RUs (red areas, numbered)

Comparison of these eight wetland RUs with quaternary catchments previously identified as having either moderate or high importance for wetlands (Rountree in Louw *et al.*, 2010b) showed considerable overlap (Figure 4.4). Quaternary catchments denoted as highly important for wetlands supported wetland RUs 2, 5 and 8, while quaternary catchments denoted as moderately important for wetlands supported wetland RUs 4 and 5 with additional areas surrounding and between wetland RUs 4 and 5 (Figure 4.4).

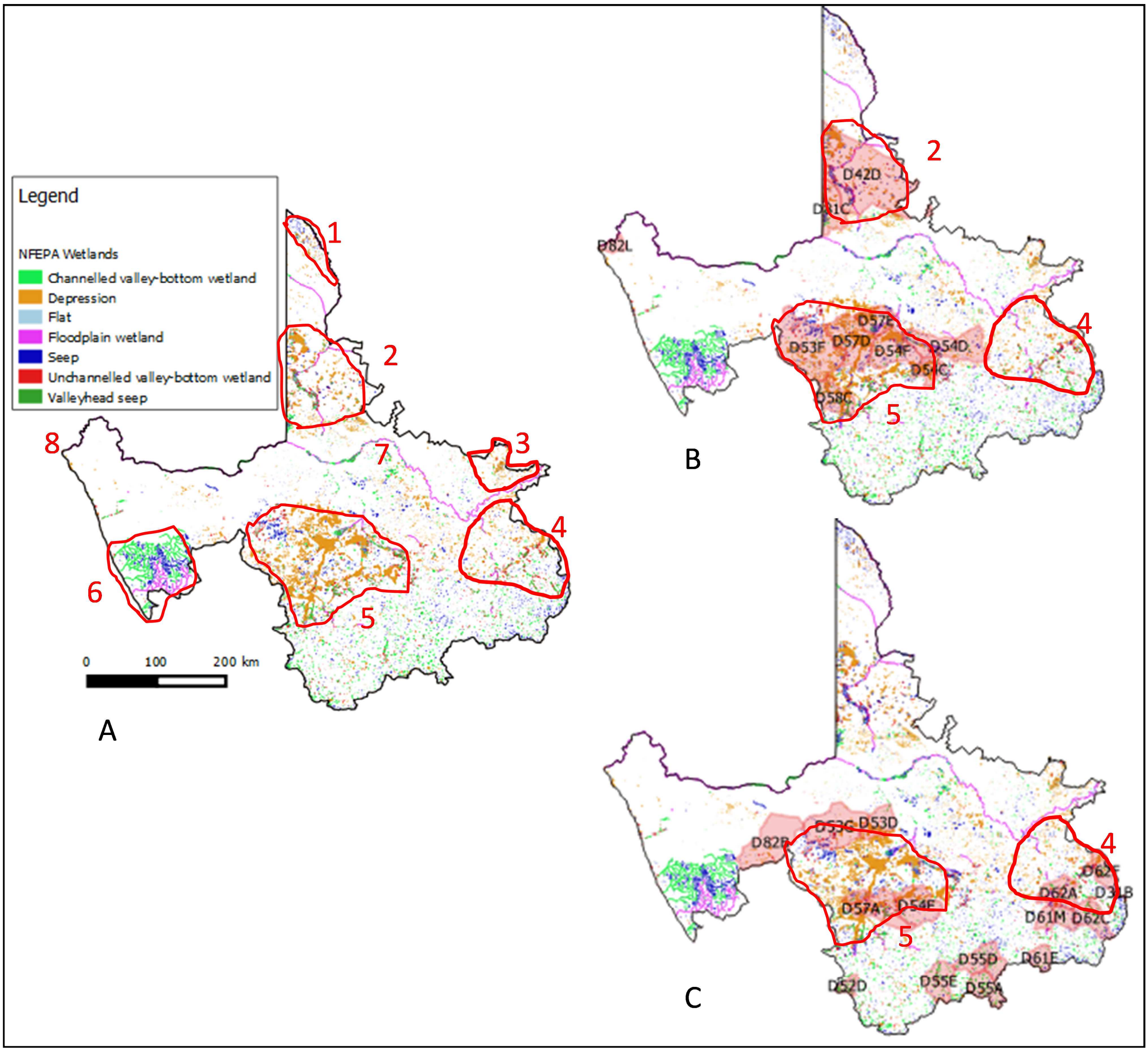


Figure 4.4 Wetland RUs (A) and quaternary catchments previously denoted as highly (B) and moderately (C) important for wetlands (Rountree in Louw *et al.*, 2010b)

4.2.2 Priority Wetlands

NFEPA Criteria

Wetland HGM units that were denoted as important for cranes or amphibians in the NFEPA database (Nel *et al.*, 2011), or were designated as RAMSAR sites or associated with a RAMSAR site, were automatically included as priority wetlands. Hence, wetlands associated with the Orange River mouth, which is a RAMSAR site, are automatically high priority. Similarly, wetlands in wetland RU 4, 5 and 6 are considered high priority due to their importance for cranes and threatened frogs respectively (Figure 4.5). Cranes also occur in wetlands between wetland RU 4 and 5 however, (Figure 4.5) but these are included in the previously assessed quaternary D54D which was considered to have a high priority (Figure 4.4).

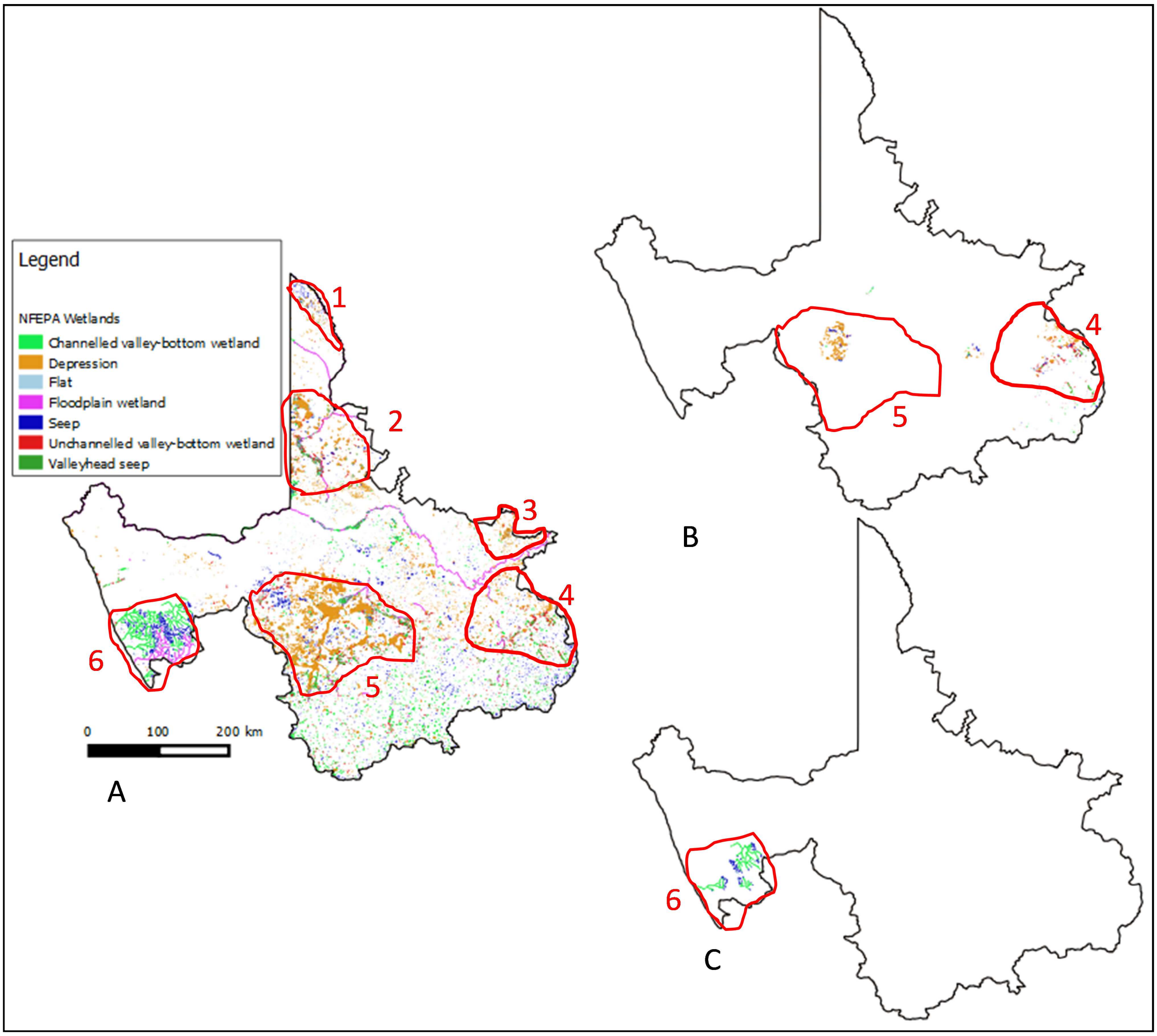


Figure 4.5 Wetland RUs (A) and NFEPA wetlands important for cranes (B) and amphibians (C)

Previous wetland assessment by Rountree

A preliminary desktop assessment by Rountree (in Louw *et al.*, 2010b) identified 12 catchments with an expected high importance for wetlands (Table 4.1 and Figure 4.4B). Only those with high importance (expected importance score = 3) were considered. These 12 quaternary catchments were subsequently assessed for PES, EI and ES in order to determine a combined assessment of wetland integrated ecological importance (Table 4.2). Results showed that wetland integrated ecological importance for all 12 quaternary catchments were either high or very high.

Table 4.1 Quaternary catchments with moderate or high expected wetland importance (taken from Rountree in Louw *et al.*, 2010b)

Catchment No.	Characteristics of the wetlands in the catchment	Expected Importance*
D31A	Moderate density of small wetlands - seeps and eroded drainage lines.	2
D31B	Moderate density of small wetlands - large valley-bottom (VB) wetlands, good condition.	2
D31C	Moderate density of small wetlands – VBs.	2
D32J	Moderate density - large VBs.	2

Catchment No.	Characteristics of the wetlands in the catchment	Expected Importance*
D33E	Some large pans, also irrigated lands.	2
D33H	Numerous small wetlands along river, also some irrigation.	2
D35C	Moderate density - seeps, VBs, but also irrigated lands.	2
D35D	Moderate density - seeps, VBs, but also irrigated lands.	2
D41A_R1	Unchannelled valley bottom wetlands - Peat system.	3
D41A_R2	Unchannelled valley bottom wetlands - Peat system.	3
D41A_R3	Unchannelled valley bottom wetlands - probably naturally more seasonal and thus less sensitive.	2
D42D	Numerous large pans and washouts - groundwater linked.	3
D52D	Large wetlands in the upper catchment.	2
D53D	Large washout VB at top of catchment.	2
D53F	High density of endorheic large pans, washouts, within the catchment.	3
D53G	Moderately high density of large pans.	2
D54C	Very large pans present.	3
D54D	Some large pans, numerous interdune wetlands present	3
D54E	Some large washout/pan areas.	2
D54F	Extremely large pan present.	3
D55A	High density of small wetlands in the upper catchment.	2
D55C	High density of small wetlands in the upper catchment.	2
D55D	High density of small wetlands in the upper catchment.	2
D55E	High density of small wetlands in the upper catchment.	2
D57A	Number of large pans.	2
D57B	Large pan.	2
D57C	Number of large pans.	2
D57D	Extremely large pans present.	3
D57E	Extremely large pans present.	3
D58C	Extremely large pans present.	3
D61E	Numerous small wetlands.	2
D61L	Numerous small wetlands.	2
D61M	Large pan and large dam.	2
D62A	Numerous large and small wetlands.	2
D62C	Some wetlands, also farm dam, washouts along river.	2
D62F	Large pan, some smaller pans.	2
D81C	Some large pans and many interdune pans - river linked.	3
D82B	Number of pans - river linked.	2

Importance score:
2 = Moderately important 3 = Highly important

Table 4.2 Integrated wetland importance (taken from Rountree, in Louw *et al.*, 2010b) for select quaternary catchments

Quaternary catchment	EIS[1]	PES	Integrated Wetland Importance
D53F	Moderate	A	VeryHigh
D54C	Moderate	B/C	High
D54D	Moderate	A	VeryHigh
D54F	High	A	VeryHigh
D57D	High	A	VeryHigh
D57E	Moderate	A	VeryHigh
D58C	High	A	VeryHigh
D81C	Moderate	A	VeryHigh
D82L	VeryHigh	C	High
D41A_R1	High	A	VeryHigh
D41A_R2	Moderate	B/C	High
D42D	High	A	VeryHigh

1 Ecological importance and Sensitivity

PESEIS

Data generated from the PESEIS study (DWS, 2014) were used to compliment the prioritising of wetlands (or areas with wetlands). Of the 1668 SQs assessed in the lower Orange River catchment, only 482 were highlighted as potentially high priority according to assessment criteria, of which 39 triggered for PES, EI and ES, 25 for PES and EI, two for PES and ES, and 48 for ES and EI. As stated before, assessment criteria were the EI was high, or ES was high or very high, or PES was A or B (Table 4.3) was considered. It is acknowledged that data presented in the PESEIS study are frequently not relevant to wetlands (except for floodplain and channelled valley bottom wetlands), but nevertheless it provides insight into the Ecological Status and condition of the area as well as potentially threatened species or habitats, and impacts at each site.

Table 4.3 Summarised data from the PESEIS study (DWS, 2014) for each SQ with applicable criteria

(Colours as follows: no colour – a single criterion triggered; Orange – two criteria triggered; Red – three criteria triggered; where criteria were the PES, EI, and ES).

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D31B-05079	D31B		Hondeblaf	B	Low	Moderate
D31D-04446	D31D			B	Low	Low
D31D-04530	D31D		Berg	B	Low	Low
D31D-04573	D31D			B	Low	Moderate
D31D-04585	D31D			B	Low	Low
D32C-06047	D32C		Klein-Seekoei	B	Moderate	Moderate
D32C-06188	D32C		Klein-Seekoei	B	Moderate	Moderate
D32E-06012	D32E		Seekoei	B	Moderate	Moderate
D32E-06160	D32E		Seekoei	B	Moderate	Moderate
D32E-06193	D32E		Seekoei	B	Low	Low

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D32J-05435	D32J			B	Moderate	
D32J-05449	D32J			B	Moderate	
D33G-04051	D33G	7	Orange	C	High	High
D33K-03723	D33K	7	Orange	C	High	Moderate
D34A-05196	D34A		Orange	C	High	High
D34A-05282	D34A		Orange	E	Moderate	High
D34E-05154	D34E		Orange	C	High	High
D34E-05280	D34E		Orange	C	Moderate	High
D34F-05174	D34F		Orange	C	High	High
D34G-04986	D34G		Orange	C	High	High
D35G-05732	D35G			B	Low	Low
D35G-05789	D35G			B	Low	Low
D35G-05790	D35G			B	Moderate	Low
D41A-01138	D41A		Molopo	D	High	High
D41A-01251	D41A			B	Moderate	VeryLow
D41B-01239	D41B		Mareetsane	B	Moderate	Low
D41B-01279	D41B		Setlagole	B	Moderate	VeryLow
D41G-02041	D41G			B	Moderate	Low
D41G-02054	D41G			B	Moderate	Moderate
D41J-02536	D41J		Ga-Mogara	B	Moderate	Low
D41J-02558	D41J		Ga-Mogara	B	Low	Low
D41J-02531	D41J		Ga-Mogara	B	Moderate	VeryLow
D41K-02141	D41K		Ga-Mogara	B	Moderate	VeryLow
D41L-02333	D41L		Kuruman	A	Moderate	VeryLow
D41M-01756	D41M		Kuruman	B	Moderate	VeryLow
D42A-01082	D42A	7 (1)	Nossob		High	VeryLow
D42C-01754	D42C	7 (2)	Molopo	B	Moderate	VeryLow
D42C-01940	D42C	7 (2)	Molopo	A	Moderate	VeryLow
D42D-01899	D42D	7 (2)	Molopo	A	Moderate	VeryLow
D42D-02283	D42D	7 (2)	Molopo	B	Moderate	Low
D42E-02738	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D42E-02812	D42E	7 (2)	Molopo	B	Moderate	VeryLow
D42E-02913	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D42E-03047	D42E	7 (2)	Molopo	B	Moderate	VeryLow
D42E-03060	D42E	7 (2)	Molopo	B	Moderate	VeryLow
D42E-03064	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D42E-03065	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D42E-03087	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D42E-03103	D42E	7 (2)	Molopo	A	Moderate	VeryLow
D51B-07105	D51B			B	Moderate	Moderate
D51C-06793	D51C		Boesmanfontein se Laagte	B	Moderate	Low
D52B-07131	D52B		Klein-Vis	B	Moderate	Low
D52B-07250	D52B			B	Low	Low
D52C-06927	D52C			B	Moderate	Low
D52F-06327	D52F		Rooivlak se Laagte		Moderate	High

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D53A-04100	D53A		Mottels	B	Moderate	Low
D53A-04126	D53A			A	Moderate	Low
D53A-04140	D53A		Mottels	B	Moderate	Low
D53A-04197	D53A		Hartbees	B	Moderate	Low
D53A-04238	D53A			B	Moderate	Low
D53A-04285	D53A		Hartbees	B	Moderate	Moderate
D53A-04286	D53A			B	Moderate	Low
D53A-04303	D53A		Hartbees	B	Moderate	Low
D53A-04309	D53A		Lat	B	Moderate	Low
D53A-04345	D53A		Lat	B	Moderate	Low
D53A-04382	D53A		Hartbees	B	Moderate	Low
D53A-04387	D53A		Hartbees	B	Moderate	Moderate
D53B-03892	D53B		Rugseers	B	Moderate	Low
D53B-03948	D53B		Rooiput se Leegte	B	Moderate	Low
D53B-03972	D53B		Rugseers	B	Moderate	Low
D53B-03978	D53B		Rooiput se Leegte	B	Moderate	Low
D53C-03648	D53C		Sandnoute	B	Moderate	Low
D53C-03682	D53C		NRougas se Loop	B	Moderate	Low
D53C-03807	D53C		Hartbees	B	Moderate	Low
D53C-04093	D53C		Driekop se	B	Moderate	Low
D53D-03879	D53D	5	Tuins	B	Moderate	Low
D53D-03909	D53D	5		B	Moderate	Low
D53D-03959	D53D	5	Tuins	B	Moderate	Low
D53D-04022	D53D	5	Tuins	B	Moderate	Low
D53D-04031	D53D	5	Graafwaters	B	Moderate	Low
D53E-03557	D53E		Hartbees	B	Moderate	Low
D53E-03639	D53E		Hartbees	B	Moderate	Low
D53E-03744	D53E		Hartbees	B	Moderate	Low
D53E-03791	D53E		Hartbees	B	Moderate	Low
D53E-03816	D53E		Hartbees	B	Moderate	Low
D53F-05096	D53F	5			High	
D53G-03944	D53G	5	Brulkolk se Holte		Low	High
D53G-04028	D53G	5	Sout	B	Moderate	Low
D53H-03564	D53H		Sout	A	Moderate	Low
D53H-03651	D53H		Sout	B	Moderate	Low
D53H-03836	D53H		Sout	B	Moderate	Low
D53H-03897	D53H		Sout	B	Moderate	Low
D53H-04030	D53H		Sout	B	Moderate	Low
D53J-03458	D53J		Hartbees	B	Moderate	Low
D54A-05272	D54A		Holsloot	B	Moderate	Low
D54A-05287	D54A			B	Moderate	Low
D54A-05418	D54A		Holsloot	B	Moderate	Low
D54A-05427	D54A		Kalksloot	B	Moderate	Low
D54A-05434	D54A		Holsloot	B	Moderate	Low
D54A-05500	D54A		Kalksloot	B	Low	Low

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D54B-05217	D54B			B	Moderate	Low
D54B-05266	D54B		Bitterpoortloop	B	Low	Low
D54B-05278	D54B		Carnarvonleegte	B	Moderate	Low
D54B-05293	D54B		Carnarvonleegte	B	Low	Low
D54B-05549	D54B			B	Moderate	Low
D54B-05661	D54B		Carnarvonleegte	B	Moderate	Low
D54D-04630	D54D	5	Carnarvonleegte	B	Moderate	Low
D54E-05188	D54E	5	Ysterdoringspan	B	Low	Low
D54E-05199	D54E	5	Ysterdoringspan	B	Moderate	Low
D54E-05283	D54E	5	Ysterdoringspan	B	Moderate	Low
D54E-05310	D54E	5	Ysterdoringspan	B	Moderate	Low
D54E-05383	D54E	5		B	Moderate	Low
D54E-05406	D54E	5		B	Moderate	Low
D54E-05555	D54E	5		B	Moderate	Low
D54E-05632	D54E	5			High	
D54E-05637	D54E	5			High	
D54F-04776	D54F	5	Hartogskloof	B	Moderate	Low
D54F-05004	D54F	5	Hartogskloof	B	Moderate	Low
D54G-04307	D54G		Brandholteloop	B	Moderate	Low
D54G-04407	D54G		Hartbees	B	Moderate	Low
D54G-04474	D54G		Keelafsnyleegte	B	Moderate	Low
D54G-04527	D54G		Hartbees	B	Moderate	Low
D54G-04607	D54G		Hartbees	B	High	Low
D55A-07234	D55A		Sak	B	Moderate	Low
D55B-06615	D55B		Sak	B	Moderate	Low
D55B-06697	D55B			B	Moderate	Low
D55B-06847	D55B		Damfontein se		Low	High
D55B-06938	D55B				Low	High
D55B-06952	D55B		Damfontein se		Moderate	High
D55B-07043	D55B		Damfontein se		Moderate	High
D55B-07076	D55B				Moderate	High
D55C-06596	D55C			B	Moderate	Low
D55D-06547	D55D				Low	High
D55D-06570	D55D				Moderate	High
D55D-06593	D55D				Moderate	High
D55E-06496	D55E		Sak	B	Moderate	VeryLow
D55E-06502	D55E		Sak	B	Moderate	VeryLow
D55E-06582	D55E		Sak	B	Moderate	VeryLow
D55E-06614	D55E				Moderate	High
D55E-06663	D55E		Sout	B	Moderate	VeryLow
D55E-06713	D55E		Sout	B	Moderate	Low
D55E-06728	D55E				Low	High
D55E-06729	D55E		Sout	B	Moderate	Low
D55E-06825	D55E		Sout	B	Moderate	Low
D55E-06854	D55E		Sout	B	Moderate	Low

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D55F-05911	D55F		Kareebergleegte	B	Low	VeryLow
D55F-05969	D55F		Reitzvilleleegte	B	Moderate	VeryLow
D55F-06209	D55F		Kareebergleegte	B	Moderate	VeryLow
D55H-06259	D55H		Sak	B	Moderate	VeryLow
D55H-06358	D55H		Sak	B	Moderate	VeryLow
D55H-06381	D55H		Sak	B	Moderate	VeryLow
D55H-06401	D55H		Sak	B	Moderate	VeryLow
D55J-05900	D55J			B	Moderate	VeryLow
D55J-06120	D55J		Sak	B	Moderate	VeryLow
D55J-06212	D55J		Beeswaterleegte	B	Low	VeryLow
D55J-06284	D55J		Sak	B	Moderate	VeryLow
D55K-06347	D55K		Klein-Sak	B	Moderate	VeryLow
D55K-06357	D55K		Klein-Sak	B	Low	VeryLow
D55K-06382	D55K				Low	High
D55K-06537	D55K				Low	High
D55K-06572	D55K		Hongerkloof se Leegte	B	Low	VeryLow
D55K-06618	D55K		Ploegfontein se Leegte		Low	High
D55K-06631	D55K		Ploegfontein se Leegte		Low	High
D55M-05851	D55M		Sak	B	Moderate	VeryLow
D55M-06022	D55M		Sak	B	Moderate	VeryLow
D55M-06054	D55M		Sak	B	Moderate	VeryLow
D56A-07624	D56A			B	Moderate	Low
D56A-07650	D56A			B	Moderate	VeryLow
D56A-07652	D56A		Portugals	B	Moderate	VeryLow
D56B-07416	D56B				Moderate	VeryHigh
D56B-07428	D56B		Riet	B	Moderate	Low
D56C-07254	D56C		Riet	B	Moderate	Low
D56C-07304	D56C			B	Moderate	Low
D56C-07325	D56C		Riet	B	Moderate	Low
D56C-07342	D56C			B	Moderate	Low
D56C-07389	D56C			B	Moderate	Low
D56D-06822	D56D		Riet	B	Moderate	Low
D56D-07081	D56D		Riet	B	Moderate	Low
D56D-07091	D56D		Riet	B	Moderate	Low
D56E-07308	D56E		Klein-Riet	B	Moderate	Low
D56E-07320	D56E		Spinnekopkraal se	B	Moderate	VeryLow
D56E-07337	D56E				Low	High
D56E-07456	D56E				Low	VeryHigh
D56E-07461	D56E				Moderate	High
D56F-06969	D56F		Nuweveld		Low	High
D56F-07018	D56F		Klein-Riet	B	Moderate	Low
D56F-07049	D56F		Klein-Riet	B	Moderate	VeryLow
D56F-07050	D56F		Klein-Riet	B	Moderate	Low
D56F-07067	D56F		Karee		High	Moderate
D56F-07074	D56F		Klein-Riet	B	Moderate	VeryLow

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D56F-07144	D56F		Klein-Riet	B	Moderate	Low
D56F-07151	D56F				Moderate	VeryHigh
D56G-06780	D56G				Low	High
D56G-06917	D56G		Klein-Riet	B	Moderate	Low
D56G-06932	D56G		Klein-Riet	B	Moderate	VeryLow
D56G-06940	D56G				Moderate	High
D56H-06719	D56H		Riet	B	Moderate	VeryLow
D56J-06597	D56J		Riet	B	Moderate	VeryLow
D57A-05497	D57A	5	Sak	B	Low	VeryLow
D57C-05215	D57C	5	Sak	B	Moderate	VeryLow
D57C-05254	D57C	5	Sak	B	Moderate	VeryLow
D57D-04972	D57D	5	Sak	B	Moderate	VeryLow
D57D-05050	D57D	5	Sak	B	Moderate	VeryLow
D57D-05090	D57D	5	Sak	B	Moderate	VeryLow
D57D-05127	D57D	5	Sak	B	Moderate	VeryLow
D57E-04338	D57E	5	Bosduiflaagte	B	Moderate	VeryLow
D57E-04374	D57E	5	Sak	B	Moderate	VeryLow
D57E-04423	D57E	5	Sak	B	Moderate	VeryLow
D57E-04534	D57E	5	Sak	B	Moderate	VeryLow
D57E-04535	D57E	5	Sak	B	Moderate	VeryLow
D61A-06166	D61A		Ongers	B	Moderate	Moderate
D61A-06245	D61A		Ongers	B	Moderate	Moderate
D61A-06277	D61A				High	Moderate
D61C-05866	D61C	4	Ongers	B	Moderate	Low
D61C-05912	D61C	4	Ongers	B	Moderate	Low
D61D-06156	D61D		Brakpoort	B	Low	Low
D61D-06352	D61D		Brakpoort	B	Moderate	Moderate
D61E-06276	D61E			B	Moderate	Low
D61E-06470	D61E				High	Low
D61F-06222	D61F			B	Moderate	Moderate
D61F-06261	D61F			B	Moderate	Moderate
D61G-06077	D61G				High	Moderate
D61G-06153	D61G		Klein Brak	B	Moderate	Low
D61H-05878	D61H		Brak	B	Moderate	Low
D61H-05963	D61H		Brak	B	Moderate	Low
D61H-05974	D61H		Brak	B	Moderate	Low
D61H-05998	D61H		Brak	B	Moderate	Low
D61J-05654	D61J		Groen	B	Moderate	Low
D61J-05758	D61J		Groen	B	Moderate	Low
D61J-05883	D61J			B	High	Low
D61J-05921	D61J			B	Moderate	Low
D61J-05924	D61J		Groen	B	Moderate	Low
D61J-05939	D61J		Groen	B	Moderate	Low
D61K-05639	D61K	4	Groen	B	Moderate	Low
D61K-05678	D61K	4			High	Moderate

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D61M-05417	D61M	4	Ongers	B	Low	Low
D61M-05469	D61M	4	Ongers	B	Moderate	Low
D61M-05749	D61M	4	Ongers	B	Moderate	Low
D62D-05183	D62D	4	Brak	B	Moderate	Low
D62D-05227	D62D	4	Brak	B	Moderate	Low
D62D-05332	D62D	4	Brak	B	Low	Low
D62E-04938	D62E	4	Hondeblafspruit		High	Moderate
D62F-04509	D62F	4			High	Moderate
D62G-04755	D62G	4	Brak	B	Moderate	Low
D62J-04231	D62J	7 (4)	Brak	B	High	Low
D62J-04430	D62J	7 (4)	Brak	B	Moderate	Low
D71A-03610	D71A	7 (3)	Orange	D	High	High
D71A-03865	D71A	7 (3)	Orange	C	High	High
D71A-03870	D71A	7 (3)	Orange	D	Moderate	High
D71C-03874	D71C	7 (3)	Orange	D	High	High
D71D-04003	D71D	7	Orange	C	Moderate	High
D71D-04075	D71D	7	Orange	C	High	High
D71D-04124	D71D	7	Orange	C	High	High
D71D-04165	D71D	7	Orange	C	High	High
D71D-04218	D71D	7	Orange	C	Moderate	High
D72A-04169	D72A	7	Orange	C	Moderate	High
D72A-04276	D72A	7	Orange	C	High	High
D72A-04313	D72A	7	Orange	D	Moderate	High
D72B-03941	D72B	7	Orange	C	High	High
D72B-04035	D72B	7	Orange	C	High	High
D72B-04059	D72B	7	Orange	C	Moderate	High
D72B-04070	D72B	7	Orange	B	High	High
D72B-04106	D72B	7	Orange	C	Moderate	High
D72B-04158	D72B	7	Orange	C	High	High
D72B-04268	D72B	7	Orange	C	High	High
D72B-04273	D72B	7	Orange	C	High	High
D72C-03720	D72C	7	Orange	C	High	High
D72C-03877	D72C	7	Orange	B	High	High
D72C-03891	D72C	7	Orange	C	Moderate	High
D72C-03924	D72C	7	Orange	B	High	High
D72C-04000	D72C	7	Orange	C	Moderate	High
D73B-03617	D73B	7	Orange	C	High	High
D73B-03630	D73B	7	Orange	C	High	High
D73D-03158	D73D	7	Orange	D	Moderate	High
D73D-03202	D73D	7	Orange	D	Moderate	High
D73D-03234	D73D	7	Orange	D	Moderate	High
D73D-03267	D73D	7	Orange	D	High	High
D73E-02740	D73E	7 (2)	Orange	D	Moderate	High
D73E-02957	D73E	7 (2)	Orange	D	Moderate	High
D73E-03072	D73E	7 (2)	Orange	D	Moderate	High

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D73F-03000	D73F	7	Orange	D	Moderate	High
D73F-03032	D73F	7	Orange	D	Moderate	High
D73F-03151	D73F	7	Orange	E	Moderate	High
D73F-03193	D73F	7	Orange	D	Moderate	High
D73F-03235	D73F	7	Orange	D	Moderate	High
D73F-03291	D73F	7	Orange	D	Moderate	High
D73F-03297	D73F	7	Orange	C	Moderate	High
D73F-03327	D73F	7			Moderate	High
D73F-03347	D73F	7	Orange	E	Moderate	High
D73F-03358	D73F	7	Orange	D	Moderate	High
D73F-03393	D73F	7	Orange	D	Moderate	High
D81A-03148	D81A	7	Orange	B	High	High
D81A-03174	D81A	7	Kamkierie		High	Low
D81A-03199	D81A	7	Orange	C	High	High
D81A-03239	D81A	7	Orange	C	High	High
D81A-03269	D81A	7	Orange	D	Moderate	High
D81A-03311	D81A	7	Orange	D	Moderate	High
D81A-03367	D81A	7	Orange	D	Moderate	High
D81B-03079	D81B	7	Orange	C	Moderate	High
D81B-03130	D81B	7	Orange	C	Moderate	High
D81B-03140	D81B	7	Orange	C	Moderate	High
D81D-03093	D81D	7	(only Orange)	C	High	High
D81D-03118	D81D	7	(only Orange)	C	High	High
D81D-03164	D81D	7	(only Orange)	B	High	High
D81E-03200	D81E	7	(only Orange)	C	High	High
D81E-03349	D81E	7	(only Orange)	C	High	High
D81F-03445	D81F	7	(only Orange)	B	High	High
D81G-03731	D81G	7	T_Goob se Laagte	B	Moderate	Moderate
D82A-03580	D82A	7	(only Orange)	B	High	High
D82A-03588	D82A	7	(only Orange)	C	High	High
D82A-03595	D82A	7	(only Orange)	B	High	High
D82A-03607	D82A	7	Fontein se	B	High	Moderate
D82A-03653	D82A	7	Orange	C	High	High
D82A-03675	D82A	7	(only Orange)	B	High	High
D82D-03653	D82D	7	(only Orange)	C	High	High
D82D-03772	D82D	7	Karis		High	Low
D82E-03540	D82E	7	(only Orange)	B	High	High
D82E-03546	D82E	7	(only Orange)	B	High	High
D82F-03531	D82F	7	Orange	C	High	High
D82G-03477	D82G	7	(only Orange)	C	High	High
D82G-03508	D82G	7	(only Orange)	B	High	High
D82G-03522	D82G	7	Orange	C	High	High
D82H-03279	D82H	7	(only Orange)	B	High	High
D82H-03355	D82H	7	(only Orange)	B	High	High
D82J-02869	D82J	7	(only Orange)	C	High	High

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
D82J-02886	D82J	7	Orange	C	High	High
D82J-03022	D82J	7	(only Orange)	C	High	High
D82J-03026	D82J	7	(only Orange)	C	High	High
D82J-03124	D82J	7	(only Orange)	C	High	High
D82K-00000	D82K	7	Orange	B	High	High
D82K-02994	D82K	7	(only Orange)	B	High	High
D82K-03084	D82K	7	(only Orange)	C	High	High
D82K-03166	D82K	7	(only Orange)		Moderate	High
D82K-03175	D82K	7	Orange	B	High	High
D82L-03166	D82L	7(8)	Orange	C	High	High
D82L-03238	D82L	7(8)	(only Orange)	C	High	High
D82L-03298	D82L	7(8)	ORANGE	C	High	High
D82L-03314	D82L	7(8)	(only Orange)	C	High	High
F10A-03321	F10A		Gaigas	B	High	High
F10A-03345	F10A			B	High	High
F10A-03402	F10A		Kook	B	High	High
F10A-03414	F10A			B	High	High
F10A-03454	F10A		Gaigas	B	High	High
F10A-03456	F10A		Kook	B	High	High
F10A-03520	F10A		Gaigas	B	High	High
F10A-03534	F10A		Holgat	B	High	High
F10A-03573	F10A		Modderfontein	B	High	High
F10A-03578	F10A		Holgat	B	High	Moderate
F10B-03391	F10B		Holgat	B	High	Moderate
F20A-03743	F20A				High	Low
F20A-03818	F20A				High	Low
F20A-03824	F20A				High	Low
F20A-03912	F20A				High	Low
F20A-03983	F20A			B	High	Low
F20A-04038	F20A			B	High	Low
F20A-04090	F20A			B	Moderate	Low
F20A-04112	F20A				High	Low
F20B-04001	F20B				High	Low
F20B-04053	F20B			B	High	Low
F20B-04092	F20B				High	Low
F20B-04160	F20B			B	Moderate	Low
F20B-04183	F20B			B	Moderate	Low
F20C-03777	F20C			B	High	Low
F20C-03863	F20C				High	Low
F20C-03866	F20C			B	High	Low
F20C-03902	F20C		Kamma	B	High	Low
F20C-04012	F20C		Kamma	B	High	Low
F20E-04290	F20E		Kwaganap	C	High	Low
F30A-04774	F30A	6			Moderate	High
F30A-04782	F30A	6	Buffels	B	Moderate	Low

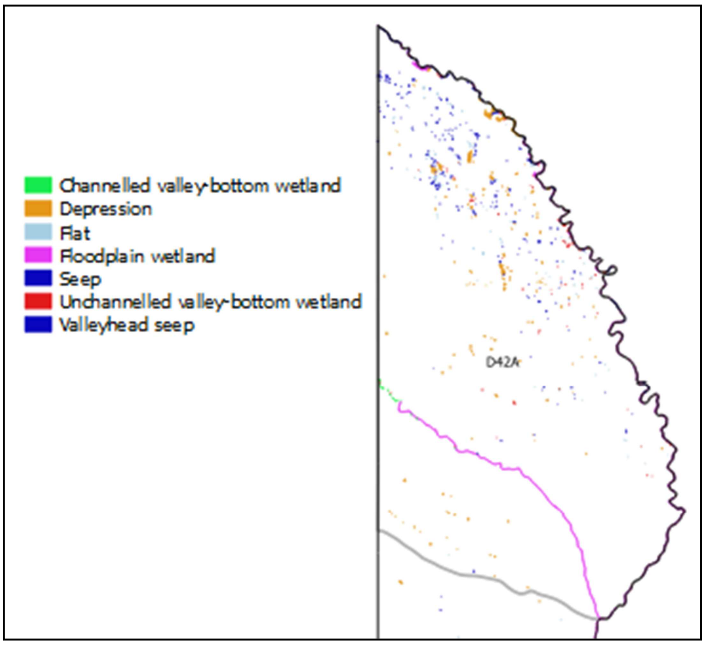
SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
F30A-04803	F30A	6	Buffels	B	Moderate	Moderate
F30A-04839	F30A	6	Buffels	B	Moderate	Low
F30A-04851	F30A	6			High	
F30A-04858	F30A	6		B	Moderate	Low
F30A-04894	F30A	6	Buffels	B	Moderate	Low
F30A-04921	F30A	6	Gasab		High	
F30A-04943	F30A	6	Buffels	B	Moderate	Low
F30A-05001	F30A	6	Buffels	D	High	Moderate
F30A-05047	F30A	6	Buffels	B	Moderate	Low
F30A-05054	F30A	6	Buffels	B	Moderate	Low
F30A-05069	F30A	6	Papkuils	B	Moderate	Moderate
F30A-05077	F30A	6	Buffels	B	Moderate	Low
F30A-05084	F30A	6	Klein-Nou	C	High	Moderate
F30A-05099	F30A	6			Moderate	VeryHigh
F30A-05101	F30A	6			High	High
F30B-04507	F30B	6	Kourkamma se Holte		Moderate	High
F30B-04525	F30B	6			Moderate	High
F30B-04570	F30B	6			Moderate	High
F30B-04578	F30B	6	Brak	B	Moderate	Moderate
F30B-04610	F30B	6	Brak	A	Moderate	Moderate
F30B-04650	F30B	6	Brak	B	Moderate	Moderate
F30B-04741	F30B	6	Brak	B	Moderate	Moderate
F30B-04742	F30B	6	Brak	B	Moderate	Low
F30C-04634	F30C	6	Buffels	B	Moderate	Low
F30C-04705	F30C	6	Brand	B	Moderate	Low
F30C-04771	F30C	6	Buffels	B	Moderate	Low
F30C-04822	F30C	6	Buffels	B	Moderate	Low
F30C-04823	F30C	6	Buffels	B	Moderate	Low
F30C-04825	F30C	6	Rooiplatklip		High	
F30C-04829	F30C	6	Buffels	A	Moderate	Low
F30C-04855	F30C	6	Ybeep	B	Moderate	Low
F30C-04900	F30C	6	Wolwepoort	B	Moderate	Low
F30C-05008	F30C	6	Wolwepoort	B	Moderate	Low
F30D-04502	F30D		Eselsfontein	C	High	Low
F30D-04598	F30D		Buffels	B	Moderate	Low
F30D-04684	F30D		Buffels	A	High	Low
F30D-04891	F30D		Buffels	A	Moderate	Low
F30E-04042	F30E		Doring	C	High	Low
F30E-04230	F30E				High	Moderate
F30E-04314	F30E		Skaap	B	High	Low
F30E-04317	F30E		Doring	B	Moderate	Low
F30E-04381	F30E		Skaap	A	High	Low
F30E-04417	F30E				High	Moderate
F30E-04444	F30E		Skaap	B	Moderate	Low
F30F-04163	F30F				High	Moderate

SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
F30F-04166	F30F		Stry		High	
F30F-04179	F30F				High	Moderate
F30F-04255	F30F		Stry		High	Moderate
F30F-04348	F30F		Buffels	B	Moderate	Low
F30F-04406	F30F				High	Moderate
F30F-04436	F30F		Buffels	B	Moderate	Low
F30G-04318	F30G		Buffels	B	Moderate	Low
F30G-04371	F30G				Moderate	High
F30G-04409	F30G		Buffels	B	Moderate	Low
F30G-04517	F30G		Komaggas	B	Moderate	Low
F40B-04698	F40B	6	Wildeperdehoek se Brak	B	High	Low
F40B-04758	F40B	6	Kourkam se Brak		High	Low
F40B-04917	F40B	6	Wildeperdehoek se Brak	B	Moderate	Low
F40C-04882	F40C	6	Swartlintjies	B	High	Low
F40C-05007	F40C	6	Swartlintjies	A	Moderate	Low
F40D-04789	F40D	6	Swartlintjies	B	Moderate	Low
F40D-05029	F40D	6	Swartlintjies	A	Moderate	Low
F40D-05032	F40D	6			High	High
F40E-05132	F40E	6	Horees	B	High	Low
F40E-05135	F40E	6	Spoeg	B	High	Low
F40E-05208	F40E	6		B	High	Low
F40E-05223	F40E	6	Brand		High	Moderate
F40E-05318	F40E	6	Spoeg	B	Moderate	Low
F40E-05331	F40E	6	Spoeg	B	High	Low
F40F-05159	F40F	6	Spoeg	B	High	Low
F40G-05320	F40G	6	Bitter	C	High	Low
F40H-05531	F40H	6	Outeep		High	High
F50A-05191	F50A	6	Hartbees	C	High	Moderate
F50A-05242	F50A	6			High	VeryHigh
F50A-05402	F50A	6	Sout se		High	
F50A-05426	F50A	6	Hartbees	C	High	Moderate
F50A-05586	F50A	6	Hartbees	B	Moderate	Moderate
F50A-05626	F50A	6	Hartbees	B	Moderate	Moderate
F50A-05702	F50A	6			High	
F50B-05307	F50B	6	Swart-Doring	B	High	High
F50B-05397	F50B	6		B	High	High
F50B-05473	F50B	6			High	
F50B-05502	F50B	6	Swart-Doring	B	Moderate	Moderate
F50B-05515	F50B	6	Swart-Doring	B	Moderate	Moderate
F50B-05636	F50B	6	Swart-Doring	B	Moderate	Moderate
F50C-05557	F50C	6	Ondertuins		High	Moderate
F50C-05612	F50C	6	Swart-Doring	B	Moderate	Low
F50C-05735	F50C	6	Swart-Doring	B	Moderate	Low
F50C-05764	F50C	6	Swart-Doring	B	Moderate	Low
F50D-05726	F50D	6	Swart-Doring	B	Moderate	Low

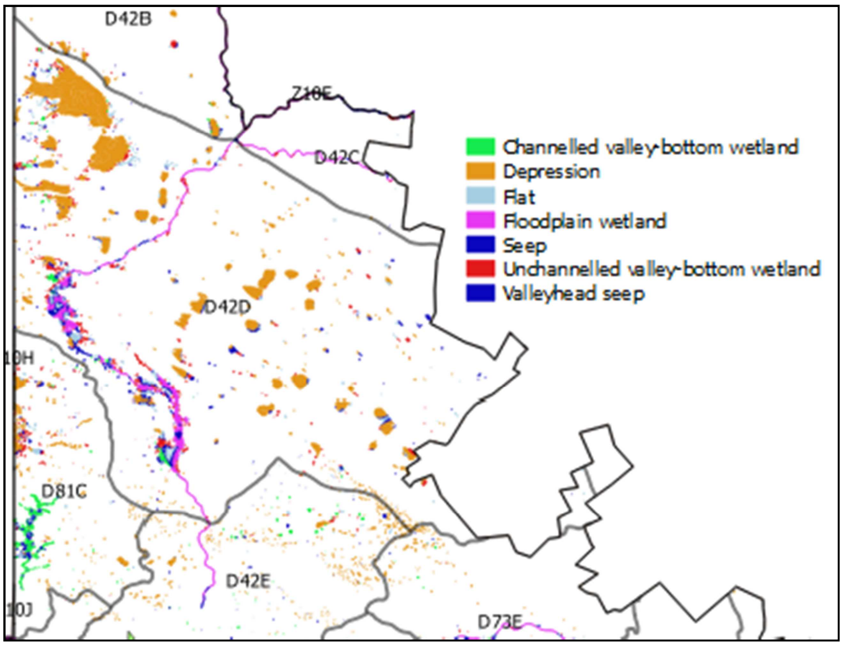
SQ Reach	Quaternary catchment	Wetland RU	SQ name	PES	Mean EI Class	Mean ES Class
F50D-05729	F50D	6	Groen	A	Moderate	Low
F50D-05784	F50D	6		B	Moderate	Moderate
F50E-05260	F50E	6	Wilgerhouts	B	High	Moderate
F50F-05560	F50F	6	Groen	B	Moderate	Low
F50F-05562	F50F	6		B	Moderate	Moderate
F50G-05578	F50G	6			High	Moderate
F50G-05620	F50G	6	Groen	B	Moderate	Moderate
F50G-05755	F50G	6	Groen	A	Moderate	Low
F60A-05886	F60A	6	Brak	B	High	High
F60B-06001	F60B	6	Klein-Goerap	B	Moderate	VeryHigh
F60B-06006	F60B	6	Klein-Goerap	B	High	High
F60B-06043	F60B	6	Klein-Goerap	B	Moderate	VeryHigh
F60B-06044	F60B	6	Bitterfontein	B	High	VeryHigh
F60B-06071	F60B	6		B	High	VeryHigh
F60C-05907	F60C	6	Sout	B	High	High
F60C-06045	F60C	6		B	High	High
F60C-06147	F60C	6	Sout	B	High	High
F60C-06201	F60C	6	Sout	B	High	High
F60D-06171	F60D	6	Vorsbrak	B	High	Moderate
F60D-06231	F60D	6	Sout	B	High	High
F60D-06236	F60D	6	Groot-Goerap	B	High	High
F60D-06293	F60D	6	Groot-Goerap	B	High	High

4.2.3 Wetland RU 1

Wetlands in this RU comprise seeps and depressions in the northern part of the southern Kalahari and are all confined to the Kgalagadi Transfrontier Park. They occur in the D42A quaternary catchment but are not directly associated with any SQ and all occur between the Nossob and Auob rivers. Due to their protection within a National Park, sensitivity would be low and risk low to non-existent. As a result, none of the wetlands in this RU has a high priority. Floodplain wetlands associated with the Nossob and Auob rivers are considered in wetland RU 7 (see below) due to their linear arrangement and connectivity and association with riparian zones.

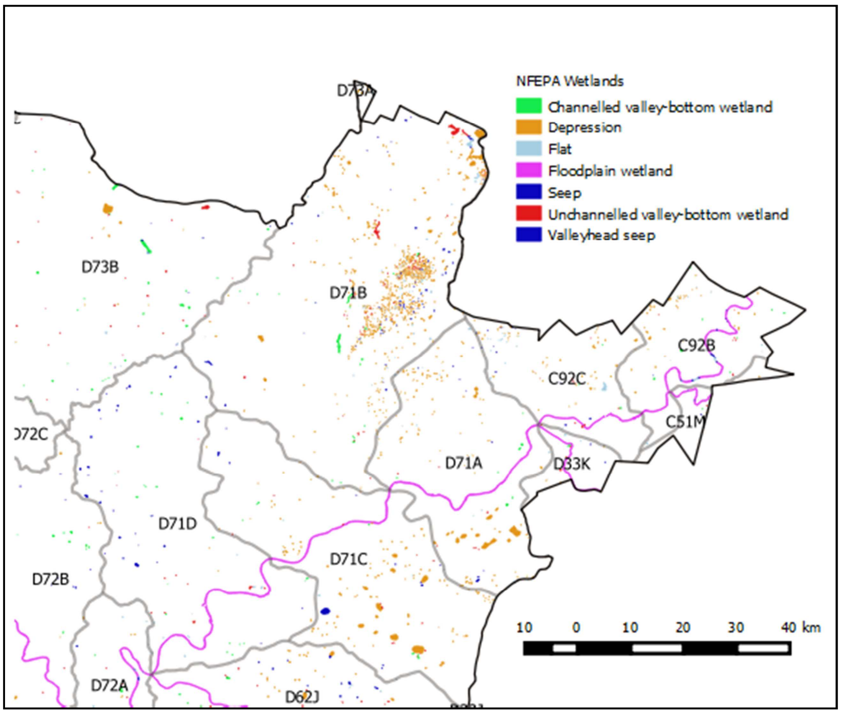


4.2.4 Wetland RU 2



Wetlands in this RU comprise mainly depressions in the southern part of the southern Kalahari, but include some flats, seeps and unchannelled valley bottom wetlands. Many wetlands in this RU are not directly associated with any SQ and include quaternary catchments D42B, D42C, D42D, D42E, D73E and D81C. Wetlands in D42D and D81C in particular were highlighted as having a very high integrated wetland importance (Rountree, in Louw, *et al*., 2010b). Floodplain wetlands associated with the Molopo River are considered in wetland RU 7 due to their linear arrangement and connectivity and association with riparian zones.

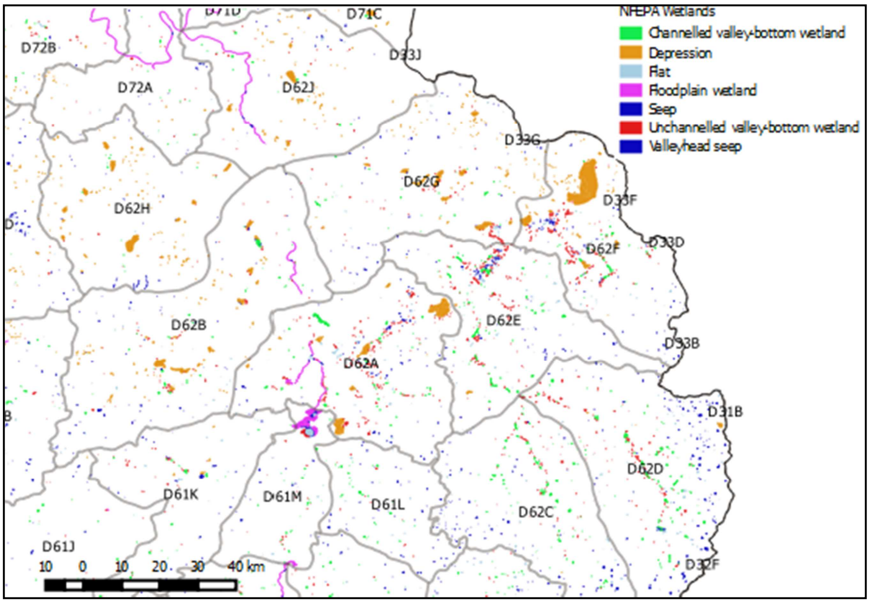
4.2.5 Wetland RU 3



Wetlands in this RU comprise mainly depressions in the Ghaap Plateau and part of the southern Kalahari, but includes some seeps and unchannelled valley bottom wetlands. Many wetlands in this RU are not directly associated with any SQ and include quaternary catchments D71A, D71B, D71C. Floodplain wetlands associated with the Molopo River are considered in wetland RU 7 due to their linear arrangement and connectivity and association with riparian zones.

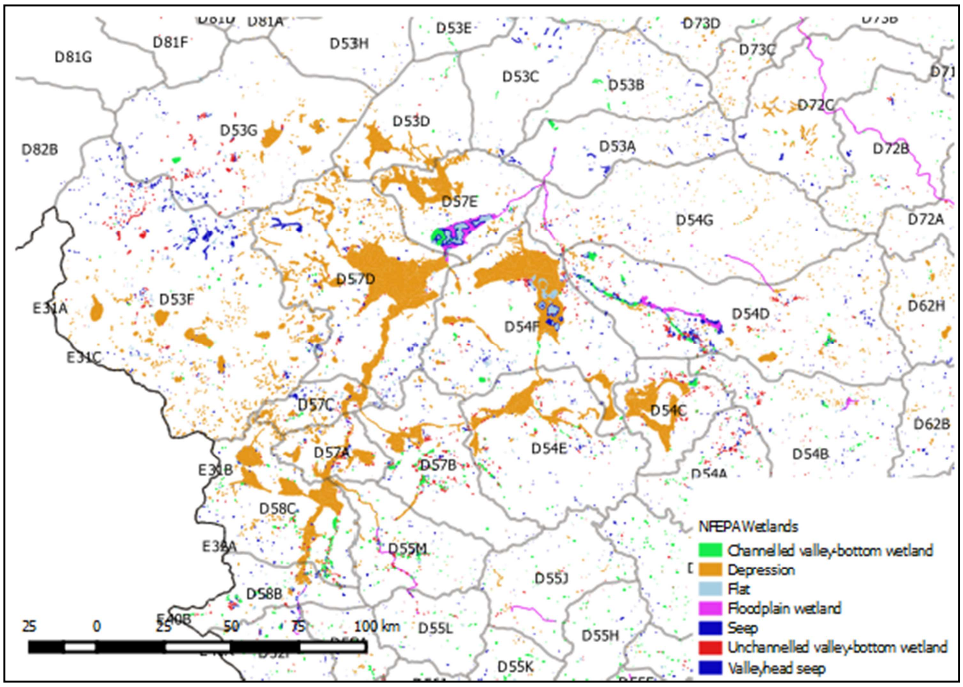
4.2.6 Wetland RU 4

Wetlands in this RU comprise mainly large depressions in the Nama Karoo, but include many flats, seeps, channelled valley bottom and unchannelled valley bottom wetlands. Many wetlands in this RU are not directly associated with any SQ and include quaternary catchments D61C, K, L, M and D62A-J. Many of the wetlands in this RU have been highlighted as important for crane breeding sites (NFEPA data, Nel *et al.*, 2011).

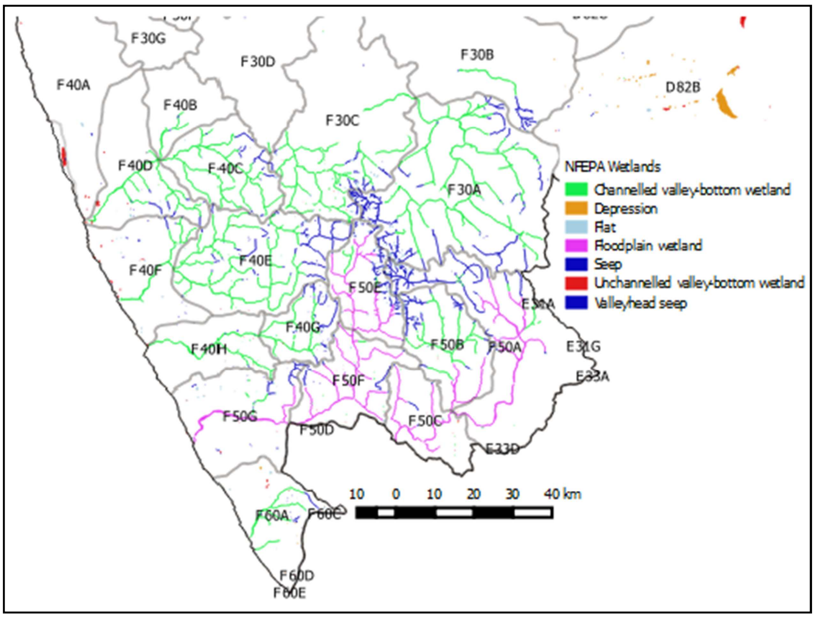


4.2.7 Wetland RU 5

Wetlands in this large RU comprise mainly large depressions in the Nama Karoo, but include many seeps and unchannelled valley bottom wetlands. Many wetlands in this RU are not directly associated with any SQ and area includes quaternary catchments D53D, F and G, D54C-F, D57A-E, D58B, C and D82B. The wetland RU as indicated above should be extended to include quaternary D54D since this catchment was highlighted as having a very high integrated wetland importance (Rountree, in Louw *et al.*, 2010b). Many of the wetlands in this RU have been highlighted as important for crane breeding sites (NFEPA data, Nel *et al.*, 2011).

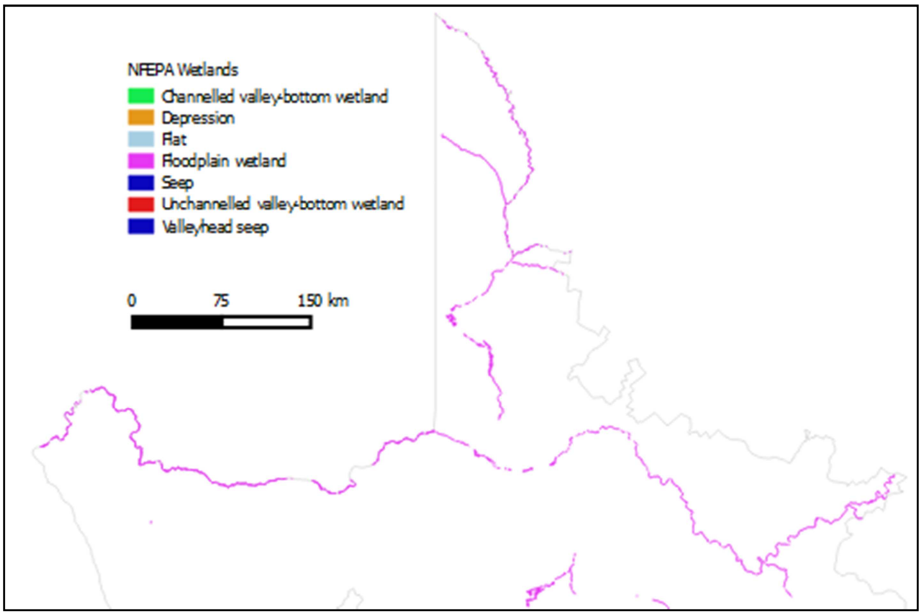


4.2.8 Wetland RU 6



Wetlands in this RU comprise mainly channelled valley bottom and floodplain wetlands in the Namaqua Highlands and Western Coastal Belt, but also include several seep areas. Notable quaternary catchments include F30A-C, F40B-H, F50A-G and F60A-D. This wetland RU is highlighted mainly due to the density of drainage channels in the area, many of which have high PES values and high EI and ES scores. This is partly due to the area being designated as important for threatened frog species in the NFEPA database (Nel *et al.*, 2011), notably the Desert Rain Frog (*Breviceps macrops*). Although the Desert Rain Frog is listed as vulnerable due to its restricted distribution and loss of habitat to diamond mining (du Preez and Carruthers, 2009), the biology, breeding and habitat preferences of the species are not related directly to wetlands or riparian zones.

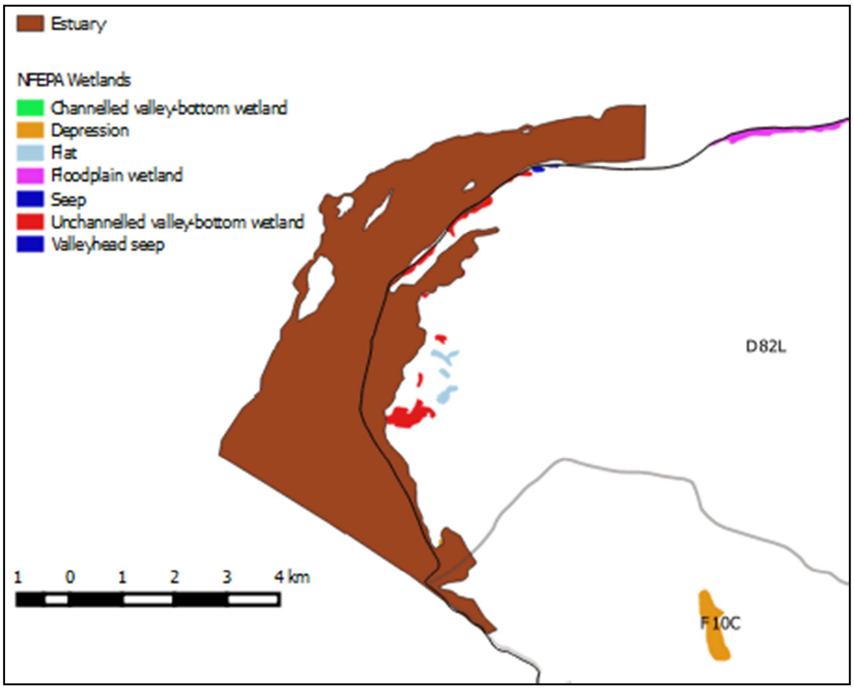
4.2.9 Wetland RU 7



Wetland RU 7 comprises floodplain wetlands along the riparian zones of the Nossob, Auob, Molopo and Orange rivers, and hence traverses several of the other wetland RUs. The reason for separation from other wetland types is related to their affinity with the main river channel, which means that their condition, status, management and flow requirements can be directly related and linked to the main river. This also makes the PESEIS data (SQs) directly applicable, as these wetlands would have been directly considered in all assessments of the riparian zone (see Table 4.3 for high priority SQs).

4.2.10 Wetland RU 8

Wetlands in this RU comprise a few unchannelled valley bottom wetlands and flats associated with the Orange River mouth estuary in quaternary catchment D82L. The area has been classified as a RAMSAR site and therefore is automatically considered a high priority.



5 GROUNDWATER RESOURCE UNITS

5.1 APPROACH

The objective of this task is to delineate Groundwater Resource Units (GRUs) based on quaternary catchment boundaries, aquifer type, and other physical, management and/or functional criteria.

Quaternary catchments form the basic unit of delineation. These can be grouped when of similar geohydrological properties, or be further subdivided if significant geohydrological features cut through catchments. Areas of similar character are grouped and mapped into distinct units, termed GRUs. Criteria that can be utilised to group or disaggregate catchments to form GRUs include:

- Interaction with other components of the hydrological cycle such as wetlands and rivers.
- Nature of the aquifers (primary, secondary dolomitic, alluvial etc.).
- Lithology when it affects borehole yields and groundwater quality.
- Topography.
- Groundwater dependence and use.
- Groundwater quality.
- Recharge and available groundwater resources.

The key outcome of this delineation process is a map demarcating GRUs, each of which is to be subsequently classified, a Reserve assessment undertaken, and Resource Quality Objectives (RQOs) set.

The approach followed in this study for grouping and delineation in hierarchical order is:

- An original primary delineation by quaternary catchment boundary as demarcated in Water Resources South Africa 2012 (WR2012).
- Geological age and lithology based on (GSSA, 2006).
- Identification of ground water regions based on geological considerations.
- Identification of catchments with baseflow to surface water bodies, as listed in Groundwater Resource Assessment Phase II (GRAII) (DWAF, 2006).
- Climate, recharge, and Harvest Potential (DWAF, 2006).
- Groundwater levels from the DWS National groundwater monitoring network.
- Groundwater quality from the DWS National water quality monitoring network.
- Groundwater dependent ecosystems and or wetlands based on Nel *et al*. (2011).
- Groundwater use and stress from the WARMs[2] data base.

5.2 GEOLOGY

Very diverse lithostratigraphic units, varying in age from Randian to Quaternary, underlie the Lower Orange WMA. The lithologies cover the broad spectrum of intrusive and extrusive igneous rocks, sedimentary and metamorphic rocks, and unconsolidated sediments.

Since the bulk of the WMA has no baseflow and is reliant on groundwater for water supply purposes, the significance of delineating RUs by hydrogeologic criteria is magnified. This process requires simplifying the complex geology by grouping units that behave in a similar manner.

[2] Water Resources Simulation Model 2000. The Pitman Model with Sami Model Groundwater interactions.

The first step undertaken was to identify the geologic units present (Table 5.1), and group them by potentially similar hydrogeologic environments. The selected grouping of geological units is shown in Table 5.1 and Figure 5.1. The grouping was based on:

- Geological age.
- Similar lithology.
- Structural terranes.

The following geological units were identified:

- Marydale Group: This greenstone belt is 2910-3000Ma in age and is located from 20 km SSW of Prieska up to the vicinity of Copperton and Marydale.It is at the south western edge of the Kaapvaal craton and forms a narrow belt of discontinuous outcrops under Tertiary cover extending for about 100 km in a SE direction. It is subdivided into the Prieskapoort and Doornfontein Subgroups. They form part of the Namaqualand Metamorphic Province and occur as a compound syncline that is steeply folded and highly metamorphosed to greenstone level.
- Randian intrusives and volcanics: This grouping consists of 2700-2900 Ma age granites and granitic gneisses outcropping in the vicinity of the Marydale Group.
- Ventersdorp Supergroup: The Sodium Group outcrops SE of Prieska and consists of volcanic grits and tuffs, lavas, arkose, porphyry, limestone, chert. It rests on a floor of Randian intrusive granite and is 2640 Ma in age. The Zeekoebaart Formation is exposed south of Boegoeberg dam and consists almost entirely of volcanic andesite and dacite, with some porphyry, tuff and breccia. It has limited exposure related to extensive erosion, and the rocks are only encountered in 2-5very small isolated inliers between Prieska and Douglas. The Allanridge and Bothaville Formations are 2600 Ma and outcrop in the vicinity of Vryburg and west of Kimberley to the NE of the WMA.
- Transvaal ironstones, sediments and volcanics: These rocks are found in the vicinity of Vryburg, Prieska and Morokweng. The 2640 Ma Vryburg Formation overlies the Ventersdorp rocks in Griqualand West. The Asbestos Hills banded ironstones and Koegas Subgroup are 2500-2400 Ma in age and form the Asbestos Hills and the Kuruman Hills. The Makganyene Formation was deposited over a regional unconformity cut deeply down into the Koegas Subgroup rocks. The Ongeluk Formation is overlain over another unconformity over the Makganyene Formation and is 22200 Ma.
- GhaapGroup dolomite: These rocks form the Ghaap plateau and are 2600-2500 Ma in age. They are a significant aquifer hence have been separated from the remainder of the Transvaal Group ironstones and other sedimentary rocks. The bulk of the dolomitic outcrop occurs over quaternary catchments D71A, B and C92C and stretches across the WMA boundary into the Lower Vaal WMA. A further narrow strip of dolomite, approximately 50km long and less than 5km wide outcrops in a roughly north-west to south-east orientation along the Doringberg Fault, west of Peiring. The main body of the outcrop is located in catchment D72B.
- Olifantshoek Supergroup: The lower part of this grouping consists of clastic sediments and volcanic rocks, which grade upward to rudaceous sediments. These rocks are encountered west of Posmasburg and east of Olifantshoek and build the foothills of the Langeberg, Korannaberg and Eselberg. They form a prominent north trending mountain range from Boegoeberg northward to the Korannaberg. They overlie Transvaal Supergroup rocks with a regional unconformity and are about 1900 Ma in age.
- Namaqua-Natal Province: The region consists of metamorphic rocks formed or metamorphosed between 2000 - 1000 Ma. These rocks range from an assembly of compact sedimentary and volcanic rocks, to extrusive and intrusive rocks including homogenous granites to migmatites and gneisses. The area underlain by the Namaqualand-Natal Province

is situated in the vicinity of the Orange River between Prieska to Upington and Springbok. It consists of:

- o Early Mokolian age (2000 Ma) sediments and volcanics that are metamorphosed.
- o Intrusive and extrusive rocks formed during rifting and subduction (1600 - 1200 Ma) and subsequently metamorphosed.
- o Syn and post tectonic granitoids formed between 1200 - 1000 Ma.

It has been divided into sub-terranes based on marked changes in lithology across structural discontinuities:

- o Richtersveld subprovince: The rocks are 2000 Ma and consist of low to medium grade metamorphosed extrusive and intrusive rocks along the Namibian border. Thrusts or shears bound the subprovince. It consists of volcano-sedimentary rocks of the Orange River Group and intrusive granitoid of the Vioolsdrift Suite.
- o Bushmanland Terrane: The Terrane consists of granitic gneisses and medium to high-grade deformation of sedimentary and volcanic rocks. The northern boundary of this Terrane is the Richtersveld subprovince and in the east, it abuts against the Kakamas Terrane at the Hartbees River Thrust. It consists of basement gneisses of 2050 - 1700 Ma, mixed sedimentary and volcanic metamorphosed rocks of 1900 - 1200 Ma, and syn and post tectonic Namaqua age intrusive granites and charnokites.
- o Kakamas Terrane: The terrane consists of metamorphosed sedimentary rocks and subsequent granitic intrusions. It lies to the east of the Bushmanland Terrane and is bounded in the east by the Boven Rugzeer shear zone. It stretches from the Onseepkans area south 200 km to Kenhardt- Putsonderwater. High-grade metamorphism characterises the rocks of the Terrane.
- o Areachap Terrane: This Terrane consists of a NNW trending belt of medium grade 1300 Ma metamorphosed rocks of sedimentary and volcanic origin, and subsequent 1000 Ma granitic intrusions.
- o Kaaien Terrane: This Terrane forms the eastern margin of the Namaqua-Natal Province and consists of deformed quartzite and volcano sedimentary rocks. It is bounded in the west by the Brakbosch shear zone and in the east by Dabep Thrust. The Brulpan Group build the Skeurberg to the west of the Langeberg.
- o Koras Group: The Koras Group lies in the Kaaien Terrane, however, because it consists of relatively undeformed and unmetamorphosed rocks, it is considered a separate geological unit. It lies unconformably over the metamorphic rocks to the east and north of Upington and post-dates the shear zone, which marks the boundary of the Kaaien Terrane. It is 1180 Ma in age.

- Namibian Successions: These rocks are grouped into the Richtersveld Suite, the Gariep Supergroup and the Nama and Vanrhynsdorp Groups, and are intruded by granites. The Richtersveld Suite consists of felsic rocks intruded into rocks of the Vioolsdrift Suite and Orange River Group. The Gariep Supergroup are a meta-volcanic and sedimentary succession that fill a tectonic belt running from Kleinsee to Namibia. They have been extensively deformed and are about 700 Ma in age. The Nama and Vanrhynsdorp Groups were deposited in foreland basins and are separated from The Gariep Belt geographically.
- The Karoo Supergroup is represented by the Dwyka, Ecca and Beaufort Groups. They, occupy the southern lobe of the WMA, and comprise thick successions of sedimentary rocks ranging from mudrocks through coarser varieties (sandstones, conglomerates) to diamictites and rhythmites. Karoo or Jurassic dolerite is common throughout the sequence and frequently intrudes older rocks. They have been subdivided based on the following considerations:

  - Dwyka Tillite: This massive tillite consists of highly compacted diamictite and is separated from the remainder of the Karoo SuperGroup as it is a poor aquifer of low permeability and storage.
  - Carbonaceous Ecca Group shales: the Prince Albert and Whitehill Formations form thick sequences of black carbonaceous shale with the highest fracking potential where they underlie other Karoo rocks. They have been separated from the remainder of the Ecca Group due to their poor water quality as a unique GRU.
  - Other Ecca Groupshales and sandstones: Ecca Group rocks are of marine origin and are often more saline than Karoo rocks that are younger in the Sequence. Consequently, they are treated separately.
  - Beaufort Group rocks are of fluviatile and generally of continental origin. Their salinity is related to low recharge rather than connate marine water like in the Ecca.
- Sutherland Suite: This 66 Ma Cretaceous dome structure is an intrusion consisting of volcanic breccia, carbonatite, trachyite and olivine melilitite. Water quality can be poor but it is of geohydrological relevance due to the fracturing it induced in the surrounding Beaufort Group rocks during intrusion. Since this one intrusion only occurs in the Beaufort Group, it is grouped with the Beaufort Group.
- Quaternary and Tertiary dune deposits, consisting of “Kalahari red sands”, occupy the extreme northern part of the WMA bordering on Namibia. These dune deposits are of considerable thickness and comprise fine aeolian sands with occasional coarser gravel deposits.

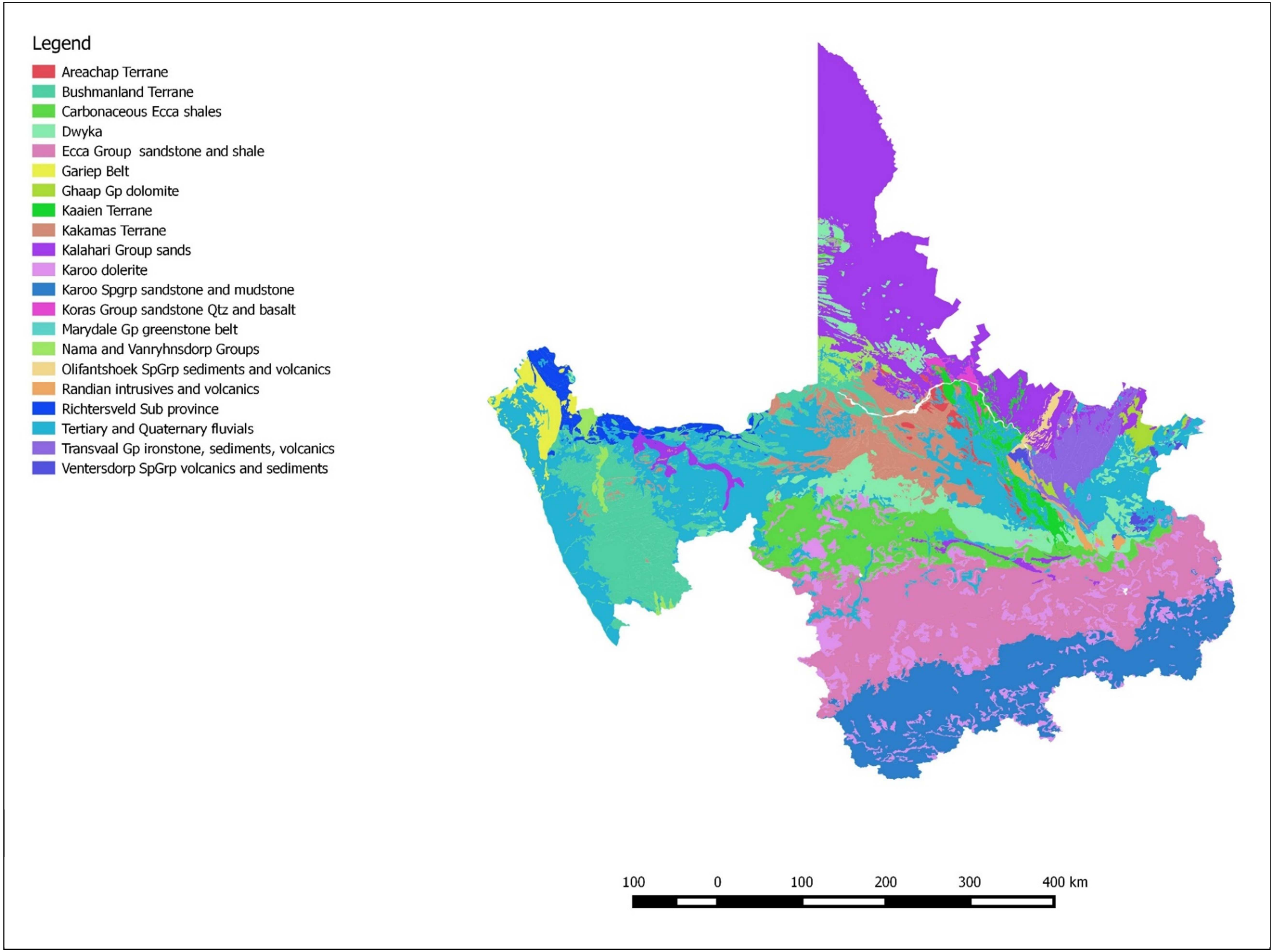


Figure 5.1 Simplified geology of the Lower Orange WMA

Table 5.1 Lithological units of the Lower Orange WMA

Age	SuperGroup	Group	Subgroup	Formation/Suite	Lithology	Simplified Group
Randian		Marydale	Prieskapoort		Conglomerate, subgreywacke, quartzite meta lava and tuff	Marydale Group greenstone belt
			Doornfontein		Banded ironstone, amphibolite, quartzite	
				Skalkseput Granite	Granite	Randian intrusives and volcanics
				Draghoender Gneiss	Granitic gneiss	
	Ventersdorp	Sodium			Grits, tuffs, lavas, arkose, porphyry, limestone, chert	Ventersdorp Supergroup volcanics and sediments
				Zeekoebaart	Andesite, dacite, porphyry, tuff and breccia	
Vaalian				Bothaville	Conglomerate, sandstone, quartzite	
				Allanridge	andesite	
	Transvaal			Vryburg	Siltstone, shale, quartzite, lava	Transvaal Group ironstone, sediments, volcanics
		Ghaap	Schmidtsdrif		Dolomite, shale, limestone, sandstone	Ghaap Group Dolomite
			Campbell Rand		Dolomite, chert, limestone	
			Asbestos Hills		Banded ironstone, amphibolite, shale	Transvaal Group ironstone, sediments, volcanics
			Koegas		Mudstone, amphibolite, quartzite, jaspilite, dolomite, ironstone	
		Postmasburg		Makganyene	Diamictite, jaspilite, dolomite, sandstone, siltstone	
			Cox	Ongeluk	andesite	
		Pretoria		Daspoort	quartzite	
	Olifantshoek			Lucknow	Quartzite, phyllitic shale, lava	Olifantshoek Supergroup sediments and volcanics
				Hartley	Andesitic lava, tuff, conglomerate	
Mokolian		Volop	Matsap		Conglomerate, greywacke, sandstone, quartzite	
			Brulsand		quartzite	
	Namaqualand Metamorphic Province	Orange River	De Hoop		Mafic lava, tuff, andesite, porphyry	Richtersveld Subprovince
				Klipneus and Paradysrivier	Tuff, andesitic lava, conglomerate	
				Rosyntjieberg	Quartzite, schist	
				Windvlakte	Volcanics	
			Haib		Porphyry, pumice, tuff, andesite	

Age	SuperGroup	Group	Subgroup	Formation/Suite	Lithology	Simplified Group
				Violsdrif	Mafic and ultramafics, diorite, monzonite	
		Bushmanland	Hom and Guadom		Gneiss, amphibolite, metaquartzite, schists, calc-silicates	Bushmanland Terrane
		Okiep	Een Riet and Aardvark		Schist, gneiss, quartzite	
			Khurisberg		Quartzite, schist	
			Garies		Gneiss	
			Bitterfontein		Gneiss, quartzite, schists	
		Grunau			Kinzingite, gneiss	
				Gladkop	gneiss	
				Little Namaqualand	gneiss	
				Spektakel	Granite, gneiss	
				Biesiesfontein	granite	
				Naab granite	granitoid	
		Geelvloer			Quartzite, calc-silicates	Kakamas Terrane
		Korannaland			Gneiss, quartzite, calc-silicates, amphibolite, schists	
				Toeslaan	Kinzingite	
				Naros granite	granite	
				Stolzendfels enderbite	Charnockite	
				Augrabies granite	Granite-gneiss	
			Vyfbeker Metamorphic Suite		Granite, gneiss	
			Keimoes	Cnydas	Granite, monzonite	
				Friersdale charnockite	charnockite	
				Vaalputs gneiss	gneiss	
				Daberas	granodiorite	
				Eendoorn	granite	
				Hoogoor	gneiss	
				Witwater granite	granite	
				Oranjekom Complex	Noriite epidiorite	
				De Bakken Granite	granite	

Age	SuperGroup	Group	Subgroup	Formation/Suite	Lithology	Simplified Group
				Lat River granite	granite	
				Jannelsepan	Amphibolite, schist, calc-silicates, gneiss	Areachap Terrane
				Upington granitoid	granite	
		Brulpan		Groblershoop	Quartzitic schist, metalava	Kaaien Terrane
				Uitdraai	Quartzite, schist	
		Kaaien		Dagbreek	Quartz schist, quartzite, amphibolite, calc-silicates	
				Sultanaoord	Quartzite, phyllite	
		Wilgenhoutsdrif		Zonderhuis	Quartzite, phyllite, schist, greenstones	
				Leerkrans	Schist, greenstones, phyllite,	
		Koras			Sandstone, grit, conglomerate, quartzite, shale, porphyry, tuff, mudstone, basalt	Koras Group sandstone, quartzite and basalt
Namibian				Richtersveld	granites	Gariep belt
				Grootderm	Basalt, andesite, breccia, tuff, schist	
				Oranjemund	Dolomite, phyllite, schist, quartzite	
	Gariep	Port Nolloth		Stinkfontein	Conglomerate, sandstone, quartzite, arkose, dolomite, phyllite,	
				Hilda	Quartzite, arkose, conglomerate, dolomite, schist	
				Numees	Tillite, sandstone, phyllite, dolomite	
				Holgat	Arkose, shale, quartzite, conglomerate, phyllite, limestone, schist	
				Kuboos granite	granite	
		Nama	Kuibis		Sandstone quartzite	Nama and Vanrhynsdorp Group sedimentary
			Schwarzrand		Limestone, shale	
			Fish River		Sandstone, quartzite, , shale	
		Vanrhynsdorp	Knersvlakte		Siltstone, mudstone, shale, sandstone, limestone	
Paleozoic	Karoo	Dwyka			Tillite, shale, mudstone, sandstone	Dwyka tillite
		Ecca		Prince Albert	shale	Carbonaceous Ecca shales
				Whitehill	Shale	
				Tiersberg	Shale. Siltstone, sandstone	Ecca Group sandstone and shale
				Koedesberg	Sandstone, greywacke	

Age	SuperGroup	Group	Subgroup	Formation/Suite	Lithology	Simplified Group
		Beaufort	Adelaide		Mudstone, sandstone	Beaufort Group sandstone and mudstone
Mesozoic				Karoo dolerite	Dolerite	Dolerite
				Sutherland	Breccia, tuff, trachytoid, carbonatite, basalt	Beaufort Group sandstone and mudstone
Cainozoic		Kalahari			Gravel, claystone, calcareous sandstone. sand	Kalahari Group sands
				Quaternary sands	Sand and calcrete of alluvial origin	Quaternary fluvials

5.3 GROUNDWATER REGIONS

The Vegter groundwater regions (Vegter, 2001) and simplified geology are shown in Figure 5.2. The underlying geology in each region and the quaternary catchments incorporated are described in Table 5.2. The Vegter regions in many cases match the simplified geology, but in some cases, their boundaries run through the geological regions. The Vegter Regions also run across quaternary boundaries.

Consequently, it was decided to use the Vegter regions as a basis for delineation but with the following modifications:

- Shift the border of groundwater regions to match quaternary boundaries, using the dominant geology where only minor portions of a quaternary were in a region.
- Shift the borders of the regions where they don't match lithological boundaries.
- Eliminate the Karoo regions and subdivide them based on groundwater potential.
- Subdivide the regions to incorporate the more varied geology of Table 5.1.

The first tier delineation of groundwater regions is shown in Figure 5.3.

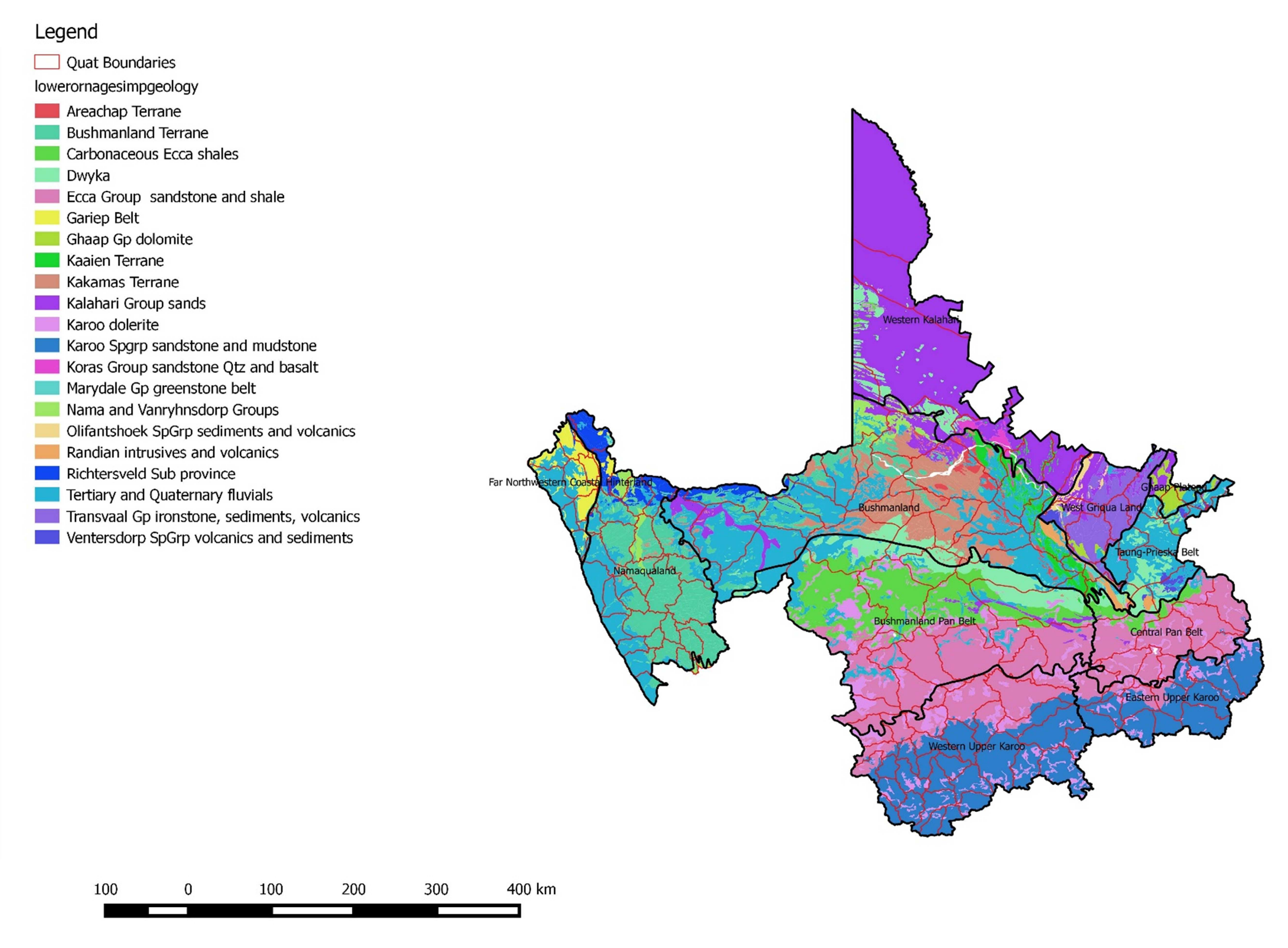


Figure 5.2 Vegter groundwater regions

Table 5.2 Lithology and catchments of Vegter groundwater regions

Groundwater Region	Lithology and stratigraphy	Baseflow	Quaternary catchment
23. Western Kalahari	Kalahari Group Gravel, calcareous sandstone and clay over Brulpan Group muscovite, quartzite and schist Wilgenhoutsdrif Group greenstone, quartzite and phyllite Koras Group sandstone quartz porphyry and basalt Dwyka tillite Prince Albert shale Karoo dolerite sills		D42A, D42B, D42C, D42D, D42E D73C, D73D, D73E D81C
24. Ghaap Plateau	Campbell Rand and Schmidtsdrif Subgroups dolomite, limestone, shale and chert		C92C D71A, D71B D72B
	Vryburg Formation shale sandstone and andesite		C92B, C92C D71A, D71B
25. West Griqualand	Transvaal banded ironstone, mudstone, iron formation, riebeckite, shale, diamictite, jaspilllite, andesite and dolomite Olifantshoek quartzite, limestone shale andesite and greywacke Brulpan Group muscovite-quartzite and schist Wilgenhoutsdrif Group phyllite quartzite and lava Koras Group sediments and volcanics		D71B, D71D D72A,D72B, D72C
		x	D73B
26. Bushmanland	Mokolian metasediments and metavolcanics consisting of gneisses, schists, amphibolite, metaquartzite Intrusive granites and gneisses Randian metasediments and volcanics Tertiary and Quaternary fluvial deposits		D42E D53A, D53B, D53C, D53D, D53E, D53G, D53H, D53J D54D, D54G D62H D72A,D72B, D72C D73C, D73D, D73E, D73F D81A, D81B, D81C, D81D, D81E, D81F, D81G D82A, D82B, D82C, D82D
27. Namaqualand	Mokolian metasediments and metavolcanics consisting of gneisses, schists, amphibolite, metaquartzite, andesite, quartz porphyry Intrusive granites, gneisses, granodiorite, tonalite, mafic and ultramafics Tertiary and Quaternary fluvial and coastal deposits		D82D, D82E, D82F, D82G, D82H, D82J F20A, F20B F30A, F30B, F30C, F30D, F30E, F30F, F30G F40A, F40B, F40C, F40D, F40E, F40F, F40G, F40H F50A, F50B, F50C, F50E, F50F, F50G F60A
29. Taung-Preiska belt or Dry Harts-Vaal-Orange lowland	Ventersdorp Supergroup andesite, dacite, quartz porphyry, breccia, conglomerate, shale sandstone Dwyka tillite Prince Albert shale Karoo dolerite		C51M C92B, C92C D33K D62B, D62G, D62H, D62J D71A, D71B, D71C, D71D
31. Central Pan Belt	Ecca Group Tierberg formation shale and dolerite intrusions		D61J, D61K, D61L,D61M D62A, D62B, D62C, D62D, D62E,D62F, D62G, D62H
34. Bushmanland Pan Belt	Dwyka tillite and shale Prince Albert, Whitehill and Tierberg Formations shale and dolerite sheets		D52F D53D, D53G

Groundwater Region	Lithology and stratigraphy	Baseflow	Quaternary catchment
			D54A, D54B, D54C, D54D, D54E, D54F, D54G D55M D57A, D57B, D57C, D57D, D57E D58A, D58B, D58C D82B
37. Western Upper Karoo	Waterford Formation shale and sandstone Adelaide subgroup mudstone, shale and sandstone Dolerite intrusions	x	D51A
			D51B, D51C D52A, D52B, D52C, D52D, D52E, D52F D54B D55A, D55B, D55C, D55D, D55E, D55F, D55G, D55H, D55J, D55K, D55L D56A, D56B, D56C, D56D, D56E, D56F, D56G, D56H, D56J D58A
38. Eastern Upper Karoo	Adelaide and Tarkastad subgroups, mudstone, shale, sandstone and dolerite Waterford Formation shale and sandstone		D61A,D61B,D61C,D61D,D61E,D61F,D61G, D61H, D61J, D61K, D61L D62C, D62D
54. Richtersveld- Far northwestern Coastal Hinterland	Nama Group quartzite, arkose, arenitelimestone, dolomite, diamictite, phyllite, schist, amphibolite, gneiss and ultramafics Cape granite Tertiary raised beach deposits and alluvium		D82K,D82L F10A, F10B,F10C F20B, F20C,F20D,F20E

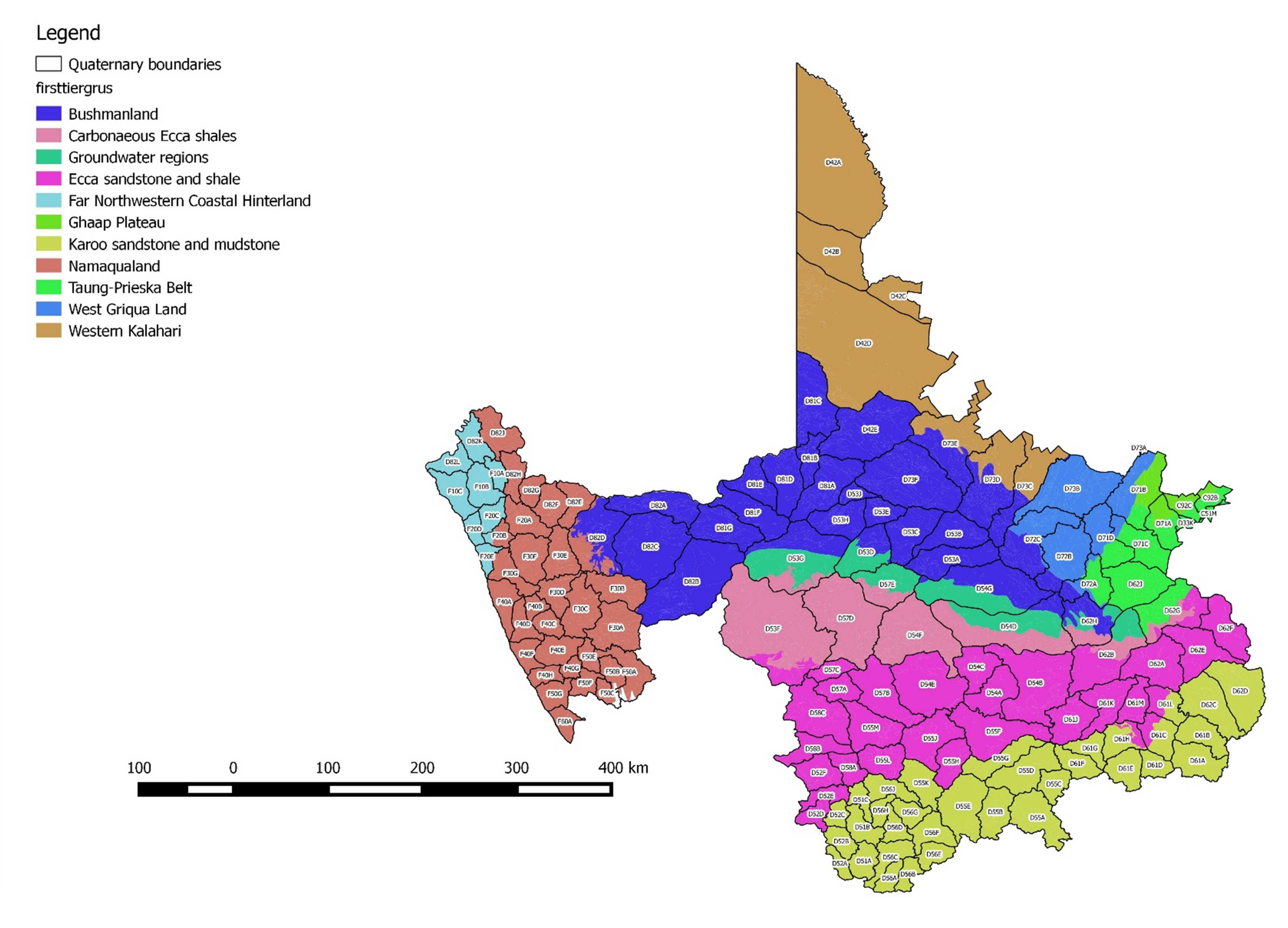


Figure 5.3 First tier Groundwater Resource Units

5.4 SURFACE GROUNDWATER INTERACTIONS

According to GRAII, only two catchments have baseflow (Table 5.3). Consequently, groundwater plays a minimal role in maintaining baseflow in rivers.

Table 5.3 Catchments with baseflow

Quaternary catchment	Area (km^2)	MAP[1] (mm/a)	Baseflow (million m^3/a)	Baseflow (mm/a)
D51A	797	312	0.1594	0.2
D73B	3721	258	0.11163	0.04

1Mean Annual Precipitation

5.5 GROUNDWATER RECHARGE AND EXPLOITATION POTENTIAL

Variations in groundwater recharge across a groundwater region could potentially warrant subdivision of a groundwater resource unit due to variations in available groundwater resources. Groundwater recharge and Exploitation Potential as given in GRAII were plotted by quaternary catchment (Figures 5.4 and 5.5). A clear distinction exists between east and west of a line from Copperton-Loxton. For this reason, the Karoo groundwater regions were divided into eastern and western sections and separate GRUs (Table 54).

An issue to be noted for future clarification is that in some cases the Exploitation Potential is higher than recharge in GRAII. This will have implications for setting numerical values to volumes of groundwater that can be allocated in subsequent phases of the project.

5.6 GROUNDWATER LEVEL

A map of mean groundwater level in each quaternary catchment is shown in Figure 5.6. No clear distinction in water level can be observed within groundwater regions, hence subdivision of groundwater regions based on water levels was not considered warranted.

5.7 GROUNDWATER QUALITY

A map of mean groundwater level in each quaternary catchment is shown in Figure 5.6 Mean groundwater electrical conductivity per quaternary catchment is shown in Figure 5.8. Groundwater is generally poor the western Kalahari, the Carbonaceous Ecca Shales and Dwyka tillite. The Bushmanland and Namaqualand regions have variable water quality, which warrants subdividing these regions (Table 5.4).

Figures 5.19 and 5.10 show the mean nitrate and fluoride concentration per catchment. The western Kalahari, Bushmanland, Dwyka Tillites and Ecca carbonaceous shales have high nitrate concentrations. Elevated fluoride is also of concern over large areas of the WMA.

5.8 WETLANDS

The location of wetlands is shown in Figure 5.11. Significant tracts of pans exist in the western parts of the Carbonaceous shale and Ecca shale and sandstone groundwater regions to the north and south of Brandvlei. Another belt of pans exists in the east from Vosburg to Strydenburg. This belt warrants subdividing these regions due to potential groundwater interactions, as these areas serve as evaporation zones for groundwater during wet periods.

5.9 DESCRIPTION OF GRUs

The final delineation of GRUs is shown in Figure 5.12 and Figure 5.13.

5.9.1 Bushmanland west

The Bushmanland west GRU is underlain by rocks of the Namaqua-Natal metamorphic Province, which are largely covered by Tertiary cover. Extensive outcrop exists only in the central region from Augrabies to Kenhardt. Recharge is less than 1 mm/a. Mean groundwater depth increases from less than 20 m near Kenhardt to over 50 m to the west near Aggeneys. Water quality is generally poor and of Class 3 or 4 due to high salinity, with the worst quality water being located in the north from Concordia to Augrabies.

5.9.2 Bushmanland east

The Bushmanland east GRU is underlain by rocks of the Kaaien and Areachap Terranes of the Namaqua-Natal metamorphic Province. Tertiary cover is less extensive than to the west. Recharge is from less than 1 mm to over 3 mm/a increasing south-eastward with rainfall. Groundwater levels average 20 - 25 metres below ground level (mbgl). Groundwater quality is less saline than in the western area and is generally of class 2.

5.9.3 Dwyka Tillite

The Dwyka Tillite GRU is underlain by tillites and largely devoid of sediment cover. Recharge is less than 1 mm/a, except in the eastern pocket where rainfall is higher. Groundwater levels are from 18 - 25 mbgl, but above 15 mbgl in the eastern portion. Groundwater is of unacceptable quality due to salinity of class 4.

5.9.4 Ecca Carbonaceous shale

The Ecca carbonaceous shales overlie Dwyka Tillites and are extensively intruded by dolerite sheets. Recharge is less than 1 mm/a, except in the eastern portion where rainfall is higher. Groundwater levels are from 15 - 25 mbgl. Groundwater quality is poor and of class 3.

5.9.5 Ecca sandstone and shale west

The Ecca sandstones and shales overlie the carbonaceous shales and have a recharge of 0.5 - 1 mm/a. Groundwater levels are shallow and are 10 - 15 mbgl. Groundwater quality is good to marginal and of class 1 - 2.

5.9.6 Ecca sandstone and shale central and south west

The Ecca sandstones and shales overlie the carbonaceous shales and have a recharge of from 1 - 3.5 mm/a, increasing towards the east. Groundwater levels are shallow and 10 - 15 mbgl. Groundwater quality is highly variable but generally of class 1 - 2.

5.9.7 Ecca sandstone and shale east

The Ecca sandstones and shales overlie the carbonaceous shales. They have a recharge of from 4 - 11 mm/a, increasing from Carnarvon to east of Britstown due to increasing rainfall. Groundwater levels are shallow and 7 - 15 mbgl. Groundwater quality is good and of class 1.

5.9.8 Far northern Coastal Hinterland

The Gariep belt, extensively covered by Tertiary and Quaternary sediments, underlies the Far Northern Coastal Hinterland. It has recharge of less than 1 mm/a. Groundwater levels are from 25 - 45 mbgl. Groundwater is of poor to unacceptable quality, class 3 - 4.

5.9.9 Ghaap Plateau

The Ghaap Plateau GRU is underlain by Ghaap Plateau dolomites, which are covered by Kalahari and Tertiary sediments in some. It is the most significant aquifer in the WMA. Recharge is from 7 - 10 mm/a. Groundwater levels are 15 - 20 mbgl. Groundwater quality is of class 1.

5.9.10 Karoo sandstone and shale west

The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Recharge increases from 1 - 3 mm/a from north to south, being highest in the vicinity of Sutherland. Groundwater levels are from 5 - 15 mbgl. Groundwater quality is of class 1 - 2.

5.9.11 Karoo sandstone and shale east

The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Recharge increases from 3 mm/a near Loxton, to nearly 12 mm/a around De Aar. Groundwater levels are from 5 - 15 mbgl. Groundwater quality is good to marginal, of class 1 - 2, with the marginal groundwater found in the South east between Richmond and De Aar.

5.9.12 Namaqualand west

The Namaqualand west GRU is underlain by rocks of the Nama and Vanrhynsdorp groups. Along the coast, they are covered by Tertiary and Quaternary sediments. Recharge is less than 1 mm but can range to over 3 mm in the vicinity of Garies due to higher rainfall (Figure 5.13). Groundwater levels are from 12 to 50 mbgl, being deeper near the coast. Groundwater is of poor to unacceptable quality, class 3 - 4.

5.9.13 Namaqualand east

The Namaqualand east GRU is underlain by rocks ofthe Nama and Vanrhynsdorp groups. Recharge is from less than 1 mm to 2 mm. Groundwater levels are from 12 - 30 mbgl. This GRU was delineated due to a higher water class than the rest of Namaqualand and water quality is of class 2 - 3 for domestic purposes.

5.9.14 Taung-Prieska belt

The Taung-Prieska Belt is underlain by Dwyka tillite and, Ventersdorp Supergroup rocks, with extensive Tertiary cover. Recharge is from 3.5 mm/a near Prieska up to 9.5 mm/a near Douglas. Groundwater levels are 15 - 20 mbgl. Groundwater quality is of class 1 - 2.

5.9.15 West Griqualand

The West Griqualand GRU is underlain by the Olifantshoek Supergroup, the Ventersdorp Super Group, some dolomites, and Transvaal Group ironstones. Recharge is from 2 - 6 mm/a and increases to the east. Groundwater levels are 20 - 35 mbgl. Groundwater quality is of class 1 - 2.

5.9.16 Western Kalahari

The Western Kalahari GRU consists of Quaternary sand cover overlying largely Dwyka Tillite, Koras Group sandstone, or metamorphics of the Kaaien Terrane. Recharge is less than 1 mm.

Groundwater levels are from 25 to 90 mbgl. Groundwater quality is of class 4 and only improves in the SE around Karos and Grootdrink, where it is of class 2.

5.9.17 Richtersveld

The Richtersveld is underlain by rocks of the Richtersveld Subprovince. Recharge is less than 1 mm. Groundwater levels are from 30 - 50 mbgl, being deeper to the east. Groundwater is of marginal to unacceptable quality, class 2 - 3.

5.9.18 Namaqualand coastal

The Namaqualand west GRU is underlain by rocks of the Nama and Vanrhynsdorp groups, which are covered by Tertiary and Quaternary sediments. Recharge is from less than 1 mm to 2 mm. Groundwater levels are from 40 - 50 mbgl. Groundwater is of poor to unacceptable quality, class 3 - 4.

5.9.19 Karoo sandstone and shale southwest

The Karoo sandstones and shales of the Beaufort Group overlie the Ecca Group. Small volumes of baseflow potentially exist in the vicinity of Sutherland due to higher rainfall (Figure 5.13). Recharge increases from 3 - 8 mm/a from north to south, being highest in the vicinity of Sutherland. Groundwater levels are from 5 - 13 mbgl. Groundwater quality is of class 1 - 2.

5.10 GROUNDWATER DEPENDENT COMMUNITIES

A map of communities supplied by groundwater, as determined during the All Towns study is shown in Figure 5.14. Groundwater use is primarily in the Ecca, Karoo sandstone and shale, Namaqualand west, Bushmanland east and Ghaapplateau. Poor quality in Bushmanland, the carbonaceous shales and the Dwyka tillites precludes extensive groundwater use.

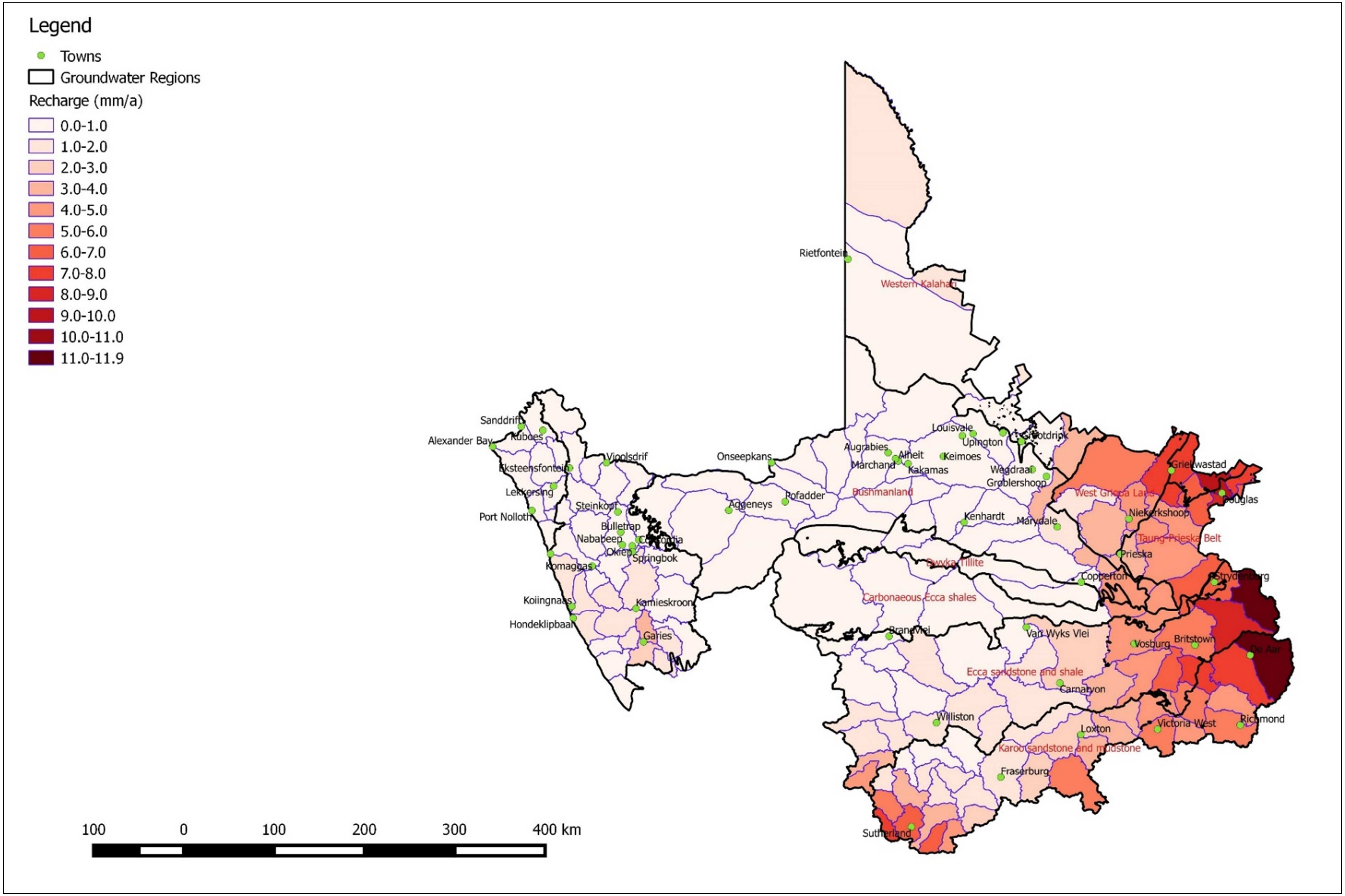


Figure 5.4 Groundwater recharge

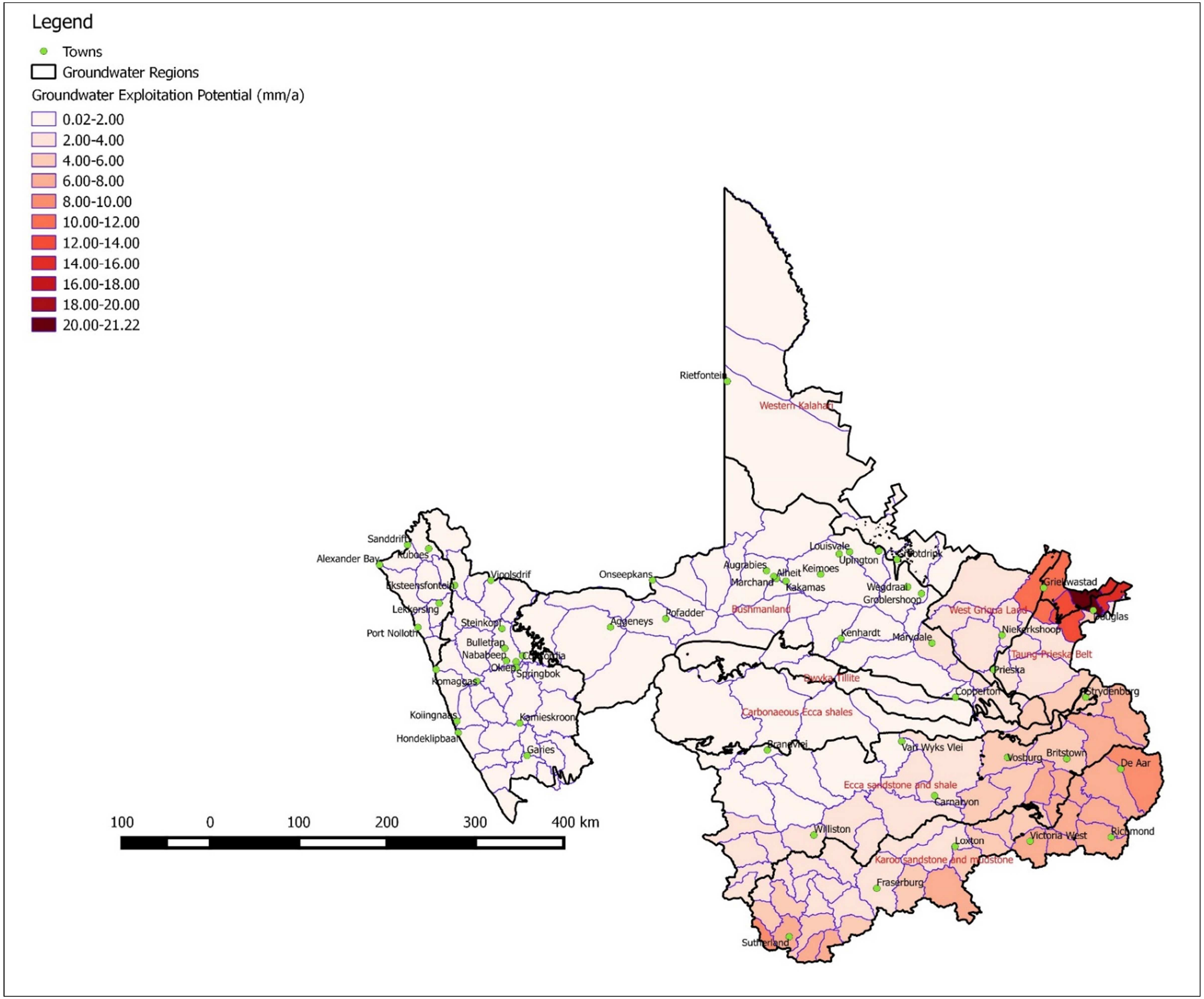


Figure 5.5 Groundwater exploitation potential

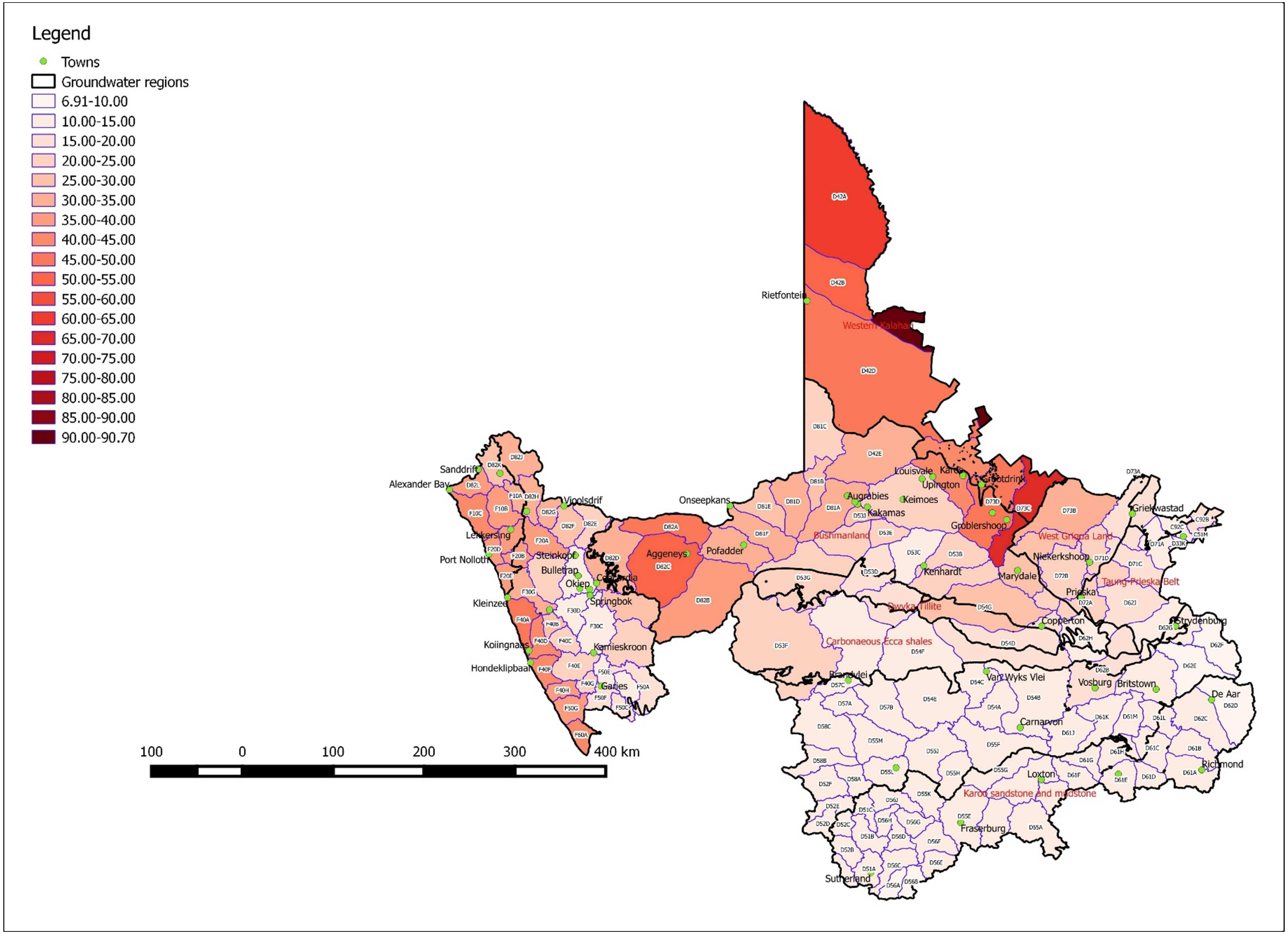


Figure 5.6 Mean groundwater level in mbgl

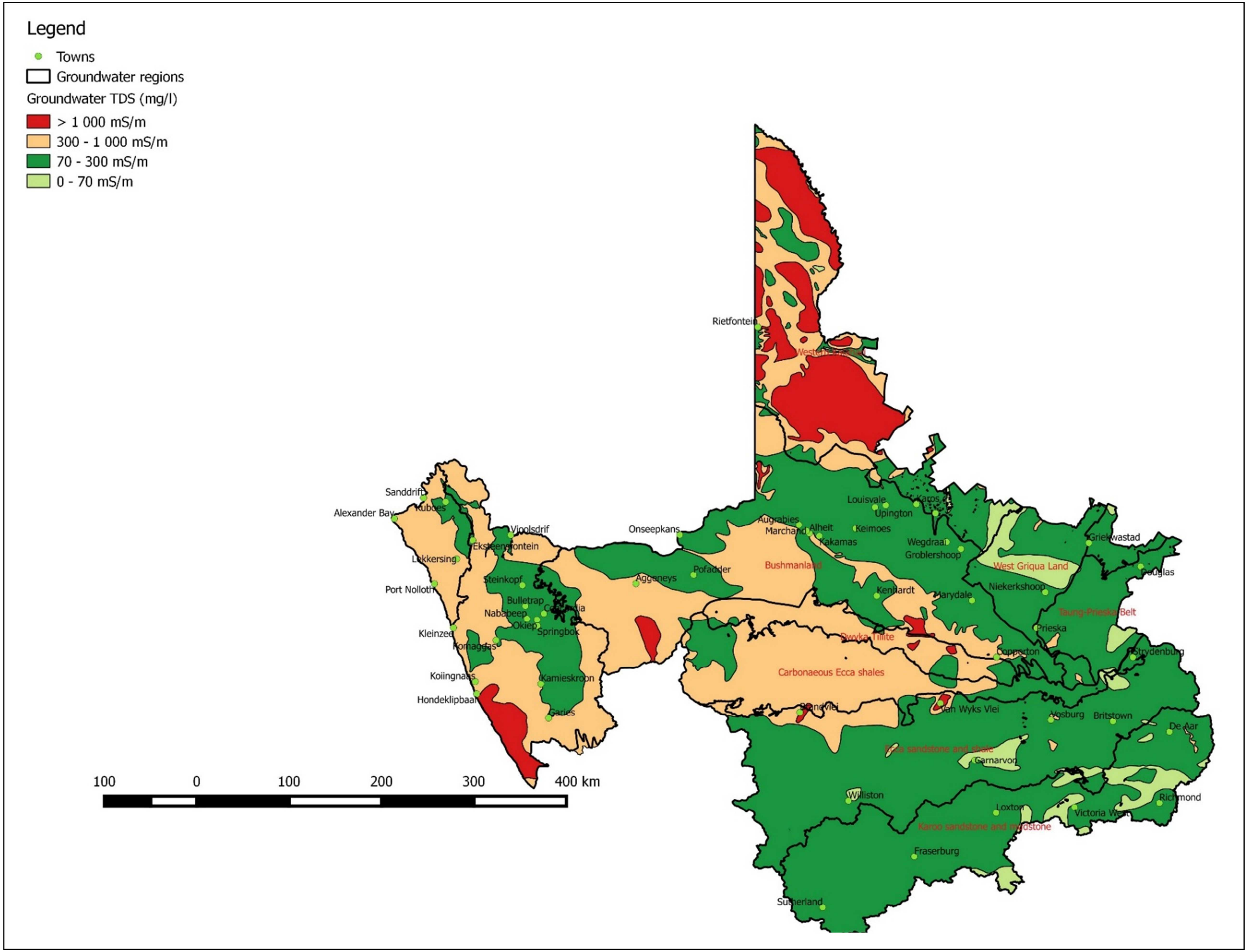


Figure 5.7 Groundwater electrical conductivity

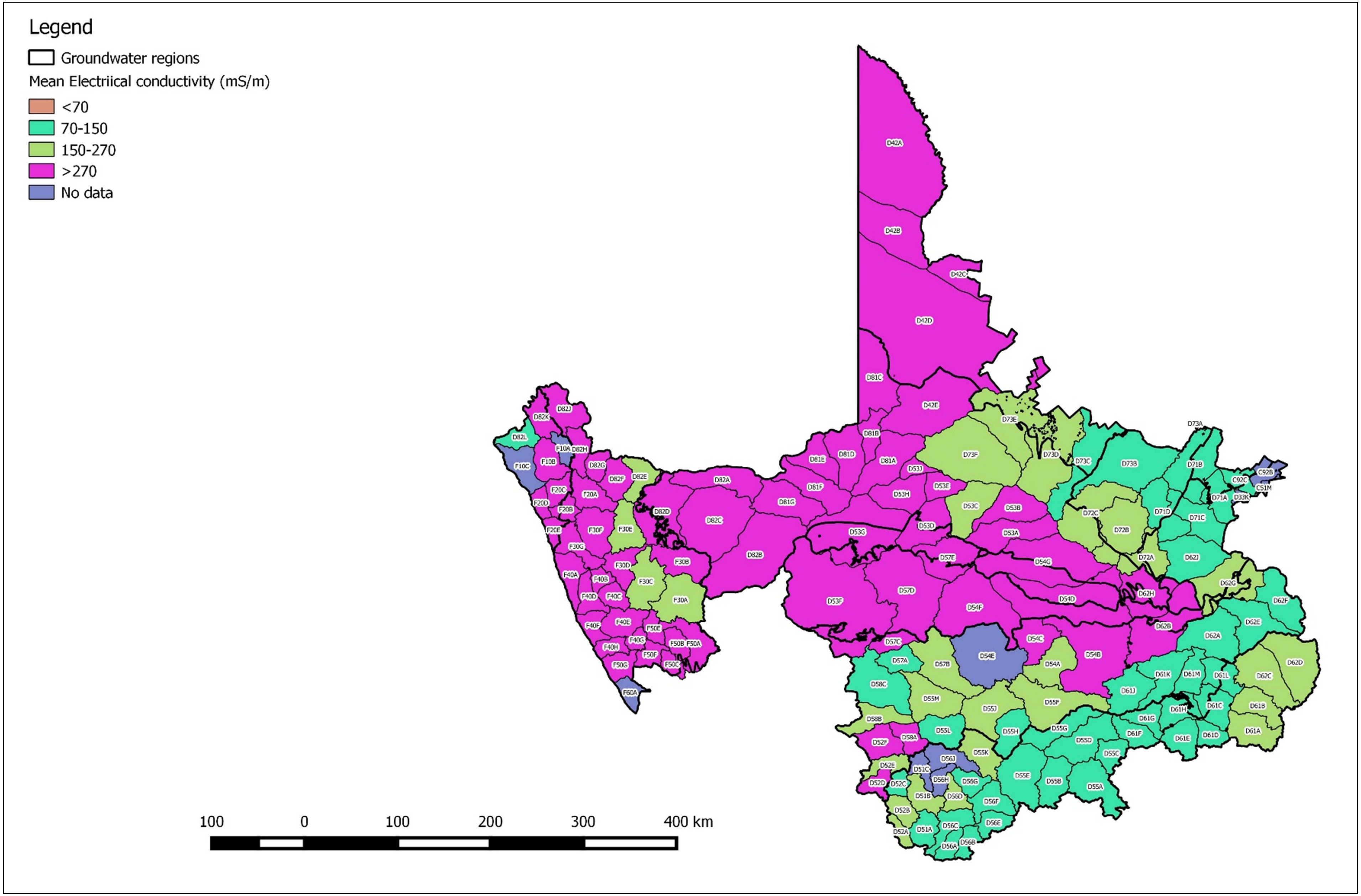


Figure 5.8 Mean groundwater quality class by EC for domestic use per quaternary catchment

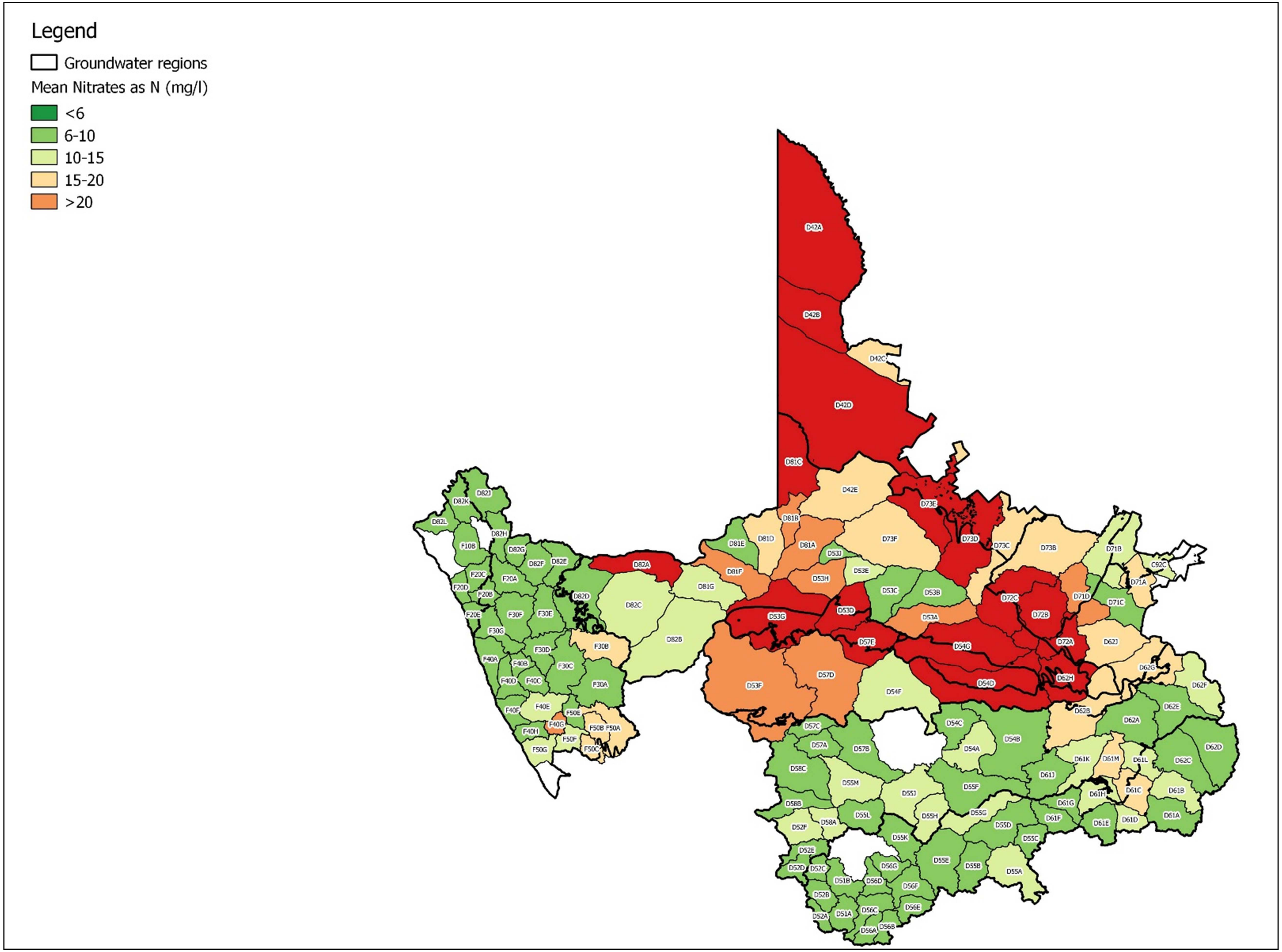


Figure 5.9 Mean groundwater quality class by nitrates for domestic use per quaternary catchment

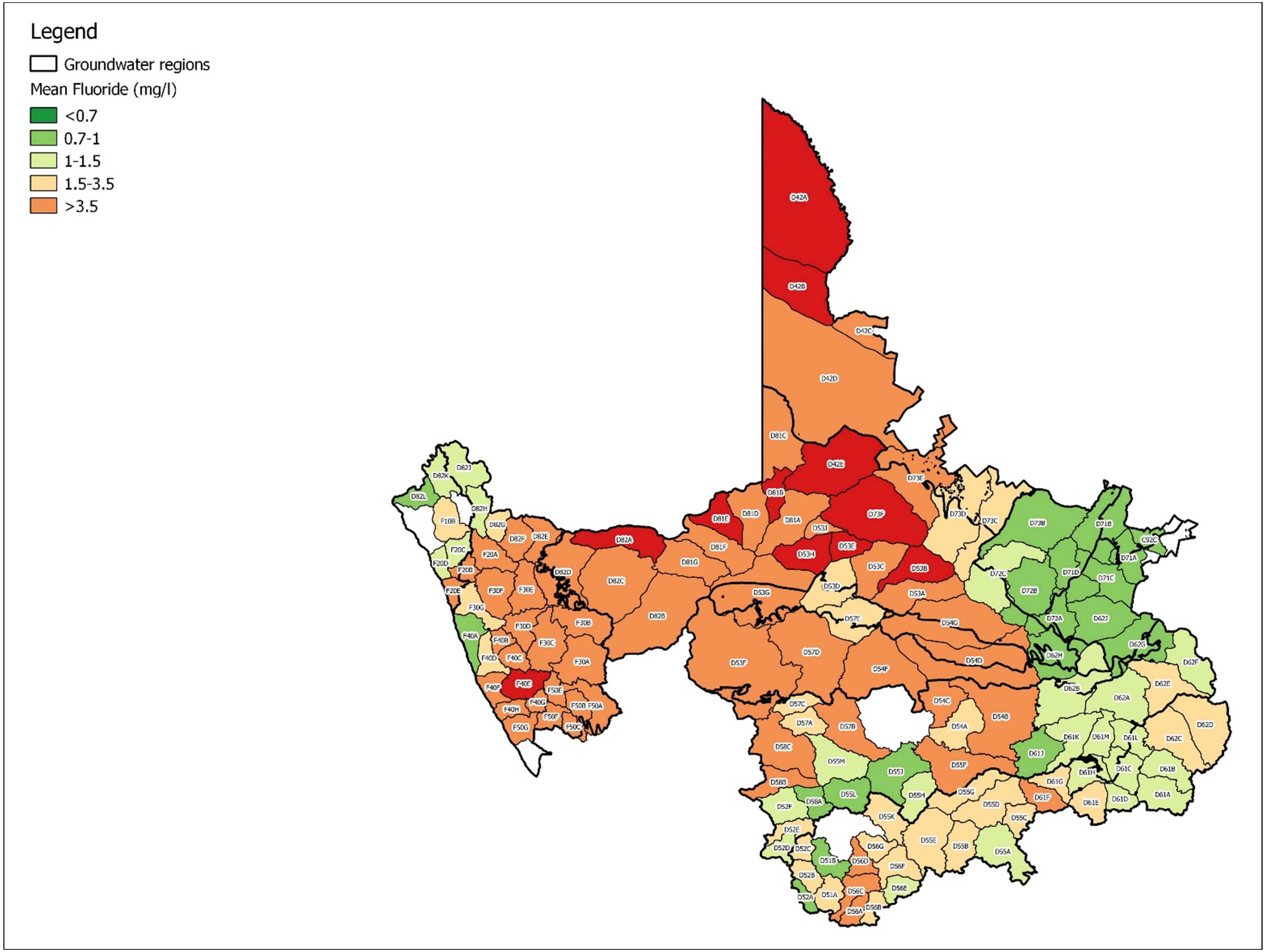


Figure 5.10 Mean groundwater quality class by fluoride for domestic use per quaternary catchment

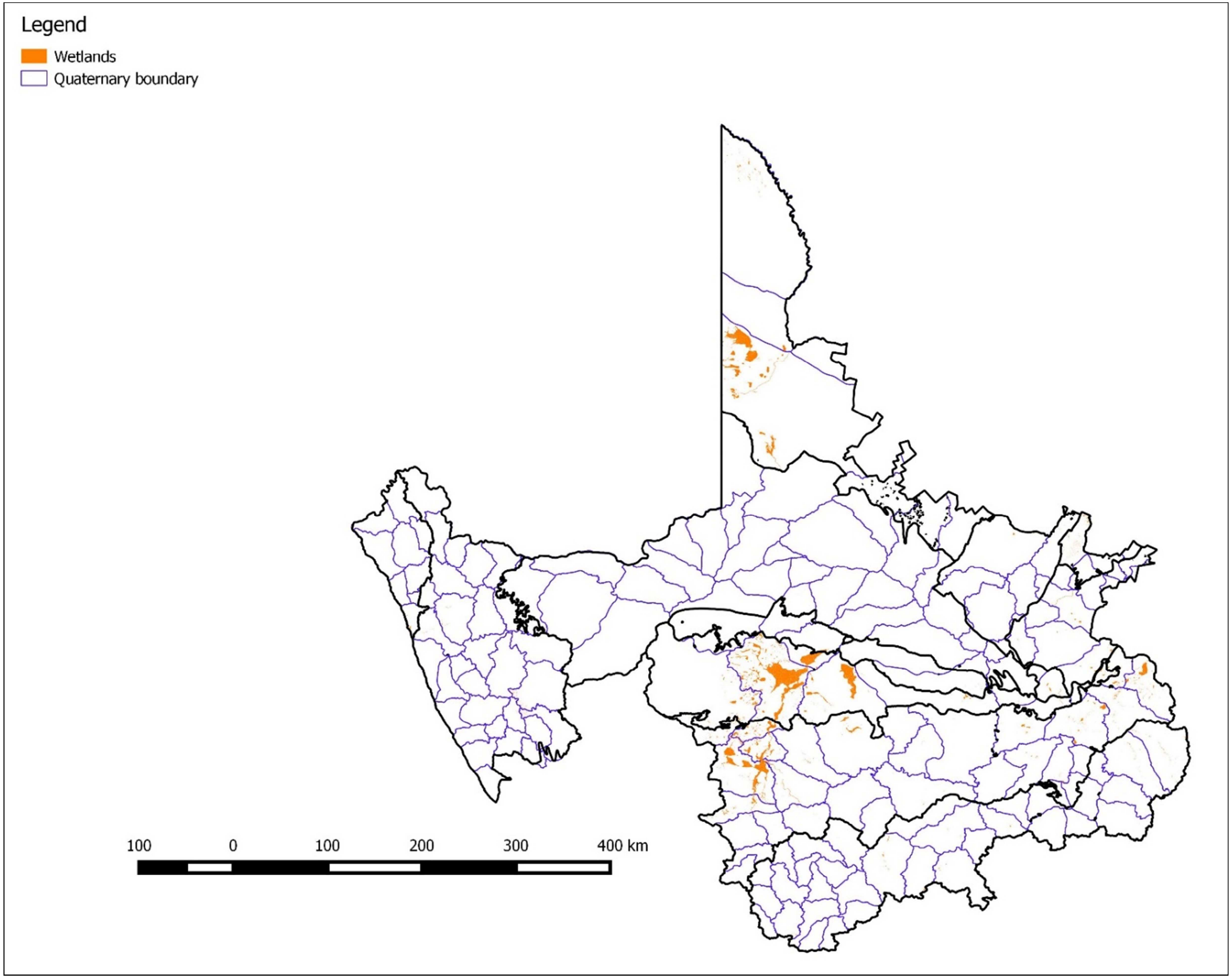


Figure 5.11 Location of identified wetlands

Table 5.4 Description of GRUs

GRU No.	GRU	Main Characteristic	Quaternary catchment
1	Bushmanlandeast	Metamorphic Terrane	D53C D62H D72A, D72B, D72C D73C, D73D, D73E, D73F
2	Bushmanland west	Metamorphic terrane Poor water quality	D42E D53A, D53B, D53D, D53E, D53G, D53H, D53J D54D, D54G D81A, D81B, D81C, D81D, D81E, D81F, D81G, D82A, D82B, D82C, D82D
3a	Ecca Carbonaceous shales west	Poor groundwater quality from marine sediments	D53F, D53G D54D, D54F, D57D, D57E
3b	Ecca Carbonaceous shales east	Higher Recharge than western region with better water quality	D62B, D62H, D62G
4a	Dwyka tillite	Poor yield and groundwater quality	D53D, D53F, D53G, D54D, D54G D57E
4b		Poor yield and groundwater quality Higher Recharge than western region	D62H, D62G, D62J
5	Ecca sandstone and shale west	Better water quality than other Ecca shales Pans	D53F D54E D55M D55M D57A, D57B, D57C D58B, D58C
6	Ecca sandstone and shale south and central	Lack of pans	D52D, D52E, D52F D54A, D54B, D54C, D55F, D55J, D55L, D58A, D61J,
7	Ecca sandstone and shale east	Higher recharge than the western region	D61C, D61H, D61K, D61L, D61M D62A, D62B, D62C, D62D, D62E, D62F, D62G
8	Far Northwestern Coastal Hinterland	Coastal metamorphic Terrane	D82K, D82L F10A, F10B, F10C F20B, F20C, F20D, F20E
9	Ghaap Plateau	Dolomitic area	C92B, C92C D71A, D71B
10	Karoo sandstone and shale west	Potential for fracking	D51B, D51C

GRU No.	GRU	Main Characteristic	Quaternary catchment
			D52C D55A, D55B, D55C, D55D, D55E, D55G, D55K D56D, D56F, D56G, D56H, D56J D61F, D61G
11	Karoo sandstone and shale east	Potential for fracking Higher recharge than the western region	D61A, D61B, D61C, D61D,D61E, D61H, D61L D62C, D62D
12	Namaqualand east	Metamorphic Terrane	D82D, F30A, F30B, F30C, F30D, F30E,
13	Namaqualand west	Metamorphic Terrane Poor water quality	F20A, F20B F30F, F30G F40B, F40C, F40E, F50A, F50B, F50C, F50E, F50F,
14	Taung-Prieska belt	Tertiary cover over underlying geology	C51M C92B, C92C D33K D62G, D62J D71A, D71B, D71C, D71D D72A, D72B
15	West Griqualand	Ironstones	D71B, D71C, D71D D72A, D72B, D72C D73A
		Baseflow	D73B
16	Western Kalahari	Kalahari cover	D42A, D42B, D42C, D42D D73C, D73D, D73E
17	Richtersveld	Metamorphic Terrane	D82A, D82D, D82E, D82F, D82G, D82H, D82J
18	Namaqualand coastal	Sediment cover over Nama and Vanrhynsdorp Group	F40A, F40D, F40F F50G F60A
19	Karoo sandstone and shale southwest	Higher rainfall	D52A, D52B D56A, D56B, D56C, D56E
		Baseflow	D51A

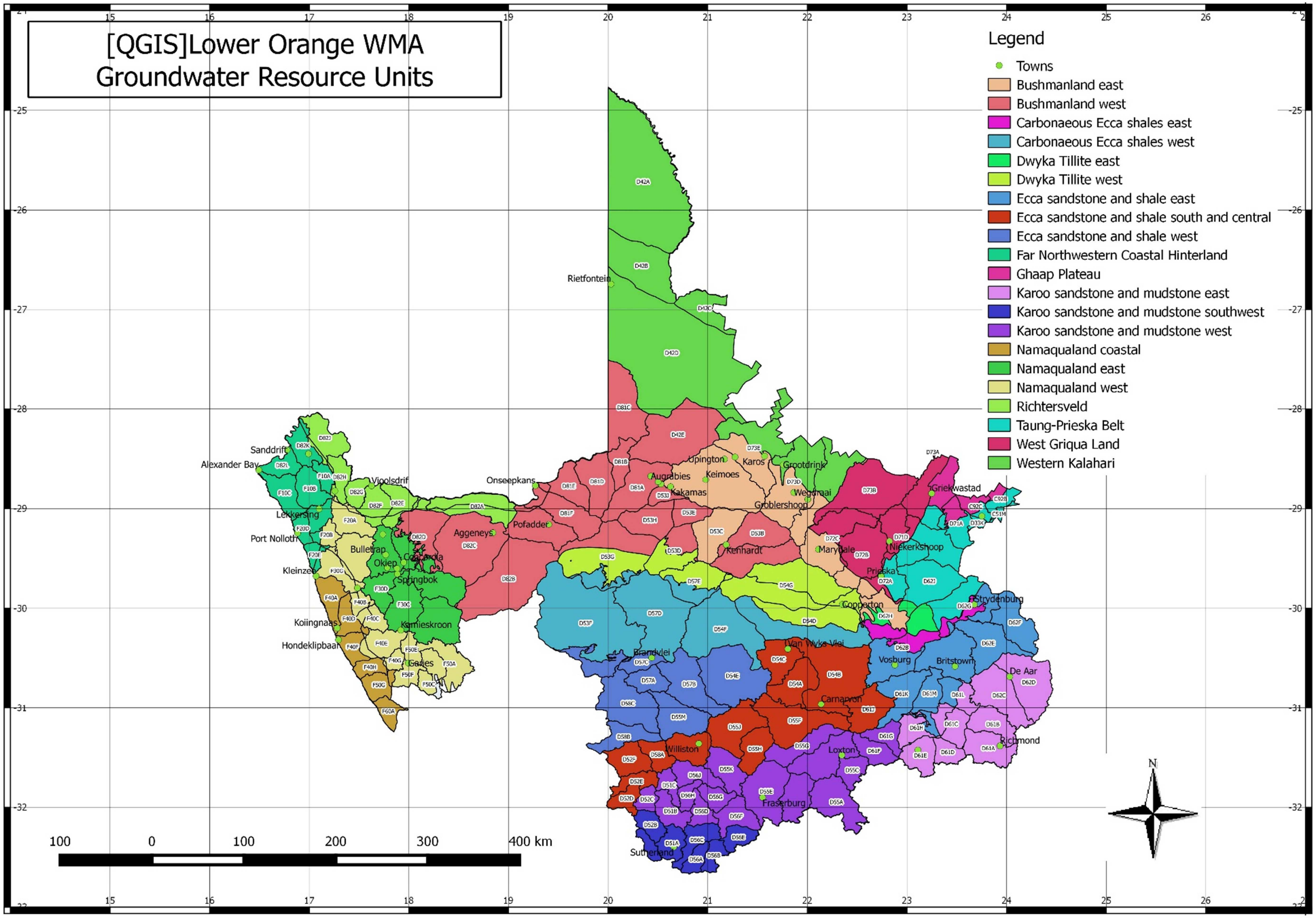


Figure 5.12 Groundwater Resource Units of the Lower Orange WMA

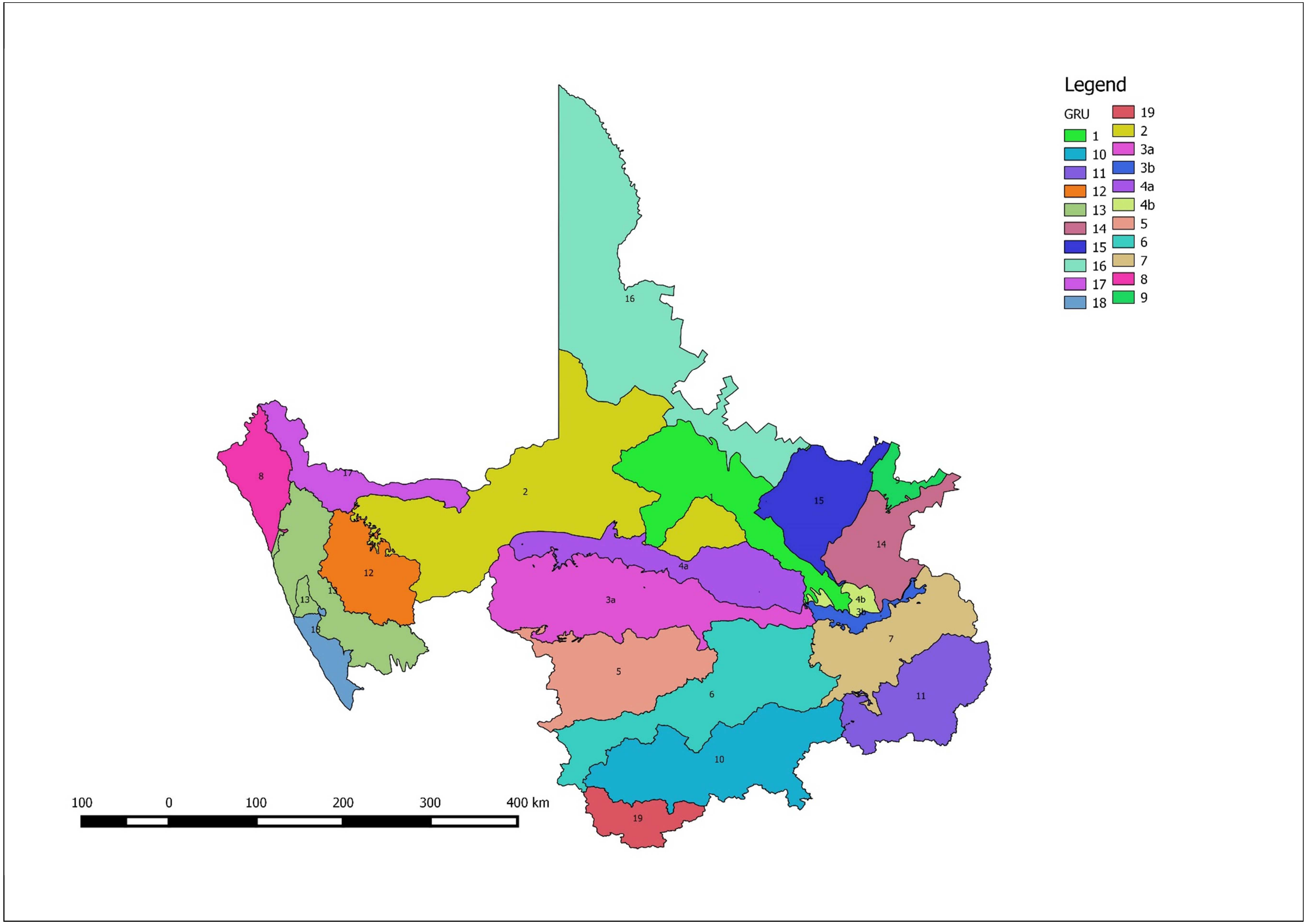


Figure 5.13 Preliminary GRU numbers

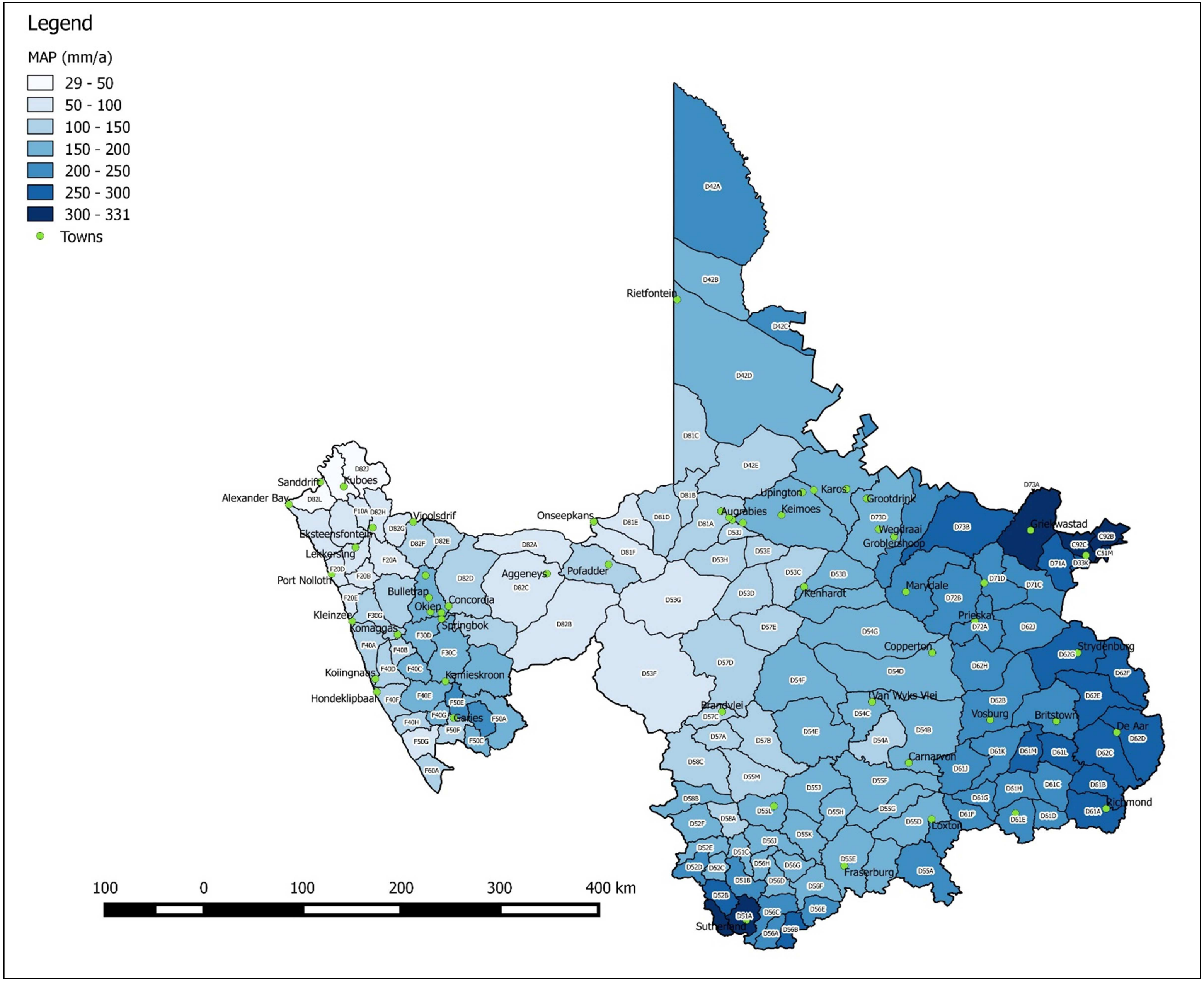


Figure 5.14 Mean Annual Precipitation per quaternary catchment

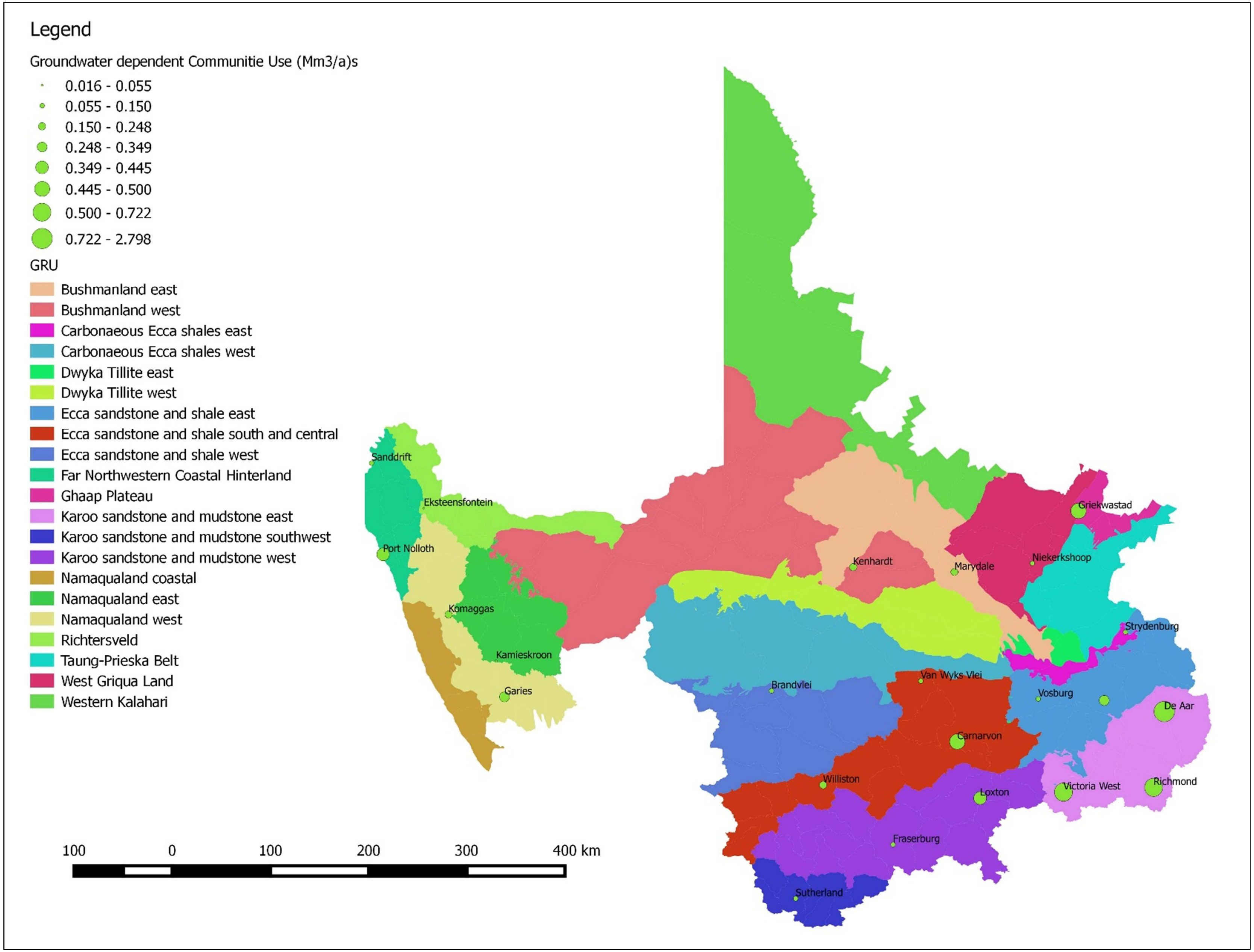


Figure 5.15 Groundwater use by municipal schemes

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7 APPENDIX A: COMMENTS REGISTER

	Section	Report statement	Comments	Changes made?	Author comment
	Comments received from RDM: 12 May 2016				
1	General		The reviewer felt that the delineation is mainly from a geology perspective instead of mainly from a geohydrological perspective. Though these are connected by the reviewer felt that the delineation should be more from a geohydrological perspective than mainly a geological point of view.	No	The approach followed for delineation in hierarchical order is: ▪ An original primary delineation by quaternary catchment boundary as demarcated in Water Resources South Africa 2012. ▪ Geological age and lithology. ▪ Identification of ground water regions based on geological considerations. ▪ Identification of catchments with baseflow to surface water bodies, as listed in Groundwater Resource Assessment Phase II (GRAII). ▪ Climate, recharge, and Harvest Potential. ▪ Groundwater levels from the DWS National groundwater monitoring network. ▪ Groundwater quality from the DWS National water quality monitoring network. ▪ Groundwater dependent ecosystems and or wetlands. ▪ Groundwater use and stress from the WARMs[3] data base. ▪ Except for geology, all the remainder are geohydrological considerations.
2	Fig 1.1		Groundwater is lacking in Figure 1.1 yet all the other water resources are included	Yes	Note, the blocks delineating rivers, wetlands and estuaries are not water resources but ecosystems. The water resources are in the left block and is relevant for both groundwater and surface water. However, the figure was removed as these steps are changing as we speak as comments on a parallel project are being received. It is therefore probably premature to include the figure.

[3] Water Resources Simulation Model 2000. The Pitman Model with Sami Model Groundwater interactions.

	Section	Report statement	Comments	Changes made?	Author comment
3	5.9, Fig 5.12	The final delineation of GRUs is shown in Figure 5.12	Perhaps also include another map after Fig 5.12 in which the GRUs are labelled in the map for easy identification of the GRUs since some of the colours in Fig 5.12 might not be easy to differentiate when interpreting on the legend. This map need NOT have the quaternary catchments but just the GRU boundaries and then label them as GRU 1, 2, 3 etc.	Yes	Such a map has been added.