RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA

ECOSPECS AND MONITORING REPORT

April 2023







Department of Water and Sanitation

Chief Directorate: Water Ecosystem Management

DEPARTMENT: WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS MANAGEMENT

RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA

WP11340

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ACRONYMS AND ABBREVIATIONS

AEC	Attainable Ecological Category
ASPT	Average Score per Taxon
CSIR	Council for Scientific and Industrial Research
D:RDM	Directorate: Resource Directed Measures
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EcoSpecs	Ecological Specifications
EcoStatus	Ecological Status
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystems Priority Areas
GIS	Geographic Information System
GRU	Groundwater Resource Units
l/s	Litre per second
mbgl	meters below ground level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MIRAI	Macro Invertebrate Response Assessment Index
mm/a	millimetre per annum (precipitation)
mS/m	milliSiemens per meter (measurement of the electrical conductivity of water)
NWA	National Water Act
PES	Present Ecological State
psu	practical salinity unit
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANBI	South African National Biodiversity Institute
SANS	South African National Standard
SASS5	South African Scoring System Version 5
SAWS	South African Weather Service
TEC	Target Ecological Category
TMG	Table Mountain Group
TPC	Thresholds of Potential Concern

WMA Water Management Area

WR2012 Water Resources 2012

WRC Water Research Commission

WRSM Water Resources Simulation Model

GLOSSARY

ANTHROPOGENIC	Caused by human activity.
AQUATIC	Relating to water.
AQUIFER	Underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt)
BASEFLOW	That part of stream flow is contributed by groundwater and discharged gradually into the channel.
BIOTA	The living organisms occupying a place together, e.g. plants, animals, bacteria, etc in the aquatic biota, or terrestrial biota.
CATCHMENT	The area from which any rainfall will drain into the watercourse or watercourses, through surface or subsurface flow.
ECOCLASSIFICATION	The term used for Ecological Classification refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers compared to the natural or close to the natural reference condition. The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints has to be considered.
ECOLOGICAL HEALTH	A descriptive non-specific term for the combination of all factors, biotic and abiotic, that make up a particular environment and its organisms
ECOREGIONS	Areas of similar ecological characteristics.
ECOSYSTEM	A community of animals, plants and bacteria with its physical and chemical environment.
EPHEMERAL	An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year
ENVIRONMENT	All of the external factors, conditions, and influences that affect the growth, development, and survival of

	organisms or a community. This includes climate, physical, chemical, and biological factors, nutrients, and social and cultural conditions.
ESTUARY	A partially or fully enclosed body of water that is open to the sea permanently or periodically, and within which the seawater can be diluted, to a measurable extent, with fresh water drained from land.
FLOW REGIME	Recorded or historical sequence of flows used to create a hydrological profile of the water resource.
HABITAT	The environment or place where a plant or animal is most likely to occur naturally.
HYDRAULICS	Of, involving, moved by, or operated by a fluid, especially water, under pressure.
HYDROLOGY	The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.
IMPACTS	The measurable effect of one thing on another.
INDIGENOUS	Living or growing naturally in a particular area, but not naturally confined only to that area or any resource consisting of (a) any living or dead animal, plant or other organisms of an indigenous species, (b) any derivative of such animal, plant or other organisms; or (c) any genetic material of such animal, plant or other organisms.
LEGISLATION	A law or a series of laws
MANDATE	The authority to do something, given to an organisation or government, by the people who support it.
MODIFIED	Changed, altered.
POLICY	A plan of action, statement of ideals, etc. proposed by an organization, government, etc.
PRISTINE	Remaining in a pure or natural state.
PREDATION	A predator is an animal that kills and eats other animals. Predation is the capturing of prey as a means of maintaining life.
PRESENT ECOLOGICAL STATE	The current state or condition of a resource in terms of its various components, i.e., drivers (physico-chemical, geomorphology, and hydrology) and biological response

	(fish, riparian vegetation and aquatic invertebrates). The prequel to recommended ecological category.
QUATERNARY CATCHMENT	A fourth-order catchment in a hierarchical system in which the primary catchment is the major unit.
RIPARIAN	Of, on, or relating to the banks of a watercourse, including the physical structure and associated vegetation. The area of land adjacent to a stream or river that is influenced by stream-induced or related processes.
SPECIES	A kind of animal, plant or other organism that does not normally interbreed with individuals of another kind, and includes any sub-species, cultivar, variety, geographic race, strain, hybrid or geographically separate population
TERTIARY CATCHMENT	A third-order catchment in a hierarchal classification system in which a primary catchment is a major unit.
SURFACE WATER	All water that is exposed to the atmosphere, e.g., rivers, reservoirs, ponds, the sea, etc.
VARIABILITY	The tendency to vary i.e., to change.
WATERCOURSE	“A natural channel or depression in which water flows regularly or intermittently” (definition in the NWA)
WATER QUALITY	The value or usefulness of water, determined by the combined effects of its physical attributes and its chemical constituents and varying from user to user
WETLANDS	“Land which is transitional between terrestrial and aquatic systems where the water table is usually at, or near the surface or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support vegetation typically adapted to life in saturated soil” (definition in the NWA)

1. INTRODUCTION

1.1 Background

The Chief Directorate: Water Ecosystems Management of the Department of Water and Sanitation (DWS) has embarked on a preliminary Reserve determination study for the G30 and F60 catchments (Figure 1). These are the two remaining Tertiary Catchments of the Berg Olifants Water Management Area (WMA) that still require a higher level of confidence Reserve determination. The Verlorevlei within the study area was designated as a Wetland of International Importance (Ramsar Site) on 28 June 1991 under the Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat. In addition, peat wetlands have been identified to occur in the area that is associated with the Verlorevlei that provide important ecological services but are under severe threat and require urgent protection. It is therefore crucial that the Reserve calculations are revisited and the water resources with the Sandveld catchments addressed holistically, with a clear understanding of the surface and groundwater interactions and interdependencies as well as the rainfall and flow patterns being well researched and documented.

1.2 Objectives

This study aims to identify gaps in previous Reserve Determination Studies and to determine the Reserve at a high level of confidence to yield results that could be gazetted and provide legal protection specifications. The following objectives are listed:

1. Determination of the water quantity and quality for the protection of rivers at various Ecological Water Requirement (EWR) sites;
2. Determination of the water quantity and quality for the protection of priority wetlands, pans and lakes;
3. Determination of the water quantity and quality of estuarine freshwater requirements for the protection of various identified estuaries;
4. Determination of the groundwater quantity and quality requirements for the protection of groundwater resources; and
5. Determination of the quantity and quality of water required for the provision of Basic Human Needs.

1.3 Purpose of this Report

The purpose of this report is to identify the Ecological Specifications (EcoSpecs), Thresholds of Potential Concern (TPCs) and Reserve monitoring requirements for the rivers, wetlands, estuaries and groundwater in the F60 and G30 catchments.

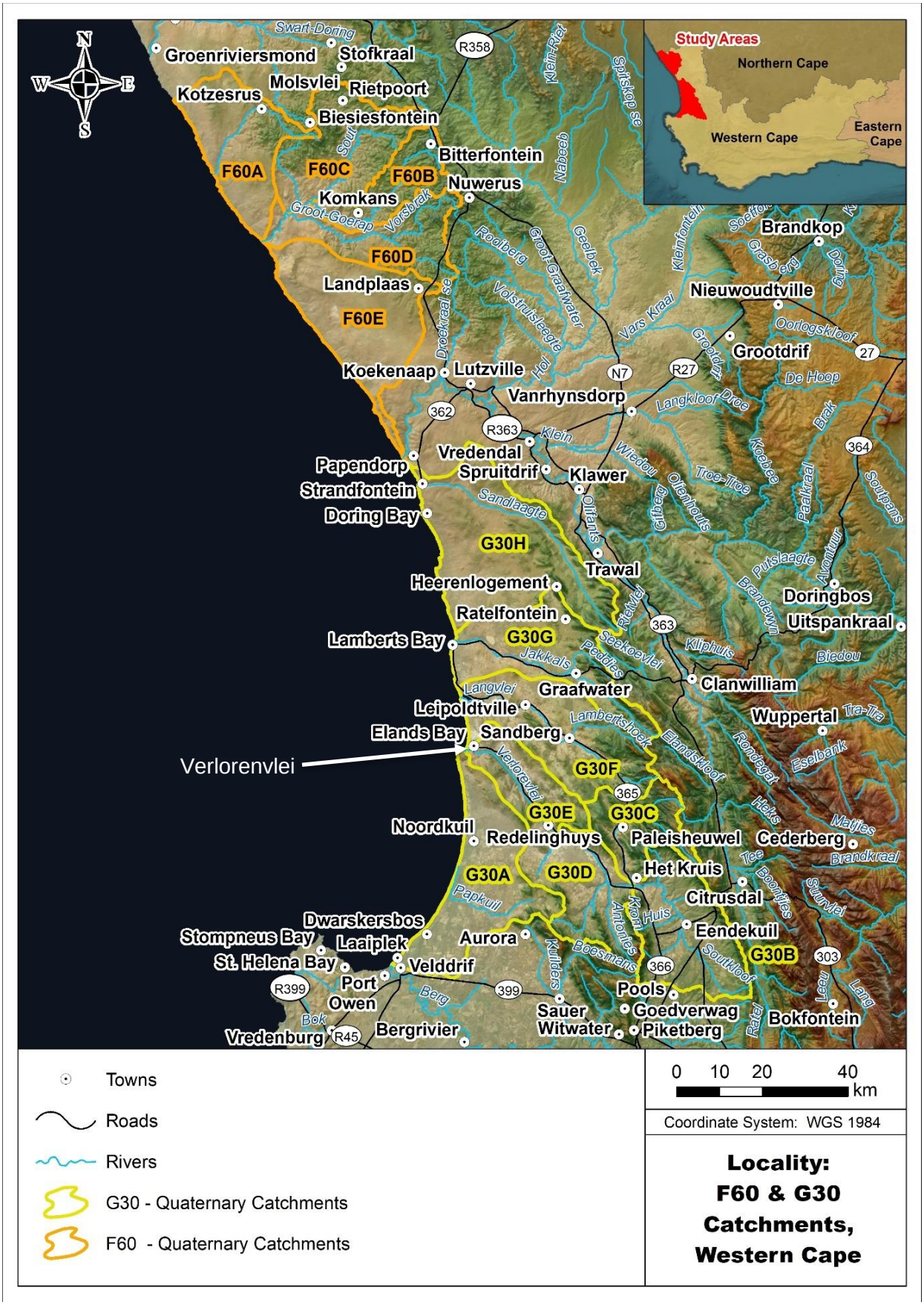


Figure 1: Map of the study area with the location of the G30 and F60 Catchments and main aquatic features shown

1.4. The Study Area

The study area comprises two Tertiary Catchments, the G30 (Sandveld) and the F60 (Knersvlakte) Catchments. The majority of the G30F60 Catchment Area falls within the Western Cape Province, with a small section of the most northerly section of the catchment falling within the Northern Cape Province.

The Sandveld consists of the coastal plain along the west coast of South Africa, bordered by the Olifants River catchment in the north and east, the Berg River catchment in the south and the Atlantic Ocean coastline in the west. The area contains the following seasonal river and wetland systems:

- Verlorenvlei River System with its main tributaries, the Kruismans, Bergvlei, Krom Antonies and Hol Rivers, as well as the Verlorenvlei Estuary;
- Langvlei River with the Wadrift wetland and pan;
- Jakkals River and Jakkalsvlei Estuary;
- Sandlaagte River;
- Rocherpan and Papkuil River; and
- Several smaller wetland areas along watercourses, coastline and on hillslopes.

The Ramsar-designated Verlorenvlei estuarine and wetland system is the best-known of the systems and has a clear responsibility of actively conserving the unique wetland and the biological diversity that it supports. Several rare species have been recorded in the estuarine and wetland system including the white pelican and eight other threatened birds. Over multiple surveys, more than 75 different species have been recorded with numbers of individual birds exceeding 6 500. The site is one of the most important wetlands for wading birds in the Western Cape as it provides feeding, nesting and resting habitats to a large variety of birds.

The Groot Goerap/Sout and Brak River Catchments to the north of the Sandveld are in the even more arid Knersvlakte region. The area comprises ephemeral rivers and wetlands, including:

- Sout River System with its main tributaries, the Groot and Klein Goerap Rivers and the South Estuary;
- Brak River and Estuary; and
- Several mostly isolated depression wetlands.

Groundwater in the G30 (Sandveld) catchment enables extensive agricultural activity and is the sole source of freshwater for most of the towns and settlements within the catchments. Groundwater also plays a significant role in sustaining surface water ecosystems. The catchments contain both fractured and intergranular areas. Average yields range from very low (0.5 l/s) to high yielding (> 5 l/s), with identified paleochannels and other geological pathways, producing boreholes of a yield higher than 25 l/s. Groundwater quality is described as being good across the G30 catchments, however, where Malmesbury Group formations occur, the main aquifer can be identified as yielding groundwater of poor quality. The main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg and Piketberg Mountain ranges. The Graafwater aquifer

management area coincides largely with the Jakkals River Catchment in the larger G30 catchment.

Groundwater availability in the F60 catchments is much lower than in the G30 catchments. The geological setting of the area is also more complex. The area has been classified as containing both intergranular and fractured aquifers (DWAF 2005). The regional expected yields are very low (0.1 - 0.5 l/s) with higher-yielding boreholes (up to 2 l/s) at the most southern point of the F60 catchments. Groundwater quality across the catchment is generally categorised as poor, with EC values of over 1000 mS/m.

Land use in the area consists largely of livestock farming (sheep and goats), with small areas being used for dryland farming. fishing and ecotourism around the coastal resort towns. Intensive irrigation of citrus and potatoes is undertaken in the G30 Catchment.

Urban and rural areas are small, with the main towns being Redelinghuys, Elands Bay, Eendekuil, Leipoldtville, Graafwater, Lamberts Bay, Strandfontein and Bitterfontein. Water use in the urban areas is supplied by coastal aquifers where seasonal peaks relating to tourism influx need to be provided for.

There is very little quantitative knowledge of surface groundwater interaction in the study area. Concerns have been raised about the impact of groundwater abstraction on the surface water ecosystems in the G30 Catchment where water abstraction from surface and groundwater in the southern portion of the study area has significantly modified the flow of the aquatic ecosystems, particularly in summer. Modified flows have reduced habitat integrity and, consequently, the goods and services provided by these ecosystems.

Baseflow is low to zero in the regolith-dominated sub-areas of the F60 Catchment, indicating a very low, negligible groundwater contribution to surface water bodies.

1.5. Study Methodology and Approach

The river, wetland, estuarine and groundwater components of the Reserve determinations will use the latest RDM recommended methodologies. While the standard methodologies for the determination of the Basic Human Needs and ecological Reserve are followed in the study, the need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers has been recognised. This adapted approach is deemed to be necessary to address the following:

- Most of the surface water features within the study area are non-perennial with a hydrological regime that has high variability in flow both spatially and temporally with a highly unpredictable surface water flow;
- Surface water ecosystems in these systems are primarily groundwater-fed during the dry season. They thus have a strong wetland character and are often confined to isolated pools towards the end of the dry season. The aquatic biota associated with these habitats comprises hardy species with low diversity, although both the habitat and biota may be of high ecological importance;

- The estuaries within the area comprise mostly coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems. As a result, they tend to be hypersaline;
- Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) was thus critical; and
- The products from the groundwater specialists have provided an improved understanding of the surface water ecosystems and the delineation of the river reaches and wetland regions as well as the water supply to those ecosystems. The Wetland component in particular needed to provide inputs to and rely on inputs from the Rivers and Groundwater specialists.

The revised generic procedure is provided in Figure 2 (DWAF, 2008), which shows the process for the determination of the Ecological Water Requirement in the context of the larger Resource Directed Measures process, with possible links to issues such as the stakeholder process, classification, implementation and operation, indicated as suggested ways to integrate the Reserve determination process.

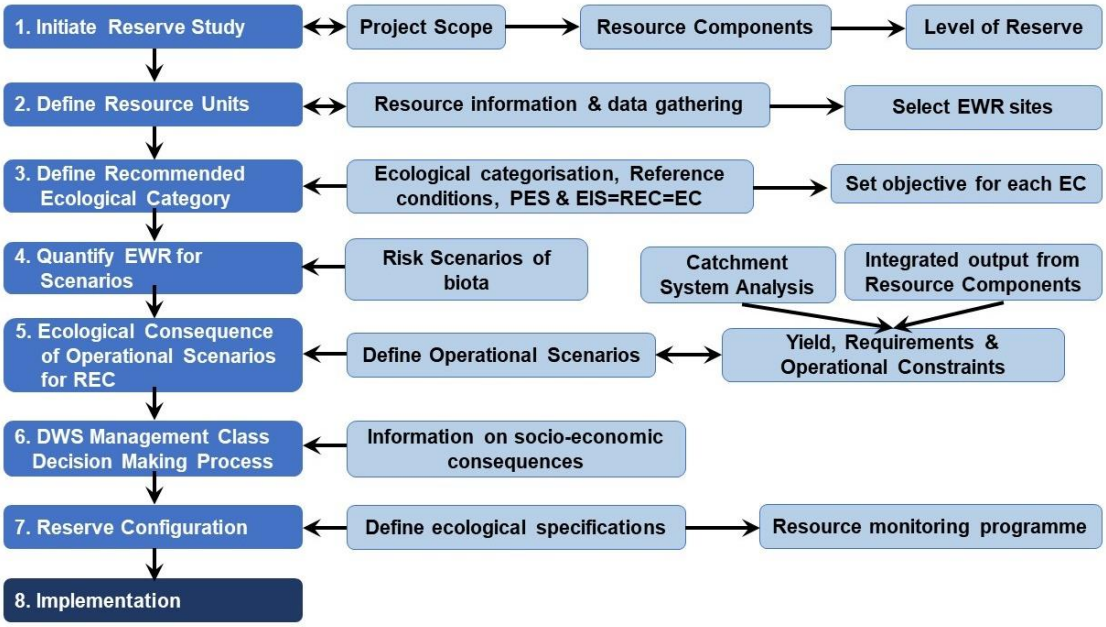


Figure 2: The Reserve Determination Process (adapted from DWAF, 2008)

This report provides the outcome of the seventh step in the above Reserve determination process, which is to define the ecological specifications and resource monitoring programme for the recommended ecological Reserve.

2. INTRODUCTION TO ECOSPECS AND ECOLOGICAL MONITORING

The final step in a Reserve determination study is to define EcoSpecs, Thresholds of Potential Concern (TPCs) and monitoring recommendations for the implementation of the ecological Reserve. This is in line with the National Water Act (Act No. 36 of 1998) (NWA) requirement that Resource Quality Objectives (RQOs) be defined for all significant water resources, based on their water resource class. RQOs provide clear, auditable goals relating to the Recommended Ecological Category of the relevant water resources.

The ecological component of RQOs is referred to as EcoSpecs. These are clear and measurable specifications of ecological attributes (e.g. flow, water quality, biological integrity), that define the Recommended Ecological Category (REC). The purpose of EcoSpecs is to establish clear goals relating to resource quality (Kleynhans et al. 2005) that can inform the implementation of the ecological Reserve. EcoSpecs refer explicitly to ecological information while RQOs include social and economic objectives.

The main aim of ecological Reserve monitoring is to measure and determine how the resource is changing over time, and to ensure that resource remains within acceptable limits of change for the REC. Monitoring therefore provides the critical link between objectives and management interventions.

An essential requirement of a monitoring programme is a clearly defined baseline condition against which future changes may be compared, clearly defined objectives, and clearly defined TPCs. TPCs are the upper and lower levels within a continuum of change for the selected environmental (abiotic or biotic) indicators. The TPCs provide specific targets or the limits of acceptable change in an ecosystem structure, function and composition. In essence, TPCs should provide early warning signals of potential non-compliance to ecological specification (i.e. not the point of ‘no return’). This implies that the indicators (or monitoring activities) selected as part of a long-term monitoring programme need to include biotic and abiotic components that are particularly sensitive to changes in flow. These limits may need to be modified as the knowledge and understanding of the ecosystem improves.

The following are thus provided in this section:

- Baseline Conditions: To assess the suitability of available data for defining baseline conditions for monitoring the ecological Reserve and to recommend additional baseline data requirements, if needed;
- EcoSpecs: To define the EcoSpecs for the Recommended Ecological Category (REC) at each ecological Reserve monitoring site, and;
- Threshold of Potential Concern: To define the associated Thresholds of Potential Concern (TPCs) for each monitoring site.

3 ECOSPECS AND MONITORING RECOMMENDATIONS

3.1. Groundwater Reserve Monitoring Recommendations

The Reserve determination process for groundwater and surface water is typically done separately for each of the disciplines according to selected appropriate resource units, where river catchments and sub-catchments usually determine the resource units. For this study, the occurrence of groundwater, aquifer characteristics and site-specific groundwater-related phenomena were taken into account during the process of delineation of the Groundwater Resource Units (GRUs) within the F60 and G30 catchments.

EcoSpecs as described in the previous section relate specifically to surface water resources with their associated aquatic ecosystems. It is thus RQOs that are specified for groundwater resources. Specifying RQOs for groundwater is however complex as the movement of groundwater is governed by aquifers and is not bound to surface drainage regions.

Because the groundwater Reserve and their associated RQOs for this study ultimately have to be linked to the surface water Reserve and EcoSpecs, it was decided to use quaternary catchments for the GRUs where possible. The quaternary catchments in the study area also tend to incorporate a single valley that relates well with perceived groundwater flow and surface water contribution.

RQOs exist for the quaternary catchments (The proposed classes and resource quality objectives are determined for all or part of every significant water resource within the catchments of the Olifants -Doorn Water Management Area, Government Gazette No 39943, dated 22 April 2016). In this study, the RQOs were revised and supporting monitoring recommendations were provided.

The groundwater RQO monitoring recommendations are provided in **Table 2** for each quaternary catchment. Additional groundwater Reserve monitoring recommendations are provided in Section 3.2.

Table 1: Groundwater RQO Monitoring Recommendations for F60 and G30 catchments

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
G30A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0.7 - 1.74	<11 mg/l	It recommended that this seepage area be installed with a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter. DWS monitoring needs to increase to include sites around spring.
		Salts	EC (mS/m)		28 - 14994	50 - 84.1	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Currently, the spring flow at Papkuils Seepage Area is not being monitored. This is a vital wetland and currently, the exact flow is unknown. The WARMS abstraction point linked to the spring is also seen as very conservative as the volume registered would not result in a wetland of this size.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.1 - 150	1 - 8.7	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 28	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
G30B	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that the Eendekuil municipal spring be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		10 - 860	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Currently, the spring flow at Eendekuil is not being monitored and it is recommended that a flow meter be installed on the 63 mm pipe between the spring collection box and the dam.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.06 - 56.08	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0 - 21.47	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30C	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 4.5	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		2 - 180	5.2 - 59	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Spring flow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study. Some springs are reportedly still flowing, but these could not be identified.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	1.3 - 100	0.3 - 111.8	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently very little DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area and in the recharge area of the Citrusdal Mountains.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0 - 25.01	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30D	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 2.68	<11 mg/l	Matroozefontein spring is being monitored by Bergrivier Municipality. Data must be shared with DWS. It recommended that springs in the mountainous areas be identified and be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		42 - 640	24.1 - 330	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	The Matroozefontein spring acts as the sole water supply for the town of Redelinghuys and has been equipped with a flow monitoring system by the Bergrivier Municipality. Springs in the mountains are not being monitored.	-	n/a	Need to be determined from stream flow monitoring.	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.64 - 60.13	0 - 78	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area and the recharge area of the Piketberg Mountains.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.1 - 43.06	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30E	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 14	<11 mg/l	It is recommended that this Kruisfontein seepage area be installed with a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter. A sampling at current monitoring boreholes needs to increase the parameters being analysed borehole monitoring sites are sufficient, but boreholes around Kruisfontein spring would be beneficial. Elevated nitrate levels in some boreholes need to be investigated.
		Salts	EC (mS/m)		20 - 3498	20 - 3498	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Kruisfontein seepage areas are located towards the northeast of Redelinghuys. The water from the various spring eyes flows into one channel that flows down and joins the Verlorenvlei River at Redelinghuys. Currently, this is not being monitored	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are	0 - 109.7	0.7 - 42	Should be maintained per borehole. In areas of groundwater-surface water interaction,	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.			groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 23	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30F	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 12	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter. Elevated nitrate levels in some boreholes need to be investigated.
		Salts	EC (mS/m)		31 - 2450	35 - 344	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study. Some springs are reportedly still flowing, but these could not be identified.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream	0 - 121.9	1.3 - 112	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must	DWS borehole monitoring sites need to be increased in the delineated important aquifer and the Swartberg Mountains.

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				location. Water levels should recover during the wet season.			decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 31.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30G	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 0.63	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		12 - 2330	46 - 870	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Springflow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	3.5 - 150	11.4 - 60	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	DWS borehole monitoring sites need to be increased to include boreholes in the upper reaches of the Jakkals river system.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered	0.01 - 23	n/a	n/a	The 2018 Government Gazette regarding the monitoring of

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.				groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30H	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 4.56	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		11 - 1361	364	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0 - 5	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.01 - 230	32.23 - 48	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	DWS borehole monitoring sites need to be increased to include boreholes in the upper reaches of the Sandlaagte river system.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 13.33	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
		Salts	EC (mS/m)		793 - 2450	-	n/a	spring flow infrastructure and that the water quality is also monitored every quarter.
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	2.12 - 121.92	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. This should include municipal boreholes at Lepelsfontein.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 7.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		793 - 2450	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	2.12 - 121.92	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 7.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60B	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		108 - 1345	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream	0.35 - 76.2	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must	DWS does have monitoring sites around the Bitterfontein wellfield that is located across the quaternary boundary in E33D. It is recommended that a monitoring network needs to be installed around waste ponds at the desalination plant at Bitterfontein.

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				location. Water levels should recover after rain.			decrease or stop if a continued negative trend is observed.	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.02 - 5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60C	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that some of the springs identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		200 - 3554	33.6 - 1184	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Springs have been identified and although they do not need larger surface water systems; these are extremely important for the local communities and ecosystems.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0 - 83	0 - 43	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when	0.01 - 6.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				baseflow and streamflow are impacted.				of abstraction data must be developed per catchment
F60D	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not shall not deteriorate from natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		142 - 3433	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Springflow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0 - 163	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 2.1	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60E	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		15 - 3434	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Springflow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0.23 - 127	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 8.2	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment

3.2. Additional Groundwater Reserve Monitoring Recommendations

Over and above the monitoring recommendations specifically relating to the recommended groundwater RQOs, the following additional groundwater Reserve monitoring and assessment recommendations are provided:

To develop and or use groundwater sustainably in the area, the following needs to be taken cognizance of:

- A groundwater monitoring programme must be established where there is currently no existence of groundwater quality and quantity monitoring.
- The directive from the 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment. This will vastly improve the accuracy of any reserve study for the area.
- For the G30 catchments not part of the Verlorenvlei system, it is recommended that isotope and inorganic sampling commences investigating the link between the E10 and the coastal G30 catchments of the northern Sandveld. It is hypothesized that the same system of lateral recharge from the mountainous areas towards the coastal areas occurs here as well as what has been found for the Piketberg mountains and the adjacent coastal catchments, but due to the lack of isotope and inorganic analysis data for this portion of the Sandveld, it could not be proven during this study. Thus, it is recommended that the sampling be done and analysed to investigate whether the northern Sandveld does obtain its recharge from the Cederberg and Swartberg Mountains as is assumed.
- For the G30 catchments, more monitoring sites need to be included in the Piket-Bo-Berg area, as well as the Swartberge and Citrusdal Mountains which are the assumed peak recharge areas for these catchments. Monitoring sites are also vitally needed in the Bergvallei and Jansekraal valleys, as no monitoring data could be obtained for these areas. For the G30D (Moutonshoek) area, one company does monitor the water levels in their boreholes that have been installed with telemetry monitoring systems, and they have shown interest in sharing this dataset with DWS. Monitoring sites in the upper Krom-Antonies and Hol systems are still needed. Important aquifers have been delineated to assist in guiding monitoring site areas, as well as delineating areas where baseflow and spring flow could be affected by groundwater abstraction.
- It is understood that the Papkuils, Langvlei and Jakkals systems would each be unique, but due to a lack of baseflow separation and streamflow data, the relationship between the surface and groundwater for these systems could be proven during this study. For systems where some observations could be interpreted to link the surface and groundwater systems, like for the Langvlei, the average breakdown between groundwater and surface water for the Verlorenvlei system was used. It is however recommended that each of these systems should have similar baseflow estimations done as what has been done for the Verlorenvlei systems. It is understood that these are costly and time-consuming studies and thus it would be recommended that universities be contacted to assist with these proposed studies.

- G30A: Currently, the spring flow at Papkuils Seepage Area is not being monitored. This is a vital wetland and currently, the exact flow is unknown. The WARMS abstraction point linked to the spring is also seen as very conservative as the volume registered would not result in a wetland of this size. It recommended that this seepage area be installed with a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter.
- G30B: Currently, the spring flow at Eendekuil is not being monitored and it is recommended that a flow meter be installed on the 63 mm pipe between the spring collection box and the dam.
- G30B: It is important to note that NO groundwater monitoring is being done in this GRU by DWS. It is recommended that monitoring sites be identified in the delineated important aquifer area, near the Steenebrug area.
- G30E: Kruisfontein Springs, located towards the northeast of Redelinghuys, NEEDS to be monitored. The water from the various springs flows into one channel that flows down and joins the Verlorenvlei River at Redelinghuys. It would be recommended that a flow measuring and monitoring system be installed just before the streams join and where the Kruisfontein stream flows underneath the road.
- G30E: During the drought of 2016-2018, it was reported that when this area of the upper Verlorenvlei wetland dried up completely, a small pool of water in the centre of the wetland area kept getting wet during the night and then dried during the day. This report could not be investigated as that portion of the wetland did not completely dry up during 2021 and 2022, but it would be recommended that if this occurs again, the pool is sampled. It would be difficult to sample (because of the mud layer) but could be done with a drone.
- G30E: For the monitoring boreholes adjacent to the Verlorenvlei wetland, more sampling and analysis are needed to link these changes with the specific activities and/or specific hydrogeological processes, thus increased water quality monitoring would be recommended for these boreholes.
- G30F: Some boreholes in this GRU highlighted the localised nature of the elevated nitrate levels that have been monitored and thus it would not be recommended to extrapolate the increase in nitrate that has been observed in certain boreholes across large areas until additional sampling be done. It would be recommended that in areas where high nitrates have been observed, surrounding boreholes be sampled to measure the extent of the higher nitrate area.
- G30G: For the upper reaches of the Jakkals river system, no boreholes are being monitored, but multiple NGA boreholes have been registered for this area. It is recommended that at least one of these boreholes be included in the monitoring system as it would be useful to monitor groundwater in this area.
- F60E: At Namaqua Sands Mine, the effect of mining activities has created a pollution plume. This is being closely monitored and modelled and the mine is working with DWS to minimise the impacts of the mining activities, but it does show that even in areas with a deep-water level and very high ECs, the mining could still impact the groundwater quality and levels. It is thus vital that any mining activity in these areas must if approved, continually monitor and model

the groundwater and their effects on it. It is recommended that any proposed mining activity, or any other proposed activity that could impact the groundwater in that, be closely evaluated, based on site-specific conditions, before any decision is made to approve such an activity.

- F60_Sampling of rivers and streams during flow events: At Namaqua Sands Mine, boreholes adjacent to the Groot Goerap do form part of their monitoring and sampling network and it would thus be recommended that the river must be sampled when it next flows to compare the surface water to that of boreholes drilled in the riparian zone of the river. It was also observed that some of the production boreholes at Bitterfontein seem to be drilled near drainage channels, and although these boreholes are located across the quaternary boundary in the E33D quaternary catchment, it would be recommended that isotope and inorganic sampling and analyses be done during surface water flow periods to investigate the relationship between these boreholes and the surface water systems in these areas. It is also recommended that the local community leaders be asked to sample any of the other rivers in the F60 catchments when they flow. As these river systems are remote and far away from any DWS office, it would be recommended that the local people be incorporated into a river sampling network to gain information on these systems.
- F60B: The trends observed in the DWS monitoring boreholes could not be linked to the Bitterfontein production boreholes for the municipality. It is recommended that the monitoring data from the actual production boreholes be obtained and incorporated into the DWS monitoring system. Because these boreholes and the desalination plant supply all the settlements and small towns in the area with their only source of water, it is vital that the sustainability of the system be monitored. Some form of telemetry system is installed, but the current system does not seem to store groundwater water level data.
- F60B: A last recommendation for this municipal setup would be to monitor groundwater quality surrounding the Bitterfontein evaporation dams linked to the desalination plant. The municipality noted that this is currently not being done and it would be recommended that sampling in a 1km radius around these dams should be done to monitor the potential pollution risk these dams pose.
- For some of the quaternary catchments, there is no baseflow to meet the needs of the ecological component of the Reserve. For such catchments, the Reserve comprises the Basic Human Needs component and the Regional Office may need to take this into account when evaluating water use licences.

Borehole-specific recommendations for groundwater use licence conditions include:

a) An “observation pipe” needs to be installed (32 mm inner diameter, class 10) from the pump depth to the surface, closed at the bottom and slotted for the bottom 5 – 10 m, for the production borehole. This allows for a ‘window’ of access down the borehole which enables manual water level monitoring and can house an electronic water level logger.
b) Continuous monitoring of groundwater levels using a pressure transducer in the borehole is ideal. The water level in the borehole may not drop below the critical water level. These water levels should be calculated from yield test data done according to the National Standard (SANS 10299-4:2003, Part 4 – Test pumping

of water boreholes). If the water level in the borehole drops below the critical water level, DWS must be contacted.

c) Water quality monitoring which includes sampling and analysis of the groundwater at an accredited laboratory is important. A sampling interval of quarterly is recommended for the first year of monitoring, thereafter, the water quality monitoring should be reviewed and can potentially be reduced to bi-annual or annually as seen in **Table 2**.
d) The monitoring data should be reviewed quarterly at first and can then be scaled down to bi-annually.
e) Installation of a sampling tap at the production borehole (to monitor water quality) is essential.
f) Installation of flow volume meters at the production boreholes (to monitor abstraction rates and volumes) is also important. External flow (e.g., mag-flow) meters are recommended.
g) Abstraction volumes must be monitored and recorded by a designated person on site. Depending on the frequency of use, daily, weekly or monthly abstraction should be recorded.
h) The appropriate borehole pumps must be installed, i.e. not an oversized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then the duration of pumping time can be increased (not the flow rate).
i) The borehole and pump should be serviced annually.
j) A geohydrologist should review the above information at least annually to ensure optimal groundwater abstraction and management occurs.

Table 2: Proposed groundwater monitoring parameters.

Parameter	Frequency
Groundwater Level	Ideally every 15 minutes with a data logger
Chemical parameters	
pH (at 25 ºC)	Quarterly (Field Chemistry)
Electrical Conductivity (mS/m) (at 25 ºC)	Quarterly (Field Chemistry)
Total Dissolved Solids (mg/L)	Quarterly (Field Chemistry)
Turbidity (NTU)	Quarterly*
Colour (mg/L as Pt)	Quarterly*
Sodium (mg/L as Na)	Quarterly*
Potassium (mg/L as K)	Quarterly*
Magnesium (mg/L as Mg)	Quarterly*
Calcium (mg/L as Ca)	Quarterly*
Chloride (mg/L as Cl)	Quarterly*
Sulphate (mg/L as SO_4)	Quarterly*
Nitrate & Nitrite Nitrogen (mg/L as N)	Quarterly*
Nitrate Nitrogen (mg/L as N)	Quarterly*
Nitrite Nitrogen (mg/L as N)	Quarterly*
Ammonia Nitrogen (mg/L as N)	Quarterly*
Total Alkalinity (mg/L as $CaCO_3$)	Quarterly*
Total Hardness (mg/L as $CaCO_3$)	Quarterly*

Parameter	Frequency
Fluoride (mg/L as F)	Quarterly*
Aluminium (mg/L as Al)	Quarterly*
Total Chromium (mg/L as Cr)	Quarterly*
Manganese (mg/L as Mn)	Quarterly*
Iron (mg/L as Fe)	Quarterly*
Nickel (mg/L as Ni)	Quarterly*
Copper (mg/L as Cu)	Quarterly*
Zinc (mg/L as Zn)	Quarterly*
Arsenic (mg/L as As)	Quarterly*
Selenium (mg/L as Se)	Quarterly*
Cadmium (mg/L as Cd)	Quarterly*
Antimony (mg/L as Sb)	Quarterly*
Mercury (mg/L as Hg)	Quarterly*
Lead (mg/L as Pb)	Quarterly*
Uranium (mg/L as U)	Quarterly*
Cyanide (mg/L as CN-)	Quarterly*
Total Organic Carbon (mg/L as C)	Quarterly*
E.coli (count per 100 ml)	Quarterly*
Total Coliform Bacteria (count per 100 ml)	Quarterly*
Heterotrophic Plate Count (count per ml)	Quarterly*
Total Petroleum Hydrocarbons (TPH)	Quarterly*
*Can be reduced to bi-annually or annually if reviewed and deemed appropriate	

3.3. River and Wetland EWR sites

From the perspective of the rivers, the most logical resource unit is the river catchments. The study area comprises seven river catchments (Papkuils, Verlorenvlei, Langvlei/Wadrift, Jakkals and Sandlaagte in the G30 catchment and the Sout and Brak in the F60 catchment). Only the Verlorenvlei catchment has been subdivided further into the upper catchment, upstream of the Krom Antonies Tributary, and the lower catchment which includes the Verlorenvlei and Krom Antonies Rivers. The selection of Wetland Resource Units for EWR determination in the study area was based on expert judgement. Many of the sites listed below have both river and wetland characteristics.

EWR1 RW-F60A BRAK STRAN Brak River and Valley Bottom Wetland

EWR2 W-F60A DEPR NUWEB Northwest Fynbos Depression Wetland

EWR3 RW-F60B GRGO KOMKA Sout/Groot-Goerap River

EWR4 W-F60C DEPR ADOON Knersvlakte Depression Wetland

EWR5 W-F60E DEPR ELSIE Sandveld Depression Wetland

EWR6 RW-G30H SAND HOLLE Sandlaagte River

EWR7 RW-G30G JAKK KOOKF	Jakkals River and Valley Bottom Wetland
EWR8 RW-G30F LANG BRAND	Langvlei River and Valley Bottom Wetland
EWR9 W-G30F WADR WAGEN	Wadrift Valley Bottom Wetland
EWR10 RW-G30D KRUI EENHE	Lower Kruismans River and Valley Bottom Wetland
EWR11 RW-G30D KROM GOERG	Krom Antonies River and Floodplain Wetland
EWR12 RW-G30E VERL WITTE	Lower Verlorenvlei River and Floodplain Wetland
EWR13 W-G30A DUNE FA277	West Strandveld Duneslack Wetland
EWR14 W-G30A ROCH FA272	Rocherpan Wetland
EWR15 RW-G30A PAPK BOOKR	Papkuils River and Valley Bottom Wetland
EWR16 W-G30A PAPK RIETF	Upper Papkuils Seep Wetland

Details of the EWR assessment sites are provided below, together with the recommended Ecospecs and monitoring requirements. The locations are shown in Figure 3.

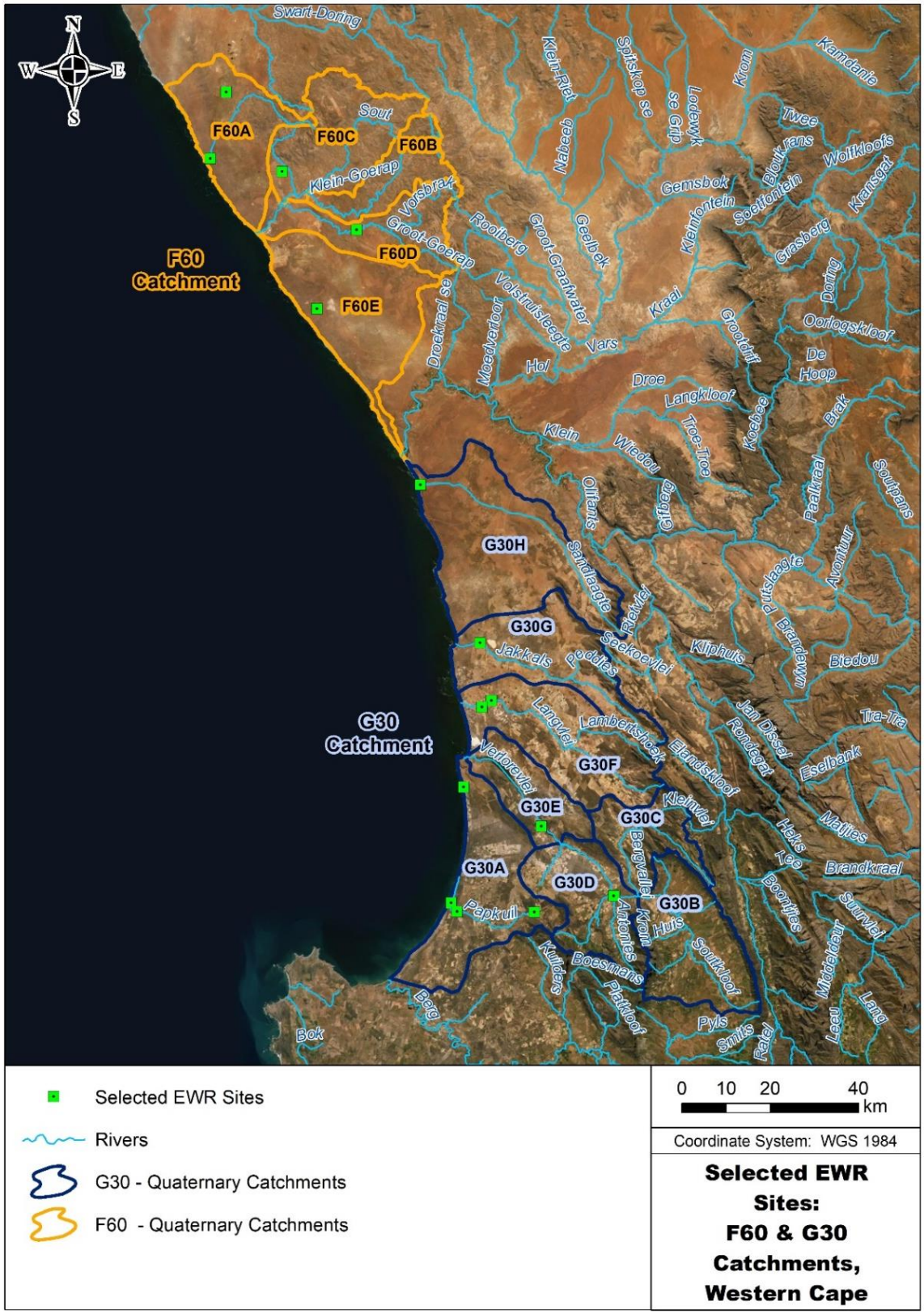


Figure 3. Map of the proposed EWR sites for rivers and wetlands in the F60 and G30 Catchments

3.3.1. EWR Site 7

A description of the EWR site is provided below.

Table 3. Characteristics and View of EWR 7

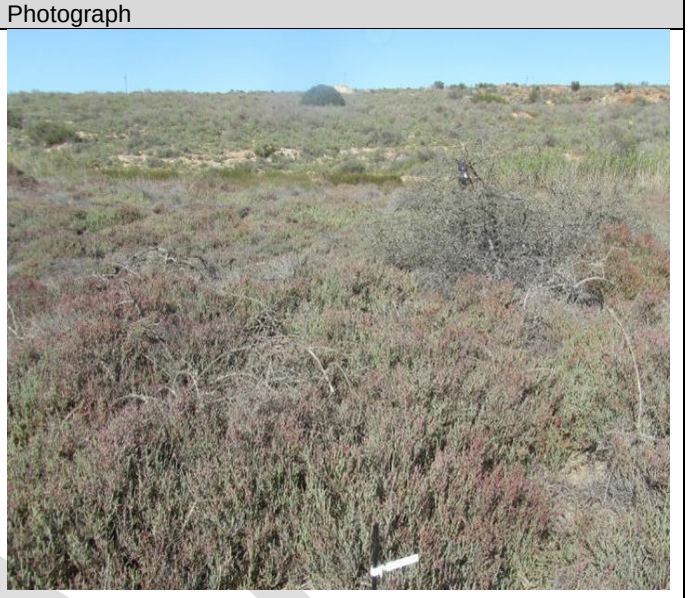
<table>
<tr><th colspan="2">Site information</th><th>Photograph</th></tr>
<tr><td>EWR site</td><td>EWR 7</td><td rowspan="9">  </td></tr>
<tr><td>Name</td><td>Lower Jakkals</td></tr>
<tr><td>Description</td><td>Combined river and wetland site immediately upstream of the estuarine functional zone of the Jakkals River</td></tr>
<tr><td>River</td><td>Jakkals</td></tr>
<tr><td>Quaternary</td><td>G30G</td></tr>
<tr><td>Resource Unit (RU)</td><td>Jakkals River Jakkals River RU; Lower Jakkals River VB Wetland RU U; Lower Jakkals Valley Bottom (VB) Wetland RU</td></tr>
<tr><td>Coordinates</td><td>32° 4'59.30"S; 18°22'20.10"E</td></tr>
<tr><td>Ecological Importance</td><td>Moderate; FEPA and NWM5 Mapped wetland</td></tr>
<tr><td>Level of assessment</td><td>Site survey with cross-section, wetland, river, vegetation, water quality</td></tr>
<tr><td>PES, EIS, REC and AEC</td><td colspan="2">• PES: C/D Impacts due to abstraction of groundwater, agricultural and peri-urban activities. Impacts are largely flow related.
• EIS: Moderate
• REC: B/C The EIS is moderate; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow
• AEC = C Better monitoring and management of groundwater use (particularly unauthorised use is required)</td></tr>
<tr><td>Satellite image of the site</td><td colspan="2"> 
</td></tr>
</table>

Table 4. EcoSpecs and Monitoring Recommendations for EWR 7

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Jakkals River (REC = C)			
Fish	No fish present	No fish present	None
Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.3.2. EWR Site 8

A description of the EWR site is provided below.

Table 5. Characteristics and View of EWR 8

Site information		Photograph
EWR site	EWR 8	
Name	Lower Langvlei	
Description	Combined river and wetland site immediately upstream of the Wadrift Wetland and Wadrift Pan	
River	Langvlei	
Quaternary	G30F	
Resource Unit (RU)	Langvlei River RU; Lower Langvlei VB Wetland RU	
Coordinates	32°12'5.82"S; 18°23'54.02"E	
Ecological Importance	Moderate; FEPA and NWM5 Mapped wetland	
Level of assessment	Site survey with cross-section, wetland, river, vegetation, water quality	
PES, EIS, REC and AEC	• PES: E Impacts due to the abstraction of groundwater, and agricultural activities. Impacts are largely flow related. • EIS: Moderate	

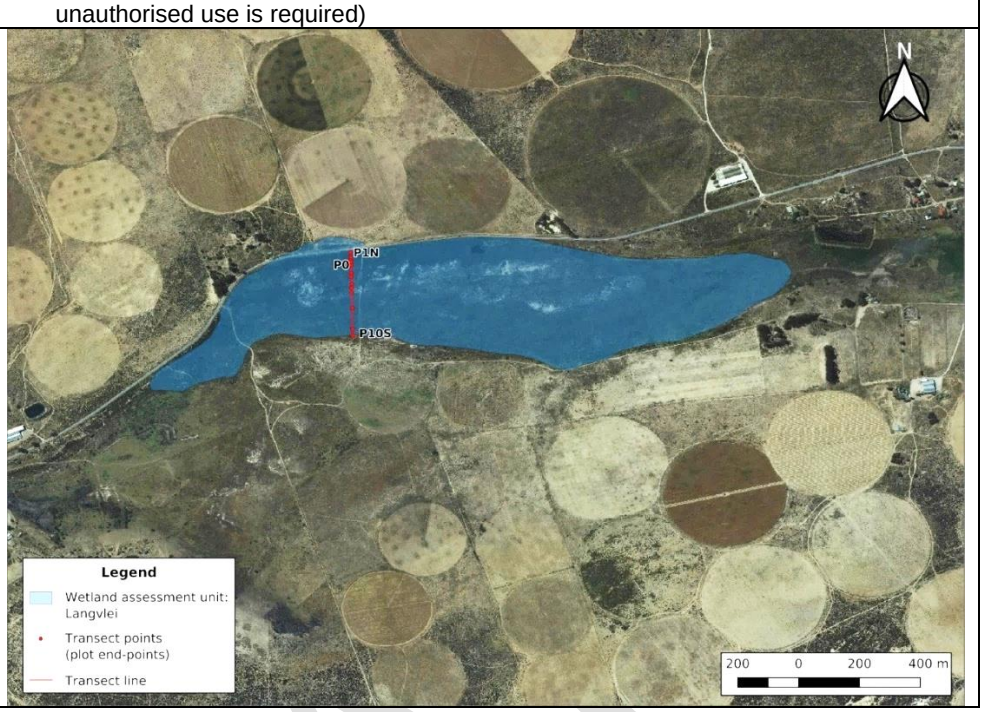
	• REC: D The EIS is moderate; therefore, the REC is a slight improvement of the PES. Should be returned to a sustainable ecosystem functioning level. Need to restore the groundwater contribution to baseflow • AEC = REC Better monitoring and management of groundwater use (particularly unauthorised use is required)
Satellite image of the site	

Table 6. EcoSpecs and Monitoring Recommendations for EWR 8

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Langvlei River (REC = D)			
Fish	No fish present	No fish present	None
Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 40 to 59	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.3.3. EWR Site 10

A description of the EWR site is provided below.

Table 7. Characteristics and View of EWR 10

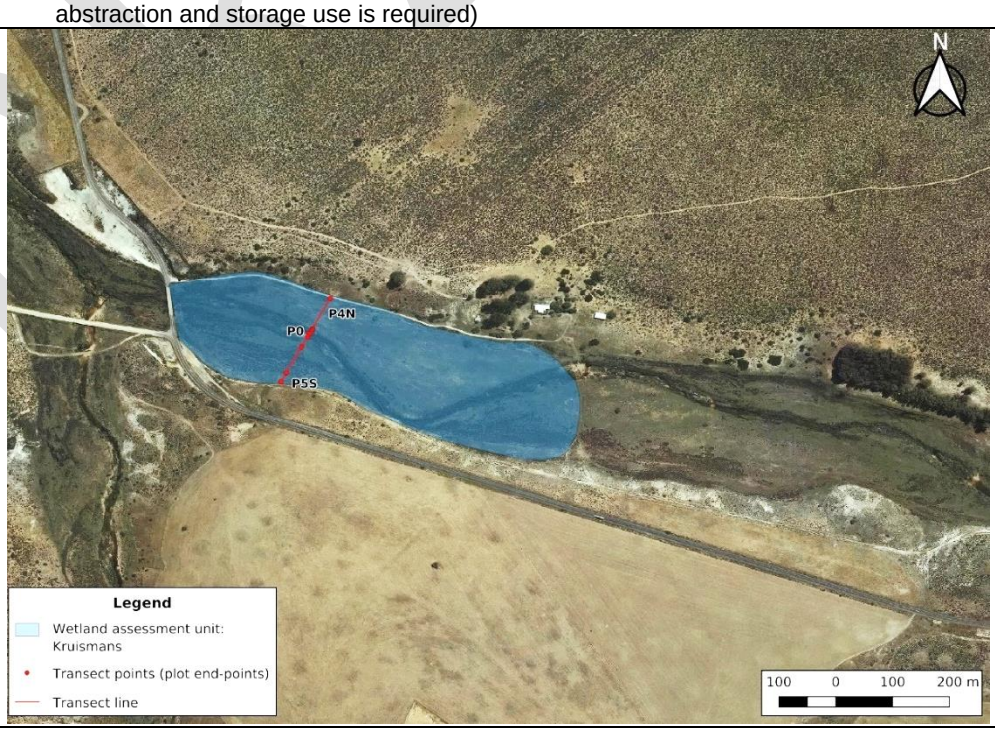
<table>
<tr><th colspan="2">Site information</th><th>Photograph</th></tr>
<tr><td>EWR site</td><td>EWR 10</td><td rowspan="9">  </td></tr>
<tr><td>Name</td><td>Lower Kruismans</td></tr>
<tr><td>Description</td><td>Combined river and wetland site immediately upstream of the confluence of the Kruismans with the Krom Antonies River</td></tr>
<tr><td>River</td><td>Kruismans</td></tr>
<tr><td>Quaternary</td><td>G30D</td></tr>
<tr><td>Resource Unit (RU)</td><td>Lower Kruismans River RU; Lower Kruismans River VB Wetland RU</td></tr>
<tr><td>Coordinates</td><td>32°36'0.58"S; 18°41'34.83"E</td></tr>
<tr><td>Ecological Importance</td><td>High; FEPA and NWM5 Mapped wetland; upstream Ramsar site</td></tr>
<tr><td>Level of assessment</td><td>Site survey with cross-section, wetland, river, vegetation, water quality</td></tr>
<tr><td>PES, EIS, REC and AEC</td><td colspan="2">• PES: D Impacts due to abstraction of groundwater, and agricultural activities. Impacts are largely flow related.
• EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes
• REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow as well as surface water runoff
• AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)</td></tr>
<tr><td>Satellite image of site</td><td colspan="2"> 
</td></tr>
</table>

Table 8. EcoSpecs and Monitoring Recommendations for EWR 10

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Kruismans River (REC = C)			
Fish	There should be at least two of the native species	One species was captured during netting and juveniles or adults absent	Summer sampling with overnight fyke net
Invertebrates	SASS5 Score>60 ASPT>4.5 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.3.4. EWR Site 11

A description of the EWR site is provided below.

Table 9. Characteristics and View of EWR 11

Site information		Photograph
EWR site	EWR 11	
Name	Lower Krom Antonies	
Description	Combined river and wetland site immediately upstream of the confluence of the Krom Antonies with the Kruismans River	
River	Krom Antonies	
Quaternary	G30D	
Resource Unit (RU)	Krom Antonies River RU; Krom-Antonies River Floodplain (FP) Wetland RU	
Coordinates	32°36'4.02"S; 18°41'28.52"E	
Ecological Importance	High; FEPA and NWM5 Mapped wetland; upstream Ramsar site	
Level of assessment	Site survey with cross-section, wetland, river, vegetation, water quality	

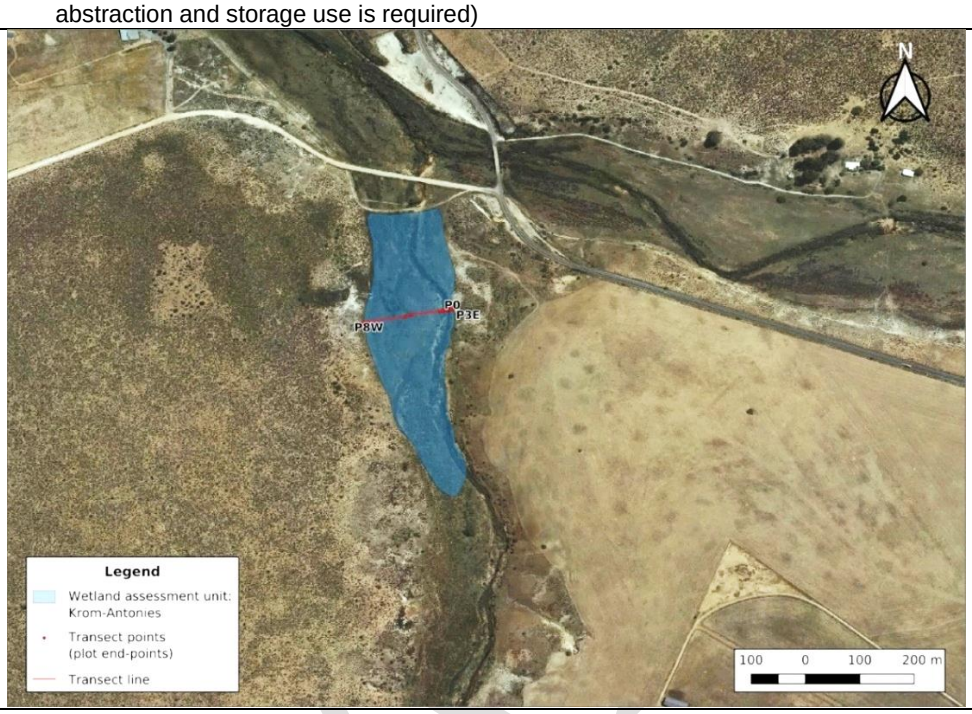
PES, EIS, REC and AEC	• PES: C/D Impacts due to abstraction of groundwater, agricultural and peri-urban activities. Impacts are largely flow related. • EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes • REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow • AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)
Satellite image of site	

Table 10. EcoSpecs and Monitoring Recommendations for EWR 11

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Krom Antonies River (REC = C)			
Fish	There should be at least two of the native species	One species was captured during netting and juveniles or adults absent	Summer sampling with overnight fyke net and snorkel during the day
Invertebrates	SASS5 Score>60 ASPT>4.8 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and the effects of changes within each reach.

3.3.5. EWR Site 12

A description of the EWR site is provided below.

Table 11. Characteristics and View of EWR 12

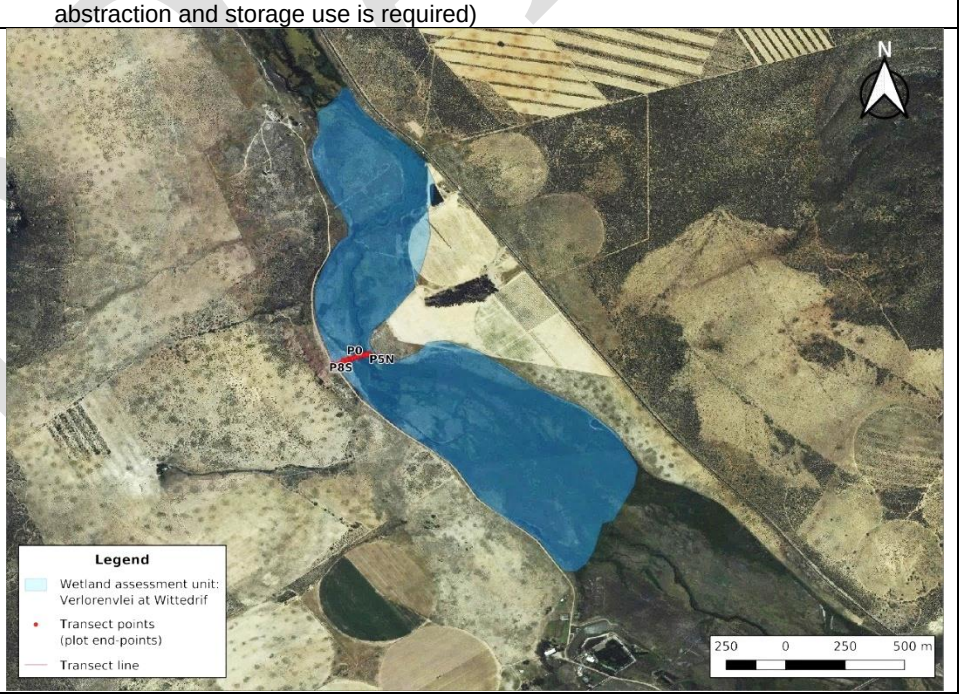
<table>
<tr><th colspan="2">Site information</th><th>Photograph</th></tr>
<tr><td>EWR site</td><td>EWR 12</td><td rowspan="9">  </td></tr>
<tr><td>Name</td><td>Lower Verlorenvlei</td></tr>
<tr><td>Description</td><td>Combined river and wetland site immediately upstream of the estuarine functional zone of the Verlorenvlei</td></tr>
<tr><td>River</td><td>Verlorenvlei</td></tr>
<tr><td>Quaternary</td><td>G30E</td></tr>
<tr><td>Resource Unit (RU)</td><td>Lower Verlorenvlei River RU; Lower Verlorenvlei River FP Wetland RU</td></tr>
<tr><td>Coordinates</td><td>32°27'29.91"S; 18°31'2.19"E</td></tr>
<tr><td>Ecological Importance</td><td>High; FEPA and NWM5 Mapped wetland; upstream Ramsar site</td></tr>
<tr><td>Level of assessment</td><td>Site survey with cross-section, wetland, river, vegetation, water quality</td></tr>
<tr><td>PES, EIS, REC and AEC</td><td colspan="2">• PES: D Impacts due to abstraction of groundwater, and agricultural activities. Impacts are largely flow related.
• EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes
• REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow as well as surface water runoff
• AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)</td></tr>
<tr><td>Satellite image of the site</td><td colspan="2"> 
</td></tr>
</table>

Table 12. EcoSpecs and Monitoring Recommendations for EWR 12

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Verlorenvlei River (REC = B/C)			
Fish	There should be at least two of the native species	One species was captured during netting and juveniles or adults absent	Summer sampling with overnight fyke net
Invertebrates	SASS5 Score>70 ASPT>4.8 MIRAI of 75 to 85	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.2.6. EWR Site 13

A description of the EWR site is provided below.

Table 13. Characteristics and View of EWR 13

Site information		Photograph
EWR site	EWR 13	
Name	G30A duneslack wetland	
Description	Isolated duneslack/depression wetland	
River	-	
Quaternary	G30A	
Resource Unit (RU)	West Strandveld dune slack Wetland RU	
Coordinates	32°22'39.14"S; 18°19'48.28"E	
Ecological Importance	Moderate; FEPA and NWM5 Mapped wetland	
Level of assessment	Brief site assessment with wetland, vegetation	

PES, EIS, REC and AEC	• PES: C Impacts due to abstraction of groundwater, infrastructure development (road) and agricultural activities. Impacts are largely flow related. • EIS: Moderate • REC: B/C The EIS is moderate; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution. AEC = C Better monitoring and management of groundwater use (particularly unauthorised use is required)
Satellite image of site	

Table 14. EcoSpecs and Monitoring Recommendations for EWR 13

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Dune slack wetland (REC = C)			
Fish	No fish present	No fish present	None
Invertebrates	Not applicable	Not applicable	None
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.2.7. EWR Site 14

A description of the EWR site is provided below.

Table 15. Characteristics and View of EWR 14

<table>
<tr><th colspan="2">Site information</th><th>Photograph</th></tr>
<tr><td>EWR site</td><td>EWR 14</td><td rowspan="9">  </td></tr>
<tr><td>Name</td><td>Rocherpan</td></tr>
<tr><td>Description</td><td>Isolated depression/duneslack wetland that is fed from groundwater and two minor streams</td></tr>
<tr><td>River</td><td>Vlei</td></tr>
<tr><td>Quaternary</td><td>G30A</td></tr>
<tr><td>Resource Unit (RU)</td><td>Rocherpan Wetland RU</td></tr>
<tr><td>Coordinates</td><td>32°36'49.34"S; 18°17'55.89"E</td></tr>
<tr><td>Ecological Importance</td><td>High; FEPA and NWM5 Mapped wetland; Wetland of high importance for wading birds and eco-tourism, located in a nature reserve</td></tr>
<tr><td>Level of assessment</td><td>Brief site assessment with wetland, vegetation</td></tr>
<tr><td>PES, EIS, REC and AEC</td><td colspan="2">• PES: D Impacts due to abstraction of groundwater. Impacts are largely flow related.
• EIS: High
• REC: C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution.
• AEC = C Better monitoring and management of groundwater use (particularly unauthorised use is required)</td></tr>
<tr><td>Satellite image of the site</td><td colspan="2"> 
</td></tr>
</table>

Table 16. EcoSpecs and Monitoring recommendations for EWR 14

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Rocherpan (REC = B)			
Fish	Fish	No fish present	No fish present
Invertebrates	Invertebrates	Not applicable	Not applicable
Riparian/wetland vegetation	Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.

3.2.8. EWR Site 15

A description of the EWR site is provided below.

Table 17. Characteristics and View of EWR 15

Site information		Photograph
EWR site	EWR 15	
Name	Lower Papkuils	
Description	Combined river and wetland site in the lower Papkuils River	
River	Papkuils	
Quaternary	G30A	
Resource Unit (RU)	Papkuils River RU; Lower Papkuils FP Wetland RU	
Coordinates	32°37'53.62"S; 18°18'46.32"E	
Ecological Importance	Moderate; FEPA and NWM5 Mapped wetland	
Level of assessment	Brief site assessment with wetland, vegetation	
PES, EIS< REC and AEC	PES: D Impacts due to abstraction of groundwater, and agricultural activities. Impacts are largely flow related. EIS: Moderate REC: C The EIS is moderate; therefore, the REC is a slight improvement of the PES. Need to restore some groundwater contribution to baseflow AEC = REC Better monitoring and management of groundwater use (particularly unauthorised use is required)	

Satellite image of site	

Table 18. EcoSpecs and Monitoring Recommendations for EWR 15

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Papkuils River (REC = C)			
Fish	There should be at least two of the native species present in the upper river reaches	One species was captured during netting and juveniles or adults absent	Summer sampling within the upper river reaches with small seine and overnight fyke net
Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.2.9. EWR Site 16

A description of the EWR site is provided below.

Table 19. Characteristics and View of EWR 16

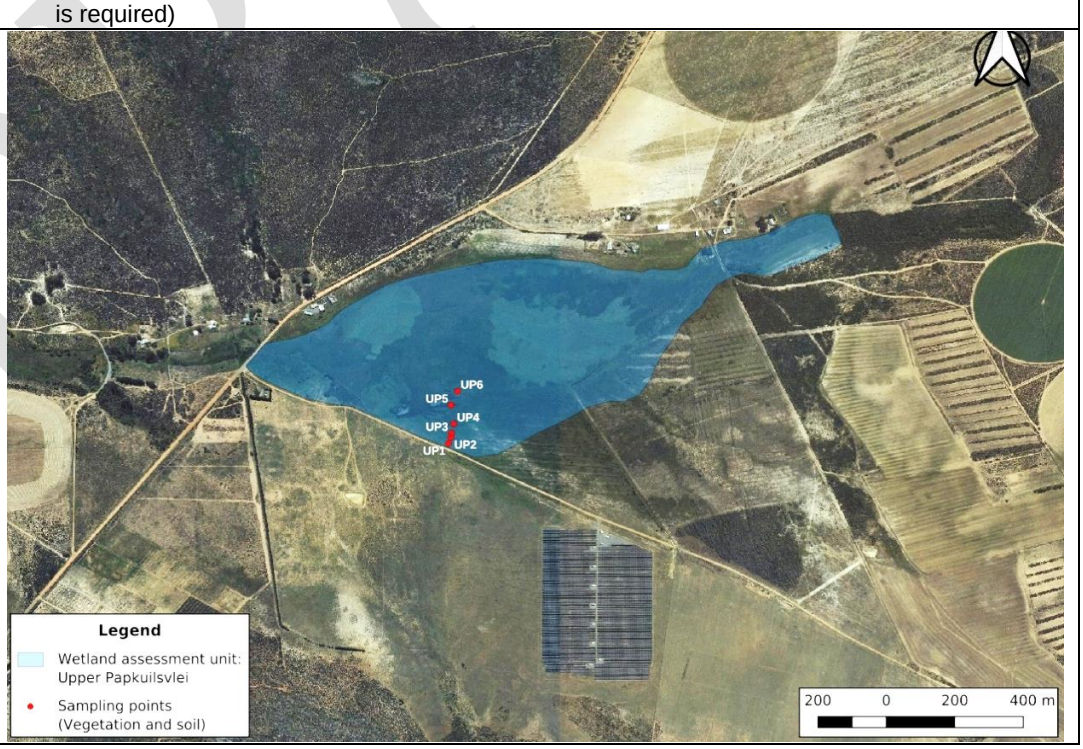
Site information		Photograph
EWR site	EWR 16	
Name	Papkuilsvlei	
Description	Wetland site in the upper Papkuils River	
River	Papkuils	
Quaternary	G30A	
Resource Unit (RU)	Upper Papkuils FP Wetland RU	
Coordinates	32°38'1.26"S; 18°29'56.29"E	
Ecological Importance	High; FEPA and NWM5 Mapped wetland; upstream Ramsar site	
Level of assessment	Brief site assessment with wetland, vegetation	
PES, EIS, REC and AEC	• PES: D Impacts due to abstraction of groundwater, invasive alien vegetation, infrastructure development and agricultural activities. Impacts are largely flow related. • EIS: High • REC: C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution. • AEC = C Better monitoring and management of groundwater use (particularly unauthorised use is required)	
Satellite image of site		

Table 20. EcoSpecs and Monitoring Recommendations for EWR 15

Indicator	Ecological Specification	**Threshold of Potential Concern**	**Recommended Monitoring**
Papkuilsvlei (REC = C)			
Fish	There should be at least two of the native species present in the upper river reaches adjacent to Papkuilsvlei	One species was captured during netting and juveniles or adults absent	Summer sampling within the upper river reach adjacent to Papkuilsvlie with small seine and overnight fyke net
Invertebrates	Invertebrates	Not applicable	Not applicable
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as the basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches are necessary to determine the sources of perturbations and of the effects of changes within each reach.

3.4. Additional River and Wetland Monitoring Recommendations

3.4.1. Flow Monitoring

- Hydrometeorological data is the primary input data for the WRSM2000 Pitman model. Of the fourteen rainfall gauges used in the WR2012 study, only eight had remained operational with data which could be included for extension of the rainfall input files. For this study, rainfall records for a further nine stations belonging to DWS or SAWS were sourced and one rainfall record from a private source was provided. The reduction in the number of operational rainfall gauges and their deteriorating spatial distribution over the study area are of serious concern. It is strongly recommended that DWS and SAWS undertake a coordinated campaign to reinstate all strategically placed previously closed rainfall stations.
- There are no operational flow gauging stations in the study catchments; therefore, no recent streamflow data were available for verification of the updated WRSM2000 Pitman model. It is strongly recommended that DWS undertakes reinstatement of closed gauging stations and installation of new gauging stations, and calibrated sections for flow measurements.

- Although the WRSM2000 Pitman model performed adequately, there are some limitations with the modelling of the integration of surface water and groundwater. Therefore, it is recommended that for future modelling in these catchments, alternative modelling software is considered which represents surface water–groundwater interactions more appropriately.

3.4.2. Water Quality Monitoring

Resource Quality Objectives (RQOs) are specified during Water Resource Classification. with EcoSpecs defined during Reserve studies forming the ecological input to the RQOs. EcoSpecs are associated with the Ecological Reserve process and are provided at EWR sites, as the output of the Reserve Study. EcoSpecs are the detailed or numerical ecological input to RQOs as they are quantifiable, measurable, verifiable, and enforceable and, therefore ensure the protection of all components of the resource, which together define ecological integrity. As EcoSpecs are presented in a numerical quantitative format, they can be used for monitoring and compliance purposes. When setting EcoSpecs, the work is usually based on field surveys to establish a monitoring baseline and future monitoring is either to ensure that the present state is maintained, or that the REC is reached (DWS, 2015a; DWS, 2015b).

EcoSpecs (water quality specifications or objectives for the PES and REC) are set for physico-chemical, quantifiable, and measurable, parameters, and are presented as percentiles. However, percentiles should be calculated within the framework of the current assessment method (DWAF, 2008), i.e. using the PES monitoring point at the EWR site, and the most recent three to five years of data, equivalent to a minimum of 60 data points (DWS, 2015a). However, there are not sufficient water quality data available for both G30 and F60 catchments to determine EcoSpecs in terms of percentages.

The EWR sites provide possible monitoring locations for monitoring the Ecospecs. These are only suggestions, and the locations may be adjusted according to the requirements of ongoing or forthcoming monitoring programmes. However, due to the high spatial variability of the water quality in the G30 catchment, ideally, the water quality monitoring should be at the EWR sites as a slight change of monitoring point, downstream or upstream of the EWR site, may give very different water quality results. There are ongoing monitoring activities in the G30 WMA (DWA: Western Cape Regional Office), and where possible, these should be taken into account in recommending future monitoring locations.

Ideally, surface water quality and groundwater quality should be measured at the same time and location, as the groundwater and surface water interaction is important in the G30 and F60 catchments. During the dry, summer months, some of the EWR sites are maintained only by groundwater or completely dry out, making monitoring of the EWR sites challenging. However, the above suggestion would imply an ideal situation and the practicality should be investigated.

The Ecospecs suggested are preliminary values since there are very limited data available to determine the Ecospecs. Long-term data sets are needed to ratify the Ecospecs to be able to test whether the Reserve requirements are being met.

It is recommended that the implementation of the additional baseline surveys and long-term monitoring programmes be undertaken in collaboration with various responsible departments in the DWS, as well as other national and provincial departments and institutions responsible for natural resource management such as, but not limited to, a catchment management agency, as well as relevant municipal authorities and even the local farming communities.

Water quality indicators to be monitored for Ecospecs, are proposed to be the following:

- Nutrients - Phosphate (PO_4-P), Total inorganic nitrogen calculated from NO_2+NO_3-N plus NH_4-N
- Salinity - Electrical conductivity and/or Total Dissolved salts
- System variables – pH, water temperature, dissolved oxygen (DO), and turbidity/suspended sediments

The Sandveld Monitoring Programme (DWS: Western Cape Regional Office) collects water quality samples on a monthly and quarterly intervals, provided there is surface water and flow at a sampling point. It is recommended that the EWR sites be linked to this programme. It is also recommended that monthly intervals be maintained for monitoring the water quality to be able to refine the Ecospecs at the EWR sites.

All water quality data collected should be stored in a central location where it is accessible to officials and the public. Ideally, this should be the Department's Water Management System (WMS) where the data for the various national monitoring programmes are stored.

Water quality data for the EWR sites should be abstracted and analysed every two years after a baseline study of at least five years or 60 data points. Compliance can only be assessed once the baseline is established. Summary statistics should be calculated (e.g. 50th and 95th percentiles) for the variables of concern and at least time series plots produced and examined for temporal trends. It is expected that there will be data gaps at the EWR sites that dry up during the summer months.

3.4.3. Biological Monitoring

Fish:

Riemann et al. (2014) recommended the following RQO for Verlorenvlei River at Redelinghuys and Langvlei above Wadrift wetland (Table 21). The RQO for the Langvlei cannot be met, due to the extirpation of the three native species. The RQO for Demographics for non-native fishes makes no sense and should be omitted.

Table 21. RQO's recommended by Riemann et al. (2014) for the previous Reserve study.

Sub-component	RQO Native fishes	RQO Non-native fishes
Species Assemblage	There should be at least two of the native species	The following species should represent less than 10% of the catch – *M. salmoides, M. dolomieu, C. carpio, O. mossambicus, T. tinca, T. sparrmani*
Demographics	There should be at least 2 age classes present. At least 30% of the catch should comprise juvenile fishes (<30mm)	There should be at least 2 age classes present. At least 30% of the catch should comprise juvenile fishes (<30mm)
Fish Health	Parasites, lesions and deformities should be present on < 5% of the catch	Parasites, lesions and deformities should be present on < 5% of the catch

According to Riemann et al. (2014), the RQOs for fish assemblages assume the application of a range of gear types including fyke nets in mainstem pools, seine nets on sandy beaches if they are present (5 X 2 m) and electrofishing in rocky riffles and runs. For most Verlorenvlei sites, overnight fykes are recommended and set as described by Rieman et al. (2014). Snorkel assessments can be undertaken at the Krom Antonies site because of the excellent water clarity there in summer. Chakona et al. (2019) highlighted the need for long-term monitoring of the native fishes of the Verlorenvlei system, to focus on their temporal and spatial distribution and habitat use patterns, as well as understanding the breeding biology and other life history traits.

Based on the above, it is recommended that fish sampling be conducted annually at sites listed in the table below.

Table 22. Recommended monitoring sites for freshwater fish for the Reserve study area

River system and river	Monitoring site	Sampling time, Gear
Verlorenvlei, Kruismans	Roadbridge pool 32º 44' 45" S; 18º 49' 05" E	Summer, overnight fyke
Verlorenvlei, Krom Antonies	Above causeway 32º 43' 15" S; 18º 42' 39"E	Summer, overnight fyke and snorkel during the day
Verlorenvlei	Near Hol confluence 32º 35' 53" S; 18º 41' 22"E	Summer, overnight fyke
Verlorenvlei	Game farm 32º 35' 53"S; 18º 41' 22"E	Summer, overnight fyke
Verlorenvlei	Below Redelinghuys bridge 32º 28' 14"S; 18º 32' 07"E	Summer, overnight fyke
Papkuils	Wetland 32º 37' 55"S; 18º 30' 22"E	Summer, small seine and overnight fyke

3.5. Estuary EWR Sites

Details of the Estuary EWR sites are provided below, together with the recommended Ecospecs and monitoring requirements.

3.5.1. Verlorenvlei Estuary

Verlorenvlei, an Estuarine Lake, located in the Verlorenvlei Catchment in Quaternary Catchment G30E.

Downstream boundary (estuary mouth):	32°18'58.34"S; 18°20'5.96"E
Upstream boundary:	32°25'55.82"S; 18°29'57.78"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 4. Geographical boundaries of the Verlorenvlei Estuary

The Best Attainable State for the Verlorenvlei Estuary without significant restoration interventions is a C Category. While this represents a significant improvement on the observed PES (2022), attaining the REC would require restoring flow to the system (82.6% to remain in the system) and improving the water quality, as well as addressing some of the existing non-flow-related issues affecting the estuary.

Ecological Specifications and thresholds of potential concern (TPC) were defined for **Category B.**

Table 23. Ecological Specifications and TPC associated with an Ecological Category B in the Verlorenvlei River Estuary

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Reference condition; State 5 (Closed, Low water level hypersaline) should not occur at all.	• Salinity in Zone A > 45 (for 3 years) • Salinity in Zone B > 3

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
		• Salinity in Zone C > 1.5 
	Water quality in **river inflow** does not detrimentally affect water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: • pH of river inflow exceeds 8.5 • Dissolved oxygen (DO) less than 4 mg/ℓ • Turbidity persistently exceeds 10 NTU • Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ • Dissolved Inorganic Phosphorus (DIP) should this be persistently greater than 50 µg/ℓ • Toxic substance concentrations (e.g. heavy metals and agrochemicals exceed South African Water Quality Guidelines (freshwater and coastal marine)
	Water quality **in estuary** does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: • pH drop below 6, or persistently above 9 • DO less than 4 mg/ℓ • Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) • Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) • Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
Hydrodynamics	Estuary should be allowed to function as naturally as possible with minimal human intervention	• The mouth is breached artificially • No connectivity between Zone A, B and C
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	• As for hydrodynamics above
Microalgae	Phytoplankton communities should reflect a diverse community, with moderate to low biomass (measured as chlorophyll-a concentration), and reduced occurrence of HABs. Benthic	Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}. High-biomass HABs (> 60 µg Chl-*a* l^{-1} dominated by a single taxon, e.g., cyanophytes) in spring/summer. Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. Benthic diatom diversity (*H'*) less than 2.

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
	microalgal communities should reflect moderate biomass and medium- (closed phase) to high (open phase) benthic diatom diversity.	
Macrophytes	Monitor the distribution of plant community types i.e. reeds and sedges, submerged macrophytes, salt marsh during water level fluctuations. Maintain reeds and sedges and open water habitat which supports associated biota. Reeds and sedges are dependent on groundwater discharge. Increases in upper reaches are in response to sediment and nutrient input. Monitor acidic soils as long-term effects on the recovery of macrophytes are unknown. Important risk factors are pH and salinity, particularly in the groundwater and sediment. Water column turbidity is important for submerged macrophytes.	Greater than 20% change in the area covered by different macrophyte habitats. Open water area below 1.2 ha (Zone A), 405 ha (Zone B) and 14.3 ha (Zone C) results in exposure to acidic soils. Groundwater salinity above 10 to 5 reduces the growth of reeds and sedges. Sediment salinity > 75 results in no significant growth. Seed germination hampered below 15.
Invertebrates	The estuary should contain a diverse invertebrate community that includes representatives of all functional groups listed in this report, particularly the freshwater and brackish species including the macroinvertebrates.	A decline in the abundance and diversity of crustacea and insect larvae in zooplankton (baseline to be determined).
Fish	Retain the following fish assemblages in the estuary (based on abundance): estuarine-resident species (20-30%), estuarine-associated marine species (60-70%) and indigenous freshwater species (<1%). All numerically dominant indigenous species are represented by 0+ juveniles within 12 months of the system being open.	Level of estuary-associated marine species drops below 50% of total abundance. Occurrence of alien freshwater species in the estuary. Absence of 0+ juveniles of any of the dominant fish species within 12 months of the system being open.

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Birds	The estuary should contain a diverse avifaunal community that includes representatives of all functional guilds listed in this report, particularly the migratory waders and waterfowl. The estuary should support thousands of birds in summer and hundreds in winter.	Reduced abundance of piscivores (< 3 species; or <100 birds). Numbers of waterfowl drop below 600 or waders below 100 in summer. Overall numbers of waterbirds drop below 2000 for 3 consecutive counts in summer.

3.5.2. Wadrift Estuary

Wadrift, an Arid, Predominantly Closed estuary, is located in the Langvlei Catchment in Quaternary Catchment G30F.

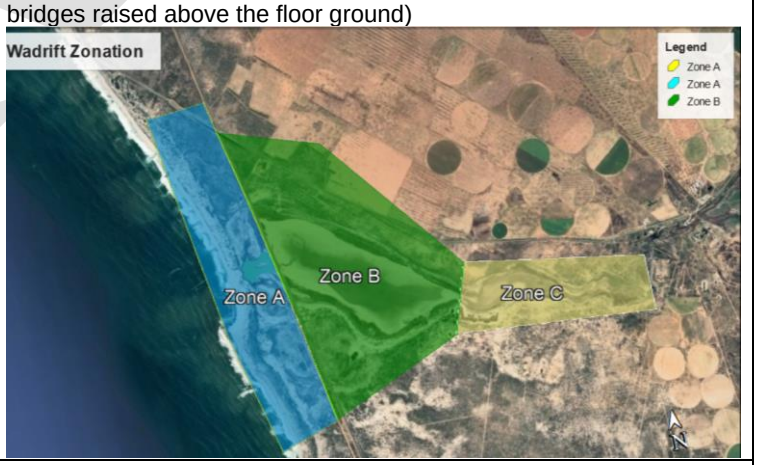
Downstream boundary (estuary mouth):	32°12' 15.54"S; 18°19' 32.43"E
Upstream boundary:	32°12' 49.87"S; 18°22' 37.15"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 5. Geographical boundaries of the Wadrift Estuary

The REC for the Wadrift Estuary is a C Category, representing a significant improvement on the PES. Attaining this state would require restoring a certain amount of flow to the system (77% to remain in the system) as well as addressing some of the existing non-flow-related issues affecting the estuary.

Ecological Specifications and thresholds of potential concern (TPC) were defined for **Category C.**

Table 24. Ecological Specifications and TPC associated with an Ecological Category C in the Wadrift River Estuary

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with Reference condition; State 5 should not occur (Closed, Low water level hypersaline)	• Salinity in any part of the estuary exceeds 65
	Water quality in **river inflow** does not detrimentally affect water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: • pH of river inflow exceeds 8.5 • Dissolved oxygen (DO) less than 4 mg/ℓ • Turbidity persistently exceeds 10 NTU • Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ • Dissolved Inorganic Phosphorus (DIP) should this be persistently greater than 50 µg/ℓ • Toxic substance concentrations (e.g. heavy metals and agrochemicals exceed South African Water Quality Guidelines (freshwater and coastal marine)
	Water quality **in estuary** does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: • pH drop below 6, or persistently above 9 • DO less than 4 mg/ℓ • Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) • Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) • Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
Hydrodynamics	Estuary should be allowed to function as naturally as possible with minimal human intervention	• No connectivity between Zone A and B (culvert levels in bridges raised above the floor ground) 
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	• As for hydrodynamics above

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Microalgae	Phytoplankton communities should reflect a diverse community, with moderate to low biomass (measured as chlorophyll-a concentration), and reduced occurrence of HABs. Benthic microalgal communities should reflect moderate biomass and medium-(closed phase) to high (open phase) benthic diatom diversity.	Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}. Frequent and monospecific (>90% relative abundance) high-biomass HABs (>60 µg Chl-*a* l^{-1}) Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. Benthic diatom diversity (*H'*) less than 2.
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges. Although peat swamps in the upper reaches will not return, increased freshwater inflow will increase habitat diversity and reduce terrestrial species that have now replaced lost habitat..	Greater than 20% change in the area covered by different macrophyte habitats for baseline open and closed mouth conditions.
Benthic Invertebrates Zooplankton	Retain the present invertebrate assemblages	Baseline to be determined
Fish	Retain the present fish assemblages	No fish present. Occurrence of alien freshwater species in the estuary.
Birds	The estuary should contain a rich avifaunal community that includes representatives of all the original groups, significant numbers of migratory waders and terns, as well as a healthy breeding population of resident waders. The estuary should support thousands of birds in summer and hundreds in winter.	Numbers of waterfowl drop below 600, waders below 100 in summer, and terns below 250 Overall numbers of bird species drop below 1000 for 3 consecutive counts.

3.5.3. Jakkals Estuary

Jakkalsvlei or Jakkals Estuary, is a Large, Temporarily Closed estuary, located in the Jakkalsvlei Catchment in Quaternary Catchment G30G.

Downstream boundary (estuary mouth):	32° 5' 5.39"S; 18°18' 48.25"E
Upstream boundary:	32° 5' 26.89"S; 18°20' 1.32"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

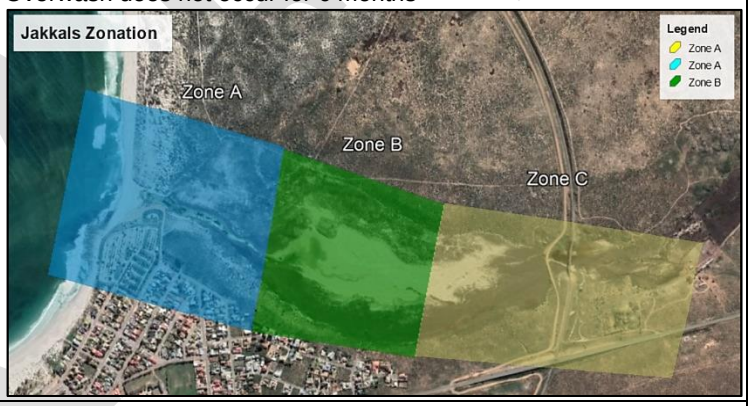
Figure 6. Geographical boundaries of the Jakkals Estuary

The REC for the Jakkals Estuary is a D Category, which requires the maintenance of its present state, i.e. PES D Category. Thus, it was agreed that the flow requirements for the estuary are the same as those described for the Present (57% to remain in the system).

Ecological Specifications and thresholds of potential concern (TPC) were defined for **Category D.**

Table 25. Ecological Specifications and TPC associated with an Ecological Category D in the Jakkals River Estuary

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Present State; State 1 (Closed, Low water level hypersaline) should not occur more than at present	Salinity in any part of the estuary exceeds 35
	Water quality in river inflow does not detrimentally affect water quality conditions in estuary, specifically relating to inorganic	River inflow: pH of river inflow exceeds 8.5 Dissolved oxygen (DO) less than 4 mg/ℓ Turbidity persistently exceeds 10 NTU Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
	nutrient enrichment and toxic substances	Dissolved Inorganic Phosphorus (DIP) should this be persistently greater than 50 µg/ℓ Toxic substance concentrations (e.g. heavy metals and agrochemicals exceed South African Water Quality Guidelines (freshwater and coastal marine)
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: pH drop below 6, or persistently above 9 DO less than 4 mg/ℓ Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
Hydrodynamics	Estuary should be allowed to function as naturally as possible with minimal human intervention	>11% occurrence in State 1:Closed marine/hypersaline, indicated by extensive exposure of Zone B and C. >72% occurrence in State 2:Closed marine <5% occurrence of open mouth conditions Overwash does not occur for 6 months 
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	As for hydrodynamics above
Microalgae	Phytoplankton communities should reflect a diverse community, with moderate biomass (measured as chlorophyll-a concentration), and reduced occurrence of HABs. Benthic microalgal communities should reflect moderate levels of biomass and diversity during the closed phase, and improve during periods of increased river inflow	Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}. Monospecific (>90% relative abundance) high-biomass HABs (>60 µg Chl-*a* l^{-1}) Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. Benthic diatom diversity (*H'*) less than 2.

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges.	Greater than 20% change in the area covered by different macrophyte habitats for baseline open and closed mouth conditions.
Benthic Invertebrates Zooplankton	Retain the present invertebrate assemblages	Baseline to be determined
Fish	Retain the present fish assemblages	Less than 2 of the 5 expected species of fish observed. Occurrence of alien freshwater species in the estuary. Absence of 0+ juveniles of any of the dominant fish species.
Birds	The estuary should contain a diverse although seasonally stochastic avifaunal community that includes representatives of functional guilds listed in this report, particularly the migratory waders and waterfowl. The estuary should support a few hundred waterbirds in summer in winter.	Reduced abundance of piscivores (< 2 species; or <10 birds). Numbers of waterfowl or waders drop below 50 in summer. Overall numbers of waterbirds drop below 200 for 3 consecutive counts in summer, and less than 10 species are recorded in consecutive counts

3.5.4. Sout (Noord) Estuary

Sout (Noord) Estuary, an Arid, Predominantly Closed estuary, is located in the Sout/Goerap Catchment in Quaternary Catchment F60D. This estuary was the subject of an EWR determination in 2017 as part of the Lower Orange Water Management Area EWR Study. The Recommendations of that EWR are included in this report for completeness' sake.

Downstream boundary (estuary mouth):	-31.247111° S; 17.853361° E
Upstream boundary:	-31.210076° S; 17.891072° E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

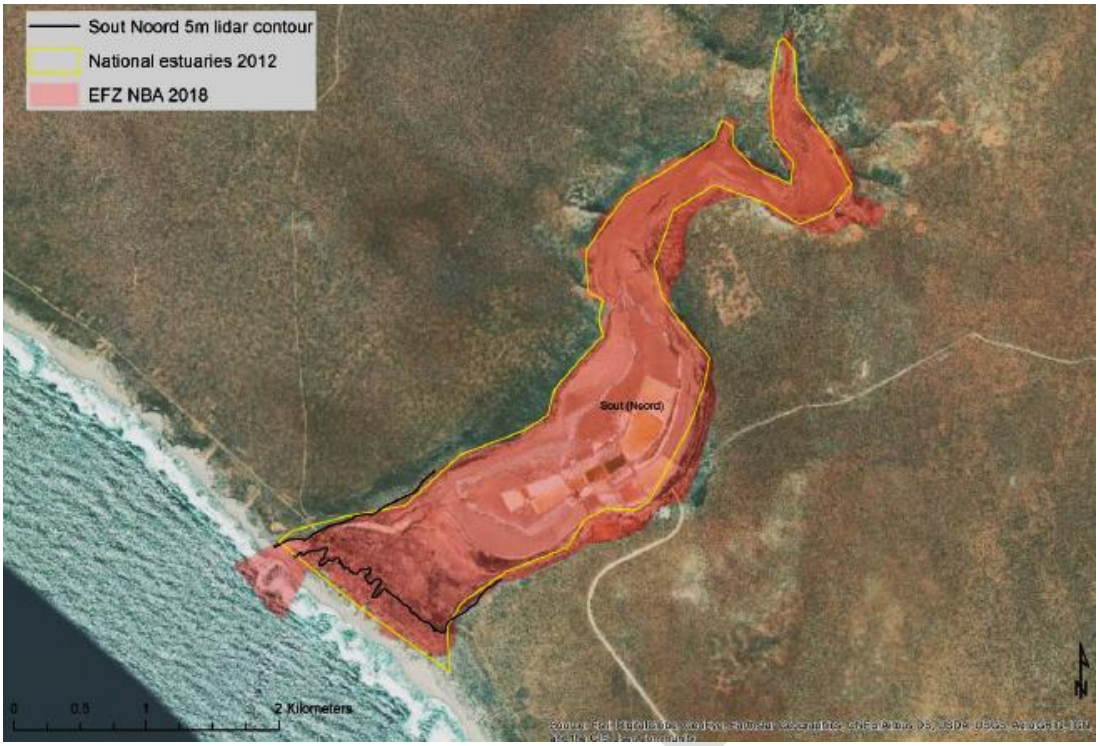


Figure 7. Geographical boundaries of the Sout (Noord) Estuary, showing the 5m topographical contour and the 2018 NBA (SANBI 2019) Estuarine Functional Zone (EFZ) boundary

The EcoSpecs, as well as the TPCs, representative of a Category D for the Sout (Noord) River estuary, are presented in Table 26.

Table 26. Ecological Specifications and TPC associated with an Ecological Category D in the Sout River Estuary

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Present State	Upper reaches < 120 psu (hypersalinity) Middle reaches < 80 psu (hypersalinity) Lower reaches < 60 psu (hypersalinity)
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: Dissolved Oxygen average > 6 mg/l Turbidity average < 10 NTU except during floods DIN average <0.1 mg/ℓ DIP average > 0.01 mg/l Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
Hydrodynamics	Estuary should be allowed to function as naturally as possible with minimal human intervention	Improved connectivity with the different water bodies and restored connectivity with the catchment through removal or modification of the weir at the head of the estuary

Abiotic/ Biotic Component	Ecological Specification	Threshold of Potential Concern
Sediment dynamics	Maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	The flood regime maintains the sediment distribution patterns and aquatic habitat. The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship. Sedimentation and erosion patterns in the estuary do not differ significantly from the present. Changes in grain size distribution patterns similar to the present. The median bed sediment diameter deviates by less than a factor of two from the present. Sand/mud distributions in middle to upper reaches do not change by more than 20% from the present over a five-year average
Microalgae	Phytoplankton communities should reflect a diverse community, with low biomass (measured as chlorophyll-a concentration)	Maintain the distribution of different phytoplankton groups and low biomass in lower reaches (less than 10 µg Chl-*a* l^{-1}.)
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges.	Maintain distribution of current macrophyte habitats (<20% change in area covered by different macrophyte habitats, Water column salinity not greater than 50 psu in lower reaches to limit salt accumulation and dieback of salt marsh (*Sarcocornia pillansii*) Prevent further disturbance and development of the salt marsh and floodplain habitat
Benthic Invertebrates Zooplankton	Retain the present invertebrate assemblages	Unincysted brine shrimp should be present in the system 75% of the time.
Fish	Not applicable	No fish are present due to hypersaline conditions.
Birds	The estuary should contain a diverse although seasonally stochastic avifaunal community, particularly the migratory waders and waterfowl.	More than 10 species of waders and waterbirds that feed on brine shrimp should be present 75% of the time.

3.6. Estuarine Monitoring Requirements

Recommended minimum estuarine monitoring requirements to ascertain the impacts of changes in freshwater flow to the estuaries and any improvements or reductions therein are listed in **Error! Reference source not found.**.

The amount of river flow reaching the estuary determines largely its physical conditions and serious concerns are warranted over the effects of past and future reduced river flow and groundwater on the estuary. It is therefore important that monitoring will be undertaken on the river and groundwater flow reaching the estuary (flow gauging) and on the (natural or artificial) mouth breachings occurring at the mouth.

Table 27. Recommended minimum estuarine requirements for long-term monitoring

Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Hydrodynamics	Record water levels	Continuous	Move middle
	Measure freshwater inflow into the estuary	Continuous	At the head of the estuary
	Satellite imagery/ photographs of the estuary	Every 3 years	Entire estuary
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth (every 100m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
	Set sediment grab samples (at cross-section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	Every 3 years (with invertebrate sampling)	Entire estuary
Water quality	Collect data on salinity/conductivity, temperature, suspended matter/turbidity, dissolved oxygen, pH, inorganic nutrients and organic content (**salinity, pH, DO and inorganic nutrients as a minimum**) in river inflow and in the main basin (Zone B)	Monthly continuous	At river inflow and at a site representative of Zone B
	Assess and better quantify wastewater input (e.g. nutrients and agrochemicals from upstream sources (e.g. agriculture)	Once-off detailed Possibly long-term (e.g. peak seasons) if input remains significant (preferably these should be mitigated)	At sources (or at source inflows in the catchment)
	Record longitudinal salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity)	Seasonally, every year	Entire estuary (~5-7 stns if water)
	Take water quality measurements along the length of the estuary (surface and bottom samples) for system variables (pH, dissolved oxygen, suspended solids/turbidity) and inorganic nutrients in addition to the longitudinal salinity and temperature profiles	Seasonal surveys, every 3 years or when a significant change in water inflows or quality expected	Entire estuary (~5-7 stns)
	Metal and selected agrochemical accumulation in sediments	Once-off and then every 6 years (grid)	Grid across at estuary (10 stns – to be confirmed)
Microalgae	Record relative abundance (i.e., cells ml^{-1}) of phytoplankton groups/classes (e.g., diatoms, dinoflagellates, cyanobacteria, cryptophytes) and record the presence of any potentially HAB-forming taxa. Chlorophyll-*a* measurements (a proxy for phytoplankton biomass, i.e., 3 replicates each) taken in the surface and bottom waters.	Seasonally, as well as after breaching events	Entire estuary (number of stations depends on available habitat)

Ecological Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
	Subtidal benthic chlorophyll-*a* measurements (a proxy for MPB biomass, i.e., 4 replicates each).	Twice a year (winter and summer)	Entire estuary (number of stations depends on available habitat)
Macrophytes	Ground-truthed maps Record the number of plant community types, identification and the total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit; Record percentage plant cover, salinity, water level, sediment moisture content and turbidity on a series of permanent transects along an elevation gradient; Take measurements of depth to the water table and groundwater salinity in supratidal marsh areas	Summer survey every 3 years	Entire estuary
Benthic Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary. Record benthic invertebrate species and abundance, based on van Veen type grab samples in subtidal and core samples in intertidal at a series of stations up the estuary, and prawn holes density. Measures of sediment characteristics at each station	Summer and winter surveys every 3 years	Entire estuary
Zooplankton	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary.	Summer and winter every 3 years	Entire estuary
Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter surveys every 3 years	Entire estuary
Birds	Undertake counts of all water-associated birds, identified to species level.	A series of monthly counts, followed by winter and summer surveys every year	Entire estuary

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