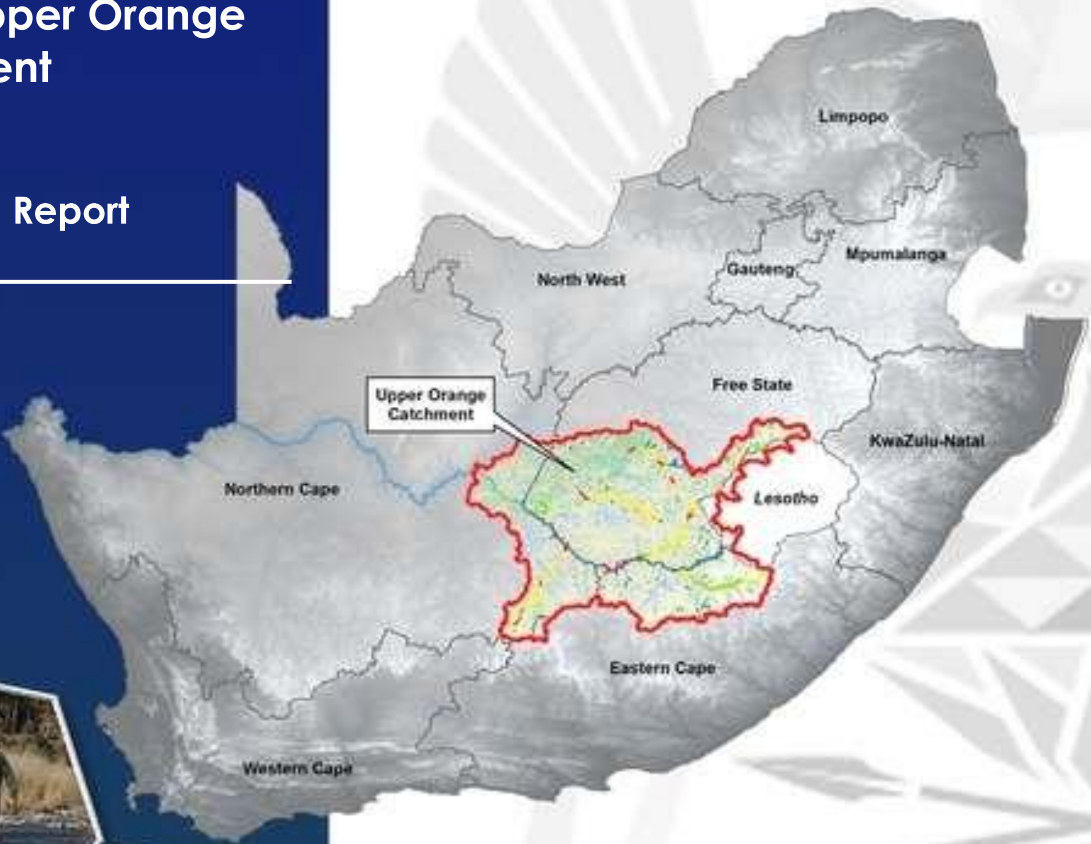
DEPARTMENT OF WATER AND SANITATION

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment

WP11343

Integrated Main Report



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Bold type indicates this report

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LIST OF ACRONYMS

AEC	Alternative Ecological Categories
BHN	Basic Human Needs
CVB	Channelled valley bottom
CD: WEM	Chief Directorate: Water Ecosystems Management
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FMP	Flow Management Plan
FRAI	Fish Response Assessment Index
FIFHA	Fish Invertebrate Flow Habitat Assessment Model
GAI	Geomorphology Driver Assessment Index
GRDM	Groundwater Resource Directed Measures
HGM	Hydrogeomorphic
IEI	Integrated Ecological Index
IWUI	Integrated Water Use Index
IHI	Index of Habitat Integrity
JBS	Joint Basin Survey
MIRAI	Macroinvertebrate Response Assessment Index
NWA	National Water Act
PES	Present Ecological State
RDM	Resource Directed Measures
RU	Resource Units
RQO	Resource Quality Objective
UCVB	Unchanneled valley bottom
VEGRAI	Riparian Vegetation Response Assessment Index
WARMS	Water use Authorization & Registration Management System
WULA	water use license applications
WRC	Water Research Commission
WMA	Water Management Area
WR2012	Water Resources 2012

WRCS	Water Resources Classification System
WWTW	Wastewater Treatment Work

EXECUTIVE SUMMARY

The definition of the Reserve, concerning both water quantity and quality, encompasses two main components: Ecological Water Requirements (EWR) and Basic Human Needs (BHN). The EWR is determined by assessing the quantity and quality of water necessary to safeguard aquatic ecosystems, including the desired state of water quantity, quality, habitat, and biota. The BHN ensures the fulfilment of essential needs for individuals reliant on the water resource. These criteria collectively strive to strike a balance between the imperative to preserve and sustain water resources and the facilitation of economic development.

The Chief Directorate: Water Ecosystems Management (CD: WEM) within the Department of Water and Sanitation (DWS) have coordinated the high confidence Reserve Determination for the Upper Orange catchment area in the Orange Water Management Area (WMA 6), following the Water Resource Classification System (WRCS). This comprehensive study encompassed both surface water (rivers and wetlands) and groundwater components of water resources. The primary objectives were to offer ample protection for potential hydraulic fracturing activities, assess various Water Use License Applications (WULA), and evaluate the impacts of current and proposed developments on water availability. Furthermore, the results from the study will guide the Department to meet the objectives of maintaining, and if attainable, improving the ecological state of the water resources. The primary deliverable was the preparation of the Reserve template for the Upper Orange catchment area, specifying the EWRs and ecological specifications (EcoSpecs) for the management of the priority rivers, wetlands and groundwater resources.

The Upper Orange catchment area includes the main stem Orange River from the Lesotho border to the confluence with the Vaal River at Douglas. The major tributaries of the Orange River include the Kraai, Caledon and Seekoei Rivers. Although the Modder-Riet River drains into the Vaal River, due to their interconnectivity (i.e., water transfers) with the Upper Orange River, are included in this study.

This study was of a technical nature being supported by stakeholder engagement and consultation. The project approach and methodology that was applied was in accordance with the 8-step process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010**,** as well as The Reserve determination process as outlined in the ‘Development of Procedures to operationalise Resource Directed Measures (DWS, 2017).

A summary of the results from the past three (3) years are as follows. In this study, 10 Intermediate, six (6) Rapid level 3 EWR sites, along with an additional 25 field verification sites, were identified and surveyed within the prioritised river RUs. The study involved calculating the PES, classifying the REC, quantifying the EWRs, determining the various operational scenarios, evaluating the ecological and socio-economic consequences, and assigning EcoSpecs and TPCs for each EWR site. For wetlands, priority was given to 12 WRUs, all of which underwent evaluation and were designated a Reserve at varying levels. However, based on the DSS findings, none of the WRUs required EWR quantification. Consequently, EcoSpecs were determined for all WRUs, which can be incorporated into WUL conditions, for effective monitoring and auditing of resource conditions. It is advised to conduct a detailed assessment and outline of the DSS during the newly initiated Classification study, which will also encompass management options for implementation. Finally, a total of 14 GRUs were prioritized. The assessment involved evaluating the Reserve through groundwater

quantification and qualitative analysis, determining the groundwater volume necessary for sustaining the EWR and BHNs. Groundwater recharge calculations, including maximum and minimum groundwater contributions to baseflows, were carried out. The study defined the Groundwater Reserve, stress index, and allocable groundwater in the catchment area per quaternary catchment. Additionally, EcoSpecs were determined, and a monitoring plan was provided. However overall, it is critical to note, that the aforementioned results had significant limitations. The primary challenge in determining the water quality Reserve stemmed from a substantial information gap, specifically the absence of historical and current water quality data. This absence significantly affected the confidence level in the Reserve results (for both surface and groundwater components). The deficiency in water quality data, encompassing both surface and groundwater, also posed difficulties in establishing reference conditions. It's important to note that this issue is a pervasive and systemic challenge within the environment in which we are operating.

Nonetheless and in general, the team is confident that the EcoSpecs outlined for all water resources will either maintain or enhance the quality of water resources (rivers, groundwater, and wetlands) in the Upper Orange catchment area. However, it is crucial that the design of the proposed monitoring programs aligns with the principles of adaptive management. In this framework, monitoring serves as the vital link between achieving the objective (i.e., the EcoSpecs) and implementing adaptive management. If the EcoSpecs are not being met, adjustments to management practices are necessary, and if they are being met, the current practices can continue. These EcoSpecs will be carried forward into the Classification study, contributing to the determination of Resource Quality Objectives (RQOs). The objective of the RQOs will be to further ensure the maintenance or improvement of water resources in the Upper Orange catchment area.

In addition to this study, two other components were included. A conceptual FMP was developed for the sacrificial zones between the Gariep and Vanderkloof Dams, and downstream of the latter dam, highlighting flow-related impacts. Despite the vital role of these dams in South Africa's water and power generation, assessments, revealed significant adverse consequences. Proposed action plans, such as incremental spring releases to improve Priority of Ecological Sensitivity (PES), should be considered in the ongoing Classification study. Secondly, a new concept was developed to assess the integration of surface and groundwater resources. This process was executed specifically for the Kraai water resources, encompassing GRU7, river RU numbers 11, 24, 25, and 27, as well as WRU 6, 16, and 17. This developed approach or concept, is suggested to be advanced into the Classification study. This would enable refinements and updates of the spatial and attribute data in the GIS layer, providing an indication of the likelihood of groundwater or surface water dependency.

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1. INTRODUCTION

1.1 Background

The National Water Act (No. 36 of 1998) (NWA) is founded on the principle that the National Government has overall responsibility for and authority over water resource management for beneficial public use without seriously affecting the functioning and sustainability of water resources. Chapter 3 of the NWA enables the protection of water resources by the implementation of Resource Directed Measures (RDM). As part of the RDM process, an Ecological Reserve must be determined for a significant water resource to ensure a desired level of protection.

The Reserve (water quantity and quality) is defined in terms of (i) Ecological Water Requirements (EWR) based on, the quantity and quality of water needed to protect aquatic ecosystems; water quantity, quality, habitat and biota in the desired state and (ii) Basic Human Needs (BHN), ensuring that the essential needs of individuals dependant on the water resource is provided for. These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources while allowing economic development.

The Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) is responsible for coordinating all Reserve Determination studies in terms of the Water Resource Classification System (WRCS). These studies include the surface water (rivers, wetlands and estuaries) and groundwater components of water resources.

The Reserve has priority over other water uses in terms of the NWA and should be determined before license applications are processed, particularly in stressed and over utilised catchments. Accordingly, the CD: WEM identified the need to determine the Reserve for the ecosystems (rivers, wetlands and groundwater) of the Upper Orange River catchment in the Orange Water Management Area (WMA 6). The aim is to provide adequate protection for (i) possible hydraulic fracturing activities, (ii) assessment of various water use license applications (WULA), and (iii) evaluation of impacts of current and proposed developments on the availability of water.

1.2 Purpose of this Study

It is important to note the following:

- Priority rivers are selected by assessing water use impacts (quantity and quality) to determine the integrated water use index (IWUI) or water stress and (ii) integrated ecological index (IEI) that considers the Presence Ecological State (PES) and the ecological importance (EI) and ecological sensitivity (ES) of each sub-quaternary reach. This results in the identification of priority resource units (RU) where the EWRs need to be quantified.
- A "high confidence study" refers to a combination of different river level assessments, from desktop extrapolation to Intermediate assessments. Furthermore, a wider

coverage of the catchment has been undertaken, not only the main stem Orange River and major tributaries, but inclusive of the smaller tributaries within the catchment. Groundwater and wetland priority resources and their interactions have also been assessed.

Therefore, the purpose of this study is to determine the Reserve (quantity and quality of the EWR and BHN) for priority rivers, wetlands and groundwater areas at a high level of confidence in the Upper Orange Catchment. The results from the study will guide the Department to meet the objectives of maintaining, and if attainable, improving the ecological state of the water resources. The primary deliverable will be the preparation of the Reserve templates for the Upper Orange Catchment, specifying the ecological water requirements and ecological specifications/ conditions for the management of the priority rivers, wetlands and groundwater areas.

1.3 Purpose of this Report

The purpose of this report is to provide an integrated summary of the findings and recommendations of the Reserve determination for surface and groundwater in the Upper Orange Catchment which forms part of the Orange Water Management Area (WMA6).

It is important that this report is read in conjunction with the following reports to understand context and obtain the required detail:

- RDM/WMA13/00/CON/COMP/0121: Inception Report;
- RDM/WMA13/00/CON/COMP/0321: Gaps Analysis Report;
- RDM/WMA13/00/CON/COMP/0422: Resource Units Report;
- RDM/WMA13/00/CON/COMP/0822: Basic Human Needs Assessment Report;
- RDM/WMA13/00/CON/COMP/0922: Wetland Report;
- RDM/WMA13/00/CON/COMP/1022: Groundwater Report;
- RDM/WMA13/00/CON/COMP/1123: Socio-Economics Outline Report;
- RDM/WMA13/00/CON/COMP/1223 (a): Eco-Categorisation Report – Volume 1;
- RDM/WMA13/00/CON/COMP/1223 (b): Eco-Categorisation Report – Volume 2;
- RDM/WMA13/00/CON/COMP/1323: Quantification of Ecological Water Requirements Report;
- RDM/WMA13/00/CON/COMP/1423: Scenario and Consequences Report; and
- RDM/WMA13/00/CON/COMP/1523: Ecological Specifications and Monitoring Plan Report.

1.4 Overview of the Study Area

The study area of the Upper Orange Catchment forms part of the Orange WMA6 (**Figure 1-1**) and includes the main stem Orange River from the Lesotho border to the confluence with the Vaal River at Douglas. The major tributaries of the Orange River include the Kraai, Caledon and Seekoei Rivers. Although the Modder-Riet River drains into the Vaal River, due to their interconnectivity (i.e., water transfers) with the Upper Orange River, are included in this study. The study area consists of 129 quaternary catchments, covering an approximate area of 106 000 km^2. This includes secondary catchments D1, D2, D3 and C5 namely:

i. The Orange River from the Lesotho Border to the Gariep Dam, including the main tributaries: Kornetspruit, Sterkspruit, Stormbergspruit and Brandwaterspruit (catchments D12, D14 and the SA part of D15 and D18);

ii. The Caledon River from its headwaters and its tributaries to the Gariep Dam (catchments D21, D22, D23, D24);
iii. The Kraai River catchment (catchment D13); and
iv. The Orange River from the Gariep Dam to Marksdrift weir (catchments D31, D33, D34 and D35), just upstream from the confluence with the Vaal River. This includes the Seekoei River (catchment D32) in the south and the Modder-Riet River (catchments C51 and C52) in the north.

The Gariep and Vanderkloof Dams on the main stem Orange River are two of the country's largest reservoirs with main uses for the generation of hydropower, transfers of water and releases for irrigation and other demands, including estuarine requirements, before reaching its confluence with the Vaal River.

The current infrastructure for water use is mainly for irrigation, transfer of water within the study area (Caledon River to Modder River, Vanderkloof Dam to the Riet River, Marksdrift on Orange River to Modder-Riet Rivers) and to other WMAs (e.g. transfer to Great Fish River in the Eastern Cape), domestic use, stock watering and power generation at the Gariep and Vanderkloof Dams. The Bloemfontein metropolitan area is the largest in the study area with smaller towns scattered throughout the catchment. Larger towns include Herscell/ Sterkspruit, Aliwal North, Burgersdorp, Ficksburg, Ladybrand, Botshabelo, Kimberley and Colesberg.

The Upper Orange-Senqu River basin coincides with a major transboundary aquifer, i.e. The Karoo Sedimentary Aquifer. The Stormberg Group of the Karoo Supergroup underlying the transboundary area comprises horizontal to sub-horizontal dipping sedimentary rocks of the Burgersdorp, Molteno, Elliot and Clarens Formations. These include fluvio-deltaic mudstones, siltstones and sandstones with dolerite ring dyke intrusions. Formation groundwater storage and flow are functions of porosity. Primary effective porosities are low due to sediment cementation and the fine-grained nature of the sediment, as well as compaction and high mudstone contents. Secondary porosities are enhanced by fracturing and dolerite dyke intrusion. The highest borehole yields are associated with the fractured dolerite and thick sandstone contacts and where these contacts are covered by alluvium. The alluvium plays an important role to enhance recharge to the subsurface lithologies. The borehole yields are variable in the catchment and range from 0.1 L/s to >5.0 L/s, dependent on the underlying geological group. According to WRC (2012), the total groundwater use in the catchment is estimated at 132Mm^3/a, of which 80% is being used for agriculture, 13% for agricultural livestock and 3% for municipal purposes. In the drier western and southern parts of the catchment, groundwater is the main source of water for rural domestic supplies and stock watering.

In terms of the wetlands throughout the study area, depression wetlands are the dominating wetland types and which are largely associated with a combination of geology, rainfall and temperature. A total of 2,868 wetlands was identified by the National Wetlands Map (NWM5) spatial layer (Van Deventer *et al.,* 2018), covering 74,378ha. The majority of the identified wetlands are in the Upper Karoo Bioregion, followed by the Mesic Highveld Grassland Bioregion. Most of the identified wetlands were categorised as Least Concern followed by Vulnerable based on the vulnerability of the wetland type and vegetation with more than half of the identified wetlands in a largely natural state with limited modifications. The main modifications affecting the integrity of the wetlands within the Catchment is associated with multiple land use impacts e.g., irrigated commercial croplands, bare areas associated with mining operations and populated areas (hardened surfaces). Other impacts include poor land use management practises and over-grazing in all three provinces. Large areas of the study area have highly dispersive soils that are a key consideration for the selection of wetlands of importance for protection and maintenance since many of these systems are already highly degraded and at risk of eroding beyond any rehabilitation potential.

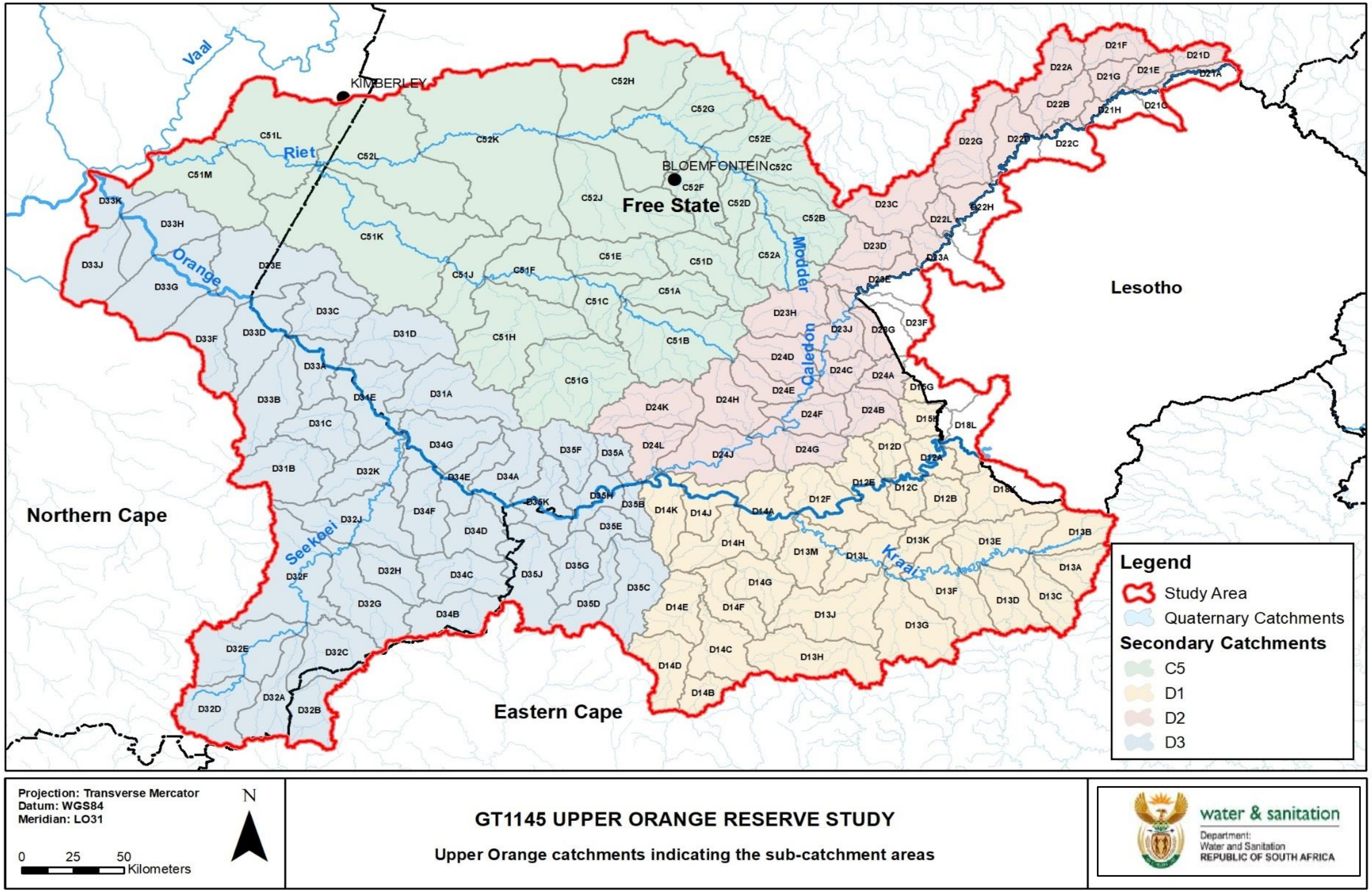


Figure 1-1: Upper Orange Catchment

1.5 Study Methodology and Approach

This study was of a technical nature being supported by stakeholder engagement and consultation. The project approach and methodology that was applied was in accordance with the 8-step process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010 (**Figure 1-2**), as well as The Reserve determination process as outlined in the study, 'Development of Procedures to operationalise Resource Directed Measures (DWS, 2017). However, to reiterate, this study excluded the gazetting of the Reserve (step 8 illustrated in **Figure 1-2**), as the Classification and Resource Quality Objective (RQO) study was initiated towards the end of 2023, which will include the water resource classes and potentially the gazetting of the Reserve.

The following 8 main aspects were undertaken for the purpose of this study:

- Review and analysis of existing information;
- Identifying and filling in of the ecological gaps identified;
- Identification of the priority resource units (RUs) (rivers, groundwater and wetlands);
- The EWRs were quantified for the priority river and groundwater RUs;
- The various management scenarios and operations were analysed, followed by assessing the ecological and socio-economic consequences to these;
- Ecological specifications and Threshold of Potential Concerns (TPCs) were identified for rivers, wetlands and groundwater, along with formulating practicable indicators for compliance monitoring and monitoring of the ecological health and integrity of the water resources;
- Stakeholder engagement, co-operative governance and consultation processes were followed;
- The Reserve template has been prepared; and
- Study management and capacity building was held and undertaken throughout the study period. The study management component monitored performance, supported client liaison, tracked expenditure and ensured the successful execution of the various study tasks.

The Study management, stakeholder engagement and capacity building task have continued throughout the study period (24 months) (**Figure 1-3**). Study tasks are for the most part not linear and ran concurrently over the project timeframe.

Overall, this report documents a summary of the outcome of all the above steps of the Reserve determination process.

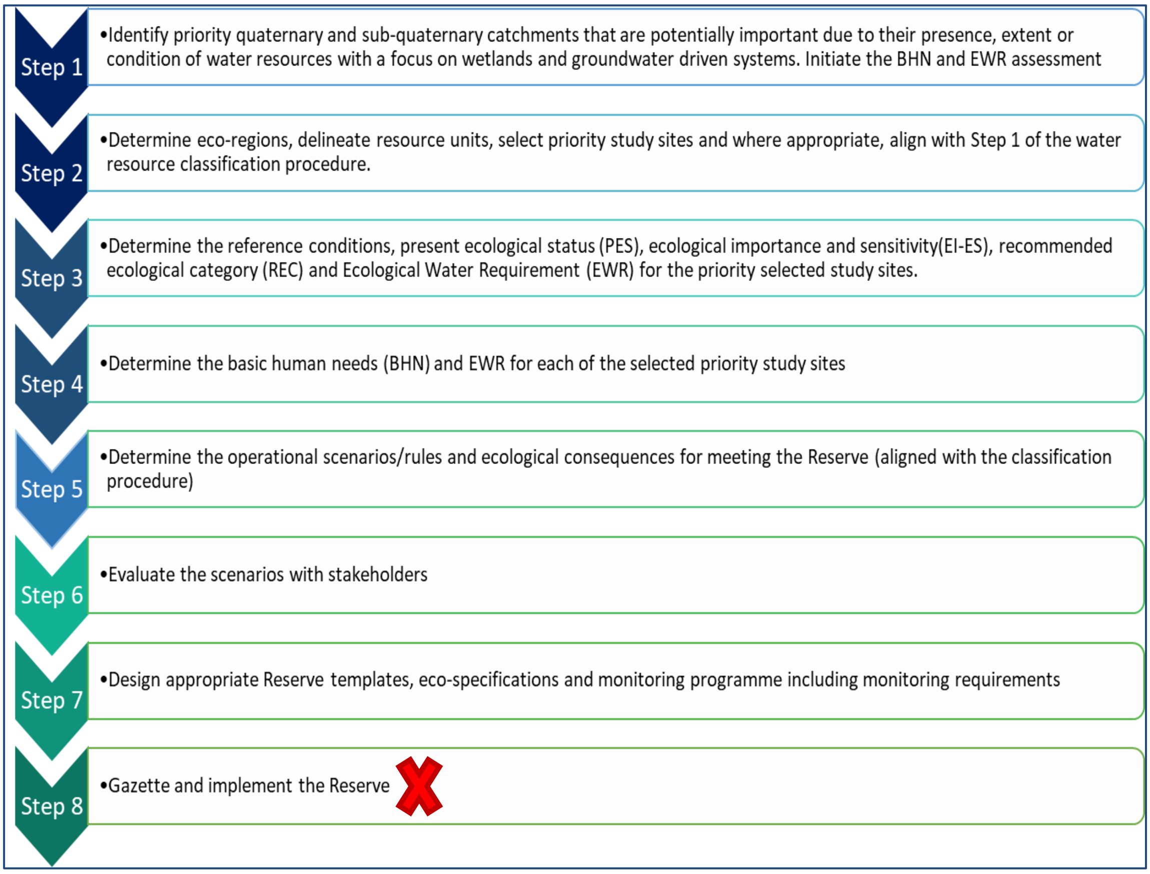


Figure 1-2: Integrated steps for the determination of the Reserve *(red cross indaties the step excluded from this scope of work)*

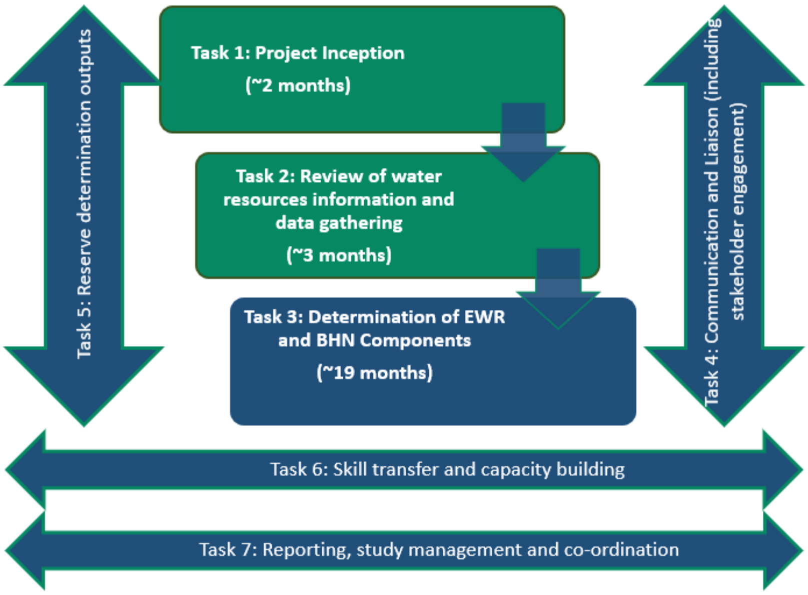


Figure 1-3: Proposed scope of work and approximate timelines

1.6 Data Gaps and Assumptions

1.6.1 All components: water quality

The major information gap for the water quality Reserve determination was the lack of historical and present-day water quality data which impacts the confidence of the Reserve results. The lack of water quality data (for both surface and groundwater) also made it challenging to determine reference conditions. Overall, this is a problem generically and systemically in this environment we are working in.

River's water quality

Reference and recent conditions of surface water quality at all river EWR sites, or the Sub-Quaternary (SQ) reach within which the sites are located, posed major gaps and concerns for this study area. Several data sources were used to collate information of the current and historical Physical-chemical state of the assessed river systems and associated catchments. The DWS Resource Quality Information Services (RQIS) website, was the obvious first choice used to obtain data from the country wide DWS monitoring network. Most of data obtained from the RQIS did not show reference/baseline conditions as most of it was collected after major impacts had been introduced in the catchments. Additionally, the lack of consistent monitoring left years' worth of gaps in data. Further, there was no recent data, which posed a challenge when attempts were made to assess the current physical-chemical state. Furthermore, the porosity in data limited the ability to assess site reference conditions confidently and accurately.

Consequently, the inadequate data that would have been provided by one or two water quality samples, had they been collected, would not have been sufficient for conducting the Physical-chemical driver Assessment Index (PAI) or obtaining highly confident results. Thus, the inadequate data available was not enough to populate the PAI and it was therefore not used in this study. However, the decision was made to use diatoms as a surrogate. This approach aimed to deduce both the reference condition and the current status of the physical-chemical conditions of the river systems under consideration. The utilisation of diatoms in water quality monitoring is extensively documented and accounts for historical conditions as well.

Groundwater quality, level and borehole yield data

Multiple attempts were made to gather reference and current conditions for groundwater quality and groundwater level data during the study. However, that data too was very sparse and the major lack of data, posed a limitation in this catchment, and impacted the confidence of the groundwater Reserve. The lack of monthly rainfall and abstraction data to determine more detailed groundwater recharge calculations, as well as the lack of rainfall chemistry data for detailed groundwater recharge calculations contributed to the limitations and gaps. Although WR 2012 rainfall data was used, the data was only until end-2009. In the absence of rainfall chemistry data, default values were used as prescribed by the Recharge Toolkit.

Overall, the data for the Groundwater Reserve determination was obtained through various sources, which included:

- The WARMS database provided by DWS;
- Groundwater quality, levels data from DWS regional offices;
    - Specifically electrical conductivity (EC) and pH was the only data readily available that provided an indication of the groundwater quality for much of the study area. Detailed water quality data from laboratory testing analysis results were not freely available and difficult to obtain.
- SanParks - which officially commenced their groundwater monitoring programme two years ago, inclusive of Mokala Nature Reserve, located within our study area;
- Department of Agriculture, land reform and rural development, although only groundwater level and yield data were obtained.

Unfortunately, municipalities, entrusted with the responsibility of collecting groundwater quality data, did not furnish any data, despite several attempts in requesting such data for the purpose of this study.

Lastly, it is important to reiterate that the Groundwater Resource Directed Measures (GRDM) methodology is currently being updated and will only be available in 2024. As the project end date for this study is March 2024, the current groundwater assessment was therefore based on WRC (2012) methodology.

1.6.2 Wetlands

While there was existing information on the general extent and distribution of wetlands in the Upper Orange catchment area, it was all predominantly limited to desktop studies. However, owing to the vast numbers of wetlands located within this study area, a comprehensive field-verification survey was not practical. Thus, the identification of the priority wetlands and the development of an integrated Priority Wetland GIS layer, combined with updated desktop delineations and categorisations was an important supplement to the study results.

Furthermore, limited flow and water quality data (especially updated information and as described above) added to the limitations on the wetland component.

2. DELINEATION OF WATER RESOURCES

Below are lists of the river EWR sites and the delineated wetland and groundwater prioritised RUs within the Upper Orange catchment area.

2.1 Rivers Priority Resource Units and EWR sites

Priority quaternary catchments (with associated river reaches) within the Upper Orange catchment were identified. The purpose of this was to identify priority sub-catchments that are (i) important from an ecological perspective or support the system to achieve the desired ecological condition, (ii) are supporting water use for various economic activities and (iii) where future large scale water resource developments are planned, which require supplementary data, information or analysis to finalise the Reserve. A prioritisation and selection of the sites was then undertaken based on a review of previous Reserve studies, existing information, expert knowledge, water resources requiring protection, the water reconciliation situation, conservation and protection areas and prevalent water quality issues.

The ecological information gaps were addressed by undertaking Intermediate, Rapid 3 Reserve determinations and various field verification surveys of the priority sites identified in the catchment. These included the following:

(i) **Intermediate Reserve Level** – an assessment of the biological responses namely the fish, aquatic macroinvertebrates and the riparian vegetation, following by running their associated models namely the Fish Response Assessment Index (FRAI); the Macroinvertebrate Response Assessment Index (MIRAI) and the Riparian Vegetation Response Assessment Index (VEGRAI). Furthermore, the drivers were also assessed namely the geomorphology, hydrology and water quality, and with running the Geomorphology Driver Assessment Index (GAI), Hydrological Assessment Index (HAI) and assessing the water quality by inferring information from the diatom community, to ultimately determine the PES using the EcoStatus Level 4 model, EI-ES, Recommended Ecological Category (REC) and possible Alternative Ecological Categories (AEC). Furthermore, this Reserve level including the hydraulics and discharge survey data (high and low flows). The Habitat-Flow-Stressor Response approach has been followed to determine the EWRs where applicable. The Fish Invertebrate Flow Habitat Assessment Model (FIFHA) has been used to assess fish and macroinvertebrate responses (ecological consequences) to the operational scenarios during low flow conditions;

(ii) **Rapid 3** – an assessment of the biological responses and interpreting the data thereof through running the MIRAI, FRAI, and Index of Habitat Integrity (IHI) (used as a surrogate to the VEGRAI when running the EcoStatus model), have been used to determine the PES/ EcoStatus, EI-ES and REC. This includes the hydraulics survey data (low flows) used to verify the DRM/RDRM results and determine the EWR. Rapid 3 Reserves are conducted specifically where there are ecological concerns due to Wastewater Treatment Works (WWTWs), smaller scale water use activities (e.g., irrigation, small farm dams) or where the results of the October 2021 diatom samples indicated poor water quality; and

(iii) **Field verification** – the objective of verification in identified reaches is to assess and compare the results of the desktop PES, EI and/ or ES and to provide specific recommendations for future management of these smaller tributaries.

Overall, ten (10) Intermediate and six (6) Rapid 3 Ecological Water Requirements (EWR) sites were selected within the priority Resource Units (RU) in the study area respectively. A further 25 field verification sites were assessed from a water quality perspective. These EWR sites are listed in **Table 2-1** and illustrated in **Figure 2-1**.

Table 2-1: Summary of the selected EWR sites and field verification sites in the study area

EWR site Number	EWR Site Name	River	Co-ordinates		EcoRegion (Level II)	Geomorphic zone	Altitude (m)	Resource Unit	Quaternary Catchment	Gauge
			Latitude	Longitude						
INTERMEDIATE EWR SITES										
UO_EWR01_I	Middle Caledon	Middle Caledon	-28.908900	27.785000	15.01	Lowland	1526	R_RU04	D22D	D2H035
UO_EWR02_I	Sterkspruit	Sterkspruit	-30.517806	27.369058	15.01	Upper Foothills	1429	R_RU01	D12B	-
UO_EWR03_I	Upper Orange	Upper Orange	-30.652793	26.823213	26.03	Lowland	1302	R_RU02a	D12F	D1H009
UO_EWR04_I	Lower Caledon	Lower Caledon	-30.436136	26.299258	26.03	Lowland	1277	R_RU05	D24G	D2H033
UO_EWR05_I	Seekoei	Seekoei	-30.534359	24.962895	26.03	Lower Foothills	1221	R_RU06	D32J	D3H015
UO_EWR06_I	Upper Riet	Upper Riet	-29.535065	25.524570	26.03	Lower Foothills	1278	R_RU08	C51F	-
UO_EWR07_I	Upper Modder	Upper Modder	-29.160017	26.572492	11.03	Lower Foothills	1333	R_RU9a	C52B	C5H003
UO_EWR08_I	Lower Kraai	Lower Kraai	-30.690070	26.741570	26.03	Lower Foothills	1298	R_RU03	D13M	D1H011
UO_EWR09_I	Lower Riet	Lower Riet	-29.038420	24.502830	29.02	Lower Foothills	1080	R_RU10	C51L	C5H014
UO_EWR10_I	Lower Orange	Lower Orange	-29.162020	23.695944	26.01	Lowland	1000	R_RU07	D33K	D3H008
RAPID 3 EWR SITES										
UO_EWR01_R	Little Caledon	Little Caledon	-28.557796	28.405709	15.03	Lower Foothills	1692	R_RU13	D21D	-
UO_EWR02_R	Brandwater/ Groot	Brandwater/ Groot	-28.680340	28.139926	15.01	Lower Foothills	1583	R_RU14	D21G	-
UO_EWR03_R	Mopeli	Mopeli	-29.101205	27.570751	15.01	Lower Foothills	1503	R_RU16	D22G	-
UO_EWR04_R	Upper Kraai	Upper Kraai	-30.851790	27.776890	15.06	Lower Foothills	1714	R_RU11a	D13E	-
UO_EWR05_R	Wonderboomspruit	Wonderboomspruit	-31.005262	26.341938	26.03	Lower Foothills	1383	R_RU12	D14E	D1H001
UO_EWR06_R	Middle Modder	Middle Modder	-28.807191	26.109695	11.08	Lower Foothills	1263	R_RU09b	C52G	-

EWR site Number	EWR Site Name	River	Co-ordinates		EcoRegion (Level II)	Geomorphic zone	Altitude (m)	Resource Unit	Quaternary Catchment	Gauge
			Latitude	Longitude						
FIELD VERIFICATION SITES										
UO_EWR01_FV	Meulspruit	Meulspruit	-28.885731	27.834944	15.01	Lower Foothills	1536	R_RU30	D22B	*
UO_EWR02_FV	Witspruit	Witspruit	-30.008260	26.928315	11.03	Lower Foothills	1389	R_RU31	D24C	
UO_EWR03_FV	Gryskopspruit	Gryskopspruit	-30.339629	27.176878	15.01	Lower Foothills	1526	R_RU22	D12D	
UO_EWR04_FV	Karringmelkspruit	Karringmelkspruit	-30.811765	27.266497	15.06	Upper Foothills	1635	R_RU26	D13K	
UO_EWR05_FV	Bokspruit	Bokspruit	-30.88469	27.884557	15.06	Lower Foothills	1760	R_RU23	D13A	
UO_EWR06_FV	Holspruit	Holspruit	-30.995316	27.056639	15.06	Lower Foothills	1413	R_RU27	D13J	
UO_EWR07_FV	Sterkspruit, tributary of Kraai	Sterkspruit, tributary of Kraai	-30.917621	27.800753	15.06	Lower Foothills	1740	R_RU11b	D13C	
UO_EWR08_FV	Bell	Bell	-30.852601	27.786557	15.06	Lower Foothills	1723	R_RU11c	D13B	
UO_EWR09_FV	Groenspruit	Groenspruit	-30.241190	26.561300	26.03	Lower Foothills	1333	R_RU32a	D24H	
UO_EWR10_FV	Skulpspruit	Skulpspruit	-30.234440	26.511340	26.03	Lower Foothills	1333	R_RU32b	D24H	
UO_EWR11_FV	Fouriespruit	Fouriespruit	-29.671211	26.074393	26.03	Lower Foothills	1357	R_RU18	C51A	
UO_EWR12_FV	Renoster	Renoster	-29.116320	26.328701	11.08	Lower Foothills	1334	R_RU37	C52F	
UO_EWR13_FV	Os-spruit	Os-spruit	-28.939170	26.511411	11.1	Lower Foothills	1334	R_RU21	C52E	
UO_EWR14_FV	Hondeblaf	Hondeblaf	-30.205138	24.718030	26.03	Lower Foothills	1197	R_RU33	D31C	
UO_EWR15_FV	Tributary of VanZylspruit	Tributary of VanZylspruit	-30.031203	25.786463	26.03	Lower Foothills	1409	R_RU40	C51G	
UO_EWR16_FV	Slykspruit	Slykspruit	-30.393003	26.120925	26.03	Lower Foothills	1282	R_RU43	D24L	
UO_EWR17_FV	Langkloofspruit	Langkloofspruit	-30.954126	27.606129	15.06	Lower Foothills	1426	R_RU11d	D13D	
UO_EWR18_FV	Wasbankspruit	Wasbankspruit	-31.155540	27.284442	15.06	Lower Foothills	1520	R_RU25	D13G	

EWR site Number	EWR Site Name	River	Co-ordinates		EcoRegion (Level II)	Geomorphic zone	Altitude (m)	Resource Unit	Quaternary Catchment	Gauge
			Latitude	Longitude						
UO_EWR19_FV	Lower Modder	Lower Modder	-28.891660	25.656445	26.02	Lowlands	1220	R_RU39	C52K	
UO_EWR20_FV	Upper Kromellenboog	Upper Kromellenboog	-30.066282	25.681056	26.03	Lower Foothills	1404	R_RU19a	C51G	
UO_EWR21_FV	Lower Kromellenboog	Lower Kromellenboog	-29.653600	25.435070	26.03	Lower Foothills	1258	R_RU19b	C51H	
UO_EWR22_FV	Tele	Tele	-30.448588	27.582337	15.02	Lower Foothills	1411	R_RU41	D18K	
UO_EWR23_FV	Upper Orange	Upper Orange	-30.398757	27.342987	15.02	Lowlands	1366	R_RU02b	D12A	
UO_EWR24_FV	Makhaleng	Makhaleng	-30.164120	27.398251	15.01	Lowlands	1416	R_RU42	D15G	

**Not applicable*

Although the river reaches below Gariep and Vanderkloof dams were prioritised for intermediate assessments, due to the operation of the two dams for hydropower, irrigation and other water demand releases downstream, a conceptual Flow Management Plan (FMP) was proposed and developed for this study (**Table 2-2**). The aim of this plan was to identify the impacts on the ecological functioning of the river and to optimise the releases. Furthermore, and importantly, it should be considered and taken forward into the Classification of the Upper Orange catchment area, with possible socio-economic trade-offs. The FMP has further provided proposed immediate, short term (0-5 years), medium term (5-20 years) and long term (>20 years) recommendations going forward. The conceptual FMP is described in **Chapter 4.1.1** below.

Table 2-2: Conceptual Flow Management Plan RUs

River	Quaternaries	Comments*
Orange	D34A, E, F, G	Assessment indicates intermediate determination for Orange between Gariep and Van der Kloof Dams. However, due to the operation of Gariep Dam with constant releases and hydropower releases that change flows daily, a FMP has been proposed.
Orange	D33A, C, D, E, F, G	Van der Kloof Dam hydropower releases and extensive irrigation along river. Existing EWR site from ORASECOM EFR study, 2010 (Louw and Koekemoer, 2010). A FMP is proposed (this is in line with the results from the 2010 ORASECOM study).

** Assessment results of the JBS3 surveys have been used to guide the surveys in terms of the components to be included to be able to specify specific changes to the flow releases*

2.2 Wetlands

Twelve wetland resource units (WRU) were selected for the Upper Orange Catchment. These systems varied drastically in terms of their type, integrity, functionality and size, but were all regarded as important. The WRUs are listed in **Table 2-3** and illustrated in **Figure 2-2**.

Table 2-3: Summary of the WRU selected for the Upper Orange Reserve study

WRU Number	Latitude	Longitude	Quaternary Catchment	Associated River/Groundwater Area
WRU 02	-28.73001	28.11370	D21G	Brandwater River
WRU 03	-28.73884	26.06407	C52H	Not associated
WRU 04	-30.48439	24.61705	D31B	Hondeblaf River
WRU 05	-31.34201	27.19072	D13G	Wolwespruit
WRU 06	-30.82522	27.46506	D13E	Klein-Wildebeesspruit
WRU 10	-29.63414	24.65006	D33C	Lemoenspruit
WRU 11	-28.99778	25.83439	C52G	Kaalspruit

WRU Number	Latitude	Longitude	Quaternary Catchment	Associated River/Groundwater Area
WRU 12	-28.71019	26.29506	C52G	Rietspruit
WRU 13	-28.93325	27.72073	D22G	Rantsho River
WRU 15	-29.81707	25.47559	C51H	Prosesspruit
WRU 16	-31.21736	27.66851	D13D	Rytjiesvlaktespruit
WRU 17	-30.67606	27.95689	D13B	Kraai River

2.3 Groundwater

Based on a variety of geohydrological, management and geo-political criteria, the catchment was subdivided into fourteen (14) Groundwater Resource Units (GRUs). The GRUs and quaternary catchments within the Upper Orange Catchment are listed in **Table 2-4** and illustrated in **Figure 2-3.**

Table 2-4: Upper Orange Catchment GRU's and Quaternary Catchments

GRU	Quaternary Catchments
GRU1	D21F, D22A, D21D, D21E, D21G, D21A, D22B, D22G, D21H, D21C, D22D, D22C, C52C, D22F, D23C, D22H, C52B, D22L, C52A, D23D, D23A, D23E, D23H, D23J, D23F, D23G
GRU2	C52A, C51D, C51A, D23H, D23J, D23F, C51B, D23G, D24D, C51G, D24C, D31A, D24C, D31A, D24E, D24A, D15G, D24H, D18L, D24K, D24B, D24F, D15H, D34G, D24G, D35F, D24J, D12D, D24L, D34A, D34E, D35A, D12A, D12E, D35K, D12C, D35H, D12F, D34F, D14A, D35B, D14K, D14J, D12B, D34D, D35E, D35J, D35G, D34C
GRU3	C52H, C52G, C52K, C52E, C52J, C52C, C52F, C51K, C52D, C52B, C52A, C51J, C51D, C51E, C51F, D23E, C51A, C51C, C51H, D23H, D23J, D23F, C51B, C51G, D24K
GRU4	C52H, C52G, C52E, C52F
GRU5	C52K, C52L, C51J
GRU6	C51K, C51J, C51F, C51H, D31D, D31A
GRU7	D18L, D15H, D12D, D12A, D12E, D18K, D12C, D18G, D12B, D13B, D13E, D13K, D13L, D13F, D13A, D13C, D13G, D13D, D13J
GRU8	D12E, D12C, D12F, D12B, D13M, D13K, D13L, D13F, D14G, D14F, D13G, D13J, D14C, D13H
GRU9	D24J, D35K, D35H, D12F, D14A, D35B, D14K, D14J, D34D, D14H, D35E, D13M, D35J, D35G, D35C, D32G, D35D, D32H, D34C, D14G, D14F, D14E, D34B, D14C, D32C, D14D, D14B, D23B
GRU10	D32F, D32G, D32E, D32C, D32A, D32D, D32B
GRU11	D34G, D34A, D34E, D32K, D34F, D32J, D34D, D32F, D35J, D32G, D32H, D34C, D34B
GRU12	D31D, D33A, D33B, D31A, D31E, D31C, D34G, D32K, D31B, D34F, D32J, D32F, D32G, D32H
GRU13	C92C, C92B, C51L, C52L, C51M, C51K, D33K, D33H, D33J, D33E, D33G, D33C, D33D, D33F, D33A, D33B, D31E, D31C, D31B

GRU	Quaternary Catchments
GRU14	C52H, C52G, C52K, C52L, C52J, C51K, C51J, D33E, C51E, C51F, D33C, C51H, D33D, D31D, C51G, D33A, D33B, D31A, D31E, D34G

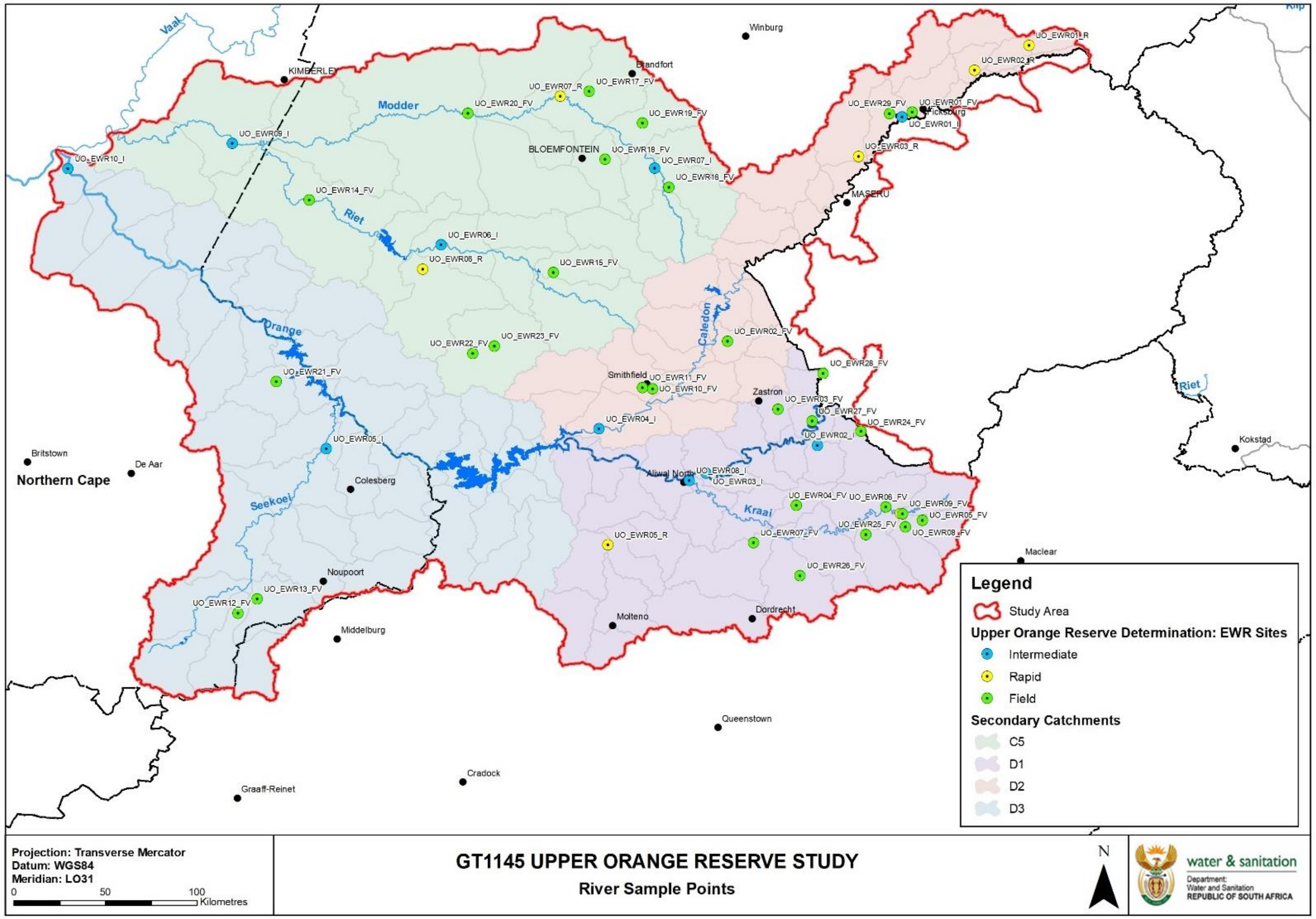


Figure 2-1: Overview of the EWR sites and field verification sites selected for the Upper Orange Catchment area

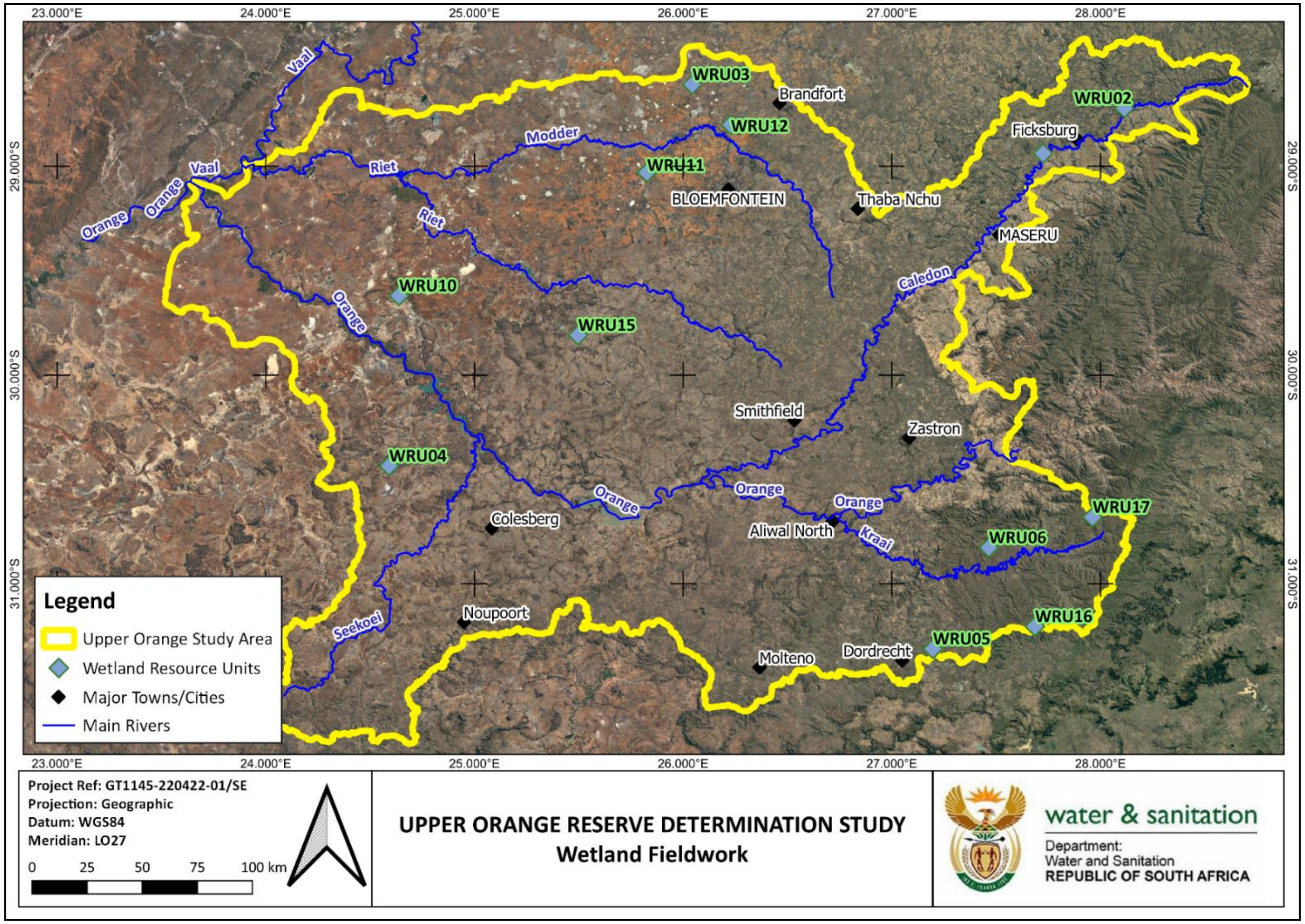


Figure 2-2: Overview of the WRU selected for the Upper Orange Catchment area

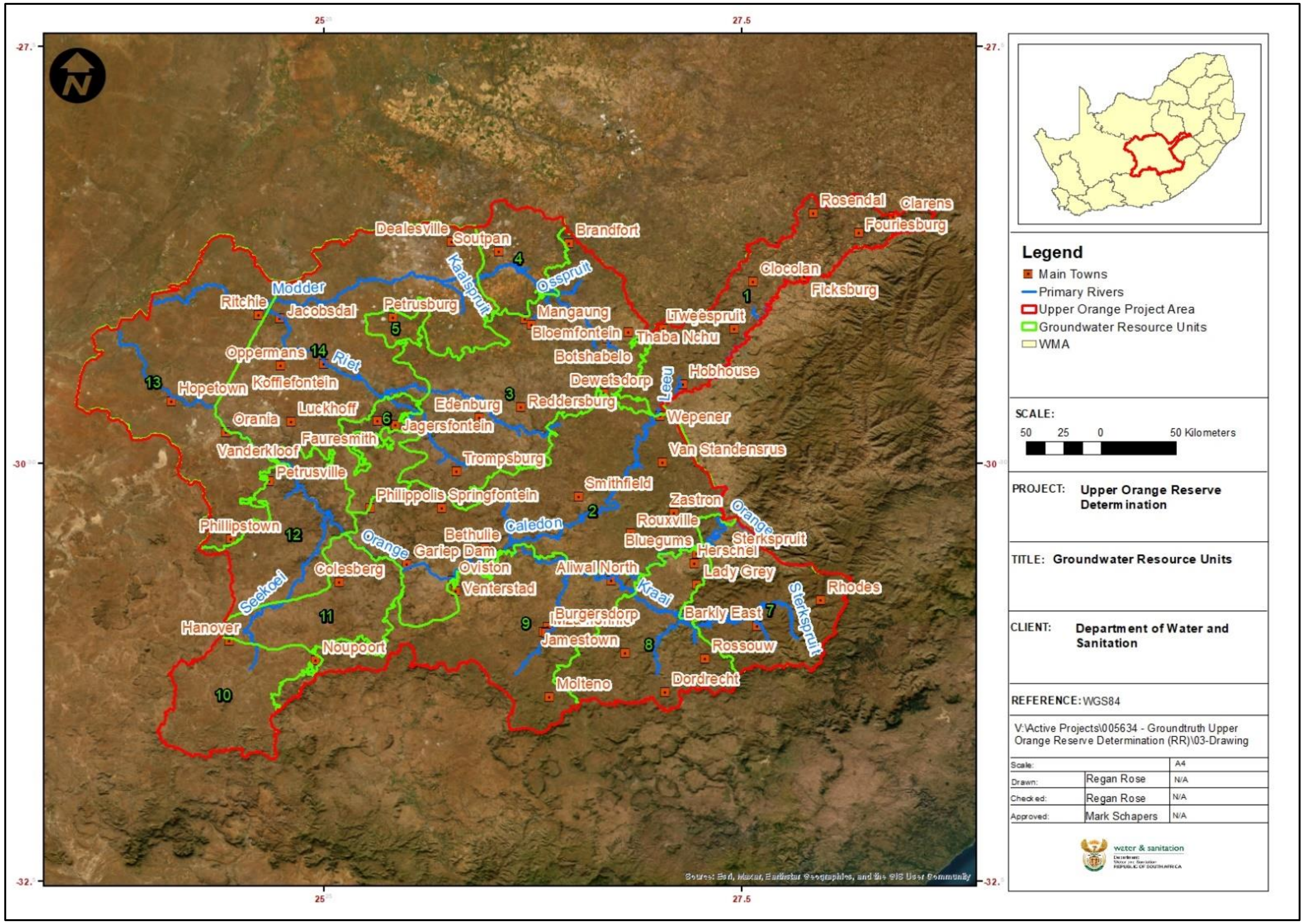


Figure 2-3: Overview of the GRU selected for the Upper Orange Catchment area

3. BASIC HUMAN NEEDS AND SOCIO-ECONOMIC PROFILE

In addition to determining the Reserve for priority rivers, wetlands and groundwater resources in the Upper Orange catchment area, the quantification of the Basic Human Needs (BHN) was undertaken across all the quaternary catchments (129) and the socio-economic conditions and well-being of the communities profiled.

The BHN component formed part of Step 4 of the Reserve Determination process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010. The socio-economic profile provides the baseline for evaluating the social consequences of potential operational flow scenarios as part of steps 5 and 6 of the Reserve Determination process 'Scenario determination, evaluation and consequences' (DWS, 2017).

3.1 Basic Human Needs

Refer to **Table 3-1** and **Table 3-2** which provides the BHN for surface water (river/stream) and groundwater Reserve required per quaternary catchment area respectively, and which are expressed as million cubic metres (MCM) per annum and as a percent of natural mean annual runoff (NMAR).

Table 3-1: The BHN for surface water (river/stream) Reserve required per quaternary catchment area

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	NMAR (MCM)	Basic human needs surface water Reserve required*	
				MCM / annum	% NMAR
C51A	1	25	15.030	0.00001	0.00006
C51B	2	25	20.070	0.00002	0.00010
C51C	1	25	9.390	0.00001	0.00010
C51D	5	25	16.180	0.00004	0.00026
C51E	1	25	18.690	0.00001	0.00003
C51F	1	25	12.120	0.00001	0.00008
C51G	4	25	42.740	0.00004	0.00008
C51H	4	25	38.710	0.00003	0.00009
C51J	1	25	13.930	0.00001	0.00008
C51K	203	25	6.100	0.00185	0.03033
C51L	189	25	3.020	0.00172	0.05711
C51M	404	25	2.320	0.00368	0.15879
C52A	9	25	28.960	0.00008	0.00028
C52B	73	25	26.270	0.00066	0.00253
C52C	13	25	10.840	0.00012	0.00108
C52D	9	25	7.690	0.00008	0.00101
C52E	3	25	11.860	0.00003	0.00021
C52F	144	25	11.200	0.00131	0.01173
C52G	14	25	24.280	0.00013	0.00052
C52H	9	25	1.650	0.00008	0.00482
C52J	12	25	3.120	0.00011	0.00339
C52K	38	25	1.440	0.00035	0.02419
C52L	42	25	1.190	0.00038	0.03212
D12A	1 038	25	26.090	0.00947	0.03629
D12B	2 690	25	40.360	0.02454	0.06081
D12C	420	25	18.050	0.00383	0.02124
D12D	1	25	15.560	0.00001	0.00006

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	NMAR (MCM)	Basic human needs surface water Reserve required*	
				MCM / annum	% NMAR
D12E	325	25	29.010	0.00297	0.01023
D12F	4	25	24.500	0.00003	0.00014
D13A	147	25	70.670	0.00134	0.00190
D13B	162	25	73.350	0.00148	0.00202
D13C	161	25	53.640	0.00147	0.00273
D13D	198	25	56.110	0.00181	0.00322
D13E	346	25	127.870	0.00316	0.00247
D13F	329	25	92.530	0.00300	0.00324
D13G	275	25	54.270	0.00251	0.00462
D13H	77	25	29.990	0.00070	0.00234
D13J	6	25	32.980	0.00005	0.00016
D13K	137	25	48.750	0.00125	0.00257
D13L	149	25	26.000	0.00136	0.00525
D13M	16	25	18.020	0.00014	0.00079
D14A	29	25	21.800	0.00026	0.00121
D14B	14	25	6.290	0.00013	0.00208
D14C	28	25	14.600	0.00026	0.00178
D14D	25	25	9.090	0.00023	0.00248
D14E	5	25	7.970	0.00005	0.00062
D14F	6	25	13.220	0.00005	0.00041
D14G	8	25	14.800	0.00007	0.00050
D14H	15	25	12.810	0.00014	0.00109
D14J	6	25	9.560	0.00006	0.00059
D14K	11	25	10.940	0.00010	0.00088
D15G	1	25	44.490	0.00001	0.00002
D15H	1	25	25.670	0.00001	0.00004
D18K	1 970	25	144.510	0.01798	0.01244
D18L	1 472	25	64.340	0.01343	0.02087
D21A	9	25	65.500	0.00008	0.00012
D21C	3	25	33.620	0.00003	0.00008
D21D	24	25	22.590	0.00022	0.00099
D21E	33	25	18.600	0.00030	0.00163
D21F	55	25	33.040	0.00050	0.00151
D21G	37	25	20.970	0.00033	0.00160
D21H	5	25	41.620	0.00005	0.00012
D22A	15	25	35.970	0.00013	0.00037
D22B	10	25	32.250	0.00009	0.00028
D22C	27	25	50.260	0.00024	0.00048
D22D	28	25	37.080	0.00026	0.00070
D22G	64	25	53.300	0.00059	0.00110
D22H	24	25	36.910	0.00021	0.00058
D22L	7	25	22.140	0.00006	0.00028
D23A	7	25	36.990	0.00006	0.00017
D23C	6	25	26.190	0.00005	0.00020
D23D	10	25	21.720	0.00009	0.00043
D23E	7	25	28.290	0.00006	0.00023
D23F	1	25	19.130	0.00001	0.00004
D23G	5	25	25.460	0.00004	0.00017
D23H	7	25	26.250	0.00007	0.00025
D23J	9	25	21.180	0.00008	0.00039
D24A	3	25	14.470	0.00003	0.00020
D24B	3	25	19.500	0.00002	0.00013
D24C	7	25	11.530	0.00006	0.00055

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	NMAR (MCM)	Basic human needs surface water Reserve required*	
				MCM / annum	% NMAR
D24D	5	25	12.930	0.00005	0.00036
D24E	3	25	10.650	0.00003	0.00028
D24F	5	25	15.040	0.00004	0.00029
D24G	4	25	20.150	0.00004	0.00019
D24H	2	25	17.220	0.00002	0.00012
D24J	13	25	19.020	0.00012	0.00063
D24K	1	25	15.560	0.00001	0.00007
D24L	10	25	8.480	0.00010	0.00113
D31A	4	25	14.510	0.00004	0.00026
D31B	20	25	3.610	0.00018	0.00503
D31C	12	25	3.920	0.00011	0.00280
D31D	39	25	8.490	0.00036	0.00422
D31E	16	25	7.690	0.00015	0.00196
D32A	1	25	3.200	0.00001	0.00029
D32B	1	25	3.670	0.00001	0.00025
D32C	1	25	3.910	0.00001	0.00023
D32D	1	25	3.710	0.00000	0.00013
D32E	1	25	2.820	0.00001	0.00032
D32F	3	25	4.970	0.00002	0.00047
D32G	5	25	5.170	0.00005	0.00090
D32H	4	25	2.750	0.00003	0.00126
D32J	36	25	4.150	0.00033	0.00801
D32K	29	25	3.400	0.00027	0.00782
D33A	28	25	2.890	0.00025	0.00882
D33B	21	25	1.580	0.00019	0.01223
D33C	75	25	3.150	0.00068	0.02172
D33D	109	25	1.220	0.00100	0.08186
D33E	257	25	1.410	0.00234	0.16610
D33F	97	25	0.250	0.00088	0.35238
D33G	253	25	1.240	0.00231	0.18614
D33H	256	25	1.730	0.00233	0.13491
D33J	45	25	0.520	0.00041	0.07857
D33K	179	25	0.940	0.00163	0.17350
D34A	5	25	8.110	0.00005	0.00059
D34B	1	25	5.390	0.00001	0.00017
D34C	7	25	4.690	0.00006	0.00138
D34D	10	25	3.980	0.00009	0.00221
D34E	5	25	4.090	0.00005	0.00118
D34F	30	25	4.010	0.00027	0.00675
D34G	9	25	8.200	0.00008	0.00100
D35A	3	25	4.340	0.00003	0.00058
D35B	5	25	3.960	0.00004	0.00111
D35C	2	25	11.720	0.00002	0.00018
D35D	1	25	6.010	0.00001	0.00011
D35E	1	25	3.830	0.00001	0.00024
D35F	2	25	8.520	0.00002	0.00019
D35G	0	25	5.640	0.00000	0.00000
D35H	3	25	6.030	0.00002	0.00039
D35J	1	25	8.130	0.00001	0.00013
D35K	1	25	6.890	0.00001	0.00020

*Note: *The Reserve is shown to 5 decimal points to avoid reporting zero results where there is a dependent population.*

Table 3-2: The BHN for the groundwater Reserve required per quaternary catchment

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	Basic human needs ground water Reserve required (MCM / annum)
C51A	489	25	0.004
C51B	804	25	0.007
C51C	313	25	0.003
C51D	1 894	25	0.017
C51E	1 140	25	0.010
C51F	528	25	0.005
C51G	752	25	0.007
C51H	1 062	25	0.010
C51J	585	25	0.005
C51K	1 833	25	0.017
C51L	1 032	25	0.009
C51M	723	25	0.007
C52A	906	25	0.008
C52B	1 394	25	0.013
C52C	594	25	0.005
C52D	590	25	0.005
C52E	750	25	0.007
C52F	5 048	25	0.046
C52G	1 609	25	0.015
C52H	3 174	25	0.029
C52J	7 480	25	0.068
C52K	2 652	25	0.024
C52L	1 690	25	0.015
D12A	4 237	25	0.039
D12B	6 317	25	0.058
D12C	1 401	25	0.013
D12D	224	25	0.002
D12E	799	25	0.007
D12F	530	25	0.005
D13A	329	25	0.003
D13B	366	25	0.003
D13C	358	25	0.003
D13D	478	25	0.004
D13E	855	25	0.008
D13F	855	25	0.008
D13G	923	25	0.008
D13H	864	25	0.008
D13J	747	25	0.007
D13K	358	25	0.003
D13L	445	25	0.004
D13M	557	25	0.005
D14A	740	25	0.007
D14B	190	25	0.002
D14C	446	25	0.004
D14D	383	25	0.003
D14E	425	25	0.004
D14F	302	25	0.003
D14G	373	25	0.003
D14H	487	25	0.004
D14J	285	25	0.003

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	Basic human needs ground water Reserve required (MCM / annum)
D14K	319	25	0.003
D15G	76	25	0.001
D15H	209	25	0.002
D18K	4 263	25	0.039
D18L	5 401	25	0.049
D21A	280	25	0.003
D21C	76	25	0.001
D21D	795	25	0.007
D21E	929	25	0.008
D21F	1 623	25	0.015
D21G	773	25	0.007
D21H	279	25	0.003
D22A	1 223	25	0.011
D22B	997	25	0.009
D22C	223	25	0.002
D22D	1 034	25	0.009
D22G	1 651	25	0.015
D22H	612	25	0.006
D22L	551	25	0.005
D23A	622	25	0.006
D23C	1 444	25	0.013
D23D	1 218	25	0.011
D23E	639	25	0.006
D23F	56	25	0.001
D23G	224	25	0.002
D23H	507	25	0.005
D23J	468	25	0.004
D24A	236	25	0.002
D24B	268	25	0.002
D24C	322	25	0.003
D24D	195	25	0.002
D24E	151	25	0.001
D24F	166	25	0.002
D24G	314	25	0.003
D24H	305	25	0.003
D24J	569	25	0.005
D24K	364	25	0.003
D24L	167	25	0.002
D31A	439	25	0.004
D31B	204	25	0.002
D31C	160	25	0.001
D31D	364	25	0.003
D31E	290	25	0.003
D32A	146	25	0.001
D32B	282	25	0.003
D32C	297	25	0.003
D32D	151	25	0.001
D32E	242	25	0.002
D32F	351	25	0.003
D32G	374	25	0.003
D32H	216	25	0.002
D32J	368	25	0.003

Quaternary catchment	Population (current requirement)	Per capita need (litres / day)	Basic human needs ground water Reserve required (MCM / annum)
D32K	272	25	0.002
D33A	169	25	0.002
D33B	217	25	0.002
D33C	178	25	0.002
D33D	250	25	0.002
D33E	669	25	0.006
D33F	294	25	0.003
D33G	549	25	0.005
D33H	446	25	0.004
D33J	385	25	0.004
D33K	180	25	0.002
D34A	288	25	0.003
D34B	364	25	0.003
D34C	366	25	0.003
D34D	271	25	0.002
D34E	201	25	0.002
D34F	403	25	0.004
D34G	341	25	0.003
D35A	96	25	0.001
D35B	124	25	0.001
D35C	404	25	0.004
D35D	228	25	0.002
D35E	112	25	0.001
D35F	215	25	0.002
D35G	191	25	0.002
D35H	181	25	0.002
D35J	362	25	0.003
D35K	246	25	0.002

Based on the adjusted 2011 census data, it was calculated that 13 271 people (1%) rely directly on river/stream sources and 102 755 (7%) on groundwater sources for household water use within the study area. At the national level, the 2011 census data indicated that 6% of the population is reliant on river/stream sources and 8% on groundwater sources as the main source for household use. Reliance on river/stream sources for household use in the study area is lower than the national average, while reliance on groundwater sources is relatively similar to the national average.

Based on a lifeline amount of 25 litres per person per day, the BHN requirement for the Upper Orange study area, at the time of assessment (2022), was estimated at 0.121 million cubic metres per annum for river/stream sources and 0.938 million cubic metres per annum for groundwater sources.

3.2 Overview of the Socio-economics Context

The socio-economic conditions and well-being of the communities of the Upper Orange Catchment area was assessed, with a particular focus on socio-economic water use and cultural importance for the Upper Orange catchment areas.

The assessment was conducted at the local municipality level, the finest scale with comprehensive representative information. Maps were utilized to depict various socio-economic aspects. This profile and data serve as the baseline for assessing the social impacts of potential operational flow scenarios.

The following indicators were reviewed and based on existing data and supporting information drawn from a range of sources, including Statistics South Africa reports and databases, municipal reports, spatial coverages, the Water use Authorization and Registration Management System (WARMS) and previous studies.

- Demographic characteristics;
- Indicators of the local economy;
- Land-use and related economic activities;
- Financial, physical, social and natural resource use characteristics of households;
- Current water use; and
- Features of cultural importance.

A high-level summary of the socio-economic profile, with a focus on water use and cultural importance, is presented in **Table 3-3** below. Furthermore, refer to **Chapter 4.5** below whereby the socio-economic baseline and associated data was subsequently used in steps 5 and 6 of the Reserve Determination process "Scenario determination, evaluation and consequences" (DWS, 2017). The socio-economic profile was integrated with information from the ecological assessments and the changes associated with the scenarios to identify and descriptively evaluate the socio-economic consequences.

Table 3-3: High level summary of the socio-economic profile, Upper Orange catchment

Socio-economic indicators and link to vulnerability to changes in water security (quantity and/or quality)	Local Municipalities of greater vulnerability
Population and settlement type Areas with larger populations require greater volumes of water (of potable quality). Areas with growing populations indicate increased future water demand. High population density drives local water demand, competition for resources and pressure on water resources. Areas of significant farm settlements may require greater volumes of water for irrigation/livestock watering (of appropriate quality). Rural settlement areas are likely to be more reliant directly on surface or groundwater sources.	Higher population size and density: Mangaung, Enoch Mgijima, Sol Plaatjie, Maluti a Phofung (only a small portion of the LM falls within the study boundary). Higher % rural settlement: Senqu, also Maluti a Phofung, Emalahleni, Elundini and Sakhisizwe (only a small portion of these LMs fall within the study boundary). Higher % farm settlement: Ubuntu, Siyancuma, Tokologo, Mohokare.
Community well-being Several household/population characteristics - financial, physical, social and natural - provide a sense of the well-being of communities. These indicate the ability of households/ people to cope with and adapt to shocks (such as changes in water quantity and quality) and suggest areas of municipal infrastructure service delivery needs. Higher levels of poverty and dependence, for example, suggest lower levels of resilience and adaptive capacity. High levels of relience on natural water sources indicate greater vulnerability to impacts on surface water, groundwater and drought (rain-water tanks) and suggest areas requiring municipal infrastructure investment.	Considering several of these indicators together provides a more nuanced sense of the vulnerability of communities to changes in river flows and quality. Senqu, Enoch Mgijima, also Maluti a Phofung, Emalahleni, Elundini and Sakhisizwe (although only a small portion of these LMs fall within the study boundary).
Overview of the economy Characteristics of the local economy indicate where people are likely to be more economically vulnerable and have fewer alternative opportunities should their livelihood activities be affected by changes in water security. The size of the local economy also indicates the capacity of municipalities to support their populations in the event of shocks (such as drought). The major economic sectors and local economic development plans of the municipalities provide a sense of where local economies may be highly dependent on water or where water demand may increase, with potential knock-on effects for local livelihoods if these sectors are impacted.	Senqu, Tokologo, Enoch Mgijima, also Emalahleni, Elundini, Sakhisizwe (although only a small portion of these LMs fall within the study boundary)
Land-use and related economic activities These indicators provide a contextual understanding of the livelihood and economic activities of the study area, with a focus on water use and users (e.g., subsistence cultivation, irrigated commercial crops, primary economic sectors). Higher water users are	A relatively higher proportion of irrigated commercial crop area: Thembelihle, Siyancuma, Sol Plaatjie, Renosterberg.

Socio-economic indicators and link to vulnerability to changes in water security (quantity and/or quality)	Local Municipalities of greater vulnerability
potentially more vulnerable to changes in water supply and/or quality in terms of greater economic or livelihood impact. The dominant land cover across the LMs are grassland, shrubland and cultivation – overall only 10% of the cultivated area across all the LMs is classed as irrigated, but irrigation accounts for 78% of registered water use. Hydroelectric power generation associated with Gariep and Vanderkloof Dams – local and regional benefits	Mangaung, Kopanong and Siyancuma -relatively higher Agriculture, Forestry and Fishing GVA, while also being identified as significantly vulnerable to future climate change trends. These areas may require irrigation support in future to maintain the agricultural sector. SWSA-GW – (1) Central Pan Belt (national importance) - parts of Letsemeng (Petrusburg area – sole GW municipal supply), Kopanong and Mangaung.
Water uses and sources These indicators provide a direct understanding of the reliance on surface and groundwater sources by different users. Areas of higher (direct) reliance are relatively more vulnerable to changes in river and groundwater water supply and quality. Household reliance on these sources for drinking water is of particular concern (and addressed through the BHN requirement and Reserve).	Registered water use Higher volumes: Letsemeng (irrigation), Mangaung (municipal supply), Thembelihle (irrigation). Higher proportional reliance on SW: Mohokare, Senqu, Setsoto, Dihlabeng. Higher proportional reliance on GW: Inxuba Yethemba, Tswelopele (however, low absolute water use in the study area). Household use and BHN Higher proportion of households reliant on SW: Senqu, Siyancuma. Higher proportion of households reliant on GW: Thembelihle, Tokologo, Mantsopa. Higher BHN SW requirements: Portions of Siyancuma, Letsemeng, Senqu, Mohokare, Thembelihle, Sol Plaatjie, Mangaung. Higher BN GW requirements: Mangaung, Letsemeng, Senqu
Sites of cultural importance Cultural ecosystem services are an important element of the well-being of people and many cultural services are connected to water and aquatic ecosystems. Cultural ecosystem services/values include heritage/culture/ tradition, recreation, aesthetic enjoyment, spiritual experience, intellectual and knowledge development, and intrinsic (biodiversity, conservation) value. Areas with several sites of cultural importance or sites of particularly greater value, which are associated with water or aquatic ecosystems, are more vulnerable to changes in water flows and/or quality and aquatic ecosystems. The	Higher diversity of cultural services/values: Dihlabeng and Sesotho (Caledon River and surrounds), Walter Sisulu and Kopanong (Gariep Dam and surrounds). Protected Areas (PAs), which are associated with a range of cultural values (e.g., Biodiversity/ Conservation/Intrinsic,

Socio-economic indicators and link to vulnerability to changes in water security (quantity and/or quality)	Local Municipalities of greater vulnerability
sensitivity to change depends on the nature of the association between the cultural site/service and water.	recreation /aesthetic/ tourism, heritage and intellectual values), are spread throughout the study area. Higher numbers of PAs: Mangaung, Kopanong,Letsemeng. Larger PAs: Siyancuma, Gariep and Vanderkloof Dam areas.

4. SURFACE WATER: RIVER RESULTS

The study area consists of 129 quaternary catchments, covering an approximate area of 106 000 km^2. This includes secondary catchments D1, D2, D3 and C5. The sub-catchments, associated rivers, catchment areas and quaternary catchments are listed in **Table 4-1** for further detail

Table 4-1: The sub-catchment areas within the study area

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
D12	Upper Orange	Orange, Hendrik Smitstroom, Kromspruit, Sterkspruit, Mpongo, Mhlangeni, Bamboesspruit, Gryskopspruit, Winnaarspruit, Knoffelspruit, Wilgespruit, Beeskraalspruit, Nuwejaarspruit	370.23	D12A
			386.25	D12B
			344.05	D12C
			356.49	D12D
			714.47	D12E
			806.27	D12F
D13	Kraai	Rifle Spruit, Bokspruit, Kraai, Sterkspruit Koffiehoekspruit, Bamboeshoekspruit, Langkloofspruit, Vrouenshoekspruit, Rytjiesvlaktespruit, Joggemspruit, Vlooikraalspruit, Three Drifts, Diepspruit, Klein-Wildebeesspruit, Saalboomspruit, Vaalhoek, Noodshulpspruit, Wasbankspruit, Wolwespruit, Rooihoogte se Loop, Holspruit, Kromspruit, Telemachusspruit, Skulpspruit, Braklaagtespruit, Leeuspruit, Karringmelkspruit, Bossielaagtespruit, Oslaagte, Rondefonteinspruit, Windvoelspruit, Elandspruit, Klipspruit	475.81	D13A
			534.04	D13B
			517.99	D13C
			636.66	D13D
			1033.54	D13E
			972.74	D13F
			1128.43	D13G
			1148.62	D13H
			1171.36	D13J
			398.40	D13K
			684.01	D13L
			680.71	D13M
D14	Upper Orange	Orange, Sanddrifspruit, Melkspruit, Stormbergspruit, Wilgespruit, Wonderhoekspruit, Bamboesbergspruit, Buitendagspruit, Klein-Buffelsvleispruit, Witkopspruit, Barnardspruit, Mooiplaasspruit, Kop-en-pootjiespruit, Modderbulrspruit, Palmietspruit	767.76	D14A
			325.52	D14B
			724.94	D14C
			683.34	D14D
			666.69	D14E
			543.46	D14F
			608.08	D14G
			700.44	D14H
			517.40	D14J
			637.24	D14K
D15 (SA only)	Makhaleng	Mantikoana, Deklerkspruit, Makhaleng (mainly in Lesotho), Worsfonteinspruit	486.22	D15G
			361.89	D15H

Sub-catchment	Main River	Associated Rivers	Catchment Area (km²)	Quaternary catchments
D18 (SA only)	Upper Orange	Tele (border between Lesotho and RSA), Blikana, Pelandaba, KwaSijoa, KwaNomlengaba, Sidwadwa , Orange	937.34	D18K
			611.26	D18L
D21	Caledon	Caledon, Little Caledon, Brandwater, Swartspruit	309.77	D21A
			211.94	D21C
			251.84	D21D
			268.79	D21E
			480.46	D21F
			278.63	D21G
			381.58	D21H
D22	Caledon	Caledon, Meulspruit, Moolmanspruit, Rantsho, Mopeli, Morakabi, McCabes Spruit, Beytelspruit, Modderpoortspruit, Tenniskopspruit, Tweelingspruit	636.91	D22A
			458.07	D22B
			486.51	D22C
			629.32	D22D
			972.07	D22G
			542.41	D22H
			377.50	D22L
D23	Caledon	Appledore Spruit Caledon, Klein-Leeu, Leeu, Mokopu, Bokpoortspruit, Sandspruit, Montsoane, Klipspruit, Rietspruit, Nuwejaarspruit, Bloemspruit	609.80	D23A
			863.98	D23C
			566.97	D23D
			704.61	D23E
			352.82	D23F
			513.33	D23G
			779.42	D23H
			535.69	D23J
D24	Caledon	Boesmanskopspruit, Witspruit, Klipspruit, Elandspruit, Witspruit, Blaasbalkspruit, Wilgeboomspruit, Vaalspruit, Caledon, Vinkelspruit,Grahamstadspruit,Leeuspruit, Eldoradospruit, Skulpspruit, Groenspruit, Slykspruit,	310.97	D24A
			472.13	D24B
			399.66	D24C
			601.03	D24D
			491.22	D24E
			569.31	D24F
			628.57	D24G
			739.25	D24H
			1037.34	D24J
			881.17	D24K
			513.36	D24L
D31	Middle Orange	Hondeblaf, Diepsloot, Berg, Orange, Kattegatspruit	1167.61	D31A
			1004.52	D31B
			682.38	D31C
			1116.49	D31D
			976.80	D31E
D32	Middle Orange	Seekoei, Klein-Seekoei, Elandskloof, Soetvlei se Loop, Noupoortspruit, Elands, Gansgatspruit	721.55	D32A
			586.23	D32B
			856.58	D32C
			858.40	D32D
			1166.88	D32E
			1454.84	D32F

Sub-catchment	Main River	Associated Rivers	Catchment Area (km²)	Quaternary catchments
			1052.82	D32G
			576.52	D32H
			1122.20	D32J
			830.52	D32K
D33	Middle Orange	Orange, Lemoenspruit	597.66	D33A
			1026.63	D33B
			811.59	D33C
			950.01	D33D
			1551.71	D33E
			870.56	D33 F
			1419.61	D33 G
			1052.19	D33 H
			873.70	D33 J
			493.06	D33 K
D34	Middle Orange	Oorlogspoort, Klipfonteinspruit, Rietkuilspruit, Orange, Vanderwaltsfonteinspruit, Paaiskloofspruit, Otterspoortspruit	798.76	D34A
			710.71	D34B
			765.62	D34C
			603.24	D34D
			522.64	D34E
			696.77	D34F
			956.17	D34G
D35	Upper Orange	Orange, Oudagspruit, Broekspruit, Winnaarsbakenspruit, Broekspruit, Bossiespruit, Brakspruit, Swarthoekspruit, Suurbergspruit, Orange	255.86	D35A
			261.53	D35B
			948.27	D35C
			589.76	D35D
			313.82	D35E
			560.73	D35F
			555.08	D35G
			501.14	D35H
			1007.80	D35J
			678.37	D35K
C51	Riet	Leeuspruit, Fouriespruit, Kroonspruit, Riet, Ruigtespruit, Ospoortspruit, Holspruit, Kromellenboogspruit, Prossesspruit, Vanzylspruit	678.73	C51A
			1700.14	C51B
			627.68	C51C
			926.16	C51D
			810.82	C51E
			882.08	C51F
			1846.09	C51G
			1793.32	C51H
			1058.71	C51J
			3659.64	C51K
			2049.75	C51L
			1534.38	C51M
C52	Modder	Kromspruit, Modder, Bo-Kromspruit, Gannaspruit, Klein-Modder, Sepane, Kgabanyane, Wildebeesspruit,	940.83	C52A
			953.30	C52B
			602.88	C52C

Sub-catchment	Main River	Associated Rivers	Catchment Area (km²)	Quaternary catchments
		Steynspruit, Korannaspruit Matjiespruit, Koringspruit, Klein-Osspruit, Osspruit, Renosterspruit, Bloemspruit, Dardoringspruit, Keeromspruit, Doringspruit, Rietspruit, Stinkhoutspuit, Kaalspruit, Klein-Kaalspruit	473.51	C52D
			901.24	C52E
			691.29	C52F
			1797.99	C52G
			2386.92	C52H
			1933.89	C52K
			4362.20	C52L

The main catchment developments, water users, as well as the impacts, primarily on the water availability and quality are summarised below per sub-catchment (DWA, 2009).

The Caledon system is mostly associated with agriculture and cattle farming. A number of dams have been constructed on tributaries to provide water for irrigation purposes, as well as for domestic use for Clarens, Fouriesburg, Ficksburg, Clocolan, Ladybrand and Wepener. Welbedacht Dam is the largest dam in this sub-catchment, however, has less than 10% storage due to sedimentation. Water is transferred from the Caledon River upstream of the Welbedacht Dam to the Knellpoort Dam (off-channel as situated on a small tributary of the Caledon River) to provide domestic water for the Bloemfontein area. Water can also be transferred into the Caledon River from Muela Dam in Lesotho during droughts. The main impacts on the water quantity and quality include:

- Localised nutrient enrichment from return flows of Wastewater Treatment Works (WWTW) from the towns, which are not being maintained or working effectively;
- Return flows from the irrigation;
- Large sediment export, primarily within the Caledon River, ultimately attributed to erosion from over-grazing, intensive agricultural activities and other land use practices within South Africa and Lesotho supporting these sediment loads. This sedimentation is having a detrimental effect on the full supply capacity within the Welbedacht Dam; and
- Transfers to the Modder River.

The Upper Orange River system is relatively undeveloped with local sparse communicates. Activities include agriculture, cattle and sheep farming including some game farms. The Jozanna's Hoek Dam is located in the head waters of the Sterkspruit to supply water to the greater Hershell Area. The Gariep Dam is situated towards the lower end of this area after the confluence of the Orange and Caledon Rivers. The main impacts on the water quantity and quality include:

- Reduced flows due to Mohali and Katse Dams in Lesotho with large volumes of water being transferred to South Africa (Upper Vaal River) from these dams ;
- Nutrient enrichment, as well as microbiological issues, from return flows of WWTW mainly from the Caledon catchment;
- Localised water quality impacts from the Sterkspruit catchment;
- Return flows from the irrigation, particularly adjacent to the main stem Orange River;
- Algal blooms within the Gariep Dam, thus a response to nutrient enrichment;

- Large sediment loads, primarily within the main stem Orange River, as a results of over-grazing and land use practices within South Africa and Lesotho;
- Transfer from Gariep Dam to the Fish River system in the Eastern Cape; and
- Impacts attributed to flow variations downstream of Gariep Dam due to hydropower and other releases.

The Kraai River system is also undeveloped, in terms of major towns or industrial activities. Some irrigation occurs along the banks of the Kraai River and the major tributaries. There are no large dams in this system, although there is prospective for a dam to be constructed on the main stem Orange River, located upstream from the confluence of the Kraai and Orange River. Although the water quality of the resources within this sub-area are still in a good condition, some of the impacts identified on the water quality include:

- Nutrient enrichment from return flows of WWTW from the towns i.e Barkly East; and
- Some return flows from the irrigation, although minimal.

Similar to the Kraai River system**, the Middle Orange River system** continues to be undeveloped and sparsely populated, with no major towns or industrial activities. Vanderkloof Dam, one of the 2 largest dams in this catchment area, is located in this system and which supplies water for a number of irrigation schemes via releases into the Orange River as well as a canal system to the Riet River catchment. The dam further releases water for hydropower generation. Agriculture is the predominant land use activity in this system, mainly with water sourced from the Orange River. There is small scale alluvial diamond mining, including prospecting diamond mining, which occurs at Koffiefontein and along the banks of the Orange River from Hopetown to Douglas. The main impacts on the water quantity and quality include:

- Localised nutrient enrichment from return flows of WWTW from the towns;
- Return flows from the irrigation impacts on the water quality of the Orange River with subsequent algal blooms in the river indicative of localised nutrient enrichment; and
- Some sediment loads, primarily owing to the alluvial diamond mining and prospecting on the banks of the Orange River. Although occurring in small pockets, these activities are evidently having an impact;
- Changed flow patterns due to transfers and movement of water for downstream irrigation; and
- Impacts owing to flow fluctuations downstream of VanderKloof Dam due to hydropower releases.

The Modder-Riet system is well developed with the main activity being industrial, agriculture and cattle farming. Bloemfontein and surrounding areas are situated in the upper reaches of tributaries of the Modder River. A number of large dams have been constructed in the Modder and Riet Rivers for water supply to the various towns and irrigation. The main impacts on the water quality include:

- Major nutrient enrichment from return flows of WWTW from the towns;
- Irrigation and return flows which continue to highly impact the lower reaches of the Riet; and
- Transfers from the Caledon catchment, through the off-channel Knellpoort Dam, supplying water to Bloemfontein. Furthermore, transfers from Vanderkloof Dam to the

Riet via a canal system and from Marksdrift weir on the Orange River just before the confluence with the Vaal River, to the lower Modder-Riet.

4.1 River surveys

This study involved two river surveys, one conducted during the dry season from 4 – 15 July 2022, and the other post-wet season from 29 May to 4 June 2023. The initial survey covered all the Reserve level assessments (Intermediate, Rapid 3, and field verification) for all prioritised RUs in the Upper Orange catchment. In contrast, the second survey focused solely on re-surveying the Intermediate sites. The EWR sites surveyed are listed in **Table 2-1** and **Figure 2-1** above. All collected data underwent the ecological categorisation (Eco-categorisation) process, as per Kleynhans and Louw's (2007) methodology.

4.2 Eco-categorisation Results for the River EWR Sites

This eco-categorisation process for rivers aimed to assess and categorise the PES and the REC based on the biophysical attributes of the river ecosystem and its integrity relative to the natural reference condition. The Eco-categorisation process played a crucial role in the Ecological Reserve determination methods. Its primary objective was to identify the reasons and sources of deviations in derived PES across various models concerning the reference condition of the river's biophysical attributes. Ultimately, the results provided valuable insights to establish future ecological objectives that are both, desirable and attainable, for the rivers as outlined by Kleynhans and Louw (2007). The ecological categories used for the river PES assessment are illustrated in **Table 4-2**.

Table 4-2: Ecological categories used for river PES assessment

Ecological Category	Ecological condition	Guideline scores
A	Unmodified/natural	>92 - 100
A/B	Close to natural condition most of the time	>88 - <= 92
B	Largely natural	>82 - <=88
B/C	Close to largely natural	>78 - <=82
C	Moderately modified	>62 - <=78
C/D	Close to moderately modified condition	>58 - <=62
D	Largely modified	>42 - <=58
D/E	Close to largely modified condition	>38 - <=42
E	Seriously modified	20 - <=38
E/F	Seriously to critically modified	>18 - <=20

Ecological Category	Ecological condition	Guideline scores
F	Critically / Extremely modified	<20

The results for the Intermediate and Rapid 3 EWR sites are summarised in **Table 4-3** and the field verification sites in **Table 4-4** below.

Table 4-3: Summary of the eco-categorisation results for the Intermediate and Rapid 3 EWR sites within the Upper Orange catchment area

INTERMEDIATE EWR SITES

UO_EWR01_I: Middle Caledon

River	**Middle Caledon**
EWR Site Code	**UO_EWR01_I**
Driver component	**PES**
HAI	C
Diatoms	D
GAI	D
Response component	**PES**
FRAI	D
MIRAI	C
VEGRAI	E
Ecostatus	D/E
EI	Moderate
ES	Moderate
REC	D

Reasons for EcoStatus

- Extensive alien invasive plants within the riparian zone;
- Poor habitat availability for both fish and aquatic macroinvertebrates;
- Degraded site with elevated sediment yields from the degrading catchment;
- Alluvial bed with sediment and high mobility;
- Trampling along the banks and alien vegetation changing the bank stability and shape; and
- Diatoms used to infer the present physical-chemical state of the system, indicating that the quality is largely driven by pollution from untreated effluent discharges upstream in Ficksburg and surrounding areas.

Present EI-ES*

- Both remained Moderate.

REC**

- The system has perennial flows – limited to no zero flows as per the HAI.

**EI-ES: Revised Ecological Importance and Ecological Senstivity using the DWS (2014) results*
****** *REC: Recommended Ecological Category based on the EcoStatus results, further using the results from the water quality (diatoms), hydrology (HAI) and geomorphology (GAI)*

UO_EWR02_I: Sterkspruit

River	Sterkspruit
EWR Site Code	UO_EWR02_I
Driver component	PES
HAI	C
Diatoms	C
GAI	D
Response component	PES
FRAI	D/E
MIRAI	D
VEGRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	C/D

Reasons for EcoStatus

- Widespread overgrazing and soil erosion in the catchment elevating fine sediment loads;
- Localised weirs along mainstem trapping coarser sediment;
- Sand mining upstream of the site;
- Trampling, overgrazing and localised alien trees along bars, banks and floodplain;
- Diatoms used to infer the present physical-chemical state of the system, indicating periodic nutrient and salinity increases at the site leading to eutrophication;
- Adjacent to the EWR site, an evaporation sewage pond directly discharging into the system; and
- Sterkspuit WWTW (although located downstream of the EWR site, but along the same sub-quaternary reach) is currently discharging untreated wastewater into the Sterkspruit River, largely impairing the Physical-chemical state of this reach and further downstream.

Present EI-ES

- ES reduced from High to Moderate due to reduced sensitive aquatic macroinvertebrate taxa and riparian-wetland vegetation intolerance to water level changes.

REC

Maintenance and upgrade of WWTW infrastructure, including the upgrade and functioning of the adjacent maturation pond.

UO_EWR03_I: Upper Orange

River	Upper Orange
EWR Site Code	**UO_EWR03_I**
Driver component	**PES**
HAI	D
Diatoms	C
GAI	C
Response component	**PES**
FRAI	D
MIRAI	C/D
VEGRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	D

Reasons for EcoStatus

- Poor habitat availability for both fish and aquatic macroinvertebrates;
- Widespread overgrazing and soil erosion in the catchment (largely within Lesotho and communal land) elevating fine sediment loads;
- Hydrological modification due to upstream impoundments within Lesotho;
- Extensive alien invasive plants within the riparian zone; and
- Diatoms used to infer the present physical-chemical state of the system, indicating heavy organic pollution. Elevated nutrient concentrations are expected to be prevalent at the site because of the Sterkspruit discharging untreated sewage upstream. Other contaminants and toxins are also expected to be present at the site given the untreated effluent discharged upstream.

Present EI-ES

- EI reduced from High to Moderate due to riparian-wetland zone habitat integrity class and instream habitat integrity class; and
- ES reduced from High to Moderate due to reduced aquatic macroinvertebrate sensitivity and riparian-wetland vegetation intolerance to water level changes.

REC

Manage and maintain the EcoStatus.

UO_EWR04_I: Lower Caledon

River	Lower Caledon
EWR Site Code	**UO_EWR04_I**
Driver component	**PES**
HAI	C
Diatoms	D
GAI	C
Response component	**PES**
FRAI	D
MIRAI	D
VEGRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	C/D

Reasons for EcoStatus

- Widespread overgrazing and soil erosion in the catchment (largely within Lesotho and communal land) elevating fine sediment loads;
- Presence of migratory barriers downstream (Gariep Dam, Van Der Kloof Dam) and upstream (Welbedacht Dam);
- Hydrological modification due to presence of Weldedacht Dam catchment activities;
- Alien invasive plants within the riparian zone, bare banks; and
- Diatoms used to infer the present physical-chemical state of the system, indicating heavy organic pollution likely from elevated nutrient concentrations. High sodium chloride salinity and especially irrigation return flows.

Present EI-ES

- EI reduced from High to Moderate due to riparian-wetland zone habitat integrity class and instream habitat integrity class; and
- ES reduced from High to Moderate due to reduced fish physical-chemical sensitivity and riparian-wetland vegetation intolerance to water level changes.

REC

- Water use and transfers to be better managed;
- Water quality can be improved (effluent from upstream centres, upstream catchment management practices, implementation of buffer zones);
- Sediment management (overall catchment management – with a focus on Lesotho); and

Management of alien invasive plant species within the riparian zone.

UO_EWR05_I: Seekoei

River	Seekoei
EWR Site Code	**UO_EWR05_I**
Driver component	**PES**
HAI	B/C
Diatoms	C
GAI	C
Response component	**PES**
FRAI	C
MIRAI	C
VEGRAI	B/C
Ecostatus	C
EI	Moderate
ES	Moderate
REC	C

Reasons for EcoStatus

- Longitudinal fragmentation due to high number of weirs along the system;
- Habitat dominated by bedrock (natural but not preferably for aquatic macroinvertebrates);
- Flow modification due to abstraction from weirs;
- Abundance of non-native (alien) fish species;
- Widespread and intensive grazing and soil erosion elevate fine sediment loads;
- Grazing along banks, but low erosion evident as bank gradient is low, very rocky and well vegetated; and
- Diatoms indicate, elevated electrolyte concentrations.

Present EI-ES

- Both remained Moderate.

REC

Water quality improvements through controlled irrigation and return flows.

UO_EWR06_I: Upper Riet

River	Upper Riet
EWR Site Code	**UO_EWR06_I**
Driver component	**PES**
HAI	C
Diatoms	D
GAI	C
Response component	**PES**
FRAI	C
MIRAI	C
VEGRAI	C
Ecostatus	C
EI	High
ES	Moderate
REC	C

Reasons for EcoStatus

- Widespread grazing and soil erosion elevate fine sediment loads;
- Dams and weirs along tributaries and mainstem trap coarser bed sediment;
- Grazing along banks and some localised erosion evident along banks, but generally well vegetated;
- Presence of non-native fish species; and

- Diatoms indicate heavily polluted waters (organic pollution) with elevated conductivities.

Present EI-ES

- Both remained High, Moderate.

REC

Water quality improvements through controlled irrigation and return flows.

UO_EWR07_I: Upper Modder

River	Upper Modder
EWR Site Code	UO_EWR07_I
Driver component	**PES**
HAI	C/D
Diatoms	D
GAI	D
Response component	**PES**
FRAI	C
MIRAI	D
VEGRAI	D
Ecostatus	D
EI	Low
ES	Moderate
REC	C

Reasons for EcoStatus

- Extensive alien invasive plants within the riparian zone;
- Widespread overgrazing and soil erosion elevate fine sediment loads;
- Dams and weirs along tributaries and mainstem trap coarser bed sediment;
- Overgrazing and trampling along banks with widespread erosion evident along banks;
- Presence of non-native fish species;
- Migration barriers (weirs and dams up- and downstream); and
- Diatoms used to infer the present physical-chemical state of the system, indicating strong organic and inorganic pollution, arising from urban runoff and poorly treated wastewater from the Botshabelo and Thaba Nchu townships upstream.

Present EI-ES

- EI reduced from moderate to low due to instream migration link class and habitat diversity class.

REC

- As water quality is the primary driver of this system from a biotic perspective, if this can be improved through various land and catchment management practices (i.e., WWTW), this will provide an opportunity to improve the biotic state of the system, coupled with adequate flows; and
- Land and catchment management (grazing, trampling, erosion and alien invasive vegetation).

UO_EWR08_I: Lower Kraai

River	**Lower Kraai**
EWR Site Code	**UO_EWR08_I**
Driver component	**PES**
HAI	B
Diatoms	C
GAI	C
Response component	**PES**
FRAI	C
MIRAI	C
VEGRAI	D/E
Ecostatus	C
EI	High
ES	High
REC	B/C

Reasons for EcoStatus

- Extensive alien invasive plants within the riparian zone, bare banks;
- Widespread grazing and some soil erosion elevate fine sediment loads;
- Low water bridges and weirs along main stem trapping course sediments;
- Localised erosion along left bank due to the weir upstream of the EWR site. Grazing along banks and bars. New inset benches forming along right bank;
- Presence of non-native fish species;
- Migration barrier (upstream weir); and
- Diatoms used to infer the present physical-chemical state of the system, indicating elevated electrolyte concentrations and pollutants.

Present EI-ES

- Both remained High.

REC

- Water quality improvements through land use activities (irrigation, abstraction, return flows) within upstream and adjacent catchment should be managed to prevent degradation of the ecological health of the system and deterioration of the water quality (buffer zones to be implemented); and
- Alien invasive vegetation to be managed.

UO_EWR09_I: Lower Riet

No image available

River	**Lower Riet**
EWR Site Code	**UO_EWR09_I**
Driver component	**PES**
HAI	C
Diatoms	C
GAI	C
Response component	**PES**
FRAI	C
MIRAI	C
VEGRAI	B
Ecostatus	C
EI	Very high
ES	High
REC	B/C

Reasons for EcoStatus

- Vegetation removal;
- Water quantity (abstraction for irrigation and small impoundments upstream of the site);
- There is degradation in the catchment due to grazing, changes in hillslope-channel connectivity and cropping elevating fine sediment loadings;
- The dams and weirs along the Modder and Riet Rivers trap bedload sediment, reducing coarser habitats at the reach;
- Disturbance along the banks and margins are localised; and
- Diatoms used to infer the present physical-chemical state of the system, indicating high electrolyte content, which is congruent with the historical data at the site. The high electrical conductivities at the site are a result of irrigation return flows from the Riet River Irrigation Scheme.

Present EI-ES

- Both remained Very High, High.

REC

- The site is located within Mokale National Park and thus requiring attention to the conservation / environmental needs. It is further a recreational fishing area (Largemouth Yellowfish).

UO_EWR10_I: Lower Orange

River	Lower Orange
EWR Site Code	**UO_EWR010_I**
Driver component	**PES**
HAI	C/D
Diatoms	D
GAI	C/D
Response component	**PES**
FRAI	B/C
MIRAI	D
VEGRAI	C
Ecostatus	C
EI	Moderate
ES	Moderate
REC	C

Reasons for EcoStatus

- Flow modification from upstream hydropower and other water use releases from Vanderkloof Dam;
- Non-native fish species;
- Migratory barriers (Marksdrift Weir);
- Habitat modification for biota as the marginal vegetation has completely been removed due to all the floods and hydropeaking (scouring and sediment deposition); and
- Diatoms used to infer the present physical-chemical state of the system, indicating very electrolyte-rich to brackish water, as a result of the irrigation return flows in the system. The return flows appear to be the major physical-chemical driving factor.

Present EI-ES

- EI reduced from High to Moderate mostly due to instream migration link class.

REC

- Gariep and Vanderkloof Dams fulfil a critical role in providing water/power generation to the country; and
- Thus in this climate, flow and dam operation cannot be avoided or altered for the time being.

RAPID 3 EWR SITES

UO_EWR01_R: Little Caledon

River	Little Caledon
EWR Site Code	**UO_EWR01_R**
Driver component	**PES**
Diatoms	C
IHI (instream)	B
IHI (riparian)	B
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	C
EI	High
ES	High
REC	B/C

Reasons for EcoStatus

- Higher than usual baseflows during surveys due to high rainfall in late summer/ autumn;
- Non-native fish species;
- Vegetation removal (trampling, wood harvesting);
- Alien invasive plants within the riparian zone;
- Cattle trampling and grazing contributing to bank erosion; and
- Diatoms used to infer the present physical-chemical state of the system, indicating organic pollution.

Present EI-ES

- ES changed from High to Moderate due to Fish no-flow sensitivity, reduced macroinvertebrate sensitivity and stream size sensitivity to modified flow/water level changes. Both remained High.

REC

Should water quality within this system improves, this REC will be achievable.

UO_EWR02_R: Brandwater

River	**Brandwater**
EWR Site Code	**UO_EWR02_R**
Driver component	**PES**
Diatoms	C
IHI (instream)	C
IHI (riparian)	B/C
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	C
EI	High
ES	Moderate
REC	B/C

Reasons for EcoStatus

- Higher than usual baseflows during surveys due to high rainfall in late summer/ autumn;
- Poor habitat availability for both fish and macroinvertebrates due to sediment loads, loss of cover features;
- Cattle trampling and grazing contributing to extensive bank erosion;
- High algae growth smothering stone biotope; and
- Diatoms used to infer the present physical-chemical state of the system, indicating nutrient enrichment due to agricultural return flows.

Present EI-ES

- ES changed from High to Moderate due to Fish no-flow sensitivity, reduced macroinvertebrate sensitivity and stream size sensitivity to modified flow/water level changes.

REC

Should water quality within this system improves, this REC will be achievable.

UO_EWR03_R: Mopeli

River	**Mopeli**
EWR Site Code	**UO_EWR03_R**
Driver component	**PES**
Diatoms	C
IHI (instream)	C
IHI (riparian)	C
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	C/D

Reasons for EcoStatus

- Higher than usual baseflows during surveys due to high rainfall in late summer/ autumn;
- Alien vegetation;

- Poor habitat availability for both fish and macroinvertebrates due to the system being dominated by bedrock, sediment loads, loss of cover features;
- Channel modification owing to upstream log jam by bridge impeding on hydraulics and scouring of the river downstream;
- High silt loads;
- Cattle trampling and grazing contributing to bank erosion; and
- Diatoms used to infer the present physical-chemical state of the system, indicating industrial organic pollution and high siltation.

Present EI-ES

- Both remain Moderate.

REC

Should water quality within this system improves, this REC will be achievable.

UO_EWR04_R: Upper Kraai

River	Upper Kraai
EWR Site Code	**UO_EWR04_R**
Driver component	**PES**
Diatoms	B
IHI (instream)	A/B
IHI (riparian)	A/B
Response component	**PES**
FRAI	D
MIRAI	C
Ecostatus	C
EI	High
ES	High
REC	B

Reasons for EcoStatus

- Good diversity of habitats for fish and aquatic macroinvertebrates
- Presence of alien fish species;
- Agricultural return flow resulting in some sediment and nutrient input;
- Floodplain/terrace cultivation;
- High abundance of Simuliidae (Blackfly larvae) smothering stones biotope; and
- Diatoms used to infer the present physical-chemical state of the system, indicating moderate to good quality waters.

Present EI-ES

- EI improved from Moderate to High due to instream habitat integrity, riparian wetland zone habitat integrity class and habitat diversity class.

REC

Owing to no upstream dams, WWTW and only localised impacts, mainly irrigation abstractions, this REC will be achievable.

UO_EWR05_R: Wonderboomspruit

River	Wonderboomspruit
EWR Site Code	UO_EWR05_R
Driver component	PES
Diatoms	E
IHI (instream)	C
IHI (riparian)	C/D
Response component	PES
FRAI	D
MIRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	C/D

Reasons for EcoStatus

- Channel and bed modification owing to cattle trampling, bridges, weirs;
- Vegetation removal owing to cattle trampling and grazing, wood harvesting and developments within the buffer zone; and
- Diatoms used to infer the present physical-chemical state of the system, indicating critically impaired water quality. High conductivity, agriculture, and organic pollution (sewage – site is located downstream of Burgersfort and unmaintained WWTW).

Present EI-ES

- Both remained Moderate.

REC

Should water quality within this system improves, this REC will be achievable.

UO_EWR06_R: Middle Modder

River	Middle Modder
EWR Site Code	UO_EWR06_R
Driver component	PES
Diatoms	D
IHI (instream)	D
IHI (riparian)	D
Response component	PES
FRAI	D
MIRAI	D
Ecostatus	D
EI	Moderate
ES	Moderate
REC	C/D

Reasons for EcoStatus

- Water abstraction and extensive irrigation in the upstream catchment;
- Flow modification owing to return flows from numerous WWTW, Rustfontein Dam in the upper catchment;
- Extensive alien invasive riparian vegetation;
- Vegetation removal from cattle grazing and trampling and various centre pivots adjacent to the river reach;

- Non-native fish species; and
- Diatoms used to infer the present physical-chemical state of the system, indicating heavy pollution; an indicator of industrial organic pollution.

Present EI-ES

- EI changed from High to Moderate due to riparian wetland zone habitat integrity class and instream habitat integrity class; and
- ES changed from High to Moderate due to reduced fish and macroinvertebrate sensitivities, stream size sensitivity to modified flow/water level changes.

REC

Should water quality within this system improves, this REC will be achievable.

Table 4-4: Summary of the eco-categorisation results for the field verification sites within the Upper Orange catchment area

EWR site code	River	Quat	EcoStatus (2023)	REC
UO_EWR01_FV	Meulspruit	D22B	D	D
UO_EWR02_FV	Witspruit	D24C	C/D	C
UO_EWR03_FV	Gryskopspruit	D12D	C	C
UO_EWR04_FV	Karringmelkspruit	D13K	B	B
UO_EWR05_FV	Bokspruit	D13A	B/C	B
UO_EWR06_FV	Holspruit	D13J	C	C
UO_EWR07_FV	Sterkspruit (trib of Bell/Kraai)	D13C	C	B/C
UO_EWR08_FV	Bell	D13B	B/C	B
UO_EWR09_FV	Groenspruit	D24H	C/D	C
UO_EWR10_FV	Skulpspruit	D24H	C	C
UO_EWR11_FV	Fouriespruit	C51A	C	C
UO_EWR12_FV	Renoster	C52F	D/E	D
UO_EWR13_FV	Os-spruit	C52E	B/C	B/C
UO_EWR14_FV	Hondeblaf	C31C	B	B
UO_EWR15_FV	Trib van Zyl	C51G	C	C
UO_EWR16_FV	Slykspruit	D24L	B/C	B/C
UO_EWR17_FV	Langkloofspruit	D13D	B/C	B
UO_EWR18_FV	Wasbankspruit	D13G	C	B/C
UO_EWR19_FV	Lower Modder	C52K	C/D	C
UO_EWR20_FV	Upper Kromellenboog	C51G	B	B
UO_EWR21_FV	Lower Kromellenboog	C51H	C	B/C
UO_EWR22_FV	Tele	D18K	C	C
UO_EWR23_FV	Orange	D12A	C/D	C
UP_EWR24_FV	Maghaleng	D15H	C/D	C/D
UO_EWR25_FV	Middle Caledon	D23A	D	C/D

Refer to **Figure 4-1** to **Figure 4-4** which visually illustrates the PES and REC trends for the Intermediate and Rapid 3 EWR sites in the study area.

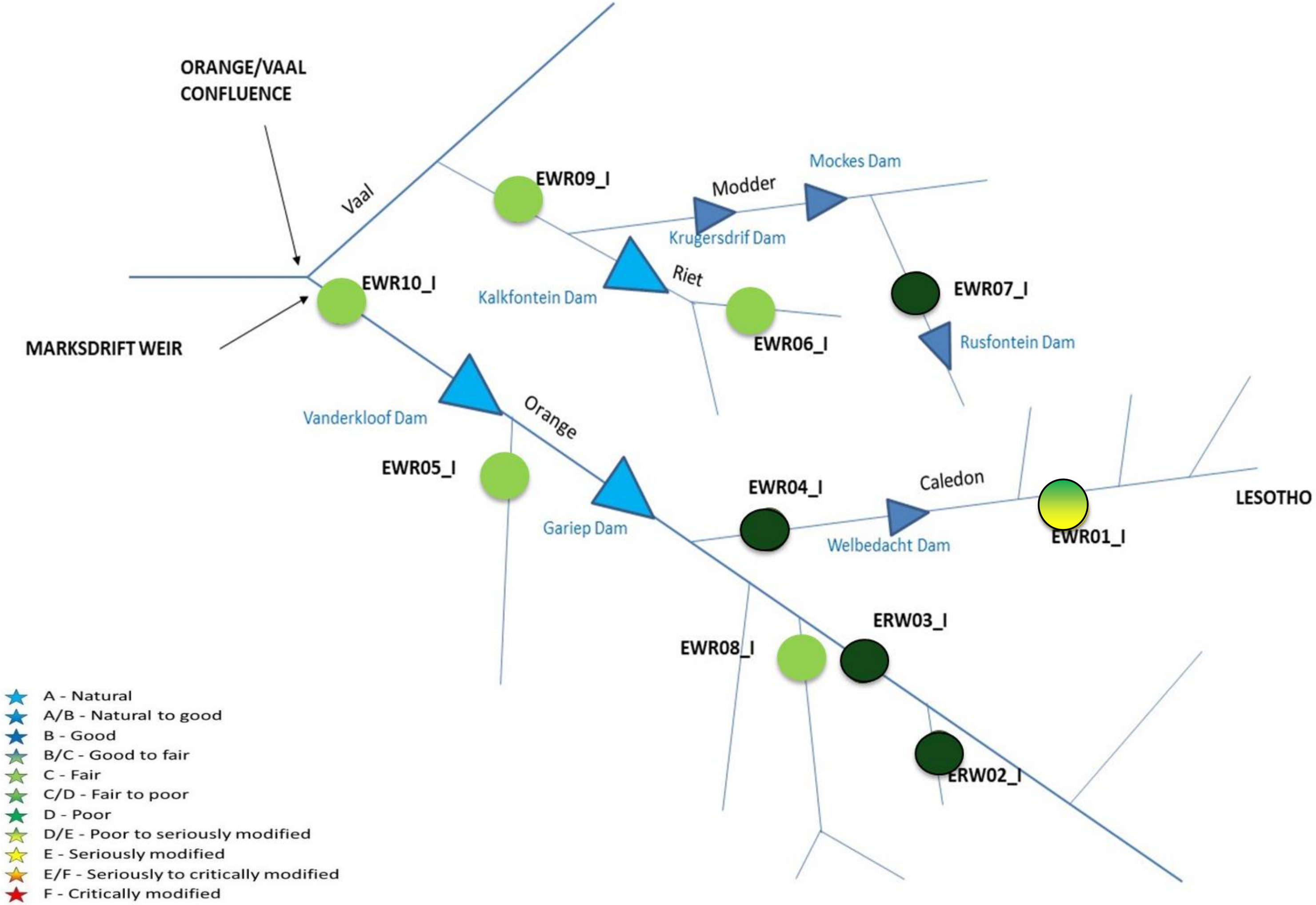


Figure 4-1: Visual illustraton of the PES for all Intermediate EWR sites

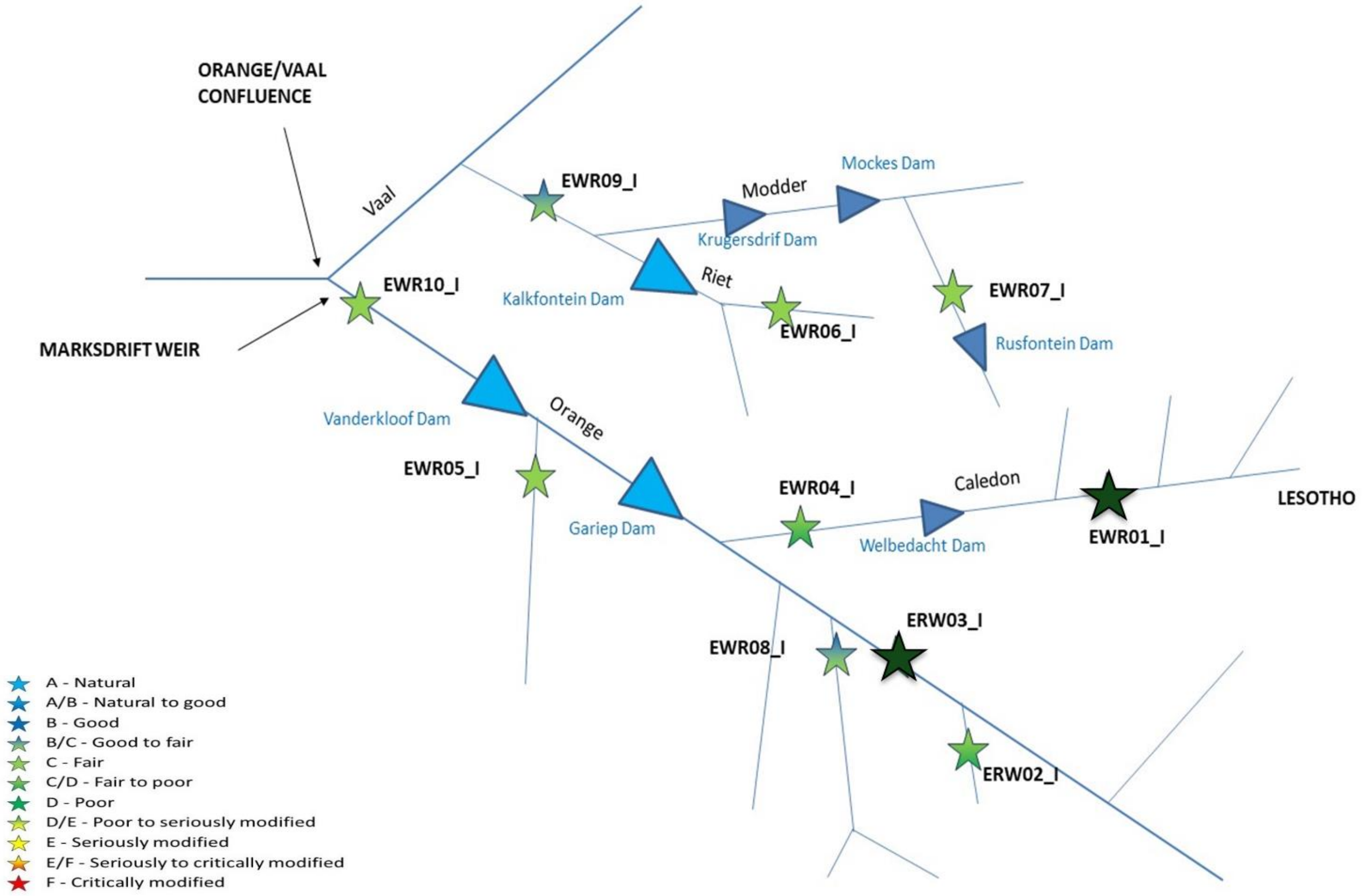


Figure 4-2: Visual illustraton of the REC for all Intermediate EWR sites

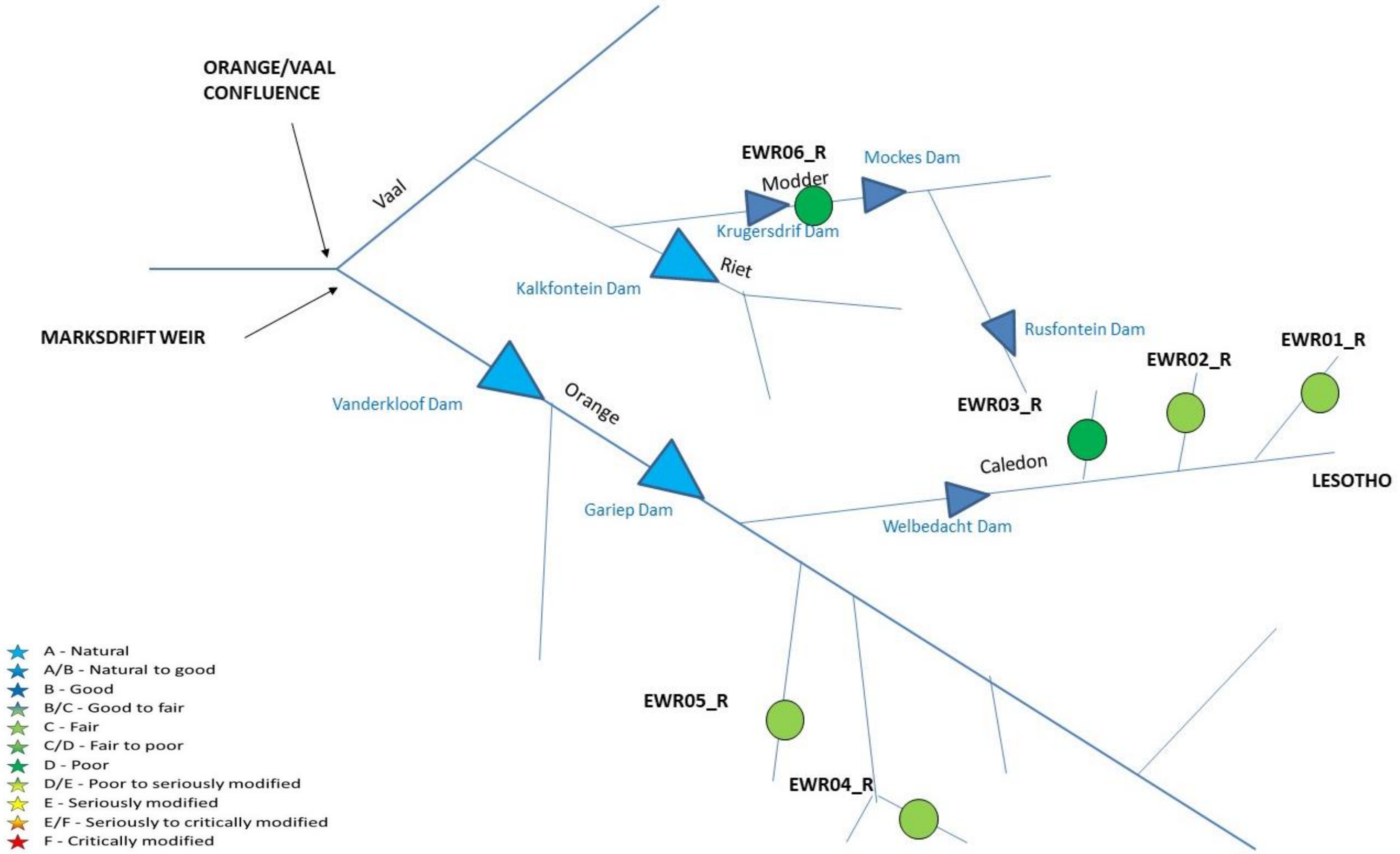


Figure 4-3: Summary of the PES trend for all Rapid 3 EWR sites

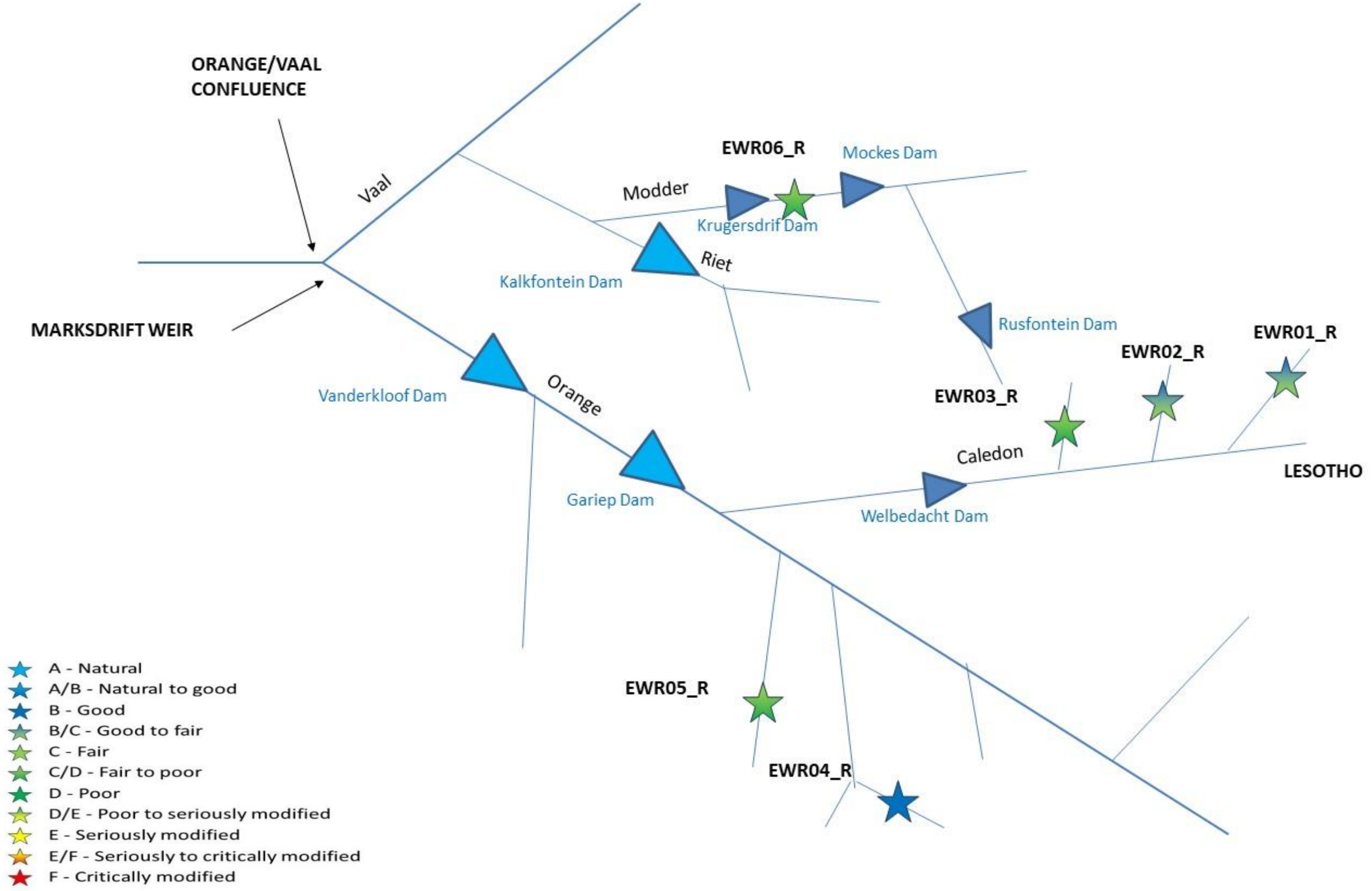


Figure 4-4: Summary of the proposed REC for all Rapid 3 EWR sites

Overall, the EcoStatus of the Upper Orange catchment area is primarily moderate to largely modified (Category C and D respectively). It is evident that deteriorated water quality is the driving factor in the streams and rivers in the Upper Orange catchment area. This is a systemic issue across the catchment illustrated by diatom results that mostly indicate moderate to seriously modified physical-chemical conditions. The causes and sources of this problem are primarily related to nutrient overload, originating from the various WWTWs associated with the towns in the catchment. Most of these are either unmaintained, dysfunctional or have either reached their capacity, if not already over-capacitated (particularly the Modder-Riet catchment area) and/or sediment deposits (particularly the Caledon and upper Orange River systems). Should water quality within the catchment be improved, the REC can be achieved. Management of the water quality status must be regarded as an urgent issue to implement. These are disastrous conditions for the environment and human needs, from a health perspective, with an overall effect on ecosystem services. If not addressed effectively, the current conditions will continue and worsen. This will result in the non-attainment of the desired state or REC for the EWR sites.

Furthermore, another significant factor is water quantity, with extensive agricultural activities necessitating water abstraction for irrigation purposes throughout. Furthermore, flow modification, particularly noticeable at the Lower Orange River, can be attributed to the presence of the two major dams, Gariep and Vanderkloof Dams, which play a crucial role in fulfilling water and power supply requirements for South Africa. Should the proposed recommendations be investigated and applied, the suggested REC can and will be achieved. See Chapter 4.1.1. for further detail.

4.3 Ecological Water Requirements Quantification

Hydraulic information was obtained during the above-mentioned river surveys, which included the selection and surveying of an appropriate cross section and longitudinal water slope and to measure the discharge. This data was used to develop the depth/discharge relationships for each EWR site. In addition, the hydraulics was further modelled using the HABitat FLOw (HABFLO) program to predict statistical distributions of hydraulic habitats for fish and macroinvertebrates. Natural and present-day hydrology was obtained from a number of sources, including the data in the water resources yield model (WRYM) and water resources planning model (WRPM) for the Integrated Vaal-Orange Water Supply System. The flow time series obtained from these studies were used and adjusted by catchment area to obtain the flows at the EWR sites.

The final EWR quantification results for all Intermediate and Rapid 3 EWR and field verification sites for the REC (presented in **Table 4-3** above) are provided in **Table 4-5** below. These EWR results were used in steps 4 and 5 of the integrated steps for the determination of the Reserve (DWS, 2017) whereby operational scenarios were developed and the ecological consequences evaluated of these scenarios to finalise the EWRs. Refer to **Chapter 4.5** for these results.

Table 4-5: Summary of the EWR quantification results for the study

EWR site	River	Quaternary	REC	Total EWR as %nMAR for REC	nMAR ($10^6 m^3$)
INTERMEDIATE					
UO_EWR01_I	Middle Caledon	D22D	D	23.2	674.0
UO_EWR02_I	Sterkspruit	D12B	C/D	38.4	30.7
UO_EWR03_I	Upper Orange	D12F	D	25.1	4 259.5
UO_EWR04_I	Lower Caledon	D24G	C/D	29.4	1 353.6
UO_EWR05_I	Seekoei	D32J	C	34.2	24.3
UO_EWR06_I	Upper Riet	C51F	C	31.1	105.2
UO_EWR07_I	Upper Modder	C52B	C	35.9	61.0
UO_EWR08_I	Lower Kraai	D13M	B/C	46.5	719.0
UO_EWR09_I	Lower Riet	C51L	B/C*	24.1	373.8
UO_EWR10_I	Lower Orange	D33K	C	21.4	6 674.2
RAPID 3					
UO_EWR01_R	Little Caledon	D21D	B/C	39.2	25.9
UO_EWR02_R	Brandwater/ Groot	D21G	B/C	30.9	56.0
UO_EWR03_R	Mopeli	D22G	C/D	29.3	49.4
UO_EWR04_R	Upper Kraai	D13E	B	40.0	200.9
UO_EWR05_R	Wonderboomspruit	D14E	C/D	32.4	25.9
UO_EWR06_R	Middle Modder	C52G	C/D	33.9	113.7
FIELD VERIFICATION					
UO_EWR01_FV	Meulspruit	D22B	D	12.5	63.6
UO_EWR02_FV	Witspruit	D24C	C	19.2	21.7
UO_EWR03_FV	Gryskopspruit	D12D	C	18.4	7.5
UO_EWR04_FV	Karringmelkspruit	D13K	B	45.1	25.9
UO_EWR05_FV	Bokspruit	D13A	B	44.0	60.4
UO_EWR06_FV	Holspruit	D13J	C	18.1	36.9
UO_EWR07_FV	Sterkspruit, tributary of Kraai	D13C	B/C	37.2	47.6
UO_EWR08_FV	Bell	D13B	B	45.1	72.5
UO_EWR09_FV	Groenspruit	D24H	C	18.0	5.02
UO_EWR10_FV	Skulpspruit	D24H	C	18.0	7.8
UO_EWR11_FV	Fouriespruit	C51A	C	17.9	13.8
UO_EWR12_FV	Renoster	C52F	D	11.2	7.9
UO_EWR13_FV	Os-spruit	C52E	B/C	21.8	8.6
UO_EWR14_FV	Hondeblaf	D31C	B	26.7	2.0
UO_EWR15_FV	Tributary of VanZylspruit	C51G	C	17.9	1.9
UO_EWR16_FV	Slykspruit	D24L	B/C	23.0	5.1
UO_EWR17_FV	Langkloofspruit	D13D	B	44.5	43.8
UO_EWR18_FV	Wasbankspruit	D13G	B/C	38.8	16.5

EWR site	River	Quaternary	REC	Total EWR as %nMAR for REC	nMAR ($10^6 m^3$)
UO_EWR19_FV	Lower Modder	C52K	C	17.8	156.8
UO_EWR20_FV	Upper Kromellenboog	C51G	B	26.8	9.3
UO_EWR21_FV	Lower Kromellenboog	C51H	B/C	26.5	85.1
UO_EWR22_FV	Tele	D18K	C	21.5	142.3
UO_EWR23_FV	Upper Orange	D12A	C	36.2	4 115.1
UO_EWR24_FV	Makhaleng	D15G	C/D	17.4	524.5

**The flows as per the Vaal comprehensive study were specified for a D category, they were checked and identified to be adequate to maintain the PES of a C.*

4.4 Operational Scenarios

The Upper Orange Reserve determination process involved an iterative configuration and evaluation of scenarios, considering ecological protection categories, conservation goals, and anticipated future usage and development. The main objective was to assess the consequences of not meeting the quantified EWR requirements using the flow time series as modelled with the WRYM. Operational scenarios accounted for potential scenarios from the Reconciliation Strategy and other studies, including water transfers between catchments and estuarine requirements. The project team evaluated these scenarios for ecological (including water quality) and socio-economic consequences, forming the basis for finalising the Reserve in Step 7.

Seven (7) proposed scenarios were identified and provided in **Table 4-6**, to which the consequences were evaluated.

Table 4-6: Summary of the proposed management scenarios for the study

Number	Code	Description
Sc1	PRS1	Present day without EWR
Sc2	PRS2	Present day with EWR for REC
Sc3	FUT1	2040 Polihali, Makhaleng (pipeline to Botswana), Pipeline from Gariep to Bloemfontein, Caledon weirs without EWR
Sc4	FUT2	2040 Polihali, Makhaleng (pipeline to Botswana), Pipeline from Gariep to Bloemfontein, Caledon weirs with EWR=REC, estuarine requirements
Sc5	FUT3	2060 Polihali, Makhaleng, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on Upper Orange, Vioolsdrift on Lower Orange, without EWR
Sc6	FUT4	2060 Polihali, Makhaleng, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on Upper Orange, Vioolsdrift on Lower Orange, with EWR=REC, estuarine
Sc7	WQ	Present day with EWR for REC (Sc2) but with progressive water quality decline

4.5 Ecological and Socio-economic Consequences

When evaluating the ecological and socio-economic consequences, focus was placed on the effects of chosen flow scenarios. The process anticipated drivers and responses in each scenario, providing insights that guided the determination of ecological categories. These insights will play a key role in determining the water resources classes within a specific Integrated Use Area (IUA) during the Classification phase of the study.

Refer to **Table 4-7** for a summary of which operational flow scenarios can be taken forward following the evaluation of the ecological consequences to finalise the EWRs that can be met.

Table 4-7: Summary of the EWR sites and operational scenarios (S1 – S6 are related to flow, while Sc7, is related to water quality)

Site	River	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
UO_EWR01_I	Middle Caledon	√	√	√	√	√	√	X
UO_EWR02_I	Sterkspruit	X	X					X
UO_EWR03_I	Upper Orange	√	√	X	X	X	X	X
UO_EWR04_I	Lower Caledon	√	√	√	√	√	√	X
UO_EWR05_I	Seekoei	√	√					X
UO_EWR06_I	Upper Riet	√	√	X	√			X
UO_EWR07_I	Upper Modder	√	√					X
UO_EWR08_I	Lower Kraai	√	√					√
UO_EWR09_I	Lower Riet	√	√	√	X			X
UO_EWR10_I	Lower Orange	√	√	√	√	√	√	X

Scenario 1 to Scenario 6 (flow scenarios)

All EWR sites could meet all scenarios, except for UO_EWR02_I (Sterkspruit), UO_EWR03_I (Upper Orange), UO_EWR06_I (Upper Riet) and UO_EWR09_I (Lower Riet), which will not meet all scenarios, due to reasons below:

- UO_EWR02_I (Sterkspruit) will not meet either Sc1 or Sc2. This is primarily owing to deterioration in the fish PES owing to inadequate flow and compromised water quality. The flows for both scenarios show that there are not adequate floods or baseflows due to the Jozannashoek Dam located upstream. In addition, water quality is highly compromised, having a negative effect on the biota. Thus, if the water quality is not going to be improved, this REC will not be achieved;

- UO_EWR03_I (Upper Orange) will not meet Sc3 – Sc6 primarily due to the EWR not being met during the dry months. Scenario 3 and Sc4, will not receive adequate baseflows due to Polihali Dam and the proposed Verbeeldingskraal Dam (Sc5 and Sc6), which is relatively close to this EWR site, will have a large impact on the sediment regime, trapping most of the suspended sediment and all the sand and gravel bed sediment. Therefore, deterioration in both the riparian vegetation and geomorphology is evident in these scenarios, ultimately having repercussions on the biotic response.

- UO_EWR06_I (Upper Riet) will not meet Sc3 only. This is primarily owing to the biotic component illustrating deterioration owing to deficits in the system and the flows not meeting the preferences of the selected indicator fish species or macroinvertebrate taxon; and

- UO_EWR09_I (Lower Riet) will not meet Sc4 only, also primarily owing to the macroinvertebrate component, illustrating deterioration, due to deficits in the system and the flows not meeting the preferences of the selected indicator macroinvertebrate taxon.

Scenario 7 (water quality)
With regards to Sc7, it is reasonable to predict that the described observations will deteriorate further and reach a critical stage for all sites, except the lower Kraai River. The ultimate consequence will be a marked decrease in the overall health and functionality of these ecosystems, particularly in its capacity to provide essential ecosystem services, primarily clean water and the ability to dilute, process, and mitigate the impact of polluted water in collaboration with its indigenous biota. Furthermore, the frequency and persistence of waterborne diseases are likely to increase. This could result in a heightened seasonal risk for local communities that rely on the river, recreational users, and have a substantial impact on the biodiversity (fish and macroinvertebrates) associated with this river system.

Holistic evaluation of the socio-economic consequences
The socio-economic profile was integrated with information from the ecological assessments and the changes associated with the scenarios to identify and evaluate the consequences, which varied throughout the study area. Some regions have moderate vulnerability, focusing on commercial agriculture with sufficient water flow. Others face high vulnerability, low GDP, and limited agriculture, risking inadequate water resources. Few areas with low vulnerability and moderate water use face potential challenges. Urban and farming communities with agriculture and tourism thrive but face socio-economic risks due to water quality. Urban and smallholder farming regions concentrating on agriculture and agro-processing also have potential socio-economic risks related to water quality and dilution.

4.5.1 Climate Change

The ORASECOM (2019) study assessed climate change impacts on the Upper Orange River and Modder-Riet River Catchments, using the same system configuration. It examined changing rainfall and evaporation effects through six Global Climate Models, incorporating these changes into Present Day simulations with the WRYM model. The study aimed to understand the impact on irrigation water requirements, a major water user, and the historical firm yield of the system.

The ORASECOM study showed that there is an increase in irrigation demands for the different catchments. The effect on long term historical yield of the different GCMs and catchment areas on average compared to observed historical hydro-climatic conditions (considering both rainfall and evaporation) is summarised in **Table 4-8**.

Table 4-8: Effect on long term historical yield of the different GCMs and catchment areas on average compared to observed historical hydro-climatic conditions

Catchment	Average % difference when comparing Climate Change Firm Yield versus Historic Observed Firm Yield
Greater Bloemfontein Water Supply System	15%
Lesotho Highland Water Project	-1%
Makhaleng River Catchment	1%
Orange River	-8%

Overall, the relevance of the ORASEOCM study results to the developed scenarios in this Study:

- Increased irrigation demand in the Upper Orange catchment is the main difference between historical and climate change scenarios. Existing regulations will require irrigators to manage higher water needs through scaled-down activities or water-efficient methods. With no planned increases in irrigation allocation, the study's scenarios remain relevant, as regulations will limit the impact of higher water use; and
- The Historical Firm Yield indicated the impact of climate change on drought severity. Modder-Riet and Lesotho catchments show improved or stable Firm Yields, while the rest of the Orange River experiences an 8% decline. The ORASEOCM Study lacks consideration for future regulating dams (Polihali, Makhaleng, Verbeeldingskraal), potentially making the scenarios in this study more severe due to higher projected water use and new reservoirs. The study emphasized the importance of controlling infrastructure, like dams, for climate resilience during droughts.

4.6 Water Quality in our Rivers within the Upper Orange Catchment: The Ultimate Driver of Catchment Conditions

It is evident that deteriorated water quality was the driving factor affecting the ecological condition at the sites on most of the streams and rivers in the Upper Orange catchment area. The source of this problem is primarily related to nutrient overload, originating from the various WWTWs (DWS, 2022) and agricultural runoff associated with the towns and cultivation in the catchment. Most WWTW in the catchment are either unmaintained, dysfunctional, or run over-capacity; a problem across most of South Africa (**Table 4-9** and **Table 4-10**).

Only 35 of the 73 WWTWs in the Upper Orange River catchment had data on the volume of wastewater treated per day. The total volume of wastewater according to these 35 was ~194 million L/day. Assuming the volume from the remaining 38 WWTW has a roughly similar value, one can broadly assume that the WWTW in the catchment are discharging ~390 million L/day into rivers in the catchment[1]. As noted for several WWTW in the discussions per site above, this value does not account for the large volumes of wastewater not reaching WWTW where the volume they are processing has decreased between 2013 and 2021, or where they operate well-below capacity. The volume of wastewater (including a huge portion that is only

[1] https://www.dailymaverick.co.za/article/2023-08-10-millions-of-litres-of-poo-a-day-never-even-reach-sas-failing-underserviced-sewage-plants/

partially, or wholly untreated) entering the rivers can therefore be safely assumed to exceed ~400 million L/day in the Upper Orange River catchment. Considering the amount of missing data for discharge, it is problematic to calculate exactly how the sewage releases contribute to the baseflows at a given site. However, considering the wastewater discharge is equivalent to at least 160 Olympic sized swimming pools per day entering rivers in the catchment, one can be sure that there is a significant contribution of wastewater to baseflows. For reference, 400 million L/day is equivalent to a discharge rate of 4.63 cubic meters per second (m3/s), a discharge rate approximately four times (~4x) higher than the modelled natural low flows in July for the Lower Riet site (EWR_09_I). This shows how much potential WWTW discharge in the catchment has for contributing to the baseflows in the dry months (**Table 4-9** and **Table 4-10**).

There were comparable data on WWTW discharge rates between 2013 and 2021 for 27 of the WWTW in the catchment (DWS, 2022). Of these, eight reported decreases in the volume of wastewater treated daily, totalling 5.44 million litres per day less than in 2013 (DWS, 2022). As mentioned above, this is even though population, urbanisation, and water access trends are consistently upward in South Africa, suggesting that the amount of water being treated should steadily increase over time. Therefore, it is likely that this wastewater, and considerably more, is still being generated but not reaching the WWTW. Consequently, it can be assumed that it is discharging, untreated and unaccounted for, into freshwater systems throughout the catchment, thus compromising water quality throughout. This is further illustrated in **Figure 4-5** below.

Table 4-9: Table showing the designed capacity use, daily volume of wastewater (million litres per day; ML/day) treated, and Green Drop (GD) score for the wastewater treatment works (WWTW) within the Upper Orange River catchment. The data for 2013 and 2021 GD reports are summarised, with the change from 2013 to 2021 calculated for each parameter. The GD scores <31% (considered by the Department of Water and Sanitation (DWS) to be dysfunctional and in need of critical intervention (DWS, 2022)) are highlighted in red, the WWTW which have shown a decrease in the daily volume of wastewater they treat are highlighted in purple, and the WWTW which have shown a decrease in their GD score from 2013 to 2021 are highlighted in orange. The EWR Intermediate sites that are in the downstream catchment and likely affected by the WWTW discharge are indicated.

Area and WWTW Details			GD 2013			GD 2021			Change 2013 - 2021			Intermediate EWR Sites
Province	Local Municipality	WWTW Name	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Sites Affected
Eastern Cape	Chris Hani	Dordrecht	100.0	1.20	48.7	100.0	2.80	100.0	0.0	1.60	51.3	EWR_08_I, EWR_10_I
		Molteno	100.0	3.46	24.0	50.0	1.35	51.0	-50.0	-2.11	27.0	EWR_10_I
	Joe Gqabi	Sterkspruit	110.0	1.10	37.0			39.0			2.0	EWR_02_I, EWR_03_I, EWR_10_I
		Lady Grey Oxidation Ponds	No data									EWR_03_I, EWR_10_I
		Herschel	1.1	0.01	44.0			36.0			-8.0	EWR_03_I, EWR_10_I
		Jamestown	20.0	0.16	49.0	83.0	1.00	68.0	63.0	0.84	19.0	EWR_08_I, EWR_10_I
		Barkly East (old)	67.0	0.40	59.0	44.0	0.32	57.0	-23.0	-0.08	-2.0	EWR_08_I, EWR_10_I
		Barkly East (new)	62.0	0.81	63.0	200.0	1.20	48.0	138.0	0.39	-15.0	EWR_08_I, EWR_10_I
		Burgersdorp Activated Sludge	77.0	1.93	54.0	224.0	5.60	35.0	147.0	3.68	-19.0	EWR_10_I
		Venterstad			47.0	45.0	0.45	44.0	45.0		-3.0	EWR_10_I
		Oviston			42.0	100.0	0.20	37.0			-5.0	EWR_10_I

Area and WWTW Details			GD 2013			GD 2021			Change 2013 - 2021			Intermediate EWR Sites
Province	Local Municipality	WWTW Name	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Sites Affected
		Aliwal North	73.0	4.02	47.0	138.0	7.59	40.0	65.0	3.58	-7.0	EWR_10_I
Free State	**Dihlabeng**	**Caledonspoort Port of Entry**									No data	EWR_01_I, EWR_04_I, EWR_10_I
		Mashaeng	89.0	1.02	28.0	45.0	0.50	41.0	-44.0	-0.53	13.0	EWR_01_I, EWR_04_I, EWR_10_I
		Clarens	60.0	1.50	49.0	56.0	1.40	52.0	-4.0	-0.10	3.0	EWR_01_I, EWR_04_I, EWR_10_I
		Mautse	36.0	0.18	27.0	17.0	0.34	33.0	-19.0	0.16	6.0	EWR_01_I, EWR_04_I, EWR_10_I
	Kopanong	**Edenburg**			14.0			41.0			27.0	EWR_06_I, EWR_09_I
		Reddersberg			12.0			16.0			4.0	EWR_06_I, EWR_09_I
		Trompsburg	151.0	1.10	13.0			46.0			33.0	EWR_09_I
		Jagersfontein			12.7			14.0			1.30	EWR_09_I
		Fauresmith			34.0			16.0			-18.0	EWR_09_I
		Gariep Dam			34.0			12.0			-22.0	EWR_10_I
		Bethulie			13.0			44.0			31.0	EWR_10_I
		Philippolis			34.0			52.0			18.0	EWR_10_I
		Springfontein			12.0			49.0			37.0	EWR_10_I
	Letsemeng	**Koffiefontein**			12.0			29.0			17.0	EWR_09_I
		Oppermans			22.0			26.0			4.0	EWR_09_I
		Jacobsdal			25.0			33.0			8.0	EWR_09_I
		Petrusburg			7.0			61.0			54.0	EWR_09_I

Area and WWTW Details			GD 2013			GD 2021			Change 2013 - 2021			Intermediate EWR Sites
Province	Local Municipality	WWTW Name	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Sites Affected
		Luckhoff			26.0			46.0		0.00	20.0	EWR_10_I
	Mangaung	Vanstadensrus			8.0	33.0	0.01	17.0			9.0	EWR_04_I, EWR_10_I
		Van Rooyenshek Port of Entry	No data									EWR_04_I, EWR_10_I
		Wepener			0.0	1.0	0.02	21.0			21.0	EWR_04_I, EWR_10_I
		Dewetsdorp			14.0	38.0	0.02	24.0			10.0	EWR_07_I, EWR_09_I
		Botshabelo	50.0	10.00	81.0	110.0	22.00	36.0	60.0	12.00	-45.0	EWR_07_I, EWR_09_I
		Thaba Nchu	75.0	4.50	81.0	70.0	3.50	41.0	-5.0	-1.00	-40.0	EWR_07_I, EWR_09_I
		Welvaart	75.0	4.50	79.0	80.0	4.00	32.0	5.0	-0.50	-47.0	EWR_09_I
		Sterkwater	164.0	18.04	83.0	128.0	25.60	33.0	-36.0	7.56	-50.0	EWR_09_I
		Bloemspruit	116.0	64.96	76.0	120.0	67.20	32.0	4.0	2.24	-44.0	EWR_09_I
		Bloemdustria	33.0	0.30	87.0	56.0	0.50	30.0	23.0	0.21	-57.0	EWR_09_I
		Bainsvlei	70.0	3.5	82.0	76.0	3.80	35.0	6.0	0.3	-47.0	EWR_09_I
		North Eastern Works			0.0	90.0	18.00	32.0	90.0	18.00	32.0	EWR_09_I
		Northern Mangaung	33.0	1.98	81.0	38.0	1.90	30.0	5.0	-0.08	-51.0	EWR_09_I
		Soutpan			30.0			0.0			-30.0	EWR_09_I
	Mantsopa	Hobhouse			51.0	80.0	0.40	31.0			-20.0	EWR_04_I, EWR_10_I
		Thaba Patchoa			20.0	100.0	1.50	33.0			13.0	EWR_04_I, EWR_10_I
		Maseru Bridge Port of Entry	No data									EWR_04_I, EWR_10_I
		Ladybrand	98.0	4.90	31.0	29.0	5.08	29.0	-69.0	0.18	-2.0	EWR_04_I, EWR_10_I

Area and WWTW Details			GD 2013			GD 2021			Change 2013 - 2021			Intermediate EWR Sites
Province	Local Municipality	WWTW Name	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Sites Affected
		Tweespruit			20.0	100.0	0.50	22.0		0.50	2.0	EWR_04_I, EWR_10_I
		Thaba Phatswa										EWR_04_I, EWR_10_I
	Masilonyana	**Soutpan**			30.0			0.0			-30.0	EWR_09_I
	Masilonyana	**Brandfort**									No data	EWR_09_I
	Masilonyana	**Acornhoek SAPS**									No data	EWR_09_I
	Masilonyana	**Naboomspruit Military Base**									No data	EWR_09_I
	Mohokare	**Zastron**			39.0	252.0	2.52	15.0			-24.0	EWR_03_I, EWR_10_I
	Mohokare	**Rouxville**			25.0	156.0	2.34	24.0			-1.0	EWR_04_I, EWR_10_I
	Mohokare	**Smithfield**			26.0	73.0	0.73	30.0			4.0	EWR_04_I, EWR_10_I
	Mohokare	**Goedemoed Correctional Center**									No data	EWR_10_I
	Setsoto	**Ficksburg**	122.0	14.88	12.2			5.0			-7.2	EWR_01_I, EWR_04_I, EWR_10_I
	Setsoto	**Clocolan**	122.0	5.12	24.0			2.0			-22.0	EWR_04_I, EWR_10_I
	Tokologo	**Dealesville**	23.0	0.46	25.0			46.0			21.0	EWR_09_I
Northern Cape	**Emthanjeni**	**Hanover**	16.0	0.27	74.0			18.0			-56.0	EWR_05_I, EWR_10_I
Northern Cape	**Renosterberg**	**Philipstown**	73.0	0.23	1.0	233.0	0.70	0.0	160.0	0.47	-1.0	EWR_10_I
Northern Cape	**Renosterberg**	**Petrusville**	66.2	0.44	1.0	157.0	1.10	0.0	90.8	0.66	-1.0	EWR_10_I
Northern Cape	**Renosterberg**	**Vanderkloof**	131.0	0.24	1.0	150.0	0.30	0.0	19.0	0.06	-1.0	EWR_10_I
Northern Cape	**Sol Plaatjie**	**Ritchie**	200.0	1.00	55.0			36.0			-19.0	EWR_09_I
Northern Cape	**Sol Plaatjie**	**Beaconsfield**	130.0	10.40	53.0	104.0	9.36	32.0	-26.0	-1.04	-21.0	EWR_09_I

Area and WWTW Details			GD 2013			GD 2021			Change 2013 - 2021			Intermediate EWR Sites
Province	Local Municipality	WWTW Name	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Capacity Use (%)	Volume Treated (ML/day)	GD Score (%)	Sites Affected
	Thembelihle	Hopetown (New)			62.0			43.0		0.00	-19.0	EWR_10_I
		Hopetown	100.0	0.80	54.0			0.0	-100.0		-54.0	EWR_10_I
	Umsobomvu	Noupoort			4.0			18.0			14.0	EWR_05_I, EWR_10_I
		Colesberg	No data									EWR_10_I
		Norvalspont	29.0	0.04	35.0			17.0			-18.0	EWR_10_I

Table 4-10: Table showing the wastewater chemical, microbiological, physical, and monitoring compliance status (as of October 2023) of the local municipalities in the Upper Orange River Catchment for which there are data in the National Integrated Water Information System (NIWIS; https://www.dws.gov.za/niwis2/wwq2) database. Compliance <50% is highlighted in red. The The EWR Intermediate sites that are likely affected by the wastewater treatment compliance of the municipalities are indicated.

Area details		Compliance Component				Intermediate EWR Sites
Province	Local Municipality	Chemical (%)	Microbiological (%)	Physical (%)	Monitoring (%)	EWR Sites Affected
Eastern Cape	Chris Hani	65	56	68	45	EWR_08_I, EWR_10_I
	Joe Gqabi	0	0	0	0	EWR_02_I, EWR_03_I, EWR_08_I, EWR_10_I
Free State	Dihlabeng	0	0	0	0	EWR_01_I, EWR_04_I, EWR_10_I
	Kopanong	0	0	0	0	EWR_06_I, EWR_09_I, EWR_10_I
	Letsemeng	0	4	58	33	EWR_09_I, EWR_10_I
	Mangaung	63	100	89	78	EWR_04_I, EWR_07_I, EWR_09_I, EWR_10_I
	Mantsopa	59	74	68	100	EWR_04_I, EWR_10_I
	Masilonyana	54	73	86	59	EWR_09_I

Area details		Compliance Component				Intermediate EWR Sites
Province	Local Municipality	Chemical (%)	Microbiological (%)	Physical (%)	Monitoring (%)	EWR Sites Affected
	Mohokare	98	99	86	87	EWR_03_I, EWR_04_I, EWR_10_I
	Setsoto	58	33	80	52	EWR_01_I, EWR_04_I, EWR_10_I
	Tokologo	0	0	0	0	EWR_09_I
Northern Cape	Emthanjeni	0	0	0	0	EWR_05_I, EWR_10_I
	Renosterberg	0	0	0	0	EWR_10_I
	Sol Plaatjie	31	0	77	69	EWR_09_I
	Thembelihle	33	0	76	41	EWR_10_I
	Umsobomvu	0	42	0	100	EWR_05_I, EWR_10_I

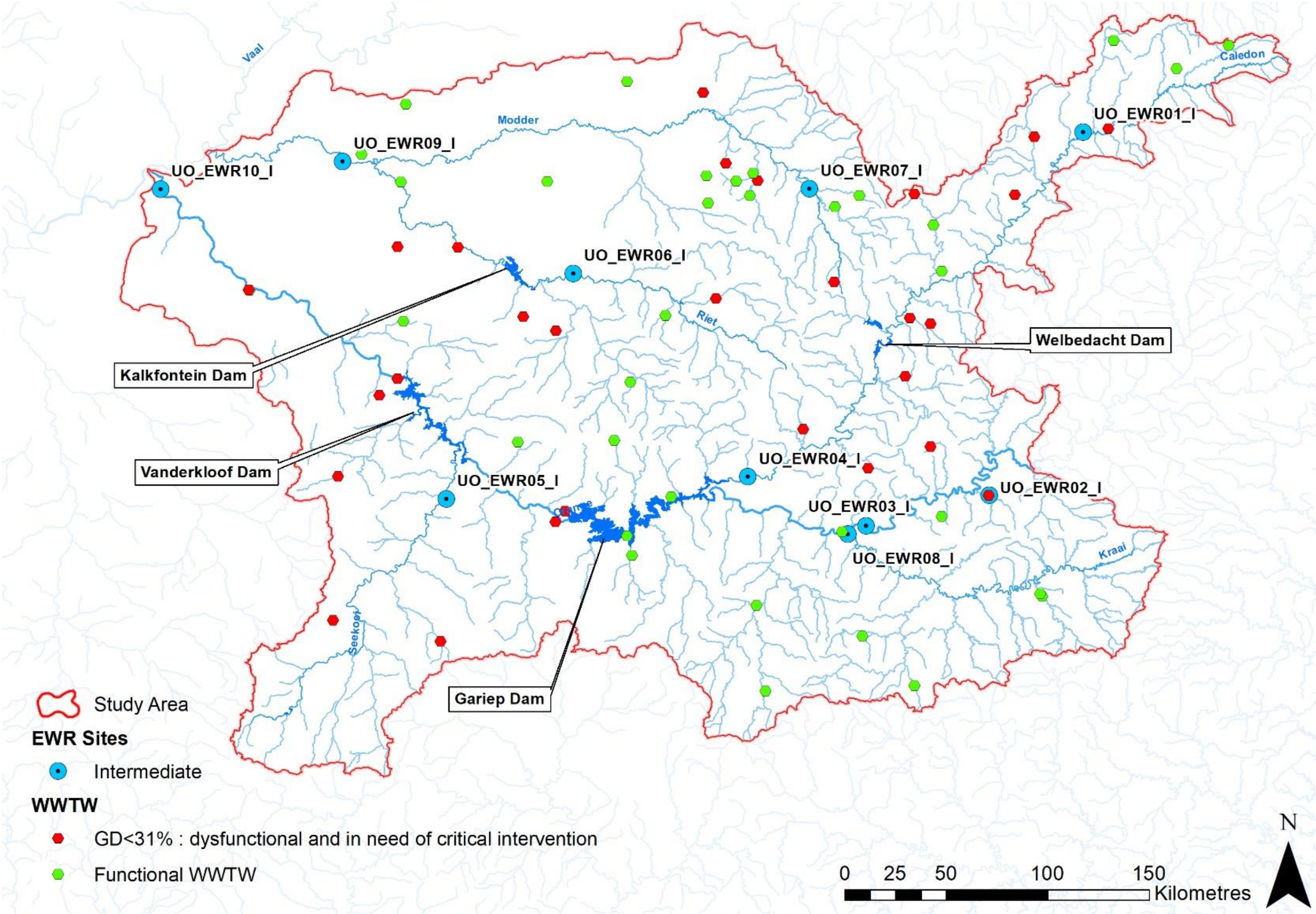


Figure 4-5: Intermediate EWR sites in conjunction with dysfunctional and in need of critical intervention WWTW

4.7 Conceptual Flow Management Plan

In the Upper Orange catchment, the establishment of the large Gariep (opened in 1971, covering 352 km^2) and Vanderkloof (opened in 1977, covering 133.4 km^2) dams has been arguably the largest driver of change in flows over the last century. The dams were founded as reservoirs for a multitude of uses, including domestic and industrial supply. However, the primary purpose of both is to supply water for hydroelectric power generation and for agricultural use via irrigation (ORASECOM, 2023).

Downstream of the Gariep and Vanderkloof dams, at the Marksdrift gauging station, zero flows were recorded in the first nine years of monitoring between 1962 and 1971. However, since then (i.e., over the last ~60 years) the Orange River has not stopped flowing due to continuous releases to supply water to downstream users and for hydroelectric power generation. Continuous releases have increased annual low flow rates, while median flows have almost doubled compared to pre-dam levels. While high flow rates remain relatively similar, the magnitude and frequency of small and medium sized floods have decreased. The frequency of large floods has been particularly affected. Nine floods have exceeded a discharge rate of 2000 m^3.s-1 over the course of monitoring (data included from 1962 – 2022). Four occurred over the ten years (i.e., one approximately every two years) before Gariep Dam became operational. Only four have occurred over the 50 years since then (i.e., one approximately every 10 years up to 2022; **Figure 4-6**). Both dams have been used near-continuously for hydroelectric power generation, causing daily hydropeaking (**Figure 4-7**). The monthly hydrograph (**Figure 4-8**) at the EWR site UO_EWR10_I downstream Marksdrift Weir (D3H008) shows the monthly changes from natural (NAT) and present day (PRS) flows. The natural baseflows (BF) are also included on the graph for comparison with the present-day flows.

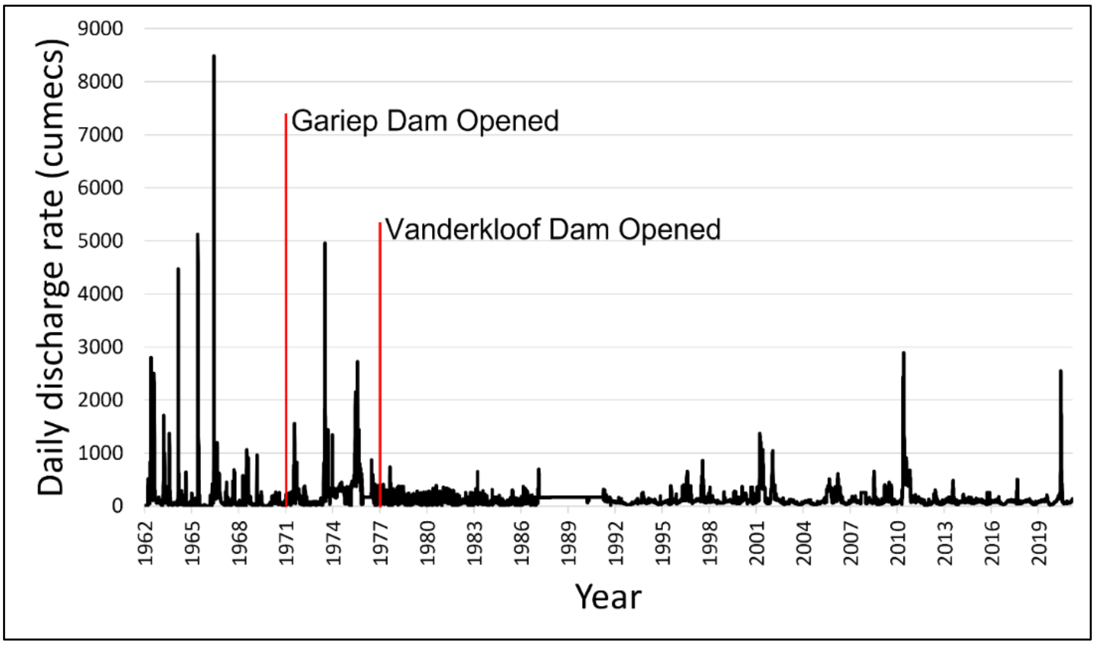


Figure 4-6: Daily discharge rate from 1962 – 2021 measured at Marksdrift gauging station (station D3H008; -29.16201, 23.69594), upstream the confluence of the Orange and Vaal rivers. Opening dates of the Gariep and Vanderkloof Dams (indicated by the red lines)

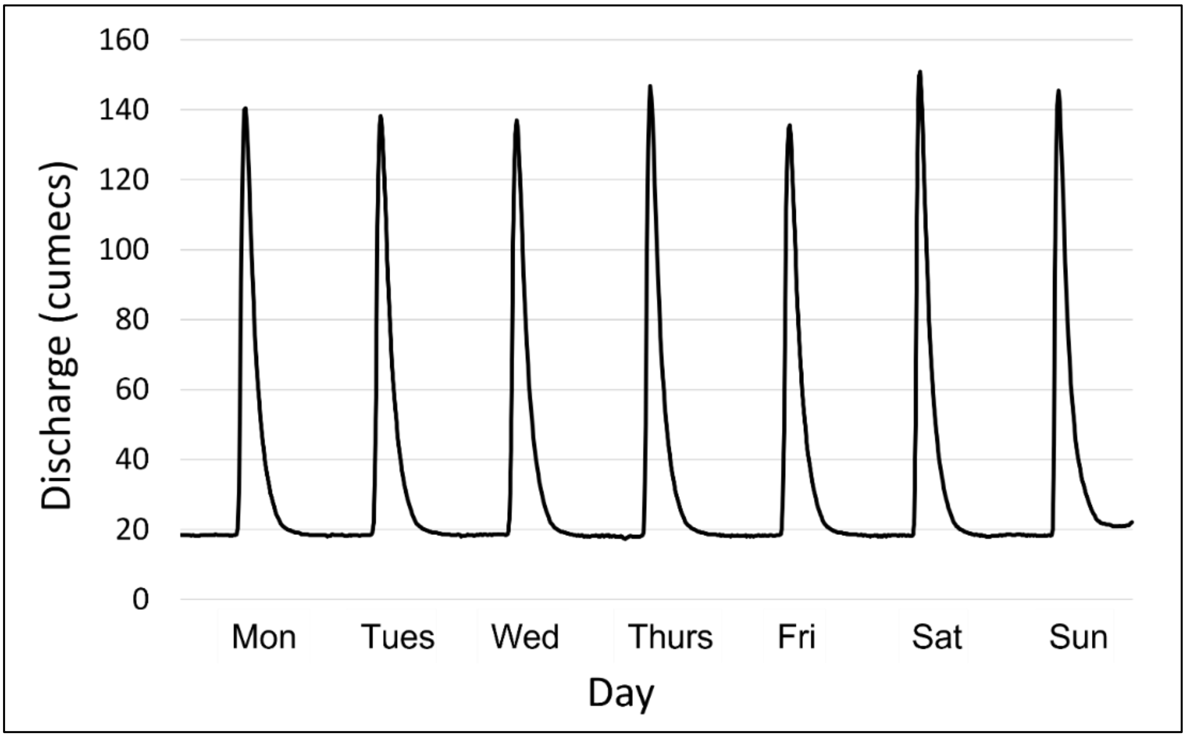
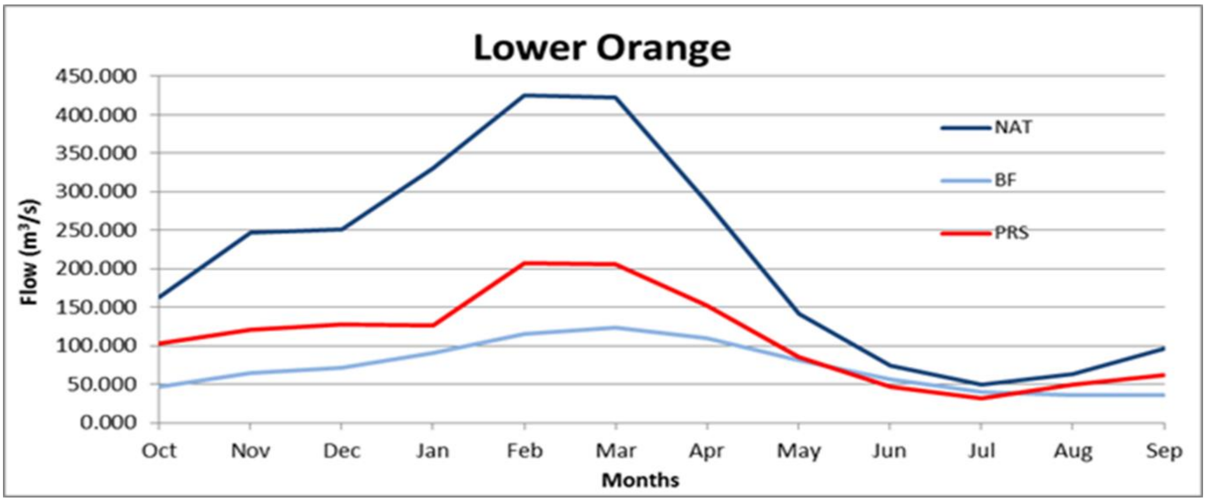


Figure 4-7: Discharge recorded from Vanderkloof Dam at gauging station (D3R003; -29.99149, 24.73189) over a one-week period (01/01/2020 – 08/01/2020). Pattern shows the daily hydropeaking resulting from hydroelectric power generation releases



NAT – Natural flows, PRS – Present day flows, BF - Baseflows

Figure 4-8: Monthly hydrograph at EWR site UO_EWR10_I downstream Marksdrift Weir indicating changes in flows

Previous assessments on the Upper Orange catchment system have highlighted the range of flow-related impacts on the system associated with the dams. These include the DWS Upper Orange study in 2014 (DWS, 2014), as well as the three joint basin surveys (ORASECOM, 2023) conducted every five years since 2010.

These studies have illustrated that the primary impacts above the Gariep Dam are associated with pollution (primarily domestic, industrial, and mine wastewater, as well as rubbish dumping, e.g., plastic) and erosion from poor agricultural/ land use practices causing high sedimentation. Furthermore, flow modifications (i.e., low flows) as well as to a certain extent, floods due to the upstream Katse and the Mohale Dams in Lesotho.

Below the dams, flow changes were isolated as the primary diver of ecosystem modification. In particular, a lack of flooding was associated with 1) a build-up of persistent organic pollutants within riverine sediments, 2) elevated Escherichia coli (E. coli) counts (linked to livestock farming in the riparian zone), 3) excessive algal growth, dense matts of submerged aquatic plants (likely associated with nutrient loading from surrounding agriculture given that organic phosphate levels were also elevated at these sites), and dominance of invasive plants in the marginal and non-marginal zones of the river channel, and 4) hindering flood-related habitat creation or maintenance for various biota (Dewson *et al.* , 2007; Górski *et al.* , 2011; Mei *et al.* , 2017; Mürle *et al.* , 2003; Schmutz & Moog, 2018; Wu *et al.* , 2019). At the conclusion of the JBS3 in 2022, the sites immediately downstream of the dams were assessed to be in largely modified states, with degraded fish, macroinvertebrate, and vegetation communities **(Figure 4-9**). Ecological condition improved progressing further downstream as the impacts of the flow alterations are slowly ameliorated (Wu *et al.,* 2019). Upstream sites were also impacted, but largely by water quality issues associated with wastewater pollution and degradation associated with agriculture (**Figure 4-9**; ORASECOM, 2023).

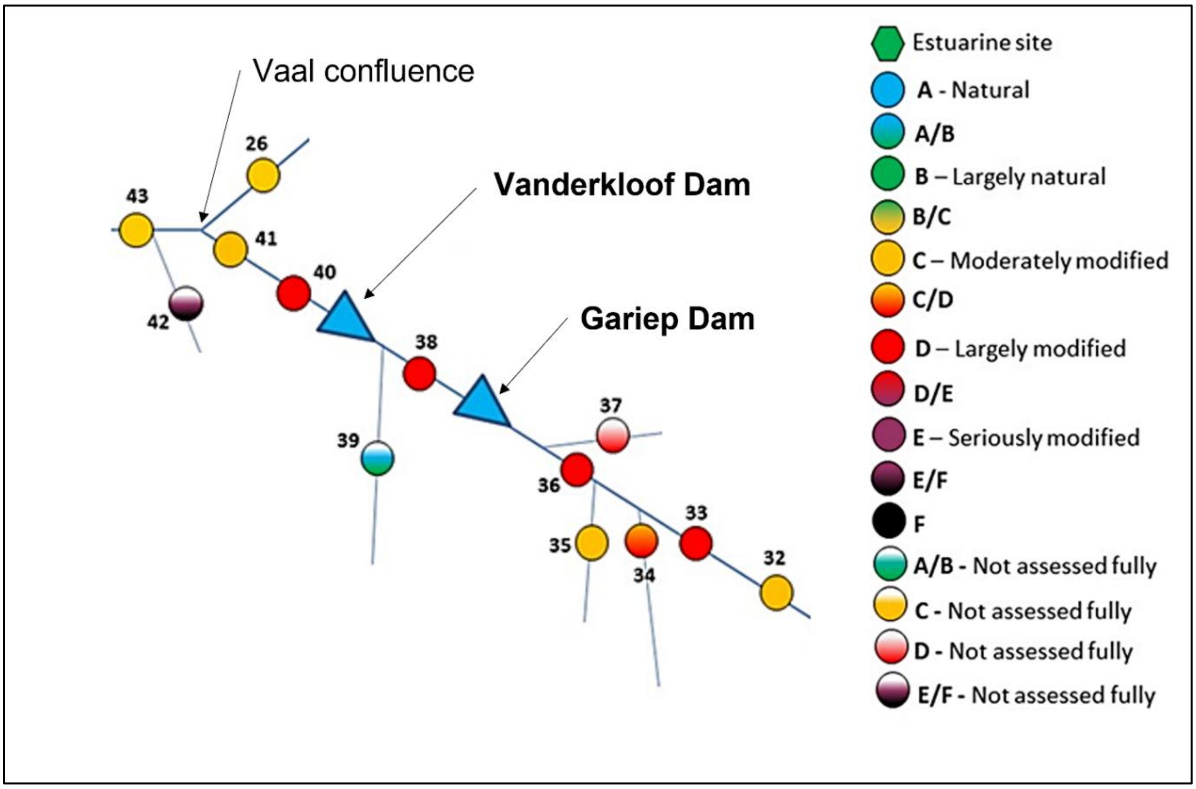


Figure 4-9: Schematic representation of the overall ecological status (key on right hand side) of relevant sample sites from the third Joint Basin Survey (JBS3) aquatic ecosystem health assessment by the Orange-Senqu River Commission (ORASECOM, 2023)

Investigations still required and the need for a conceptual Flow Management Plan

Based on the current social and economic climate of South Africa, the dams undoubtedly fulfil a critical role in providing water and power generation that cannot be ignored. However, based on the previous assessments of the Upper Orange River catchment, there are significant negative environmental, social, and economic consequences of their current flow regimes. Going forward, several avenues remain to be investigated to work toward development of an ideal EWR that maintains some of the core functionality of the dams, but allows for a healthier and sustainable river system, boosts the essential ecosystem services it can provide:

- The specific effects of the current flow regime on the habitat, biota, and people need to be thoroughly investigated to understand the advantages and disadvantages of potential changes. This will need to involve reflection on assessments performed in the region to date, targeted physical, chemical, and biological monitoring, as well as investigations of the current social and economic linkages to flow from the dams;
- The extent of the above impacts of the current flow regimes downstream of the dams needs to be measured. This will be a gradient of impact; most severe directly below the dam walls and reducing as one progresses downstream away from the dams. There may be a need for delineation of ‘sacrificial zones’ where impacts from dam flow releases are drastic and unlikely to respond to remediation over the short to medium-term; and
- Using the above information, there will be the need to develop a short-term project to investigate hydraulic and hydrological models at a daily time-step that can digitally simulate impacts of changes to flow on river geomorphology, aquatic-associated fauna and flora, and people downstream of the dams. These models will inform what impacts potential changes to flow will have, allowing development of ideal EWR recommendations.

Action Plans

Going forward, the action plan for flow-related management of the Upper Orange River catchment (specifically relating to the Vanderkloof and Gariep dams) can be delineated into four stages: Immediate (current, emergency interventions should any be identified), Short-term (actions over the next 0 – 5 years), Medium-term (action between 5 – 20 years from now), and Long-term (actions 20 years from now and beyond). Refer to **Figure 4-10** outlining a summary of the proposed action plans.

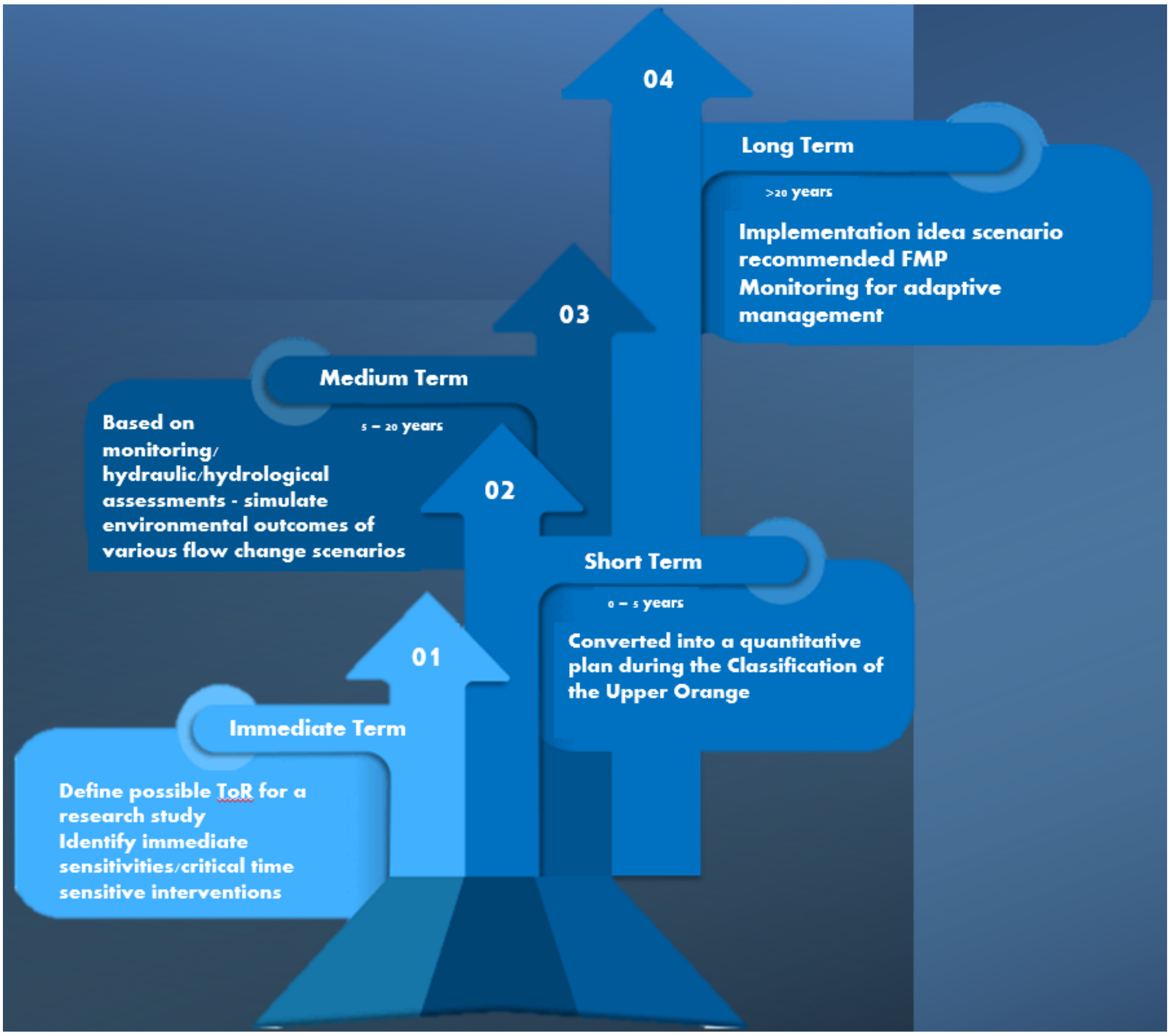


Figure 4-10: Proposed immediate, short, mediam and long term action plans

4.7.1 Proposed flow management changes to improve PES

We acknowledge that the hydro-electric power generation at both the Gariep and Vanderkloof dams will be required for the near future, given the ongoing, severe pressure on power generation in Southern Africa. There may also be limitations to potential flow management changes according to irrigation demand throughout the catchment causing a mismatch between ideal environmental flows and agricultural demand (Ramulifho *et al.,* 2019). However, we foresee two possible changes to the flow management at the dams which may have benefits for the ecosystem health and function of the river reaches below each dam:

Reduced releases during the winter (June, July, and August) months to achieve minimum flows related solely to the necessary hydro-electric power generation.

Maintaining a natural flow regime in rivers is crucial for their health, encompassing perennial flows, floods, and periods of low or zero flow. However, current flow conditions below dams deviate from natural patterns. Establishing a natural low or zero-flow regime during the dry season is vital for ecological health, influencing water properties and habitat dynamics. It promotes sediment settling, enhances water clarity, and forms essential breeding habitats. Conversely, it limits the survival of species not adapted to natural flow cycles. In the Orange River section below dams, establishing a natural flow regime can control blackfly populations, benefiting livestock farming. The JBS2 and JBS3 data indicate disturbance issues from intermittent flow releases, suggesting that stabilizing a minimum flow could aid macroinvertebrate communities in their recovery and natural cycle.

Incrementally increasing releases in the spring (September, October, and November) to closer simulate what would be the increasing natural flow regime during that period.

Potential changes in dam releases for environmental flows are contingent on water availability. However, the benefits could be outweighed if the dam becomes empty due to inadequate upstream supply. Environmental flow requirements consider not only water volume but also timing, crucial for ecosystem function. Timely high flows trigger breeding in aquatic species, and increased flows in spring benefit migratory breeding species and habitat connectedness. Timing initiation flows in landscapes is vital for ecological processes, native species cues, and revitalizing river habitats. Balancing the magnitude, duration, and timing of flows is essential for ecological health.

The interaction between the temporal and volume components of flow are illustrated by Yarnell *et al.* (2015) (**Figure 4-11**).

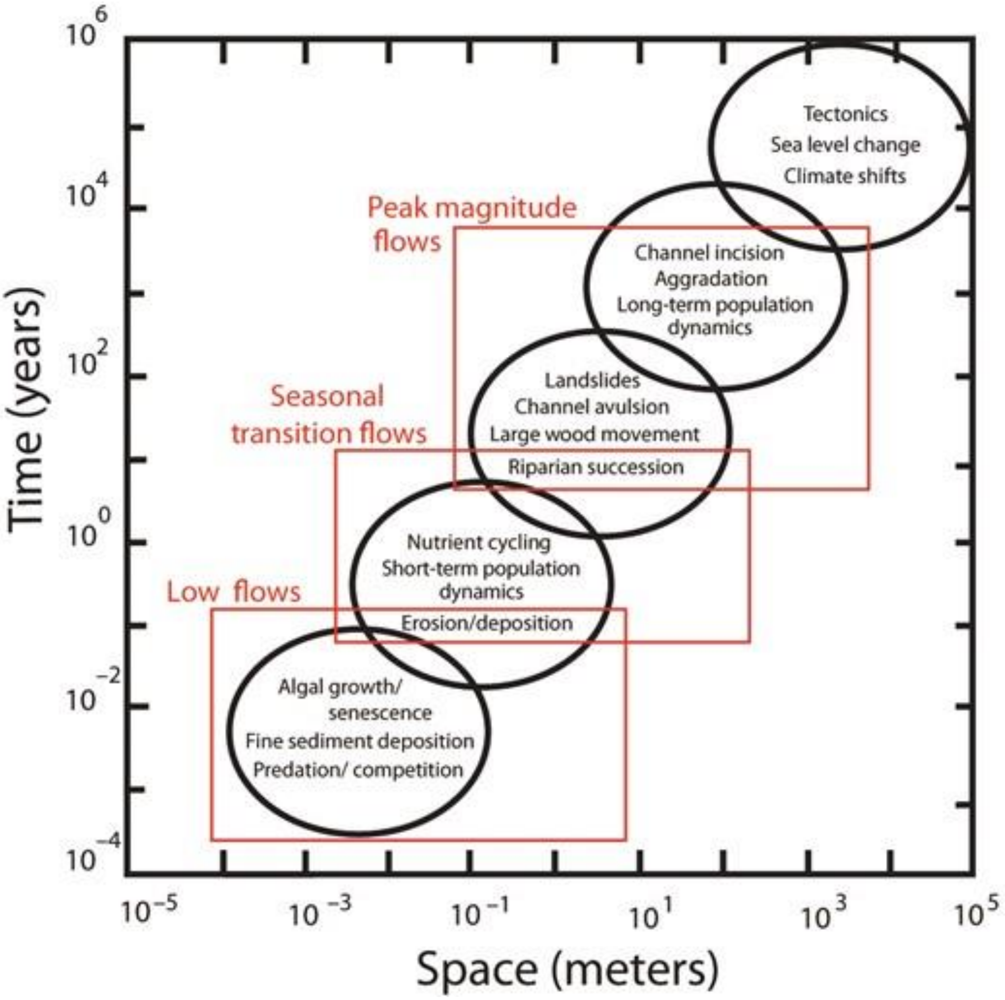


Figure 4-11: "Examples of interrelated physical and ecological riverine processes at varying spatial and temporal scales. Key functional flows supporting specific processes are shown in boxes." – from Yarnell *et al.* (2015).

Shifting to a more natural spring flow regime could bring ecological benefits, potentially aiding agriculture downstream. JBS2 and JBS3 data revealed impacts on macroinvertebrates and water quality from irregular flows. Restoring a natural spring flush may foster a seasonal response in aquatic biota, reducing disturbance from hydropeaking. Assessing these flow changes alongside frequent monitoring for adaptive management is crucial. While predicting ecosystem responses is challenging due to longstanding anthropogenic alterations, returning to natural flow patterns is likely to enhance ecosystem health, especially below heavily impacted Gariep and Vanderkloof dams.

Lastly, it is important to further note the ecological concerns linked to cost-effective hydropower, emphasizing the need for sustainable and predictable energy sources. Heavy reliance on hydropower raises questions about the long-term sustainability of energy and its impact on aquatic ecosystems. Exploring alternatives, especially solar energy, is suggested to diversify the energy mix and address associated challenges. The focus is on evaluating the economic feasibility of alternative options, considering installation costs and operational expenses. The goal is to find a stable and reliable energy supply that balances the specific needs of sectors like agriculture, ensuring consistency in power supply and supporting essential economic activities. In summary, the challenge involves diversifying energy sources from hydropower and ensuring predictable energy generation for key sectors like agriculture through exploring competitive alternatives.

4.8 Ecological Specifications

The final step in the study was to define Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) to monitor the future implementation of the Ecological Reserve. EcoSpecs are clear and measurable specifications of ecological attributes such as flow, water quality and biological integrity that define the REC. The EcoSpecs refer explicitly to ecological information, and which will relate to and expand on the Resource Quality Objectives (RQOs) that will be set during the Classification Study for the Upper Orange catchment area. They will further include economic and social objectives.

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 overall aim of Reserve monitoring is to measure and determine how a resource changes over time and to ensure that the resource remains within the defined acceptable limits of change for the REC. Monitoring, thus provides a critical link between the EcoSpecs and the required management interventions.

Below are the identified EcoSpecs for all EWR sites and field verification sites. From a water quality perspective and to reiterate for this study, diatoms were used as a surrogate to the Physical-chemical driver Assessment Index (PAI).

Due to the limitations on availability of water quality data, the South African Water Quality Guidelines for aquatic ecosystems Volume 7 (DWAF, 1996) were used for the Reference Conditions (RC). The Target Water Quality Requirements (TWQR), Chronic Effect Value (CEV), and Acute Effect Value (AEV) for each water quality parameter are thus provided in **Table 4-11** below for the water quality (driver) ecospecs. These are not to be exceeded for all parameters and are applicable for all EWR sites listed below.

Table 4-11: Target Water Quality Requirements, Chronic Effect Value, and Acute Effect Value for each water quality parameter applicable for all EWR sites throughout the Upper Orange catchment area

Water quality parameter	Unit	TWQR	CEV	AEV	Notes
Aluminium* (pH<6.5)	µg/L	5.00	10.00	100.00	†
Aluminium (pH>6.5)	µg/L	10.00	20.00	150.00	†
Ammonia (un-ionised)	µg N/L	7.00	15.00	100.00	†§
Arsenic	µg/L	10.00	20.00	130.00	†
Atrazine	µg/L	10.00	19.00	100.00	†
Cadmium* ($CaCO_3$/L = <60mg)	µg/L	0.15	0.30	3.00	†
Cadmium ($CaCO_3$/L = 60-119mg)	µg/L	0.25	0.50	6.00	†

Water quality parameter	Unit	TWQR	CEV	AEV	Notes
Cadmium ($CaCO_3$/L = 120-180mg)	µg/L	0.35	0.70	10.00	†
Cadmium ($CaCO_3$/L = >180mg)	µg/L	0.40	0.80	13.00	†
Cadmium criteria for cold water adapted fish species					†
Cadmium ($CaCO_3$/L = <60mg)	µg/L	0.07	0.15	1.80	†
Cadmium ($CaCO_3$/L = 60-119mg)	µg/L	0.10	0.19	2.80	†
Cadmium ($CaCO_3$/L = 120-180mg)	µg/L	0.15	0.29	5.10	†
Cadmium ($CaCO_3$/L = >180mg)	µg/L	0.17	0.34	6.20	†
Chlorine	µg/L	0.20	0.35	5.00	†
Chromium (VI)	µg/L	7.00	14.00	200.00	†
Chromium (III)	µg/L	12.00	24.00	340.00	†
Copper* ($CaCO_3$/L = <60mg)	µg/L	0.30	0.53	1.60	†
Copper ($CaCO_3$/L = 60-119mg)	µg/L	0.80	1.50	4.60	†
Copper ($CaCO_3$/L = 120 -180mg)	µg/L	1.20	2.40	7.50	†
Copper ($CaCO_3$/L = >180mg)	µg/L	1.40	2.80	12.00	†
Cyanide	µg/L	1.00	4.00	110.00	†
Dissolved Oxygen	%	80-120	60.00	40.00	φ
Endosulfan	µg/L	0.01	0.02	0.20	†
Fluoride	µg/L	750.00	1500.00	2540.00	†
Iron		10%**	10%**	10%**	†
Lead* ($CaCO_3$/L = <60mg)	µg/L	0.20	0.50	4.00	†
Lead ($CaCO_3$/L = 60-119mg)	µg/L	0.50	1.00	7.00	†
Lead ($CaCO_3$/L = 120 -180mg)	µg/L	1.00	2.00	13.00	†
Lead ($CaCO_3$/L = >180mg)	µg/L	1.20	2.40	16.00	†
Manganese	µg/L	180.00	370.00	1300.00	†
Mercury	µg/L	0.04	0.08	1.70	†
Nitrogen	mg/L	0.50	2.50	10.00	††
pH		5%**	5%**	5%**	§§
Phenol	µg/L	30.00	60.00	500.00	†
Phosphorus (inorganic)	µg/L	5.00	25.00	250.00	††
Selenium	µg/L	2.00	5.00	30.00	†
Total Dissolved Solids (TDS)	mg/L	15%**	15%**	15%**	φφ
Suspended solids	mg/L	10%**	10%**	10%**	†††
Zinc	µg/L	2.00	3.60	36.00	†

** Target Water Quality Requirements (TWQR), Chronic Effect Value (CEV), and Acute Effect Value (AEV) depend on the pH and / or water hardness ($CaCO_3$/L).*

*** Concentrations should be within specified percentage of background values.*

[†] 90% of all measurements should be within the TWQR. All measurements must be below the CEV to ensure protection of aquatic ecosystems. Where only sparse or sporadic data are available, interpretation should take into account the fact that the data may not be representative. In the case of accidental spills, chronic and acute toxicity effects will occur if measurements exceed the AEV.

[§] Single measurements of ammonia are of limited use. Preferably, weekly ammonia concentrations, averaged over a period of at least 4 weeks, with the minimum and maximum values should be reported and compared to the TWQR.

φ Single values are not of use. The arithmetic mean of the daily (24-hour) minimum instantaneous concentrations measured at hourly intervals over seven consecutive days or 1-day minimum concentration should be compared to the TWQR.

†† Single measurements are a poor basis for assessment. Occasional increases concentration above the TWQR are less important than continuously high concentrations. Average summer concentrations provide the best basis from which to estimate the likely biological consequences. Weekly concentrations, averaged over a period of at least 4 weeks, should be compared with the TWQR.

§§ Background pH values, in addition to diel and seasonal variability, need to be established if deviations from natural pH values are to be assessed. The significance of pH changes to aquatic biota depends on the extent, duration and timing of the changes. Small changes in pH often cause large changes in the concentration of available metallic complexes and can lead to significant increases in the availability and toxicity of most metals. All pH measurements for the site in question should be within the TWQR.

φφ Changes in electrical conductivity (EC) provide useful and rapid estimates of changes in the TDS concentration, once the relationship between EC and TDS has been established for a particular water body. However, changes in EC values provide no information on the changes in the proportional concentrations of the major ions. Similarly, the relationship between TDS and EC will not reflect changes in the concentration of minor ions and nutrients such as phosphate and nitrate. Changes in the long-term shifts in the TDS concentration are more important than single values. Therefore, mean or seasonal mean values for the concentrations in a dataset should be compared with the TWQR.

††† All TSS measurements should be within the TWQR. Changes in TSS concentration that are unrelated to natural variation (e.g., diel and seasonal patterns) may have effects on biodiversity. Background TSS levels need to be established if deviations from such "natural" levels for a particular water body at a particular time are assessed. The significance of changes in TSS depends on the extent, duration, frequency and timing of the changes. Elevated levels of TSS will have a greater effect in areas which have lower background TSS levels.

Refer to **Table 4-12** to **Table 4-27** for the EcoSpecs identified for all Intermediate and Rapid 3 EWR sites. **Table 4-28** and **Table 4-29** lists the hydrology and water quality EcoSpecs for the selected field verification sites.

Table 4-12: EcoSpecs identified for UO_EWR01_I: Middle Caledon

UO_EWR01_I: Middle Caledon								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
D	674.0	545.8	25.394	3.77	79.548	11.80	156.076	23.16
Final flood requirements								

Class 1	m^3/s	20
	# days	4
	Months	Oct-Jan, Mar, Apr
	Type	Average
Class 2	m^3/s	35
	# days	5
	Months	Nov-Mar
	Type	Average
Class 3	m^3/s	60
	# days	3
	Months	Jan, Feb
	Type	Peak

UO_EWR01_I: Middle Caledon		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	D	E or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	~ 50 m wide macro channel	Macro channel narrows to <40m or widens to >60m
Median particle size of riffle/rapid	Medium gravel (13 mm)	No gravels along faster flow paths
Extent of bank erosion	~ 50%	>70%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 40% for entire riparian zone.	Alien species cover increases above 40% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 5 - 20%. Indigenous non-woody vegetation cover maintained between 10 – 50%.	Indigenous woody vegetation cover decreases below 5% or increases above 20%. Indigenous non-woody vegetation cover decreases below 10% or increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by non-woody species.	Diversity of indigenous species within the marginal zone decreases below 5 species.

UO_EWR01_I: Middle Caledon			
Lower riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 60%.		Indigenous woody vegetation cover decreases below 10% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the lower zone, dominated by non-woody species.		Diversity of indigenous species within the lower zone decreases below 5 species.
Upper riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 30 – 60%.		Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 30% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the upper zone, dominated by non-woody species.		Diversity of indigenous species within the upper zone decreases below 5 species.
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 30 – 60%.		Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 30% or increases above 60%.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)

UO_EWR01_I: Middle Caledon			
Indicator fish species and presence	*Labeobarbus aeneus*	Present at about 25% to 50% of sites during summer (FROC = 3)	Absent from all sites during summer
	Labeo capensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Absent from all sites during summer
Fish habitats and cover features	Fast-deep Slow-deep Undercut Banks	Maintenance of fast-deep and slow-deep habitats with undercut banks	Loss of undercut banks as a cover feature
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 62.0% (Category C). The MIRAI score to be maintained as a mid-C in the range >62 – 70%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤ 61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 69 with an ASPT of 4.9. Total SASS5 score should remain >75, with ASPT value >5.2.	PES: SASS5 scores <45 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 10 families were collected during the field survey (14 families in total taking into account a survey conducted at the same site in 2021). Of these, one scored ≥ 10 sensitivity. More than 14 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present (although should	PES: Less than 10 taxa collected. Less than 2 taxa with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D.

UO_EWR01_I: Middle Caledon			
		Leptophlebiidae be recorded, this may improve the ASPT of the community).	
Physical habitat quality	Biotopes and quality	Visual - Moderate turbidity, although when water levels are lower, the clarity should increase. Moderate levels of silt.	Increase in sediment deposition, highly turbid conditions within the water column.
Physical habitat diversity	Biotopes and diversity	GSM (including pockets of gravel) and marginal vegetation should be available to sample.	A reduction in pockets of gravel and lack of inundated marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependent taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Gomphidae	Gomphidae present in ≥A abundances.	Gomphidae absent (or individuals only) on two or more consecutive surveys

UO_EWR01_I: Middle Caledon			
		These indictor taxa have a wide range of flow preferences over the GSM biotope.	GSM becomes exposed.
	Hydropsychidae 1sp	Hydropsychidae 1 spp present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Absence of Hydropsychidae 1 spp in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 8.6 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality	

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

*[*]The habitat preferences of indicator genera are listed in the Macroinvertebrate Response Assessment Index (MIRAI) worksheets, which are provided electronically. *The indicator taxa signify families that haven't been recorded but are expected for the reach, with a high FROC. Therefore, documenting these indicator taxa could potentially enhance the macroinvertebrate PES at the site, thereby potentially contributing to achieving the sites identified REC – should the REC be better than the identified PES of the macroinvertebrates assemblage. This note applies to all macroinvertebrate EcoSpecs and TPC tables throughout the report.*

Table 4-13: EcoSpecs identified for UO_EWR02_I: Sterkspruit

UO_EWR02_I: Sterkspruit								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C/D	30.7	25.2	0.016	0.05	4.712	15.33	11.814	38.43
Final flood requirements								

Class 1	m^3/s	4
	# days	4
	Type	Average
	Months	Nov, Dec, Feb, Apr
Class 2	m^3/s	10
	# days	**3**
	Type	Average
	Months	Jan, Feb
Class 3	m^3/s	15
	# days	2
	Type	Peak
	Months	Mar

UO_EWR02_I: Sterkspruit		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	D or higher	E or lower
Channel pattern	Single wandering channel	Braided or incised straight channel
Channel width	Macro channel of ~30 m wide	Macro channel width of <20 m or >40 m
Median particle size of riffle/rapid	Coarse gravels (29 mm)	Loss of gravels with cobble becoming dominant, or sand dominating the riffle habitat
Extent of bank erosion	20%	>50%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 5%. Indigenous non-woody vegetation cover maintained between 20 – 60%.	Indigenous woody vegetation cover increases above 5%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the marginal zone, dominated by *Cyperus marginatus* and a scattered presence of *Gomphostigma virgatum*.	Diversity of indigenous species within the marginal zone decreases below 10 species, with *Cyperus marginatus* not dominant and *Gomphostigma virgatum* absent.

UO_EWR02_I: Sterkspruit			
Lower riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 80%.		Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, dominated by *Cynodon dactylon*.		Diversity of indigenous species within the lower zone decreases below 10 species,
Upper riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 80%.		Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone.		Diversity of indigenous species within the upper zone decreases below 10 species.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites (FROC = 4)	Present at <50% of sites (FROC ≤3)

UO_EWR02_I: Sterkspruit			
Fish habitats and cover features		Fast-shallow velocity-depth class present in moderate abundance (3)	Fast-shallow class sparse or rare (≤2)
Substrate	Substrate within reach	Maintenance of riffle/rapid substate	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 49.4% (Category D). The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 109 with an ASPT of 5.7. Total SASS5 score should remain >115, with ASPT value >5.8. REC: SASS5 score ≥130, with ASPT value > 6.0.	PES: SASS5 scores <100 and ASPT <5.5. REC: SASS5 scores < 140, ASPT < 6.5.
Diversity of invertebrate community	-	PES: 19 families were collected during both surveys. Of these, 3 scored ≥ 10 sensitivity. More than 19 different families (taxa) should be present, with at least 4 of	PES: Less than 15 taxa collected. Less than 2 taxa with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D.

UO_EWR02_I: Sterkspruit			
		these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 25 families should occur at an abundance of A to B, which should include expected taxa with a high FROC, which were not recorded namely Leptophlebiidae and Hydropsychidae >2spp in ≥A abundances.	REC: Less than 23 families, with less than two taxa scoring ≥ 10. Taxon namely Leptophlebiidae and Hydropsychidae >2spp not recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The small cobbles area downstream, upstream and along the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples.	Perlidae absent in one of two consecutive samples.

UO_EWR02_I: Sterkspruit			
		Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s – 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys.

UO_EWR02_I: Sterkspruit			
		Flows should be adequate to ensure suitable habitats for these flow dependent taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 12.1 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality	

Table 4-14: EcoSpecs identified for UO_EWR03_I: Upper Orange

UO_EWR03_I: Upper Orange								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
D	4 259.5	3 456.3	206.669	4.85	554.061	13.01	1 067.45	25.06
Final flood requirements								

Class 1	m³/s	200
	# days	5
	Months	Oct-Dec, Mar, Apr
	Type	Average
Class 2	m³/s	400
	# days	3
	Months	Jan, Mar
	Type	Average
Class 3	m³/s	800
	# days	6
	Months	Feb
	Type	Peak

UO_EWR03_I: Upper Orange		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C or higher	D or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	~ 120 m wide macro channel	Macro channel >140 m or <100 m
Median particle size of riffle/rapid	Sand	If the bed is dominated by silt or gravel/cobble
Extent of bank erosion	40%	>60%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 40% for entire riparian zone.	Alien species cover increases above 40% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 5 - 20%. Indigenous non-woody vegetation cover maintained between 10 – 50%.	Indigenous woody vegetation cover decreases below 5% or increases above 20%. Indigenous non-woody vegetation cover decreases below 10% or increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		

UO_EWR03_I: Upper Orange			
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 60%.		Indigenous woody vegetation cover decreases below 10% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the lower zone, with a mix of woody and non-woody species (including a small proportion of terrestrial species).		Diversity of indigenous species within the lower zone decreases below 5 species and dominated by either woody or non-woody vegetation.
Upper riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained between 50 - 80%, with terrestrial species making up to 60% of the cover. Indigenous non-woody vegetation cover maintained between 10 – 30%.		Indigenous woody vegetation cover decreases below 50% or increases above 80%, with terrestrial species cover increasing above 60%. Indigenous non-woody vegetation cover decreases below 10% or increases above 30%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the upper zone, dominated by terrestrial woody species.		Diversity of indigenous species within the upper zone decreases below 5 species.
Vegetation cover	Indigenous woody vegetation cover maintained between 50 - 80%, with terrestrial species making up to 60% of the cover. Indigenous non-woody vegetation cover maintained between 10 – 30%.		Indigenous woody vegetation cover decreases below 50% or increases above 80%, with terrestrial species cover increasing above 60%. Indigenous non-woody vegetation cover decreases below 10% or increases above 30%.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)

UO_EWR03_I: Upper Orange			
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Absent from all sites during summer
	Labeo capensis	Present at most sites during summer (FROC = 4)	Absent from all sites during summer
Fish habitats and cover features	Fast-deep Slow-deep Undercut Banks	Maintenance of fast-deep and slow-deep habitats with undercut banks	Loss of undercut banks as a cover feature
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 60.5% (Category C/D). The MIRAI score to be maintained between >58 - ≤62%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤57%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 46 with an ASPT of 4.6. Total SASS5 score should remain >60, with ASPT value >5.0.	PES: SASS5 scores <40 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 10 families were collected during the field survey. Of these, no taxa scored ≥ 10 sensitivity. More than 10 different families (taxa) should be present, with at least 2 of these scoring ≥ 7, and at an abundance of A to B. Most indicators selected were not recorded but expected with high FROCs. Thus at least 2 of those expected should be recorded.	PES: Less than 10 taxa collected. Less than 2 taxa scoring ≥ 7. None of the indicator taxon recorded, especially Caenidae. Any taxon (adults) with an abundance of D.

UO_EWR03_I: Upper Orange			
Physical habitat quality	Biotopes and quality	Visual: Moderate turbidity, although when water levels are lower, the clarity should increase. Moderate levels of silt.	Increase in sediment deposition, highly turbid conditions within the water column.
Physical habitat diversity	Biotopes and diversity	GSM (including pockets of gravel) and marginal vegetation should be available to sample.	A reduction in pockets of gravel and lack of inundated marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	*Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
	*Baetidae 2spp	Baetidae >2 spp present in ≥A abundances	Baetidae 2 spp or less in two consecutive samples.

UO_EWR03_I: Upper Orange			
		Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	*Gomphidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 9.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality	

Table 4-15: EcoSpecs identified for UO_EWR04_I: Lower Caledon

UO_EWR04_I: Lower Caledon								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C/D	1 353.6	1 109.8	36.860	2.72	203.857	15.06	398.387	29.43

Final flood requirements

Class 1	m^3/s	40
	# days	5
	Months	Oct-Dec, Mar, Apr
	Type	Average
Class 2	m^3/s	65
	# days	5
	Months	Nov, Dec, Jan, Mar
	Type	Average
Class 3	m^3/s	110
	# days	4
	Months	Jan, Feb, Mar
	Type	Average

UO_EWR04_I: Lower Caledon		
Class 4	m^3/s	160
	# days	7
	Months	Feb
	Type	Peak

Metric	EcoSpec	TPC
Geomorphology		
GAI level IV	C or higher	D or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	Macro channel of ~70 m	Macro channel of <50 m or >90 m
Median particle size of riffle/rapid	Very coarse gravels (42 mm)	If the mobile sediment at the riffle changes to sand/silt or only cobble and boulder
Extent of bank erosion	~ 30%	>50%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 20% for entire riparian zone.	Alien species cover increases above 20% for entire riparian zone.
Marginal zone		

UO_EWR04_I: Lower Caledon		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 10 – 40%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 10% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 15 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 10 – 60%.	Indigenous woody vegetation cover decreases below 15% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 10% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody and non-woody species (including a small proportion of terrestrial species).	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 20 - 50%, with terrestrial species making up to 30% of the cover. Indigenous non-woody vegetation cover maintained between 30 – 60%.	Indigenous woody vegetation cover decreases below 20% or increases above 50%, with terrestrial species cover increasing above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by grasses and terrestrial woody species.	Diversity of indigenous species within the upper zone decreases below 10 species.
Fish		

UO_EWR04_I: Lower Caledon			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤3)
	Labeo capensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 46.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤41% REC: MIRAI ≤57%

UO_EWR04_I: Lower Caledon			
		REC: MIRAI ≥59%	
SASS5 and ASPT Score	-	PES: The SASS5 score was 43 with an ASPT of 4.8. Total SASS5 score should remain >60, with ASPT value >5.2. REC: SASS5 score ≥100, with ASPT value > 5.8.	PES: SASS5 scores <40 and ASPT <4.2. REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 9 families were collected during both surveys. Of these, 1 scored ≥ 9 sensitivity. More than 9 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 14 families should occur at an abundance of A to B, which should include 2 or more expected indicator taxa in ≥A abundances.	PES: Less than 8 taxa collected. No taxa scoring ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 14 families, with less than 2 taxa scoring ≥ 10. None of the expected indicator taxon recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The small artificial cobble area located just downstream of the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated	Marginal vegetation is exposed (no wetted stems).

UO_EWR04_I: Lower Caledon			
		marginal vegetation, excluding aquatic vegetation).	
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for	Aeshnidae absent in one of two consecutive samples.

UO_EWR04_I: Lower Caledon			
		this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	*Baetidae 2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Gomphidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two

UO_EWR04_I: Lower Caledon			
			consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 9.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality	

Table 4-16: EcoSpecs identified for UO_EWR05_I: Seekoei

UO_EWR05_I: Seekoei								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C	24.279	18.397	0	0	1.043	4.30	8.301	34.19
Final flood requirements								

Class 1	m^3/s	5
	# days	2
	Months	Oct-Jan, Apr, May
	Type	Average
Class 2	m^3/s	10
	# days	2
	Months	Feb
	Type	Average
Class 3	m^3/s	20
	# days	2
	Months	Mar
	Type	Peak

UO_EWR05_I: Seekoei		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C or higher	D or lower
Channel pattern	Straight to wandering channel	Braided channel
Channel width	Macro channel of ~50 m	<40 m or >65 m
Median particle size of riffle/rapid	Coarse gravels (20 mm)	If the riffle habitat has no gravels and cobbles (bedrock only), or when the riffle habitat is largely sand and silt
Extent of bank erosion	15%	>40%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 70%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		

UO_EWR05_I: Seekoei			
Vegetation cover	Indigenous woody vegetation cover maintained between 20 - 40%, with terrestrial species making up less than 20% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 40%.		Indigenous woody vegetation cover decreases below 20% or increases above 40%, with terrestrial species cover increasing above 20%. Indigenous non-woody vegetation cover decreases below 20% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with *Phragmites australis* dominating.		Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained between 30 - 60%, with terrestrial species making up to 50% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 40%.		Indigenous woody vegetation cover decreases below 30% or increases above 60%, with terrestrial species cover increasing above 50%. Indigenous non-woody vegetation cover decreases below 20% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by terrestrial woody species and low shrubs.		Diversity of indigenous species within the upper zone decreases below 10 species.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Present at <50% of sites during the summer (FROC ≤3)
	Labeo capensis	Present at most sites during summer (FROC = 4)	Present at <50% of sites during the summer (FROC ≤3)

UO_EWR05_I: Seekoei			
Velocity-depth class	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 67.2% (Category C). The MIRAI score to be maintained between >65 - ≤78%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 138 with an ASPT of 4.6. Total SASS5 score should remain >138, with ASPT value >4.8.	PES: SASS5 scores ≤61 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 30 families were collected during the field survey. Of these, 1 taxon scored ≥ 10 sensitivity. More than 30 families (taxa) should be present, with at least 2 of these scoring ≥ 10, and at an abundance of A to B. Some of the indicators selected were not recorded but expected with high FROCs. Thus at least 2 of those expected should be recorded.	PES: Less than 25 taxa collected. Less than 2 taxa scoring ≥ 9. None of the indicator taxon recorded, especially Baetidae >2spp and Hydraenidae. Any taxon (adults) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: Inundated marginal vegetation and bedrock should be available to sample.	Bedrock with extensive algae cover. Lack of inundated marginal vegetation.

UO_EWR05_I: Seekoei			
Physical habitat diversity	Biotopes and diversity	Bedrock is the dominating SASS5 biotope, with good marginal and instream aquatic vegetation which should remain.	Marginal vegetation is exposed (no wetted stems). Limited to no aquatic vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The surface of the bedrock should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae 2spp	Baetidae >2 spp present in ≥A abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR05_I: Seekoei			
	*Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s, water quality deterioration and SIC become exposed.
	*Atyidae	Atyidae present in ≥B abundances. Maintain moderate water quality and ensure the marginal vegetation is inundated.	Atyidae absent (or individuals only) on two or more consecutive surveys Water quality deterioration and marginal vegetation and stems become exposed.
	Hydraenidae	Hydraenidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Hydraenidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s, water quality deterioration and SIC, vegetation/stems become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

UO_EWR05_I: Seekoei		
Diatoms (used as a response to water quality)		
Diatoms	SPI Score: 12.4 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

Table 4-17: EcoSpecs identified for UO_EWR06_I: Upper Riet

UO_EWR06_I: Upper Riet								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C	105.2	76.2	0.078	0.07	8.721	8.29	32.671	31.05
Final flood requirements								

Class 1	m^3/s	15
	# days	5
	Months	Nov, Dec, Jan, Apr
	Type	Average
Class 2	m^3/s	25
	# days	3
	Months	Feb
	Type	Average
Class 3	m^3/s	50
	# days	3
	Months	Mar
	Type	Peak

UO_EWR06_I: Upper Riet		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C or higher	D or lower
Channel pattern	Wandering high flow and braided at low flows	Braided at high flows or wandering at low flows
Channel width	Macro channel of ~40 m	<30 m or >50 m
Median particle size of riffle/rapid	Coarse gravels (28 mm)	Loss of gravels with the riffle being dominated by sand or by cobble and boulders only
Extent of bank erosion	~ 15%	Bank erosion along 40% of the bank length
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained above 70%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Schoenoplectus brachyceras* and *Miscanthus junceus*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		

UO_EWR06_I: Upper Riet			
Vegetation cover	Indigenous woody vegetation cover maintained below 15%. Indigenous non-woody vegetation cover maintained above 70%.		Indigenous woody vegetation cover increases above 15%. Indigenous non-woody vegetation cover decreases below 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with *Cynodon dactylon* dominating.		Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone			
Vegetation cover	Indigenous woody vegetation cover maintained below 25%. Indigenous non-woody vegetation cover maintained above 60%.		Indigenous woody vegetation cover increases above 25%. Indigenous non-woody vegetation cover decreases below 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of grasses and terrestrial woody species.		Diversity of indigenous species within the upper zone decreases below 10 species.
Fish			
Metric	**Indicator**[2]	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)
	Labeo capensis	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)

UO_EWR06_I: Upper Riet			
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate within reach	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 62.0% (Category C). The MIRAI score to be maintained between >63 - ≤78%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 125 with an ASPT of 5.0. Total SASS5 score should remain >130, with ASPT value >5.2.	PES: SASS5 scores ≤90 and ASPT <4.5.
Diversity of invertebrate community	-	PES: 25 families were collected during the field survey. Of these, 1 taxa scored ≥ 10 sensitivity. More than 25 different families (taxa) should be present, with at least 2 of	PES: Less than 20 taxa collected. Less than 2 taxa scoring ≥ 9. None of the indicator taxon recorded (barring Atyidae and Aeshnidae). Any taxon (adults) with an abundance of D.

UO_EWR06_I: Upper Riet			
		these scoring ≥ 10, and at an abundance of A to B. Some of the indicators selected were not recorded but expected with high FROCs. Thus atleast 1 of those expected should be recorded.	
Physical habitat quality	Biotopes and quality	Visual: The small to large cobble area located downstream of the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation. Loss of pockets of gravel along the cross-section.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp. present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

UO_EWR06_I: Upper Riet			
		a depth of 15cm and covered and/or GSM and marginal vegetation.	
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Atyidae	Atyidae present in ≥B abundances. Maintain moderate water quality and ensure the marginal vegetation is inundated.	Atyidae absent (or individuals only) on two or more consecutive surveys Water quality deterioration and marginal vegetation and stems become exposed.
	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	Hydraenidae	Hydraenidae present in ≥A abundances, in at least one of two consecutive survey samples.	Hydraenidae absent in one of two consecutive samples.

UO_EWR06_I: Upper Riet			
		Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC, vegetation/stems become exposed.
	Gomphidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Caenidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 19.3 Category (A): High water quality	SPI Score: <16.7 Category B: Good water quality	

Table 4-18: EcoSpecs identified for UO_EWR07_I: Upper Modder

UO_EWR07_I: Upper Modder								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C	61.0	40.0	2.313	3.79	9.156	15.02	21.909	35.94
Final flood requirements								

Class 1	m^3/s	4
	# days	3
	Months	Nov, Dec, Jan, Mar, Apr
	Type	Average
Class 2	m^3/s	16
	# days	3
	Months	Jan, Mar
	Type	Average
Class 3	m^3/s	30
	# days	3
	Months	Feb
	Type	Peak

UO_EWR07_I: Upper Modder		
Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	D or higher	E or lower
Channel pattern	Straight to wandering	Braided channel pattern
Channel width	~ 20 m wide macro channel away from the engineered sections	Macro channel width of < 15m or > 30m
Median particle size of riffle/rapid	Medium gravels (12 mm)	If there is a loss of gravels, with the riffle consisting of cobble and boulder, or sand and silt only
Extent of bank erosion	~ 30%	> 50%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 30% for entire riparian zone.	Alien species cover increases above 30% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 30%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, which comprises a mix of grasses and sedges.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		

<table>
<tr><th colspan="4">UO_EWR07_I: Upper Modder</th></tr>
<tr><td>Vegetation cover</td><td colspan="2">Indigenous woody vegetation cover maintained below 40%. Indigenous non-woody vegetation cover maintained between 30 - 70%.</td><td>Indigenous woody vegetation cover increases above 40%.
Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.</td></tr>
<tr><td>Species richness and composition.</td><td colspan="2">Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with Cynodon dactylon dominating.</td><td>Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.</td></tr>
<tr><td colspan="4">Upper riparian zone</td></tr>
<tr><td>Vegetation cover</td><td colspan="2">Indigenous woody vegetation cover maintained below 30%. Indigenous non-woody vegetation cover maintained between 30 - 70%.</td><td>Indigenous woody vegetation cover increases above 30%.
Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.</td></tr>
<tr><td>Species richness and composition.</td><td colspan="2">Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with grasses dominating.</td><td>Diversity of indigenous species within the upper zone decreases below 10 species.</td></tr>
<tr><th colspan="4">Fish</th></tr>
<tr><th>Metric</th><th>Indicator[2]</th><th>EcoSpec</th><th>TPC (biotic)</th></tr>
<tr><td>FRAI score and category</td><td>PES</td><td>FRAI Score: >62% (Ecological Category C).</td><td>FRAI Score: <62% (Ecological Category C/D)</td></tr>
<tr><td rowspan="2">Indicator fish species and presence</td><td>Labeobarbus aeneus</td><td>Present at most sites during summer (FROC = 4)</td><td>Present at <50% of sites (FROC ≤3)</td></tr>
<tr><td>Labeo capensis</td><td>Present at about 25% to 50% of sites during summer (FROC = 3)</td><td>Present at <25% of sites (FROC ≤2)</td></tr>
<tr><th colspan="4">Macroinvertebrates</th></tr>
</table>

UO_EWR07_I: Upper Modder			
MIRAI Score and category	-	MIRAI score: 50.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥63%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 63 with an ASPT of 4.5. Total SASS5 score should remain >80, with ASPT value >5.0. REC: SASS5 score ≥130, with ASPT value > 6.0.	PES: SASS5 scores <60 and ASPT <4.0. REC: SASS5 scores < 140, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 14 families were collected during both surveys. Of these, 1 scored ≥ 10 sensitivity. More than 14 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 20 families should occur at an abundance of A to B, which should include expected taxa with a high FROC, which were not recorded namely Hydropsychidae >2spp, Trichorythidae and Caenidae in ≥A abundances.	PES: Less than 10 taxa collected. Less than 1 taxa scoring ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 18 families, with less than 2 taxa scoring ≥ 10. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.

UO_EWR07_I: Upper Modder			
Physical habitat quality	Biotopes and quality	Visual: The small to large cobble area located along the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample. Bedrock habitat available downstream of the cross-section.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation. Loss of pockets of gravel along the cross-section.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour, solid waste).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances.	Hydropsychidae 2 spp or less in two consecutive samples.

UO_EWR07_I: Upper Modder			
		Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Ecnomidae	Ecnomidae present in A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC are at a depth of 15cm and covered.	Ecnomidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.

UO_EWR07_I: Upper Modder			
Alien invasive macroinvertebrates and/or outbreak abundances	Chironomidae	Chironomidae present in ≤ B abundances. Chironomidae have a wide range of preferences and thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 5.6 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality	

Table 4-19: EcoSpecs identified for UO_EWR08_I: Lower Kraai

UO_EWR08_I: Lower Kraai								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
B/C	719.0	675.3	40.997	5.70	200.869	27.94	334.513	46.52
Final flood requirements								

Class 1	m^3/s	30
	# days	4
	Months	Oct, Nov, Dec, Jan, Apr
	Type	Average
Class 2	m^3/s	75
	# days	4
	Months	Jan, Feb, Apr
	Type	Average
Class 3	m^3/s	100
	# days	4
	Months	Feb
	Type	Average

UO_EWR08_I: Lower Kraai			
Class 4	m^3/s	250	
	# days	5	
	Months	Mar	
	Type	Peak	

Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C or higher	D or lower
Channel pattern	Wandering channel (alternating bars)	Braided (overwhelmed with sediment) or straight channel (loss of mobile sediment)
Channel width	100 m wide macro channel (away from engineered works)	Macro channel < 80 m or more than 120 m
Median particle size of riffle/rapid	Coarse gravels (30 mm)	Loss of gravels, with sand or cobble dominating the riffle habitat
Extent of bank erosion	~ 25%	More than 40% of banks eroding
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 30% for entire riparian zone.	Alien species cover increases above 30% for entire riparian zone.
Marginal zone		

UO_EWR08_I: Lower Kraai		
Vegetation cover	Indigenous woody vegetation cover maintained below 20%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Cyperus marginatus*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody and non-woody (*Cynodon dactylon* dominating) vegetation.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 20% of the cover. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 20%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of grasses and woody vegetation.	Diversity of indigenous species within the upper zone decreases below 10 species.

UO_EWR08_I: Lower Kraai			
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤4)
	Labeobarbus kimberleyensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites during summer (FROC ≤2)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 65.3% (Category C). The MIRAI score to be maintained as a mid-C in the range >65 – 72%, using the	PES: MIRAI ≤61%

UO_EWR08_I: Lower Kraai			
		reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	REC: MIRAI ≤78%
SASS5 and ASPT Score	-	PES: The SASS5 score was 157 with an ASPT of 6.3. Total SASS5 score should remain >160, with ASPT value >6.5. REC: SASS5 score ≥180, with ASPT value > 6.8.	PES: SASS5 scores <120 and ASPT <6.0. REC: SASS5 scores < 180, ASPT < 6.8.
Diversity of invertebrate community	-	PES: 25 families were collected during both surveys. Of these, 3 scored ≥ 10 sensitivity. More than 25 different families (taxa) should be present, with at least 4 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, with all indicator taxa recorded in ≥A abundances.	PES: Less than 20 taxa collected. Less than 1 taxa scoring ≥ 10. Some of the indicator taxon are not recorded. Any taxon (adults) with an abundance of D. REC: Less than 25 families, with less than 4 taxa scoring ≥ 10. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area upstream, from the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.

UO_EWR08_I: Lower Kraai			
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s, for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week,and biotopes become exposed.

UO_EWR08_I: Lower Kraai			
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All taxa with a preference for very low water quality are within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 13.8 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality	

Table 4-20: EcoSpecs identified for UO_EWR09_I: Lower Riet

UO_EWR09_I: Lower Riet								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
B/C	373.8	214.4	0.544	0.15	54.274	14.52	89.974	24.07
Final flood requirements								

Class 1	m^3/s	4
	# days	4
	Months	Nov, Dec, Jan, Feb, Mar, Apr
	Type	Average
Class 2	m^3/s	25
	# days	7
	Months	Nov, Dec, Jan, Feb, Mar
	Type	Average

Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C or higher	D or lower

UO_EWR09_I: Lower Riet		
Channel pattern	Wandering to anastomosing	Braided channel (overwhelmed with bed sediment)
Channel width	Macro channel width of ~100 m	Macro channel width of <80 m or more than 120 m
Median particle size of riffle/rapid	Not measured, but likely to be gravel	If gravels are no longer present at the riffles, with sand or only cobble/boulder/bedrock dominating the faster flow areas
Extent of bank erosion	~10% (low due to bedrock nature of reach)	Bank erosion of > 30%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 13% for entire riparian zone.
Marginal zone		
Vegetation cover	Maintain marginal vegetation component that is dominated by reeds covering less than 60%.	Reed vegetation increases above 60%. Woody vegetation cover increases above 20%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Maintain mix of woody and non-woody riparian species with small (<10%) cover of terrestrial woody species.	Woody vegetation cover increases above 40% with terrestrial species increasing above 10%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of indigenous grasses, shrubs and trees.	Diversity of indigenous species within the lower zone decreases below 10 species.

UO_EWR09_I: Lower Riet		
Upper riparian zone		
Vegetation cover	Maintain mix of riparian and terrestrial species.	Proportion of terrestrial woody species increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of indigenous grasses, shrubs and trees.	Diversity of indigenous species within the upper zone decreases below 10 species.

Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus kimberleyensis*	Present at about 50% of sites assessed during summer (FROC = 3)	Present at <50% of sites during summer
	Labeobarbus aeneus	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)
	Austroglanis sclateri	Present at about 50% of sites assessed during summer (FROC = 3)	Present at <50% of sites during summer
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class

UO_EWR09_I: Lower Riet			
	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach during winter low-flow period	Reduced suitability and./or abundance of slow-deep velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate within reach	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: >62 - ≤78 (Category C) The MIRAI score to be maintained as a C in the range >62 - ≤78%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤61% REC: MIRAI ≤78%
SASS5 and ASPT Score	-	PES: The SASS5 score should remain >150, with ASPT value >6.2. REC: SASS5 score ≥180, with ASPT value > 6.8.	PES: SASS5 scores <120 and ASPT <6.0. REC: SASS5 scores < 180, ASPT < 6.8.
Diversity of invertebrate community	-	PES: More than 25 different families (taxa) should be present, with at least 3 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present.	PES: Less than 20 taxa collected. Less than 1 taxa scoring ≥ 10. Some of the indicator taxon are not recorded. Any taxon (adults) with an abundance of D.

UO_EWR09_I: Lower Riet			
		REC: More than 28 families should occur at an abundance of A to B, with all indicator taxa recorded in ≥A abundances.	REC: Less than 25 families, with less than 3 taxa scoring ≥ 10. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances	Baetidae 2 spp or less in two consecutive samples.

UO_EWR09_I: Lower Riet			
		Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s, for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two

UO_EWR09_I: Lower Riet			
			consecutive surveys, must be raised immediate with DWS.

Table 4-21: EcoSpecs identified for UO_EWR10_I: Lower Orange

UO_EWR10_I: Lower Orange								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**pMAR[3] (MCM)**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C	6 674.2	3 283.8	366.113	5.49	1 047.52	15.69	1 427.81	21.39
Final flood requirements								

Class 1	m³/s	65
	# days	3
	Months	Oct-Jan, Apr
	Type	Average
Class 2	m³/s	100
	# days	3
	Months	Mar, Apr, May
	Type	Average
Class 3	m³/s	155
	# days	3
	Months	Nov, Dec, Jan
	Type	Average

UO_EWR10_I: Lower Orange		
Class 4	m³/s	229
	# days	3
	Months	Feb, Mar
	Type	Average
Class 5	m³/s	550
	# days	7
	Months	Feb
	Type	Peak

Metric	**EcoSpec**	**TPC**
Geomorphology		
GAI level IV	C/D or higher	D or lower
Channel pattern	Wandering (higher flows) to braided (during low baseflow)	Braided channel during higher flows
Channel width	Macro channel of ~ 180 m wide	Macro channel of <150 m or >220 m wide
Median particle size of riffle/rapid	Not measured, but likely to be gravel	Loss of gravels, with riffle habitat being dominated by sand or large immobile coble and boulders
Extent of bank erosion	~ 25%	> 50%
Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.

UO_EWR10_I: Lower Orange		
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody (dominated by *Salix mucronata*) and non-woody (dominated by *Cynodon dactylon* and *Phragmites australis*).	Diversity of indigenous species within the lower zone decreases below 10 species.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 60 - 80%.	Indigenous woody vegetation cover decreases below 60% or increases above 80%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by woody vegetation.	Diversity of indigenous species within the upper zone decreases below 10 species.
Fish		

UO_EWR10_I: Lower Orange			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >78% (Ecological Category B/C).	FRAI Score: <78% (Ecological Category C)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤3)
	Labeobarbus kimberleyensis	Present at about 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)
	Labeo capensis	Present at <75% of sites (FROC ≤4)	Present at <75% of sites (FROC ≤4)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of slow-deep velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 50.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >50 – 55%, using	PES: MIRAI ≤41%

UO_EWR10_I: Lower Orange			
		the reference data used in this study, or recording alterations to these. REC: MIRAI ≥63%	REC: MIRAI ≤61%
SASS5 and ASPT Score	-	PES: The SASS5 score was 51 with an ASPT of 6.4. Total SASS5 score should remain >65, with ASPT value >6.5. REC: SASS5 score ≥120, with ASPT value > 6.8.	PES: SASS5 scores <50 and ASPT <5.0. REC: SASS5 scores < 140, ASPT < 6.5.
Diversity of invertebrate community	-	PES: 8 families were collected during both surveys. Of these, 1 scored ≥ 9 sensitivity. More than 10 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 18 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely Baetidae >2spp in ≥A abundances.	PES: Less than 8 taxa collected. No recorded taxa scoring ≥ 9 sensitivity. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 18 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area far downstream from the cross-section should comprise movable cobbles.	Immobile cobbles with extensive algae and fine silt cover. Increased sediment deposition along banks, lack of marginal vegetation regrowth and/or lack of

UO_EWR10_I: Lower Orange			
		Inundated marginal vegetation and GSM should be available to sample.	inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems) and/or no marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week and biotopes become exposed.

UO_EWR10_I: Lower Orange			
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 7.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality	

Table 4-22: EcoSpecs identified for UO_EWR01_R: Little Caledon

UO_EWR01_R: Little Caledon								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**	
B/C	25.9	1.919	7.41	5.981	23.09	10.154	39.20	
Final freshet requirements								

Months	Freshets*			
	m³/s	days	m³/s	days
October	6	2		
November	5	2	10	3
December	14	3		
January	34	3		
February	45	4		
March	34	4	14	3
April	5	2		

UO_EWR01_R: Little Caledon		
Metric	**EcoSpec**	**TPC**
Habitat Integrity for instream and riparian		
Habitat integrity: Instream score and category	IHI: Instream score: 85% (B)	IHI: Instream score: ≤81% Further increase in algae growth
Habitat integrity: riparian score and category	IHI: Riparian score: 85% (B)	IHI: Riparian score: ≤81% Increase in bank erosion

Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Enteromius oraniensis*	Present at about 25% to 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Labeobarbus aeneus	Present at less than 10% of sites during summer (FROC = 1)	Absent at all sites
Velocity-depth class	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates,

UO_EWR01_R: Little Caledon			
			excessive algal growth on substrates
Non-native fish species	Any non-native fish species	No non-native fish species present	Any non-native fish species
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 57.7% (Category D). The MIRAI score to be maintained at the top end of a D in the range >56 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤41% REC: MIRAI ≤77%
SASS5 and ASPT Score	-	PES: The SASS5 score was 130 with an ASPT of 5.4. Total SASS5 score should remain >130, with ASPT value >5.5. REC: SASS5 score ≥140, with ASPT value > 6.8.	PES: SASS5 scores <100 and ASPT <4.8. REC: SASS5 scores < 170, ASPT < 6.7.
Diversity of invertebrate community	-	PES: 24 families were collected during both surveys. Of these, 3 scored ≥ 9 sensitivity. More than 24 different families (taxa) should be present, with at least 3 of these scoring ≥ 9, and at an abundance	PES: Less than 20 taxa collected. Only 1 or less taxa scoring ≥ 9 sensitivity. Some of the indicator taxon recorded (barring Hydropsychidae>2spp). Any taxon (adults) with an abundance of D (i.e. Simuliidae).

UO_EWR01_R: Little Caledon			
		of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely Hydropsychidae >2spp in ≥A abundances.	REC: Less than 28 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon (Hydropsychidae >2spp). Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area along the cross section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Water levels lowered over the causeway resulting in pooling upstream, and thus impacted flow moving downstream.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems) and/or no marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

UO_EWR01_R: Little Caledon			
		0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	
	*Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s, water quality deterioration and SIC become exposed.

UO_EWR01_R: Little Caledon			
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s, water quality deterioration and marginal vegetation become exposed.
	Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Chironomidae	Chironomidae present in ≤ B abundances. Chironomidae have a wide range of preferences and thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.

UO_EWR01_R: Little Caledon			
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 7.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality	

Table 4-23: EcoSpecs identified for UO_EWR02_R: Brandwater

UO_EWR02_R: Brandwater								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**	
B/C	56.0	2.001	3.57	11.846	21.16	17.325	30.95	
Final freshet requirements								

Months	Freshets*			
	m³/s	days	m³/s	days
October	1.3	2		
November	1.5	5		
December	1.5	5		
January	1.5	5	10	2
February	1.5	5	10	2
March	1.5	5	10	2
April	1.3	2		

UO_EWR02_R: Brandwater			
Metric	**EcoSpec**		**TPC**
Habitat Integrity for instream and riparian			
Habitat integrity: Instream score and category	IHI: Instream score: 75% (C)		IHI: Instream score: ≤61% Further increase in algae growth
Habitat integrity: riparian score and category	IHI: Riparian score: 80% (B/C)		IHI: Riparian score: ≤77%
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 57.1% (Category D). The MIRAI score to be maintained at the top end of a D in the range >56 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤41% REC: MIRAI ≤77%
SASS5 and ASPT Score	-	PES: The SASS5 score was 34 with an ASPT of 4.3 from the survey. Total	PES: SASS5 scores <30 and ASPT <3.8.

UO_EWR02_R: Brandwater			
		SASS5 score should remain >50, with ASPT value >4.8. REC: SASS5 score ≥120, with ASPT value > 6.0.	REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 8 families were collected during both surveys. Of these, 3 scored ≥ 9 sensitivity. More than 8 different families (taxa) should be present, with at least 3 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely Hydropsychidae >2spp in ≥A abundances.	PES: Less than 20 taxa collected. Only 1 or less taxa scoring ≥ 9 sensitivity. Some of the indicator taxon recorded (barring Hydropsychidae>2spp). Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 28 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon (Hydropsychidae >2spp). Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area along the cross section should comprise movable cobbles. GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Increase in steep bank erosion along both left and right banks.
Physical habitat diversity	Biotopes and diversity	The only SASS5 biotopes available to sample are (i.e. SIC, SOOC and GSM)	The loss of the small pocket of SIC and SOOC owing to increase sediment inputs from bank erosion covering the biotopes.

UO_EWR02_R: Brandwater			
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys.

UO_EWR02_R: Brandwater			
		dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 9.0 Category (C/D): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality	

Table 4-24: EcoSpecs identified for UO_EWR03_R: Mopeli

UO_EWR03_R: Mopeli								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**	
C/D	49.35	0.945	1.91	8.962	18.16	14.483	29.34	
Final freshet requirement								

Months	**Freshets***			
	m^3/s	**days**	**m^3/s**	**days**
October	1.5	2		
November	3.0	2		
December	3.0	2		
January	3.0	2	10	3
February	3.0	2	10	3
March	3.0	2	10	3
April	1.5	2		

UO_EWR03_R: Mopeli			
Metric	**EcoSpec**		**TPC**
Habitat Integrity for instream and riparian			
Habitat integrity: Instream score and category	IHI: Instream score: 71% (C)		IHI: Instream score: ≤61% Further increase in algae growth Log jam at the bridge not removed which is impeding on hydraulics and scouring of the river.
Habitat integrity: riparian score and category	IHI: Riparian score: 72% (C)		IHI: Riparian score: ≤61% Further increase in bank erosion and new growth of alien invasive plants.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Macroinvertebrates			
Macroinvertebrates were not assigned EcoSpecs and TPCs at this location due to its unsuitability for such organisms. The site is characterised by bedrock dominance, significant steep banks with erosion on the right bank, and substantial sediment deposition on the left bank. Consequently, there is a lack of marginal vegetation and suitable habitat for macroinvertebrates. The macroinvertebrate PES was influenced by water quality, but the site may prove more useful for ecological assessment from a diatom and IHI perspective			
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 10.7		SPI Score: <8.8

UO_EWR03_R: Mopeli		
	Category (C): Moderate water quality	Category D: Poor water quality

Table 4-25: EcoSpecs identified for UO_EWR04_I: Upper Kraai

UO_EWR04_R: Upper Kraai								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**	
B	200.93	9.082	4.52	64.438	32.07	80.456	40.04	
Final freshet requirement								

Months	**Freshets***			
	m³/s	**days**	**m³/s**	**days**
October	7.0	2		
November	7.0	2		
December	10.0	3		
January	10.0	3	20	2
February	10.0	3	20	2
March	10.0	3	20	2
April	7.0	2		

UO_EWR04_R: Upper Kraai			
Metric	**EcoSpec**		**TPC**
Habitat Integrity for instream and riparian			
Habitat integrity: Instream score and category	IHI: Instream score: 90% (A/B)		IHI: Instream score: ≤87%
Habitat integrity: riparian score and category	IHI: Riparian score: 90% (A/B)		IHI: Riparian score: ≤87%
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at about 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Enteromius oraniensis	Present at about 25% to 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class within reach	Maintenance of fast-shallow velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-shallow velocity-depth class

UO_EWR04_R: Upper Kraai			
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 71.6% (Category C). The MIRAI score to be maintained as a mid-C in the range >72 – ≤78%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥83%	PES: MIRAI ≤61% REC: MIRAI ≤81%
SASS5 and ASPT Score	-	PES: The SASS5 score was 94 with an ASPT of 5.5. Total SASS5 score should remain >100, with ASPT value >5.6. REC: SASS5 score ≥130, with ASPT value > 6.2.	PES: SASS5 scores <90 and ASPT <5.0. REC: SASS5 scores < 130, ASPT < 6.2.
Diversity of invertebrate community	-	PES: 17 families were collected during the single survey. Of these, 4 scored ≥ 9 sensitivity. More than 17 different families (taxa) should be present, with at least 5 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present.	PES: Less than 15 taxa collected. No recorded taxa scoring ≥ 9 sensitivity. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D (i.e. Simuliidae).

UO_EWR04_R: Upper Kraai			
		REC: More than 22 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely Hydropschyidae >2spp in ≥A and Elmidae in A abundances.	REC: Less than 22 families, with less than 4 taxa scoring ≥ 9. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The wide range of cobble selection along this reach should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR04_R: Upper Kraai			
		quality and ensure the SIC are at a depth of 15cm and covered.	
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR04_R: Upper Kraai			
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Simuliidae	Simuliidae present in ≤ B abundances.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 16.2 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality	

Table 4-26: EcoSpecs identified for UO_EWR05_R: Wonderboomspruit

UO_EWR05_R: Wonderboomspruit								
Hydrology								
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**	
C/D	25.93	0.365	1.41	4.884	18.84	8.396	32.38	
Final freshet requirement								

Months	**Freshets***			
	m³/s	**days**	**m³/s**	**days**
October			6	2
November	2.5	2		
December	2.5	2		
January	2.5	2		
February	2.5	2		
March	2.5	2	20	3

UO_EWR05_R: Wonderboomspruit				
April			6	2

Metric	EcoSpec		TPC
Habitat Integrity for instream and riparian			
Habitat integrity: Instream score and category	IHI: Instream score: 70% (C)		IHI: Instream score: ≤61% Further increase in algae growth Log jam at the bridge not removed which is impeding on hydraulics and scouring of the river.
Habitat integrity: riparian score and category	IHI: Riparian score: 61% (C/D)		IHI: Riparian score: ≤57% Physical-chemical modifications due to failing WWTW infrastructure and increased macroplastics.
Fish			
Metric	**Indicator[2]**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus umbratus*	Present at about 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Enteromius oraniensis	Present at 50% to 75% of sites (FROC = 4)	Present at <50% of sites (FROC <4)

UO_EWR05_R: Wonderboomspruit			
Velocity-depth class	Slow-shallow velocity-depth class within reach	Maintenance of Slow-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class within reach	Maintenance of fast-shallow velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Cover	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 56.9% (Category D). The MIRAI score to be maintained at the top end of a D in the range >57 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 102 with an ASPT of 5.1. Total SASS5 score should remain >110, with ASPT value >5.2. REC: SASS5 score ≥130, with ASPT value > 5.8.	PES: SASS5 scores <90 and ASPT <4.8. REC: SASS5 scores < 140, ASPT < 6.0.

UO_EWR05_R: Wonderboomspruit			
Diversity of invertebrate community	-	PES: 20 families were collected during both surveys. Of these, 1 scored ≥ 10 sensitivity. More than 20 different families (taxa) should be present, with at least 2 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present (barring the expected but not recorded indicator taxa). REC: More than 23 families should occur at an abundance of A to B, which should include both expected indicator taxa namely Hydropsychidae >2spp and Aeshnidae in ≥A and A abundances respectively.	PES: Less than 18 taxa collected. No taxa scoring ≥ 10. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 23 families, with less than 3 taxa scoring ≥ 10. None of the expected indicator taxon recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The range of cobble selection along this reach should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour and solid waste).

UO_EWR05_R: Wonderboomspruit			
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp. present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR05_R: Wonderboomspruit			
	Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
	Hydraenidae	Hydraenidae present in A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Hydraenidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC, vegetation/stems become exposed.
	*Aeshnidae	Aeshnidae present in A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	Chironomidae Turbellaria	Chironomidae and/or Turbellaria present in ≤ B abundances.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D

UO_EWR05_R: Wonderboomspruit			
Alien invasive macroinvertebrates and/or outbreak abundances		Chironomidae have a wide range of preferences. Indicator taxon thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	(>1000) abundance for more than two consecutive surveys.
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 4.6 Category (E): Seriously modified water quality	Already at lowest EC and high cause for concern.	

Table 4-27: EcoSpecs identified for UO_EWR06_R: Middle Modder

UO_EWR06_R: Middle Modder							
Hydrology							
REC	**nMAR[1] (MCM[2])**	**Drought flows (MCM)**	**Drought (%nMAR)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**Total flows (MCM)**	**Total (%nMAR)**
C/D	113.68	1.798	1.58	23.746	20.89	38.603	33.96

Final freshet requirement

Months	**Freshets***			
	m³/s	**days**	**m³/s**	**days**
October	9.0	3		
November	7.0	5		
December	7.0	5		
January	7.0	5		
February	7.0	5	20	3
March	7.0	5	20	3
April	9.0	3		

<table>
<tr><th colspan="4">UO_EWR06_R: Middle Modder</th></tr>
<tr><th>Metric</th><th colspan="2">EcoSpec</th><th>TPC</th></tr>
<tr><th colspan="4">Habitat Integrity for instream and riparian</th></tr>
<tr><td>Habitat integrity: Instream score and category</td><td colspan="2">IHI: Instream score: 54% (D)</td><td>IHI: Instream score: ≤41%

Further abstraction and irrigation.</td></tr>
<tr><td>Habitat integrity: riparian score and category</td><td colspan="2">IHI: Riparian score: 58% (D)</td><td>IHI: Riparian score: ≤41%

New growth of alien invasive plants.</td></tr>
<tr><th colspan="4">Fish</th></tr>
<tr><th>Metric</th><th>Indicator[2]</th><th>EcoSpec</th><th>TPC (biotic)</th></tr>
<tr><td>FRAI score and category</td><td>PES</td><td>FRAI Score: >42% (Ecological Category D).</td><td>FRAI Score: <42% (Ecological Category D/E)</td></tr>
<tr><td rowspan="2">Indicator fish species and presence</td><td>Labeobarbus aeneus</td><td>Present at about 25% to 50% of sites during summer (FROC = 3)</td><td>Present at <25% of sites (FROC ≤2)</td></tr>
<tr><td>Labeo capensis</td><td>Present at about 50% to 75% of sites during summer (FROC = 4)</td><td>Present at <50% of sites (FROC ≤3)</td></tr>
<tr><td rowspan="2">Velocity-depth class</td><td>Fast-deep velocity-depth class within reach</td><td>Maintenance of fast-deep velocity-depth class within reach during summer high-flow period</td><td>Reduced suitability and./or abundance of fast-deep velocity-depth class</td></tr>
<tr><td>Fast-shallow velocity-depth class at EFR site</td><td>Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period</td><td>Reduced suitability and./or abundance of fast-shallow velocity-depth class</td></tr>
</table>

UO_EWR06_R: Middle Modder			
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 55.9% (Category D). The MIRAI score to be maintained in the mid-D range of >55 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 56 with an ASPT of 5.1. Total SASS5 score should remain >70, with ASPT value >5.2. REC: SASS5 score ≥100, with ASPT value > 5.8.	PES: SASS5 scores <55 and ASPT <4.8. REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 11 families were collected during the single survey. Of these, 1 scored ≥ 9 sensitivity. More than 11 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present (barring the expected but not recorded indicator taxa).	PES: Less than 10 taxa collected. No taxa recorded with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D.

UO_EWR06_R: Middle Modder			
		REC: More than 18 families should occur at an abundance of A to B, which should include both expected indicator taxa namely Hydropsychidae >2spp and Leptophlebiidae in ≥A abundances.	REC: Less than 20 families, with less than 3 taxa scoring ≥ 10. None of the expected indicator taxon recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The range of cobble selection along this reach should comprise movable cobbles and boulders. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour and solid waste).
Indicator Taxon	*Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR06_R: Middle Modder			
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

UO_EWR06_R: Middle Modder			
	Ecnomidae	Ecnomidae present in A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC are at a depth of 15cm and covered.	Ecnomidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.
Diatoms (used as a response to water quality)			
Diatoms	SPI Score: 6.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality	

Table 4-28: Summary of hydrology EcoSpecs for field verification sites

EWR site	River	Quat[1]	REC	nMAR[2] (MCM[3])	Low flows (%nMAR)	Drought (%nMAR)	High flows (%nMAR)	Total EWR as %nMAR for REC
UO_EWR01_FV	Meulspruit	D22B	D	63.6	3.13	0.41	0.00	3.13
UO_EWR02_FV	Witspruit	D24C	C	21.7	7.78	1.33	11.40	19.18
UO_EWR05_FV	Bokspruit	D13A	B	60.4	32.01	2.95	12.98	44.99
UO_EWR06_FV	Holspruit	D13J	C	36.9	5.96	0.71	12.08	18.05
UO_EWR07_FV	Sterkspruit, tributary of Kraai	D13C	B/C	47.6	25.64	2.71	11.59	37.24
UO_EWR17_FV	Langkloofspruit	D13D	B	43.8	32.09	4.68	12.36	44.45
UO_EWR19_FV	Lower Modder	C52K	C	156.8	5.60	0.21	12.22	17.82

Table 4-29: Field verification site EcoSpecs for diatoms and habitat integrity

Metric	EcoSpecs	TPC
UO_EWR01_FV: Meulspruit (PES: D; REC: D)		
Diatoms	SPI Score: 9.3 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 71% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 61% (C/D)	IHI: Riparian score: ≤57%
UO_EWR02_FV: Witspruit (PES: C/D; REC: C)		
Diatoms	SPI Score: 6.7 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality
Habitat Integrity: Instream	IHI: Instream score: 74% (C)	IHI: Instream score: ≤61%

Metric	EcoSpecs	TPC
Habitat Integrity: Riparian	IHI: Riparian score: 86% (B)	IHI: Riparian score: ≤81%
UO_EWR03_FV: Gryskopspruit (PES: C; REC: C)		
Diatoms	SPI Score: 2.5 Category (E): Seriously modified water quality	Already at lowest EC and high cause for concern.
UO_EWR04_FV: Karringmelkspruit (PES: B; REC: B)		
Diatoms	SPI Score: 15.2 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality
Habitat Integrity: Instream	IHI: Instream score: 95% (A)	IHI: Riparian score: ≤91%
Habitat Integrity: Riparian	IHI: Riparian score: 92% (A)	IHI: Riparian score: ≤91%
UO_EWR05_FV: Bokspruit (PES: B/C; REC: B)		
Diatoms	SPI Score: 10.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 86% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 88% (B)	IHI: Riparian score: ≤81%
UO_EWR06_FV: Holspruit (PES: C; REC: C)		
Diatoms	SPI Score: 9.7 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 70% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 72% (C)	IHI: Instream score: ≤61%

Metric	EcoSpecs	TPC
UO_EWR07_FV: Sterkspruit (tributary of Bell/Kraai) (PES: C; REC: B/C)		
Diatoms	SPI Score: 12 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 82% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 82% (B)	IHI: Riparian score: ≤81%
UO_EWR08_FV: Bell (PES: B/C; REC: B)		
Diatoms	SPI Score: 17.3 Category (A): High water quality	SPI Score: <16.7 Category B: Good water quality
Habitat Integrity: Instream	IHI: Instream score: 81% (B/C)	IHI: Riparian score: ≤77%
Habitat Integrity: Riparian	IHI: Riparian score: 84% (B)	IHI: Riparian score: ≤81%
UO_EWR09_FV: Groenspruit (PES: C/D; REC: C)		
Diatoms	SPI Score: 7.3 Category (D): Poor water quality	SPI Score: <4.8 Category D: Seriously modified water quality
UO_EWR11_FV: Fouriespruit (PES: C; REC: C)		
Diatoms	SPI Score: 11.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
UO_EWR13_FV: Os-spruit (PES: B/C; REC: B/C)		
Diatoms	SPI Score: 12.8 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

Metric	EcoSpecs	TPC
UO_EWR17_FV: Langkloofspruit (PES: B/C; REC: B)		
Diatoms	SPI Score: 14.1 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality
Habitat Integrity: Instream	IHI: Instream score: 87% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 80% (B/C)	IHI: Riparian score: ≤77%
UO_EWR18_FV: Wasbankspruit (PES: C; REC: B/C)		
Diatoms	SPI Score: 12.4 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 84% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 69% (C)	IHI: Instream score: ≤61%
UO_EWR19_FV: Lower Modder (PES: C/D; REC: C)		
Diatoms	SPI Score: 12.0 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 56% (D)	IHI: Riparian score: ≤41%
Habitat Integrity: Riparian	IHI: Riparian score: 75% (C)	IHI: Instream score: ≤61%
UO_EWR21_FV: Lower Kromellenboog (PES: C; REC: B/C)		
Diatoms	SPI Score: 8.0 Category (D): Poor water quality	SPI Score: <4.8 Category D: Seriously modified water quality
Habitat Integrity: Instream	IHI: Instream score: 84% (B)	IHI: Riparian score: ≤81%

Metric	EcoSpecs	TPC
Habitat Integrity: Riparian	IHI: Riparian score: 88% (B)	IHI: Riparian score: ≤81%
UO_EWR23_FV: Orange (PES: C/D; REC: C)		
Diatoms	High load of fine sediment, very few diatom cells present	
Habitat Integrity: Instream	IHI: Instream score: 63% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 54% (D)	IHI: Riparian score: ≤41%
UO_EWR24_FV: Maghaleng (PES: C/D; REC: C/D)		
Diatoms	High load of fine sediment, very few diatom cells present	
UO_EWR25_FV: Middle Caledon (PES: D; REC: C/D)		
Diatoms	SPI Score: 10.3 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 71% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 61% (C/D)	IHI: Riparian score: ≤57%

4.9 Monitoring Programme

It is important that the design of the monitoring program for this study adheres to the principles of adaptive management, whereby monitoring provides the critical link between meeting the objective (i.e. the EcoSpecs) and adaptive management (Elzinga et al., 1998). This approach further provides guidance in addressing concerns should the specified EcoSpecs and TPCs (Rogers & Bestbier, 1997) be exceeded. Overall, this provides the evidence for management change or continuation of current practices (Elzinga *et al.,* 1998).

Please refer to **Table 4-30** which provides the primary concepts guiding the monitoring to measure whether the EcoSpecs are being achieved for each EWR site and further **Table 4-31** which provides a management programme for the rivers in the study area.

Table 4-30: Monitoring programme for rivers

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
Flow/Quantity	Changes in flow have a severe impact on habitats, dilution, and biota. Flows should be gauged at existing gauges as specified for the various sites, on a continuous time step. Where there is no gauge, the discharge should be monitored during surveys.	Continuously at existing flow gauges close to biomonitoring site, else discharge during other surveys.	All Intermediate and Rapid 3 EWR sites
Water quality	*In situ* water quality: Parameters that must be assessed at each of the sampling site must include: pH, salinity, Dissolved Oxygen (DO), EC, Total Dissolved Solids (TDS), water temperature (which further forms part of the water quality management actions); water clarity using clarity tubes to monitor the sediment loads within the systems, Escherichia coli (e-coli) test kits would be advantageous to use during *in-situ* monitoring.	Monthly	All EWR sites, including Field Verification sites
	Other water quality parameters to be tested in laboratories: pH, DO, EC, TDS and water temperature; E coli (although needs to be tested within 24 hours of sample retrieval), Cyanobacteria, Phosphates (PO_4^{-3}), Nitrate plus nitrite nitrogen (NO_3+NO_2-N).	Monthly	All Intermediate EWR sites
	Diatoms should be analysed at every EWR site with results interpreted according to the Species-specific Pollution Index (SPI). Inferences must be made from the percentage of Pollution Tolerant Valves (%PTV), percentage of deformed cells and dominant indicator species. Diatoms samples can be sent through to the North-West University, who had the baseline results of the diatoms from this study for comparison purposes.	Biennial	All EWR sites, including Field Verification sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	Important *compliance monitoring* for water quality. The DWS to ensure enforcement and accountability within the municipalities that are responsible for all WWTWs located upstream of the identified EWR sites. Green drop scores were provided within the Scenario and Consequence Report (Report No. RDM/WMA13/00/CON/COMP/1423) and thus should be taken cognisant of during DWS audits. The above compliance monitoring should be linked with the monitoring programme to meet the specified EcoSpecs for water quality.	Annually	UO_EWR01_I UO_EWR02_I UO_EWR04_I UO_EWR06_I UO_EWR07_I UO_EWR09_I
General habitat and site characteristics	General description of the aquatic sampling sites must be compiled. Fixed upstream and downstream photo point monitoring (at the cross-section point) to capture at least: • Channel and Bank condition; • Instream and marginal vegetation state and extent of inundation; • Water clarity; • Algal cover; • Depth of flow over coarse substrates (cobbles/ bedrock); • Turbulence and extent of white water in rapids; and • Morphological conditions. Furthermore, watershed features (i.e., surrounding land use, sources of pollution, erosion, new development etc.).	Bi-annually during the SASS5 surveys	All Intermediate and Rapid 3 EWR sites
	The Rapid Habitat Assessment Method (RHAM) should be undertaken. This is a rapid approach and cost-effective to assess instream habitat conditions in wade-able, and to a more limited degree, non-wade able streams. The RHAM data is used to assess habitat suitability for indicator instream biota (fish and macroinvertebrates). The premise of the RHAM is that suitable habitat conditions will indicate the likely presence, abundance and frequency of occurrence of particular biota. Baseline conditions are	Bi-annually during the SASS5 surveys	All Rapid 3 EWR sites

<table>
<tr><th>Component</th><th>Monitoring programme to meet the specified EcoSpecs</th><th>Frequency</th><th>EWR site application</th></tr>
<tr><td></td><td>used to indicate the change in habitat conditions and the derived impact on the indicator biota.</td><td></td><td></td></tr>
<tr><td rowspan="3">Riparian vegetation</td><td>Riparian vegetation should be assessed using the Riparian Vegetation Response Assessment Index (VEGRAI level 4) method to monitor the changes in vegetation, particularly in terms of woody and non-woody cover/abundance/composition, alien invasive plants (AIP), riparian drivers and impacts, etc.</td><td>Every 5 years preferably during early autumn</td><td>All Intermediate EWR sites</td></tr>
<tr><td>Conduct the IHI – it will be important especially for the riparian component of this model to be used as a surrogate to the VEGRAI score in order to run the Eco-status Model for all Rapid 3 EWR sites.</td><td>Annually</td><td>All Rapid 3 EWR sites</td></tr>
<tr><td>Desktop vegetation assessment (woody to non-woody to open area comparisons using Google Earth and/or other satellite imagery for interrogation and to compare to previous years of possible regrowth etc. Land cover information and the PESEIS 2023 should be used.</td><td>Every 5 years</td><td>All Intermediate and Rapid 3 EWR sites</td></tr>
<tr><td>Macroinvertebrates</td><td>Ensure the data and results from other monitoring programmes namely DWS quarterly REMP monitoring, monitoring conducted by SANParks, and the five yearly Joint Basin Survey (JBS) monitoring, through ORASECOM, are included with the data collected and running of the MIRAI, from this studies EWR sites and monitoring programme. These are as follows:
<table>
<tr><th>UO_EWR site</th><th>DWS REMP Site</th><th>JBS</th><th>SanParks</th></tr>
<tr><td>UO_EWR04_I</td><td>-</td><td>OSAEH_26_8</td><td>-</td></tr>
<tr><td>UO_EWR07_I</td><td>C5MODD-SANNA</td><td>OSAEH_11_18</td><td>-</td></tr>
<tr><td>UO_EWR08_</td><td>D2KRAA-ALIWA</td><td>OSAEH_26_11</td><td>-</td></tr>
</table></td><td>Annually</td><td>UO_EWR04_I
UO_EWR07_I
UO_EWR08_
UO_EWR09_I
UO_EWR10_I
UO_EWR01_R
UO_EWR02_R
UO_EWR06_R</td></tr>
</table>

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	<table><tr><th>UO_EWR site</th><th>DWS REMP Site</th><th>JBS</th><th>SanParks</th></tr><tr><td>UO_EWR09_I</td><td>C5RIET-DEKRA</td><td>OSAEH_29_5</td><td>Monitoring site</td></tr><tr><td>UO_EWR10_I</td><td>-</td><td>OSAEH_26_3</td><td>-</td></tr><tr><td>UO_EWR01_R</td><td>D2CAL-EWR01</td><td>-</td><td>-</td></tr><tr><td>UO_EWR02_R</td><td>D2GROOT-FARM1</td><td>-</td><td>-</td></tr><tr><td>UO_EWR06_R</td><td>C5MODD-SANNA</td><td>OSAEH_11_19</td><td>-</td></tr></table>		
	In addition to the routine quarterly REMP that DWS conduct, additional aquatic macroinvertebrates monitoring using the South African Scoring System 5 (SASS5) should be conducted at all other EWR sites, which are not aligned to the existing REMP sites. This will provide an indication of the state of the aquatic environment, detect trends and to ensure that the EcoSpecs are being met.	Bi-annually (wet and dry season)	All Intermediate and Rapid 3 EWR sites
	The Macroinvertebrate Response Assessment Index (MIRAI) must be conducted to identify the ecological category of the aquatic macroinvertebrates and to continually track the trends.	Annual basis for the last hydrological year	All Intermediate and Rapid 3 EWR sites
	The Integrated Habitat Assessment System (IHAS - version 2) was developed specifically for use with rapid biological assessment protocols in South Africa (McMillan, 1998), and reflects the suitability of habitat as a percentage, where 100% represents “ideal” habitat availability. IHAS is conducted in conjunction with the South African Scoring System Version 5 (SASS5).	Bi-annually with the SASS5 monitoring	All Intermediate and Rapid 3 EWR sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
Fish	If possible, and if equipment is available (electro-shocker), ichthyofauna (fish) surveys should be undertaken. Electrofishing should be conducted for at least 60 minutes and/or when all habitat-velocity-depth classes have been shocked and/or no additional fish species are being recorded. Fish species diversity and abundances should be recorded, fish health assessment and the presence of Red Data species. Whereas aquatic macroinvertebrate communities are good indicators of short-term localised conditions in a river, fish being relatively long-lived and mobile are: • Good indicators of long-term influences; • Good indicators of general habitat conditions; • Integrate effects of diverse trophic levels; and • Consumed by humans. Indigenous species should be returned to the water as soon as possible whereas introduced species should be euthanised. All results and samples should be lodged with the appropriate national databases. Any observations of *L. kimberleyensis* should be considered significant due to the widespread decline in the abundance of this species.	Annually (wet season)	All Intermediate and Rapid 3 EWR sites
	The Fish Response Assessment Index (FRAI) must be conducted to identify the ecological Category of the fish and to continually track the trends.	Annual basis for the last hydrological year	All Intermediate and Rapid 3 EWR sites
EcoStatus	The EcoStatus model should be run for all EWR sites. The riparian vegetation ecological category to be used to complete the EcoStatus for all Intermediate EWR sites, and the riparian IHI Category to be used as a surrogate to the riparian vegetation to complete the EcoStatus for all Rapid3 EWR sites.	Annually following the completion of running the MIRAI, FRAI, VEGRAI and IHI	All Intermediate and Rapid 3 EWR sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	Following the completion of the current update to the 2011 PES and EIS database for primary, secondary catchments on a sub-quaternary reach scale for the Upper Orange, the EcoStatus results from the EWR sites should be compared to the updated PES and EIS database.	Annually	All Intermediate and Rapid 3 EWR sites
Geomorphology	Conduct GAI level IV during low flow conditions. A cross sectional survey should be included to enable the channel shape, width and depth to be compared over time.	Every 5 years	All Intermediate EWR sites
	Channel pattern during low flow – this can be done based on freely available satellite images, such as through Google Earth. It is important to do the assessment for low flow periods when most of the river morphology is exposed.	Every 2 years	All Intermediate EWR sites
	Channel width – the measurement can be done across the riffle/rapid with a long tape measure or as part of a cross-sectional survey.		
	Median particle size for mobile bed sediment along riffle/rapid. A random selection of 100 mobile/loose clasts are collected and the b-axis measured. The median (D50), D16 and D84 must be calculated for monitoring purposes.		
	Extent of bank erosion – this is a visual assessment of the length of bank showing erosion compared to the length of the stable section.		
Analysis and Interpretation	The data collected from the rivers EWR sites monitoring programme should be analysed and interpreted on a bi-annual basis, with a trends report published on an annual basis. This report should be externally reviewed.	Annually	All EWR sites

Table 4-31: Management programme for rivers

Component	Management programme as a result of the monitoring programme
Flow/Quantity	• Manage and maintain all active gauging weirs and stations throughout the study area. • Investigate possible new gauging weirs close to EWR sites where no continuous flow data is available.
Quality	• With water quality being the primary driver throughout the Upper Orange catchment area, it is vital and important that the management of compliance monitoring for water quality be undertaken. DWS must ensure that water quality monitoring is being undertaken and is being managed; • All DWS laboratories are encouraged to undertake assessments and implement interventions to improve analytical performance and ensure credible and reliable analytical data; • Laboratories must aim to become accredited, if not already; • The DWS to ensure enforcement and accountability within the municipalities that are responsible for all WWTWs located upstream of the identified EWR sites; • Allocation plans, water use licensees, directives must be reviewed and managed; and • Compliance audits must be undertaken and managed.
Riparian vegetation	• Compile an alien plant control programme for riparian zones and adjacent buffers (up to 20m). The programme should seek support from landowners and should include financial incentives for landowners that can support implementation of the alien plant control programme. • Eradication and control of exotic vegetation within riverine areas should be implemented to enhance riparian functioning, increase bank stability, reduce erosion, and improve the general buffering capacity of rivers, while sustaining instream habitats for aquatic biota. • Highest priority should be given to riparian areas with sparse/scattered alien trees to limit further spread (e.g. UO_EWR01_I, UO_EWR03_I and UO_EWR07_I). Highly infested areas will require intensive and on-going management to effectively eradicate problem species, together with revegetation and ongoing maintenance. Livestock pressures (i.e. grazing and trampling) will require special consideration, especially given that rivers are freely accessed by communities and their livestock, but livestock can also be an asset for rebuilding soils and restoring vegetation cover.
	• Catchment management strategies must be developed to assist with the management of overgrazing and trampling.

Component	Management programme as a result of the monitoring programme
Overall	• Riverine buffers must be implemented for all new applications, and grazing management within these buffer zones strictly controlled.

5. SURFACE WATER: WETLAND RESULTS

Wetlands constitute a crucial element of the surface water ecosystem and were included in the Reserve determination for the Upper Orange catchment area. The results of the Reserve Determination for the selected WRUs are below. The approach towards the Reserve determination process for the WRUs incorporated Steps 3, 5 and 7 as shown in **Figure 1-2.** Recommendations for the quantification of the EWRs for specific priority wetlands and where integration between groundwater and/ or rivers and wetlands are crucial have further been made.

5.1 Wetland survey

The wetland survey was conducted from 10 – 14 April 2022 to review the greater study area and the 12 prioritised WRUs within the study area as illustrated in **Table 2-3** and **Figure 2-3**. The various WRUs were subjected to a tiered assessment approach. Three tiers were identified in which site visits and assessments for Tier 3 were of moderate intensity whilst Tier 1 and 2 were of lower intensity. Overall, the survey of the RUs allowed for the condition of the wetlands to be reviewed following on from the desktop analysis of the systems.

5.2 Eco-Categorisation, EWR Quantification and Ecological Specifications For Prioritised Wetland Resource Units

All WRUs varied drastically in terms of their type, integrity, functionality and size, but were all regarded as important enough to be included in this study.

Upon the assessment of the various WRUs, each of the systems were reviewed in terms of the necessity and relevance of quantifying the EWRs. The considerations listed below have been incorporated into a Decision Support System (DSS) which systematically guided the wetland specialist through the process of deciding whether a WRU should receive an EWR quantification or not (**Figure 5-1**). This process was applied to the twelve WRUs assessed in this study – the results being that none of the WRUs were considered suitable candidates for EWR quantifications to be undertaken. This DSS should be read in conjunction with the numbered items below which unpack the motivation for the quantification of EWRs for selected WRUs. These numbers correspond with the numbers in **Figure 5-1**.

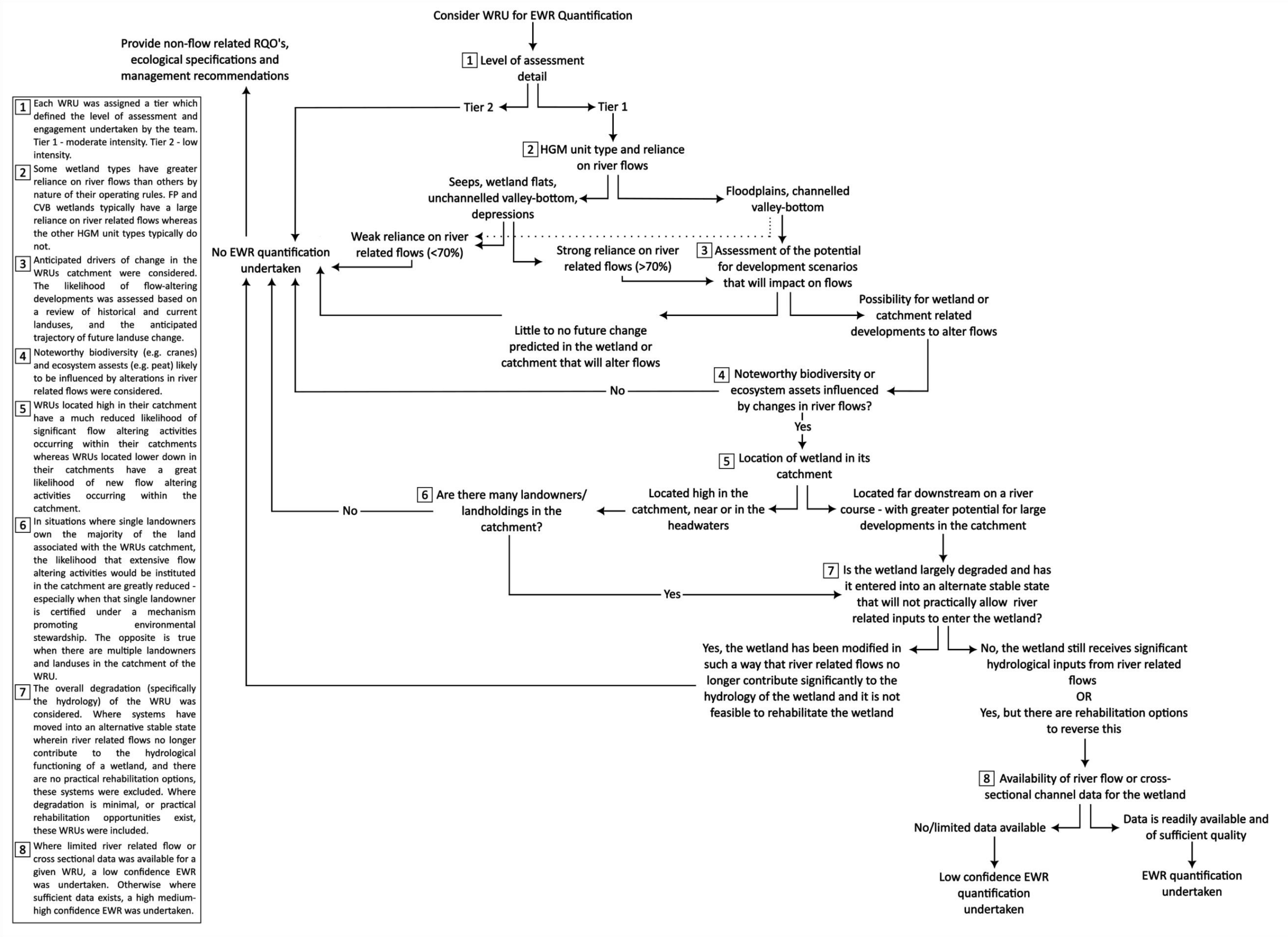


Figure 5-1: Decision support system used to determine which WRUs would receive an EWR quantification and which systems would receive detailed ecological specifications and non-flow related RQOs

1. As mentioned in Chapter 5.1, the various WRUs were subjected to a three tiered assessment approach. Any of the systems which fell within the Tier 1 and 2 level of intensity were excluded from EWR quantification, as insufficient information/data would be available to allow for the development of EWRs at an accepted confidence level;
2. The hydrogeomorphic (HGM) unit type was a significant contributing factor in terms of prioritising systems for the derivation of EWRs, as only those systems supported by a stream/river could be considered, i.e., channelled valley-bottom and floodplain wetlands. Furthermore, WRUs that met the HGM unit type criteria but water and sediment inputs into the system were mostly sustained by lateral inputs (with limited inputs from the catchment upstream) were excluded. Generally, this was considered appropriate where the upstream inputs were only considered to contribute approximately 30% of the hydrological, geomorphic and water quality inputs and functioning of the system. There are some cases where unchannelled valley-bottom wetlands are supported by river related flows. In cases where an unchannelled valley-bottom or seep wetlands received greater than 70% of their hydrological inputs from river related flows, these systems were included for consideration for EWR quantification;
3. The integrity assessments also took into account expected drivers of change in the catchments of the WRUs. This involved thorough reviews and observations of current land use practices within the catchments, including the desktop mapping of these land uses. Where applicable, the historical imagery for the WRUs and their associated catchments was also reviewed to develop an understanding of the level of modification that has occurred within these systems in recent times. For the systems located in more rural areas, and in which the catchment land use practices have not significantly changed over time, developing EWRs was not considered as it unlikely that significant modifications to the systems will occur within the short- to medium-term;
4. Significant biodiversity (e.g. cranes or endangered species) and ecosystem assets (e.g. peat wetlands or significant areas of permanently saturated wetland) likely to be influenced by changes in stream flows were considered for these systems too, and any significant features that would be detrimentally influenced by reduced flows were considered in prioritising WRUs for the development of EWRs;
5. Location of the WRU in relation to its catchment, i.e., whether the system is located near the headwaters or further downstream was also considered, with systems located in the catchment's headwaters being considered less likely to be influenced by major flow altering activities e.g. a large water storage dam;
6. The number of landholdings/owners in relation to the upstream catchment and wetland was considered in prioritising WRUs for the development of EWRs. For instance, if the upstream catchment is mainly plantation forestry owned by a single entity committed to environmental stewardship, there's a lower likelihood of water access challenges compared to a scenario with multiple farms and irrigated croplands near or upstream of the wetland;
7. The level of overall degradation of the WRU, especially relating to in-system impacts on water distribution and retention was considered. Although some of the wetlands are largely degraded, the impacts contributing to the level of degradation can be partially mitigated through the adoption of some of the prescribed management and maintenance activities. However, other priority systems which are largely degraded might be locked in these altered states and EWR quantification would not serve to influence the long-term integrity or trajectory of change for the ecosystem. These latter systems, where no rehabilitation options are available, were excluded from development and quantification of the EWRs; and

8. Finally, the availability of any river related flow data from a nearby weir and/or previous studies also influenced the prioritisation process, as without such data, any quantities set for the system would be based on a number of assumptions and thereby, be considered of low confidence.

All twelve WRUs that were identified and assessed as part of this study had some level of Reserve set for them. Based on the outcomes of the DSS in **Figure 5-1**, none of the WRUs require EWR quantification. As such, ecological specifications have been set for all WRUs. These EcoSpecs can be incorporated into Water Use License conditions to allow for monitoring and auditing of the condition of the resources.

It is important to add that the DSS will be assessed and outlined in more detail during the Classification study currently being undertaken, and which will further include management options for implementation.

The Subsequent chapters includes the eco-categorisation results of the 12 WRUs, and their assigned EcoSpecs, while Table 5-1 provides a summary of these results combined.

5.2.1 WRU 02 – Brandwater *Floodplain*

The Brandwater floodplain is a medium-sized wetland situated at the toe of the Brandwater River, 1.5 kilometers upstream from its confluence with the Caledon River. It is nourished by a vast, primarily cultivated upstream catchment of over 76,000 hectares, though no major dams are present on the main feeder streams. Despite the geological control of a dolerite sill, the wetland's channel has become incised, reaching depths of 4-6 meters, making regular overtopping unlikely. *Salix babylonica* trees have colonized the lower part of the channel, and extensive lateral flood-out areas, supporting a mix of wetland species, persist through seepage and tributary inputs. Unfortunately, drainage for agricultural purposes has significantly reduced these flood-out areas.

Wetland PES Summary				
Wetland name	WRU 02 - Brandwater Floodplain			
Assessment Unit	Brandwater Floodplain 1			
HGM type	Floodplain wetland			
Wetland area (ha)	258.6 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	3.6	2.8	1.5	5.6
PES Score (%)	64%	72%	85%	44%
Ecological Category	C	C	B	D
Combined Impact Score	3.4			
Combined PES Score (%)	66%			
Combined Ecological Category	C			

EIS	High
REC	C
EcoSpec	A desktop-based landcover assessment must be undertaken every 3-5 years to monitor the integrity of the flood-out zones adjacent to the channel within the floodplain. The density of drains within these flood-out zones must be monitored, and a qualitative assessment of the level of desiccation of these flood-outs should simultaneously be carried out using historical aerial/satellite imagery. No additional cultivation should be allowed to take place within the wetland, especially not within an intact portion or flood-out zone. There should be no further

	encroachment of Alien Invasive Plant (AIP) species within the wetland. Additional recommendations include the removal of *Salix babylonica* trees from the channel of the wetland and ensuring the control of alien invasive plants takes place within the wetland – provided that their removal can be undertaken safely and in such a way that it is beneficial both to the wetland and the landowners (i.e., their removal does not result in unnecessary and excessive ecological damage to the wetland and provided that these trees are not currently used by farmers to provide livestock with shaded areas).

5.2.2 WRU 03 - Soutpan Depression Wetland Complex

WRU 03 is a large wetland complex consisting of a total of 27 depression wetlands that range in size from 6 ha to 1 800 ha. The largest of these wetlands is known as Soutpan and is an active salt mine as the name implies (Figure 4 6). The majority of these depression wetlands are endorheic and have no clear outward-flowing connection to river systems. However, most of the depression wetlands have inward flowing streams which contribute hydrologically to their functioning but will also contribute any sediments and pollutants originating from the catchment associated with the inflowing stream. Most of the other depression wetlands within the WRU are relatively intact and do not appear to have any significant in-system impacts. However, the catchments of many of these wetlands have been extensively cultivated, which likely contributes to a decline in the present water quality and geomorphic state of these wetlands. These depression wetlands are generally characterised by seasonal wetness and associated seasonal wetland vegetation that typically consists of a mosaic of grass and sedge species. These depression wetlands provide very important nesting and feeding habitats for aquatic birds in the region.

Wetland PES Summary				
Wetland name	**WRU 03 – Soutpan Wetland Complex**			
Assessment Unit	**WRU 03a Soutpan**			
HGM type	Depression without flushing			
Wetland area (ha)	1860.7 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	3.7	2.3	3.6	4.8
PES Score (%)	63%	77%	64%	52%
Ecological Category	C	C	C	D
Combined Impact Score	3.6			
Combined PES Score (%)	64%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	**WRU 03b - Soutpan Wetland Complex**			
Assessment Unit	**WRU 03b Remaining Depression Wetlands**			
HGM type	Depression without flushing			
Wetland area (ha)	698.0 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	1.2	1.7	0.8	1.0
PES Score (%)	88%	83%	92%	90%
Ecological Category	B	B	A	B
Combined Impact Score	1.2			
Combined PES Score (%)	88%			
Combined Ecological Category	B			

EIS WRU3a	Moderate	**EIS WRU3b**	Moderate
REC WRU3a	C	**REC WRU3b**	B
EcoSpec	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the depression wetlands are under increasing pressure from the surrounding land uses. A detailed landcover-based assessment of the depression wetlands must be undertaken to assess the extent of sediment deposition and nutrient flushes from the surrounding landscape.		

5.2.3 WRU 04 – Philipstown Unchannelled Valley-Bottom Wetland Complex

WRU 04 is a complex of two different wetland types, a depression wetland approximately 1 100 ha in size and an unchannelled valley-bottom (UCVB) wetland approximately 190 ha in size. The upstream catchment areas of both wetland units are in a relatively natural condition with little to no human impact. Aside from a small number of roads and scattered farmhouses, the majority of the catchments appear to be relatively unaffected by agriculture or settlement. However, a large herd of goats and a herd of sheep were observed in the catchment of the UCVB, and evidence of light grazing was observed in both wetland catchments – which is indicative of grazing pressure which exceeds the natural situation. The UCVB wetland was included as a wetland RU for its proximity and hydrological connection to the Vanderkloof Dam downstream as the UCVB wetland provides important ecosystem services in terms of water quality enhancement and sediment trapping to these downstream freshwater ecosystems. The depression wetland was included in the WRU because it has a significant catchment and may have groundwater linkages to the valley-bottom wetland downstream. It is also an important wetland for unique assemblages of fauna and flora in the area. The large area to the east of the depression wetland (indicated by grey colours in aerial imagery) is a dam in which wetland conditions have been created.

Wetland PES Summary				
Wetland name	**WRU 04a**			
Assessment Unit	**Phillips Town Depression Wetland**			
HGM type	Depression without flushing			
Wetland area (ha)	1148.8 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	0.0	0.3	0.5	1.0
PES Score (%)	100%	97%	95%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

Wetland PES Summary				
Wetland name	**WRU 04b**			
Assessment Unit	**Phillips Town UCVB Wetland**			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	192.6 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	2.9	1.8	0.6	4.1
PES Score (%)	71%	82%	94%	59%
Ecological Category	C	B	A	D
Combined Impact Score	2.4			
Combined PES Score (%)	76%			
Combined Ecological Category	C			

EIS WRU4a	Moderate	**EIS WRU4b**	Moderate
REC WRU4a	A	**REC WRU4b**	C

EcoSpec	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the wetlands are under increasing pressure from the surrounding land uses. A further detailed landcover-based assessment of the depression wetland must be undertaken to assess the extent of sediment deposits and or nutrient flushes from the surrounding landscape. Furthermore, there must be no expansion of agricultural activities or other land uses into the remaining intact UCVB wetland areas.

5.2.4 WRU 05 – Wolwespruit Headwaters Wetland Complex

WRU 05 is a large wetland complex consisting of a series of unchannelled valley-bottom (UCVB) wetlands which are fed by multiple hillslope seep (HSS) wetlands. In total, the WRU covers an area of approximately 420 ha and forms the headwaters of the Wolwespruit River. The catchments of many of these systems have been extensively cultivated and/or grazed, with extensive areas of cultivation (incorporating contour banks and other runoff management measures) and many small dams located on the tributaries. The valley-bottom wetlands have been extensively dammed, with over 15 dams along the length of the mainstem valley. In addition, there are a total of nine road crossings within the WRU, the majority of which have insufficient allowance for flows to pass beneath them, resulting in damming of water upstream and the desiccation of the wetland downstream of the crossings. Several boreholes and wind pumps were observed adjacent to many of the valley-bottom wetlands, with some situated near or within the seepage wetlands. The wetlands are predominantly used directly for grazing and as a water source for cultivation in the catchment areas. A large number of Blue Cranes (*Grus paradisea*) and Crowned Cranes (*Balearica regulorum*) were noted in the wetland.

Wetland PES Summary				
Wetland name	**WRU 05a**			
Assessment Unit	**Wolwespruit UCVB Wetlands**			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	340.0 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	2.4	2.2	1.7	4.8
PES Score (%)	76%	78%	83%	52%
Ecological Category	C	C	B	D
Combined Impact Score	2.8			
Combined PES Score (%)	72%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	**WRU 05b**			
Assessment Unit	**Wolwespruit Seep Wetlands**			
HGM type	Seep			
Wetland area (ha)	80.5 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	2.1	2.1	1.5	4.2
PES Score (%)	79%	79%	85%	58%
Ecological Category	C	C	B	D
Combined Impact Score	2.4			
Combined PES Score (%)	76%			
Combined Ecological Category	C			

EIS WRU5a	High	**EIS WRU5b**	Moderate

REC WRU5a	C	**REC WRU5b**	C
EcoSpec	Landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor if the wetlands are under increasing pressure from the surrounding land uses.		

5.2.5 WRU 06 – Klein-Wildebeespruit Wetland Complex

WRU 06 is a large wetland complex located along the Klein Wildebeesspruit and the unnamed river to the east of the Klein-Wildebeesspruit. The WRU is comprised of a series of valley bottom wetlands which amount to approximately 950 ha in size. These valley-bottom wetlands are fed by many seep wetlands which total approximately 450 ha in size together. These two large wetland complexes are tributaries of the Kraai River and are therefore key in providing ecosystem services such as water quality enhancement and sediment trapping. The catchments of both wetland complexes are generally intact, with little to no impacts in the more distal areas of the catchments, given the remoteness and the steep topography. However, the broad and relatively flat valley-bottom areas have been utilised extensively for cultivation and there are a number of large commercial farming operations located within the valley-bottom and seep wetlands. These operations have resulted in the multiple impacts to the wetlands which include the implementation of drains, channel modification, infilling and reduction in surface roughness. High concentrations of AIP species have also promulgated along many of the channels in the valley-bottom wetlands .

Wetland PES Summary				
Wetland name	**WRU 06a**			
Assessment Unit	**Klein-Wildebeesspruit CVB Wetlands**			
HGM type	Channelled VB wetland laterally maintained (i.e. with substantial lateral inputs)			
Wetland area (ha)	949.8 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	4.4	3.0	3.0	6.8
PES Score (%)	56%	70%	70%	32%
Ecological Category	D	C	C	E
Combined Impact Score	4.3			
Combined PES Score (%)	57%			
Combined Ecological Category	D			

Wetland PES Summary				
Wetland name	**WRU 06b**			
Assessment Unit	**Klein-Wildebeesspruit Seep Wetlands**			
HGM type	Seep			
Wetland area (ha)	456.9 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	4.7	3.3	3.3	7.1
PES Score (%)	53%	67%	67%	29%
Ecological Category	D	C	C	E
Combined Impact Score	4.6			
Combined PES Score (%)	54%			
Combined Ecological Category	D			

EIS WRU6a	Moderate	**EIS WRU6b**	Moderate

REC WRU6a	D	**REC WRU6b**	C
EcoSpec	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the wetlands are under increasing pressure from the surrounding land uses.		

5.2.6 WRU 10 – Luckhof Depression Wetland Complex

WRU 10 is a large series of depression wetlands that are hydrologically connected via surface and groundwater. These depression wetlands range in size from 7 ha to 1 200 ha. These fluvially connected wetlands flow in a south-easterly direction into the Lemoenspruit River which is a tributary of the Orange River. A large number of centre pivot irrigated fields are located to the north of the wetland complex within the upstream catchment of the northern depression wetlands. These fields are supplied by a large irrigation canal which originates from the Vanderkloof Dam. Consequently, there is a low level of reliance on water from the depression wetlands. However, impacts associated with the farming activities in the catchments of these depressions were observed – specifically sedimentation and the possibility of chemical fertilizer/herbicide/pesticide entering the depression wetlands. Aside from the agriculture to the north of the depression wetlands, the catchments of these wetlands are generally natural and undisturbed. The depression wetlands themselves appear to be in a relatively natural condition, with little to no disturbance. The large area to the south of the depression wetlands initially appeared to have wetland characteristics from a desktop scan of the area, but upon arriving onsite it was clear that these features are indicative of an active dune field and not wetlands.

Wetland PES Summary				
Wetland name	**WRU 10**			
Assessment Unit	**Luckhof Depression Wetland Complex**			
HGM type	Depression with flushing			
Wetland area (ha)	1841.8 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	0.4	1.1	4.3	1.1
PES Score (%)	96%	89%	57%	89%
Ecological Category	**A**	**B**	**D**	**B**
Combined Impact Score	1.6			
Combined PES Score (%)	84%			
Combined Ecological Category	**B**			

EIS	Moderate
REC	B
EcoSpec	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the depression wetlands are under increasing pressure from the surrounding land uses. A further detailed landcover-based assessment of the depression wetlands themselves must be undertaken to assess the extent of sediment deposits and or nutrient flushes from the surrounding landscape, especially as these may be concentrated by the hydraulic linkages across the irrigation canal. All discharge points which are currently routed into the WRU must be investigated every 3-5 years for adverse impacts on the wetlands.

5.2.7 WRU 11 – Kaalspruit Wetland Complex

WRU11 is a large wetland complex consisting of several depression wetlands, a discontinuously channelled valley-bottom and a discontinuously channelled valley-bottom wetland. The mainstem valley-bottom wetland is approximately 2 800 ha in size while the depression wetlands range from 320 ha to approximately 20 ha in size. The valley-bottom wetland is located along the Kaalspruit River, which is a tributary of the Modder River. The catchments of this WRU are dominated by cultivation – predominantly maize and sunflower cultivation. The catchment land use has had a significant impact on a number of the depression wetlands in the RU through extensive sedimentation and possible nutrient loading from fertilizers used in the surrounding agricultural areas. The mainstem wetland is predominantly utilised for grazing and has impacts associated with channel incision in the lower portion of the WRU. A large dam exists in the upstream section of the mainstem wetland and is impacting the hydrological connectivity of this wetland negatively, as well as the natural sediment flux through the wetland.

Wetland PES Summary				
Wetland name	**WRU 11a**			
Assessment Unit	**Kaalspruit Valley Bottom Wetlands**			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	2839.3 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	1.9	2.2	1.9	4.1
PES Score (%)	81%	78%	81%	59%
Ecological Category	B	C	B	D
Combined Impact Score	2.5			
Combined PES Score (%)	75%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	**WRU 11b**			
Assessment Unit	**Kaalspruit Depression Wetlands**			
HGM type	Depression without flushing			
Wetland area (ha)	1050.6 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	2.3	2.6	2.7	4.2
PES Score (%)	77%	74%	73%	58%
Ecological Category	C	C	C	D
Combined Impact Score	2.9			
Combined PES Score (%)	71%			
Combined Ecological Category	C			

EIS WRU11a	High	**EIS WRU11b**	Moderate

REC WRU11a	C	**REC WRU11b**	C
EcoSpec	No further cultivation must be permitted within any of the remaining intact wetland areas, and no additional dams must be allowed within the remaining intact portions of the wetland.		

5.2.8 WRU 12 – Aardoringspruit Wetland Complex

WRU 12 is a large wetland complex that includes a large wetland flat and a discontinuously channelled valley-bottom wetland which encompasses the Aardoringspruit River. The confluence of the Aardoringspruit and Keeromspruit Rivers occurs within the WRU, from which the Rietspruit flows. The entire complex is approximately 1700 ha in size and has a very gentle longitudinal slope of 0.2% down its length. The catchment of this wetland complex is comprised of large areas of cultivation as well as large semi-natural areas which are likely utilised for grazing. Due to the extremely gently sloping nature of the majority of the catchment, very few dams have been constructed in the catchment as the landscape does not lend itself well to the construction of dams. As such, impacts to the hydrological integrity of the wetland complex are predominantly derived from within wetland impacts. The northern (upstream) section of the wetland flat is characterised by a flat wetland with shallow soils and a mix of seasonal and permanent zones. Small preferential flow paths were observed within the upslope portion of the wetland flat which is generally characterised by permanent wetland.. This wetland was included as a RU because its lower portion receives flows from Brandfort via the Keeromspruit River which, according to local stakeholders, has been receiving untreated sewage from dysfunctional wastewater treatment works in Brandfort regularly. This section of the wetland is characterised by greater relief and a more well-defined valley line that is the driver for the formation of a discontinuously channelled valley-bottom wetland. The wetland is predominantly used for grazing and some water supply dams have been constructed along the Aardooringspruit River.

Wetland PES Summary				
Wetland name	**WRU 12a**			
Assessment Unit	**Aardoringspruit Valley Bottom Wetland**			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	665.9 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.3	1.4	1.0	4.2
PES Score (%)	67%	86%	90%	58%
Ecological Category	C	B	B	D
Combined Impact Score	2.6			
Combined PES Score (%)	74%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	**WRU 12b**			
Assessment Unit	**Aardoringspruit Wetland Flat**			
HGM type	Flat			
Wetland area (ha)	1075.4 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.4	2.2	1.9	5.4
PES Score (%)	66%	78%	81%	46%
Ecological Category	C	C	B	D
Combined Impact Score	3.3			
Combined PES Score (%)	67%			
Combined Ecological Category	C			

EIS WRU12a	Moderate	**EIS WRU12b**	Moderate

REC WRU12a	C	**REC WRU12b**	C
EcoSpec	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than what they are currently. This requires that additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. While no cultivation has yet taken place in the wetland, no intensive cultivation must be permitted in the remaining intact portions of the wetland. The wetland is widely used for grazing, but the grazing pressure must be kept at an appropriate level to prevent further erosion in the discontinuously channelled portion of the HGM unit.		

5.2.9 WRU 13 – Rantsho Wetland Complex

WRU 13 is a wetland complex approximately 275 ha in size and is located between the R26 road and the Mohokare (Caledon) River on the Rantsho River. The wetland is located to the west of Ficksburg and is directly adjacent to the Peka Bridge Border Post between South Africa and Lesotho. A large proportion (<35%) of the catchment is cultivated, but only a small proportion (5% of the total catchment area) of this cultivated area is irrigated and therefore the abstraction of water from the catchment is assumed to be relatively low. There are no dams on the Rantsho River but most of the tributaries of the Rantsho River are extensively dammed. It is expected that the flows from these tributaries have been reduced The floodplain wetland has three distinct sections that are separated by a very confined section of valley. The northern lobe of the wetland is bisected by the R26 road. The section of wetland upstream of the R26 is used for hay production and grazing while the section downstream of the R26 appears only to be utilised for grazing. The channel in the northern section is moderately sinuous and does not appear to be excessively incised hence the retention of floodplain features in the valley-bottom. The northern lobe becomes confined and loses its floodplain characteristics as the valley narrows. The valley then becomes less confined again and floodplain features appear. Approximately 2 km downstream of this flood out, the channel loses confinement as well and the wetland becomes an unchannelled valley-bottom wetland. A small, stable channel has formed between the unchannelled valley-bottom wetland and the Mohokare River. Land uses in this southern section of the wetland include grazing, hay production, water supply (a small off-channel dam) and cultivation. Runoff from a chicken run was noted entering the unchannelled valley-bottom wetland.

Wetland PES Summary				
Wetland name	**WRU 13a**			
Assessment Unit	**Rantsho Floodplain Wetland**			
HGM type	Floodplain wetland			
Wetland area (ha)	95.0 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	4.9	3.1	2.8	7.0
PES Score (%)	51%	69%	72%	30%
Ecological Category	D	C	C	E
Combined Impact Score	4.5			
Combined PES Score (%)	55%			
Combined Ecological Category	D			

Wetland PES Summary				
Wetland name	**WRU 13b**			
Assessment Unit	**Rantsho CVB Wetland**			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	71.4 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	2.8	1.6	1.6	4.9
PES Score (%)	72%	84%	84%	51%
Ecological Category	C	B	B	D
Combined Impact Score	2.7			
Combined PES Score (%)	73%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	**WRU 13c**			
Assessment Unit	**Rantsho UCVB Wetland**			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	108.1 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	4.7	2.8	3.4	7.0
PES Score (%)	53%	72%	66%	30%
Ecological Category	D	C	C	E
Combined Impact Score	4.5			
Combined PES Score (%)	55%			
Combined Ecological Category	D			

EIS WRU13a	Moderate	**EIS WRU13b**	Moderate	**EIS WRU13c**	High
REC WRU13a	C	**REC WRU13b**	C	**REC WRU13c**	C
EcoSpec	To maintain the current state of the Rantsho Wetland Complex, no further cultivation or other intensive land uses must be permitted to expand into the remaining intact portions of the wetlands. Furthermore, no further infrastructure such as dams or roads must be permitted within the remaining intact portions of the wetland. Additionally, there must be no further degradation of the water quality such that it impacts the downstream freshwater ecosystems. Agricultural and livestock operations must periodically be monitored for discharge into WRU 13. There must be no further encroachment of woody alien invasive vegetation into any of the wetland areas, and efforts should be made to remove the current population of *Salix babylonica* individuals that line sections of the channel in the FP and CVB wetlands. In addition, AIPs must be managed within a 200 m radius of the wetland to avoid additional AIP propagules entering the HGM unit.				

5.2.10 WRU 15 – Jagersfontein Discontinuously Channelled Valley-Bottom Wetland

WRU 15 is a large contiguous series of wetlands that originate from four different river/watercourse systems and coalesce into a valley-bottom wetland. The wetland type can be considered to be a discontinuously channelled valley-bottom wetland as the channels are not consistent throughout the HGM unit. The catchment of this wetland is predominantly natural with scattered agricultural activities and the relatively small development associated with Jagersfontein town and the diamond mine. The entire wetland complex is approximately 1900 ha in size and flows along the Vanzylspruit and the Prosesspruit Rivers. The wetland is mainly characterised by wet grasslands and patches of sedge meadows that are characterised by longer wetness periods. The bottom portion of the HGM unit, where the stream systems converge, is characterised by a large stand of Phragmites australis and other large emergent wetland vegetation. The northern arm of the wetland receives water inputs from the Jagersfontein town, including the diamond mine and the wastewater treatment works, which appears to have caused some water quality concerns in the downstream wetland in the form of grey-coloured water which smells of sewage and white foam forming on the surface of the water downstream of the WWTW. The central two arms that flow from west to east are both characterised by straightened channels – possibly as a result of the railway embankment and associated culverts beneath the embankment. Large areas of erosion were also observed onsite.

Wetland PES Summary				
Wetland name	**WRU 15**			
Assessment Unit	**Jagersfontein Valley Bottom Wetland**			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	1907.3 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	1.5	1.5	6.7	4.1
PES Score (%)	85%	85%	33%	59%
Ecological Category	**B**	**B**	**E**	**D**
Combined Impact Score	3.2			
Combined PES Score (%)	68%			
Combined Ecological Category	**C**			

EIS	Moderate
REC	C

EcoSpec	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than they are.

5.2.11 WRU 16 - Barkley Pass Wetland Complex

WRU 16 is a significant wetland complex consisting of multiple valley-bottom and hillslope seep wetlands which, in total, spread across an area of approximately 230 ha. This large wetland complex is situated on a tributary of the Langkloofspruit River which is a tributary of the Kraai River – an extremely important water source to the Orange River. The wetlands are high up in their catchment and are therefore not impacted significantly by catchment-related impacts. These systems are controlled by a local base level which is set by a sill of resistant rock which has formed a large waterfall feature. This base level has allowed the upstream systems to grade themselves to an appropriate longitudinal slope for their discharge and should therefore have a relatively low risk of erosion. The wetlands and their immediate catchment are utilised for grazing, as the entire wetland complex is owned by a sheep farmer. Discussions with the landowner revealed that livestock stocking rates were low on the farm and that the grazing pressure was not excessive

Wetland PES Summary				
Wetland name	**WRU 16a**			
Assessment Unit	**Barkley Pass Valley Bottom Wetlands**			
HGM type	Channelled VB wetland laterally maintained (i.e., with substantial lateral inputs)			
Wetland area (ha)	189.5 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	0.0	0.3	0.4	1.0
PES Score (%)	100%	97%	96%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

Wetland PES Summary				
Wetland name	**WRU 16b**			
Assessment Unit	**Barkley Pass Seep Wetlands**			
HGM type	Seep			
Wetland area (ha)	47.4 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	0.0	0.3	0.4	1.0
PES Score (%)	100%	97%	96%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

EIS WRU16a	High	**EIS WRU16b**	High

REC WRU16a	A	**REC WRU16b**	A
EcoSpec	To maintain the current integrity of these wetlands and the REC, no land use changes should be permitted within the wetlands themselves.		

5.2.12 WRU 17 – Tiffindell Seep Wetland Complex

WRU 17 is similar to WRU 16 in that it is a high-altitude wetland complex consisting of a series of hillslope seeps and valley-bottom wetlands which cover a total area of 190 ha. The remote nature of these wetlands has resulted that the majority of their catchments remain relatively natural. However, a large number of cattle and sheep were observed in these catchments and the wetlands themselves, and grazing evidence was widespread in the wetlands and catchments. These wetlands are characterised by very shallow soils and the predominance of *Merxmuellera disticha* and *Merxmuellera macowanii*. In some of the deeper portions of the valley-bottom wetlands, a combination of the nutrient-poor and very cold water has resulted in the formation of peat. These wetlands form an important part of the headwaters of the Bell River, which is a large tributary of the Kraai River.

Wetland PES Summary				
Wetland name	**WRU 17**			
Assessment Unit	**Tiffindell Seep Wetlands**			
HGM type	Seep			
Wetland area (ha)	196.0 ha			
PES Assessment	**Hydrology**	**Geomorphology**	**Water Quality**	**Vegetation**
Impact Score	0.3	0.4	0.4	1.4
PES Score (%)	97%	96%	96%	86%
Ecological Category	**A**	**A**	**A**	**B**
Combined Impact Score	0.6			
Combined PES Score (%)	94%			
Combined Ecological Category	**A**			

EIS	Moderate
REC	A

EcoSpec	To maintain the current integrity of these wetlands and the REC, no land use changes must be permitted within the wetlands themselves, and only very specific, low-impact land uses should be allowed in these catchments. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species should be managed in the wetlands and their catchments.

Table 5-1: Summary of the PES, EIS and REC of all WRUs in the Upper Orange Catchment Area

Quaternary Catchment	WRU	Wetland Name	HGM Type	PES		Wetland EIS		REC	
D21G	WRU 02	Brandwater Foodplain	Floodplain Wetland	C		HIGH		C	
C52H	WRU 03	Soutpan Depression Wetland Complex	Depression Wetlands	C	B	MODERATE	MODERATE	C	B
D31B	WRU 04	Philiptown Unchannelled Valley-Bottom Wetland Complex	Unchannelled Valley-Bottom Depression Wetlands	A	C	MODERATE	MODERATE	A	C

Quaternary Catchment	WRU	Wetland Name	HGM Type	PES		Wetland EIS		REC	
D13G	WRU 05	Wolwespruit Headwaters Wetland Complex	Unchannelled Valley-Bottom Hillslope Seep Wetlands	C	C	HIGH	MODERATE	C	C
D13E	WRU 06	Klein-Wildebeespruit Wetland Complex	Channelled Valley-Bottom Hillslope Seep Wetlands	D	D	MODERATE	MODERATE	D	C
D33C	WRU 10	Luckhof Depression Wetland Complex	Depression Wetlands	B		MODERATE		B	

Quaternary Catchment	WRU	Wetland Name	HGM Type	PES			Wetland EIS			REC		
C52G	WRU 11	Kaalspruit Wetland Complex	Channelled Valley-Bottom Discontinuously Channelled Valley-Bottom Depression Wetlands	C	C		HIGH	MODERATE		C	C	
C52G	WRU 12	Aardoringsprut Wetland Complex	Discontinuously Channelled Valley-Bottom Wetland Flats	C	C		MODERATE	HIGH		C	C	
D22G	WRU 13	Rantssho Wetland Complex	Floodplain, Channelled Valley-Bottom Unchannelled Valley-Bottom	D	C	D	MODERATE	MODERATE	HIGH	C	C	C

Quaternary Catchment	WRU	Wetland Name	HGM Type	PES		Wetland EIS		REC	
C51H	WRU 15	Jagersfontein Discontinuously Channeled Valley-Bottom Wetland	Discontinuously Channelled Valley-Bottom	C		MODERATE		C	
D13D	WRU 16	Barkley Pass Wetland Complex	Unchannelled Valley-Bottom Channelled Valley-Bottom Hillslope Seep Wetlands	A	A	HIGH	HIGH	A	A
D13B	WRU 17	Tiffindell Seep Wetland Complex	Unchannelled Valley-Bottom Hillslope Seep Wetlands	A		MODERATE		A	

5.3 Wetlands Monitoring Programme

Wetland integrity is impacted by changes in land use, mainly driven by hydrology, geomorphology, water quality, and vegetation. Altered hydrology can lead to desiccation, increased erosion risk, and shifts in vegetation. Water quality influences ecosystem health and species composition.

Similar to the rivers, please refer to **Table 5-2** for the primary concepts guiding a proposed monitoring programme for the various wetland resource units. Based on these, some management measures have further been provided in **Table 5-3**, which should be addressed for adaptive management. To reiterate, the DSS will be assessed and outlined in more detail during the Classification Study currently being undertaken, and which will further include management options for implementation.

Table 5-2: Wetland monitoring programme

Component	Monitoring programme	Frequency	EWR site application
Water quality	*In situ* water quality: Parameters that should be assessed at each of the prioritised wetland RUs must include: pH, DO, EC, TDS and water temperature (which further forms part of the water quality management actions).	Bi-annually (wet and dry season)	All prioritised wetland RUs
	Water clarity monitoring using clarity tubes to monitor the sediment loads within the systems. These water clarity measurements can only effectively be undertaken in wetlands that have channelled flows and should be undertaken towards the bottom end of the wetland, from within the channel.		WRU 02 WRU 06 WRU 11 WRU 12 WRU 13 WRU 15 WRU 16
General Habitat Assessment	General description of the wetland sites and broader wetland habitat (as documented in the final wetland report). Parameters to be capture include; site photographs (for further identification of major changes and documentation of habitat conditions); catchment features (i.e., surrounding land use, sources of pollution, erosion, etc.).	Bi-annually (wet and dry season),	All prioritised wetland RUs
Wetland integrity assessment	An integrity assessment, using the WET-Health assessment technique (Macfarlane et al. 2020), of the WRU's should be undertaken to establish if there are any significant changes to the integrity of the system. The assessment should include a visit to the WRU's (where possible) and not be solely reliant on aerial imagery.	Every 3 – 5 years	All prioritised wetland RUs
Agriculture and/or agriculture run-off	Assessment of the wetlands to ensure no further agriculture develops within or around the wetland. Furthermore, no further agricultural runoff to be discharged into the wetlands. Assessment to be conducted during the wetland integrity assessment	Annual	All prioritised wetland RUs
Dams/impoundments or roads	Assessment of the wetlands to ensure no further dams/impoundments or roads are developed within or through the wetland. Additionally, the construction of significant dams	Annual	WRU 05 WRU 06 WRU 11

Component	Monitoring programme	Frequency	EWR site application
	in the catchment of these wetlands should also be subject to an EWR quantification for the wetland downstream of the proposed dam site.		WRU 13 WRU 15 WRU 17
Geomorphology and Erosion	Control measures should be implemented, particularly for sites where severe erosion is taking place either directly within the wetland and/or buffer zone. In many instances severe erosion within a wetland would be subject to engineered designs to halt the erosional features. However, in areas where wind erosion may be more prevalent, 'softer' rehabilitation methods may be suitable e.g. brush-packing and/or potholes or ecologs (interventions). Erosion control measures would also need to be adopted in those areas that are heavily infested with alien vegetation, following the clearing of alien vegetation. Sites will need to be assessed and implementation plans developed to properly manage erosion.	Annually. Although any rehabilitation work would be subject to a detailed rehabilitation plan.	WRU 03 WRU 10 WRU 11 WRU 15
	Sediment sources into depression wetlands must be rehabilitated.	Annually	WRU 03 WRU 10 WRU 11
Buffers	Buffer zones around depression wetlands must be maintained.	Annually	WRU11
Analysis and Interpretation	The data collected from this wetland monitoring programme should be analysed and interpreted on a bi-annual basis, with a trends report published on an annual basis. This report should be externally reviewed.	Annually	All WRUs

Table 5-3: Management programme per wetland resource unit

WRU	Management programme per wetland resource unit
WRU02	No additional cultivation should be allowed to take place within the wetland, especially not within an intact portion or flood-out zone. There should be no further encroachment of AIP species within the wetland. Additional recommendations include the removal of *Salix babylonica* trees from the channel of the wetland and ensuring the control of alien invasive plants takes place within the wetland – provided that their removal can be undertaken safely and in such a way that it is beneficial both to the wetland and the landowners (i.e., their removal does not result in unnecessary and excessive ecological damage to the wetland and provided that these trees are not currently used by farmers to provide livestock with shaded areas).
WRU04a, b	There must be no expansion of agricultural activities or other land uses into the remaining intact UCVB wetland areas.
WRU05a, b	No further dams must be permitted within any of the wetland areas, and an appropriate groundwater study must be undertaken before any further boreholes/wind pumps are constructed within the wetland and its catchment. No further cultivation must be permitted within the remaining intact portions of the wetland and there must be no further changes to the natural hydrology of the wetland – e.g., from perennial to seasonal wetness zones. No further drains must be permitted within the remaining intact portions of the wetlands and no new roads should be constructed through intact wetland areas. A WET-Health assessment of the complex must be undertaken every 2-3 years2 with a specific focus on the Hydrology module and the 'Change in water distribution and retention' score – specifically for the UCVB wetlands. Where possible, existing roads must be upgraded to incorporate sufficient through flow capacity in the form of culverts or permeable road bedding to encourage natural water distribution and retention across the width of the wetland up and downstream of the roads. In addition, rotational burning (2-3 years) of the wetland should be encouraged where possible to promote vegetation vigour although this should be sensitive to the requirements of the crane species utilising the system
WRU06a, b	No further cultivation must be permitted within the remaining intact portions of the wetland and there must be no further changes to the natural hydrology of the wetland – e.g., from perennial to seasonal wetness zones. No further drains must be permitted within the remaining intact portions of the wetlands and no new roads should be constructed through intact wetland areas. There should be no further encroachment of AIP species within the wetland. Additional recommendations include the removal of AIP trees from the channel of the wetland valley-bottom wetlands and ensuring the control of alien invasive plants takes place within the wetland – provided that their removal can be undertaken safely and in such a way that it is beneficial both to the wetland and the landowners (i.e., their removal does not result in

[2] The frequency of these assessments is high because of the threat status of the wetland and its importance as a headwater wetland.

WRU	Management programme per wetland resource unit
	unnecessary and excessive ecological damage to the wetland and provided that these trees are not currently used by farmers to provide livestock with shaded areas).
WRU10	No further agricultural runoff must be discharged into the WRU without appropriate mitigation measures being implemented. No further cultivation should be permitted within the remaining intact portions of the WRU either.
WRU11a, b	Formal buffer areas between the cultivated areas and the depression wetlands must be established and maintained with the adoption of appropriate mitigation measures. AIP species must also be managed at the current levels, and further encroachment of AIP species must be avoided. No new road must be approved through any of the remaining intact wetland areas. A large sediment deposit was observed in one of the depression wetlands. The erosion source resulting in the deposition of this sediment must be rehabilitated immediately to prevent the further loss of wetland functioning and integrity in subsequent rainfall seasons.
WRU12a, b	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than what they are currently. This requires that additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. While no cultivation has yet taken place in the wetland, no intensive cultivation must be permitted in the remaining intact portions of the wetland. The wetland is widely used for grazing, but the grazing pressure must be kept at an appropriate level to prevent further erosion in the discontinuously channelled portion of the HGM unit.
WRU13a, b	To maintain the current state of the Rantsho Wetland Complex, no further cultivation or other intensive land uses must be permitted to expand into the remaining intact portions of the wetlands. Furthermore, no further infrastructure such as dams or roads must be permitted within the remaining intact portions of the wetland. Additionally, there must be no further degradation of the water quality such that it impacts the downstream freshwater ecosystems. Agricultural and livestock operations must periodically be monitored for discharge into WRU 13. There must be no further encroachment of woody alien invasive vegetation into any of the wetland areas, and efforts should be made to remove the current population of Salix babylonica individuals that line sections of the channel in the FP and CVB wetlands. In addition, AIPs must be managed within a 200 m radius of the wetland to avoid additional AIP propagules entering the HGM unit.
WRU15	No additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. Furthermore, while no cultivation has yet taken place in the wetland, no intensive cultivation should be permitted in the remaining intact portions of the wetland and an appropriate buffer zone. The wetland is widely utilised for grazing, but the grazing numbers must be kept at an acceptable level to prevent further erosion in the discontinuously channelled portion of the HGM unit. Also, annual monitoring of water

WRU	Management programme per wetland resource unit
	quality in the HGM unit downstream of Jagersfontein town must be undertaken to ensure that the WWTW, the diamond mine and the town of Jagersfontein are not contributing to a significant decline in the water quality and the biota in the wetland. Water quality parameters that should be monitored include diatoms, E. coli, temperature, turbidity and electrical conductivity at a minimum.
WRU16a, b	Only very specific, low-impact land uses must be permitted in the catchments of these wetlands unless appropriate studies and mitigation measures are implemented. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species must be managed in the wetlands and their catchments.
WRU17	To maintain the current integrity of these wetlands and the REC, no land use changes must be permitted within the wetlands themselves, and only very specific, low-impact land uses should be allowed in these catchments. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species should be managed in the wetlands and their catchments.
Catchment management: Boreholes	Visual assessment of the wetlands and their immediate catchments to ensure no additional boreholes or windmills to be drilled in the catchment without groundwater studies. Additional authorisation of boreholes and windmills should be accompanied by groundwater studies.
Catchment management: Alien vegetation	Compile an alien weed infestation eradication implementation programme. Eradication and control of exotic vegetation within the wetland habitat should be implemented to enhance wetland integrity and functioning, increase bank stability, reduce erosion, and improve the general buffering capacity of systems. The portions of the wetland and/or buffer area with sparse/scattered alien vegetation should be prioritised to limit further spread. Highly infested areas will require intensive and on-going management to effectively eradicate problem species, together with revegetation and ongoing maintenance. Livestock pressures (i.e. grazing and trampling) will require special consideration, especially given that wetlands are freely accessed by communities and their livestock, but livestock can also be an asset for rebuilding soils and restoring vegetation cover. An Alien Plant Control Plan will need to be developed with realistic and attainable targets set;

6. GROUNDWATER: RESULTS

In accordance with WRC (2012), components of the Groundwater Reserve include groundwater recharge, BHN for groundwater (**Table 3-2**), as well as groundwater contribution to baseflow. Using the available data, the latter components were estimated to determine the Groundwater Reserve as a percentage of Recharge.

However, it is crucial to acknowledge the significant limitations associated with the groundwater component in this study:

- The lack of monthly rainfall and abstraction data to determine more detailed groundwater recharge calculations. Although WR 2012 rainfall data was used, the data is only until end-2009. Furthermore, rainfall estimates from rain gauges and satellite observations from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) was also interrogated and assessed;
- The lack of rainfall chemistry data for detailed groundwater recharge calculations. In the absence of rainfall chemistry data, a default values were used as prescribed by the Recharge Toolkit;
- The lack of groundwater quality data for the majority of the quaternary catchments;
- Incomplete surface flow monitoring data. Although WR 2012 flow data was used, the data is only until end-2009;
- Multiple attempts, with the help of DWS, to obtain groundwater data from the municipalities, was unsuccessful;
- Overall, there is very sparse and lack of data – limitation in this catchment. It is a problem generically and systemically in this environment we are working in;
- The Groundwater Resource Directed Measures (GRDM) methodology is currently being updated and will only be available in 2024 (post the completion of this study). The current assessment is therefore based on WRC (2012) methodology; and

Therefore, due to the above-mentioned limitations, the groundwater report was treated as an initial assessment for estimations of the groundwater component of the Reserve in the catchment. This needs to be updated once more detailed data and information become available during the Classification phase of the study, currently being undertaken.

6.1 Hydrocensus

A hydrocensus investigation was conducted from 25 - 29 April 2022. Due to the size and number of groundwater monitoring resources, the main focus areas were six of the prioritised GRU as summarised in **Table 6-1** and illustrated in **Figure 2-3.**

Table 6-1: Summary of Prioritised GRU

Resource Units	Quaternary Catchment/s	City / Town
GW_RU03	C52G, C52J, C52F, C52D, C51H	Bloemfontein, Jagersfontein
GW_RU04	C52H, C52G	Soutpan,
GW_RU05	C52K	Petrusburg
GW_RU14	C52K, D33K, D33C	Dealesville, Ritchie, Jacobsdal, Luckhoff
GW_RU10	D32A, D32B, D32E	Hanover, Noupoort

Resource Units	Quaternary Catchment/s	City / Town
GW_RU07	D13D, D13E, D18K, D13K, D13A,	Buckley East, Rhodes, Lady Grey

The hydrocensus focussed on WMS, Hydstra, municipal groundwater resources, as well as a few surface water bodies in proximity to groundwater resources. The objectives of the hydrocensus were to identify and verify groundwater resources in the catchment, collect field data, i.e. measurements of borehole depth, water levels, borehole yield and basic water chemistry.

6.2 Present Status of the Groundwater Resource Units

Existing monitoring data was assessed for each GRU through obtaining data from DWS, the Water use Authorization & Registration Management System (WARMS) database, SanParks and the Department of Agriculture, land reform and rural development. The data includes WMS, Hydstra and EWR surface flow data. The data provides insight regarding historical information, length of monitoring record, and whether the sites were active or non-active.

6.3 Groundwater Reserve: Quantity

Evaluating the Reserve through groundwater quantification and qualitative analysis – this initiative aimed to determine the groundwater volume essential for sustaining the EWR and BHNs. Additionally, it aimed to assess groundwater quality per GRU, focusing on a quaternary based perspective. This step was crucial for establishing the potential quantity and quality of groundwater available for allocation to current and potential users.

Based on the limited available data, the Recharge toolkit (WRC, 2012) was used to determine recharge per quaternary catchment. A summary of the recharge per quaternary catchment present within the Upper Orange Catchment area is provided in **Table 6-2**. Due to the lack of sufficient monthly water level data, recharge estimation was mainly limited to the Chloride Mass Balance (CMB) method and qualified guesses.

Table 6-2: Summary of Groundwater Recharge Calculations

Quaternary Catchment	Recharge Method	Average Annual Recharge (mm)	Recharge (% of Rainfall)	Recharge (Mm^3/a)
C51A	CMB+Qualified Guess	16.6	3.5	11.205
C51B	Qualified Guess	14.5	3.1	24.548
C51C	Qualified Guess	16.8	4.0	10.508
C51D	Qualified Guess	17.1	3.5	15.796
C51E	Qualified Guess	17.0	4.0	13.681
C51F	Qualified Guess	15.8	4.3	13.880
C51G	CMB+Qualified Guess	14.8	3.7	27.112
C51H	Qualified Guess	15.5	3.9	27.668
C51J	Qualified Guess	16.7	4.3	17.592
C51K	CMB+Qualified Guess	13.9	4.0	50.301

Quaternary Catchment	Recharge Method	Average Annual Recharge (mm)	Recharge (% of Rainfall)	Recharge (Mm^3/a)
C51L	Qualified Guess	10.3	2.9	20.906
C51M	CMB+Qualified Guess	6.8	2.1	10.364
C52A	CMB+Qualified Guess	26.5	4.9	24.854
C52B	Qualified Guess	27.4	4.9	25.978
C52C	Qualified Guess	26.4	5.0	15.868
C52D	Qualified Guess	24.3	4.7	11.440
C52E	Qualified Guess	18.4	3.8	16.466
C52F	Qualified Guess	18.9	3.7	12.988
C52G	Qualified Guess	15.9	3.3	28.516
C52H	CMB+Qualified Guess	12.6	2.8	29.795
C52J	Qualified Guess	18.0	3.9	34.508
C52K	Qualified Guess	13.1	3.2	56.603
C52L	Qualified Guess	16.3	4.3	39.179
D12A	CMB+Qualified Guess	41.7	6.6	15.376
D12B	CMB+Qualified Guess	43.6	6.1	16.802
D12C	CMB+Qualified Guess	43.6	6.8	14.955
D12D	CMB+Qualified Guess	38.1	6.3	13.523
D12E	CMB+Qualified Guess	37.7	6.4	26.824
D12F	CMB+Qualified Guess	33.6	6.2	24.992
D13A	Qualified Guess	39.2	4.8	18.600
D13B	Qualified Guess	37.9	4.8	20.209
D13C	Qualified Guess	39.4	5.6	20.376
D13D	CMB+Qualified Guess	45.5	6.7	28.928
D13E	Qualified Guess	28.0	3.7	28.904
D13F	Qualified Guess	34.0	5.1	32.999
D13G	Qualified Guess	30.7	4.9	34.568
D13H	CMB+Qualified Guess	12.4	2.3	14.231
D13J	Qualified Guess	30.0	5.4	34.980
D13K	Qualified Guess	29.7	4.1	11.809
D13L	Qualified Guess	30.4	5.1	20.704
D13M	Qualified Guess	15.1	2.8	10.246
D14A	CMB+Qualified Guess	10.2	2.1	7.834
D14B	Qualified Guess	14.6	3.0	4.741
D14C	Qualified Guess	12.4	2.5	8.964
D14D	Qualified Guess	12.0	2.7	8.141
D14E	CMB+Qualified Guess	10.9	2.5	7.239
D14F	Qualified Guess	12.4	2.5	6.725
D14G	Qualified Guess	24.8	3.9	27.944
D14H	Qualified Guess	12.1	2.8	8.410

Quaternary Catchment	Recharge Method	Average Annual Recharge (mm)	Recharge (% of Rainfall)	Recharge (Mm^3/a)
D14J	Qualified Guess	12.1	2.8	6.217
D14K	Qualified Guess	12.0	2.8	7.599
D15G	Qualified Guess	26.5	4.0	12.832
D15H	Qualified Guess	23.5	3.9	8.463
D18K	Qualified Guess	34.1	4.4	31.879
D18L	Qualified Guess	32.2	4.9	19.649
D21A	Qualified Guess	73.2	7.5	22.647
D21C	Qualified Guess	60.2	6.8	12.729
D21D	Qualified Guess	53.3	6.4	13.415
D21E	CMB+Qualified Guess	62.2	7.9	16.701
D21F	Qualified Guess	52.1	7.2	25.000
D21G	Qualified Guess	41.6	5.5	11.566
D21H	Qualified Guess	53.7	6.9	20.450
D22A	Qualified Guess	43.5	6.4	27.625
D22B	Qualified Guess	55.9	7.7	25.541
D22C	Qualified Guess	44.1	5.6	21.398
D22D	Qualified Guess	36.1	5.2	22.649
D22G	CMB+Qualified Guess	39.3	5.7	38.045
D22H	Qualified Guess	37.1	5.1	20.057
D22L	Qualified Guess	31.3	4.4	11.794
D23A	Qualified Guess	39.9	5.8	24.247
D23C	Qualified Guess	30.7	4.8	26.455
D23D	Qualified Guess	29.0	4.8	16.377
D23E	Qualified Guess	29.0	4.7	20.350
D23F	Qualified Guess	18.4	2.9	6.475
D23G	Qualified Guess	28.9	4.7	14.804
D23H	Qualified Guess	26.4	5.1	20.477
D23J	Qualified Guess	27.0	5.0	14.398
D24A	Qualified Guess	19.3	3.1	5.973
D24B	Qualified Guess	19.2	3.3	9.050
D24C	Qualified Guess	17.3	3.3	6.902
D24D	Qualified Guess	16.9	3.5	10.140
D24E	Qualified Guess	17.1	3.5	8.383
D24F	Qualified Guess	18.5	3.6	10.515
D24G	CMB+Qualified Guess	21.6	4.1	13.514
D24H	Qualified Guess	17.0	3.6	12.517
D24J	Qualified Guess	16.7	3.7	17.252
D24K	Qualified Guess	18.6	2.1	8.223
D24L	Qualified Guess	14.5	3.3	7.392

Quaternary Catchment	Recharge Method	Average Annual Recharge (mm)	Recharge (% of Rainfall)	Recharge (Mm^3/a)
D31A	Qualified Guess	11.8	3.0	13.713
D31B	Qualified Guess	10.1	3.2	10.076
D31C	Qualified Guess	10.3	3.1	6.959
D31D	Qualified Guess	13.6	3.6	15.036
D31E	Qualified Guess	10.6	3.0	10.251
D32A	Qualified Guess	10.9	3.5	7.783
D32B	Qualified Guess	11.2	3.3	6.479
D32C	Qualified Guess	11.8	3.7	10.060
D32D	Qualified Guess	10.9	3.5	9.236
D32E	CMB+Qualified Guess	8.0	2.9	9.282
D32F	Qualified Guess	10.8	3.5	15.570
D32G	CMB+Qualified Guess	10.4	3.1	10.829
D32H	CMB+Qualified Guess	10.4	3.2	5.974
D32J	Qualified Guess	10.2	3.3	14.635
D32K	CMB+Qualified Guess	9.5	2.9	7.795
D33A	Qualified Guess	15.2	4.6	9.024
D33B	Qualified Guess	10.1	3.2	10.307
D33C	Qualified Guess	12.5	3.7	10.015
D33D	Qualified Guess	11.8	4.0	11.249
D33E	Qualified Guess	12.0	3.9	18.597
D33F	Qualified Guess	13.6	4.7	11.686
D33G	Qualified Guess	11.6	4.1	16.263
D33H	Qualified Guess	8.8	3.0	9.296
D33J	Qualified Guess	8.5	3.1	7.330
D33K	Qualified Guess	9.5	3.3	4.649
D34A	Qualified Guess	11.4	3.0	9.071
D34B	Qualified Guess	11.3	3.1	8.004
D34C	Qualified Guess	11.2	3.3	8.491
D34D	Qualified Guess	11.2	3.2	6.726
D34E	Qualified Guess	11.4	3.1	5.902
D34F	Qualified Guess	11.1	3.3	7.690
D34G	Qualified Guess	11.7	3.2	10.962
D35A	Qualified Guess	12.1	2.8	3.072
D35B	Qualified Guess	11.9	2.8	3.108
D35C	Qualified Guess	11.7	2.9	11.058
D35D	Qualified Guess	11.6	3.0	6.816
D35E	Qualified Guess	11.8	2.9	3.667
D35F	Qualified Guess	11.9	2.8	6.624
D35G	Qualified Guess	11.6	.3.0	6.399

Quaternary Catchment	Recharge Method	Average Annual Recharge (mm)	Recharge (% of Rainfall)	Recharge (Mm^3/a)
D35H	Qualified Guess	12.2	3.0	6.070
D35J	CMB+Qualified Guess	19.1	5.2	19.138
D35K	Qualified Guess	12.2	3.2	8.194

Secondly, tools provided for by WRC (2012) were used to determine the groundwater contribution to baseflow. However, in consultation with the civil engineering department at the University of Pretoria, a simplified baseflow separation technique was developed for reasonable results with limited data. The approach involved extracting the lowest average monthly flows during dry months. A desktop analysis considered three options: using the single lowest, two lowest, or three lowest monthly flows. A sensitivity analysis showed insignificant differences among the options, leading to the use of an average from all three to determine the baseflow. A summary of the data is presented in **Table 6-3.** Overall, on average for all 132 quaternary catchments, the groundwater baseflow ranged from $0.12Mm^3/a$ to $64.68Mm^3/a$, averaging ~26% of the total flow.

Table 6-3: Summary of baseflow results

Maximum Groundwater Baseflow (Mm^3/a)	64.68
Minimum Groundwater Baseflow (Mm^3/a)	0.12

The available Groundwater Recharge and Use data were used to quantify the Stress Index (WRC, 2012). The stress index results showed that all quaternary catchments have a surplus of groundwater available, i.e. groundwater use is less than Recharge. The majority of the quaternary catchments fell in the "A" (Natural) category (69%), followed by the "A/B" (Natural to Good) category (16%) and "B" (Good) category (10%). The largest stress index in the Catchment is a "D/E", i.e. Poor to Seriously Modified for C52H and C52J, respectively. (**Figure 6-1**).

Lastly, a water balance approach was used to quantify allocable groundwater in the catchment. A large range in values were observed from $-35.897Mm^3/a$ to $41.447Mm^3/a$. Negative values seemed to indicate that there was no surplus groundwater available in the quaternaries after accounting for the Groundwater Reserve and vice versa. However, it must be noted that the quaternaries with negative Allocable Groundwater coincide with "A" (Natural) categories under the stress index (**Figure 6-2**).

In summary, refer to **Table 6-4** which defines the groundwater Reserve, the Stress Index and Allocable Groundwater in the Upper Orange Catchment Area. Overall, the Groundwater Reserve varies from 0.01% – 18.66% of Recharge.

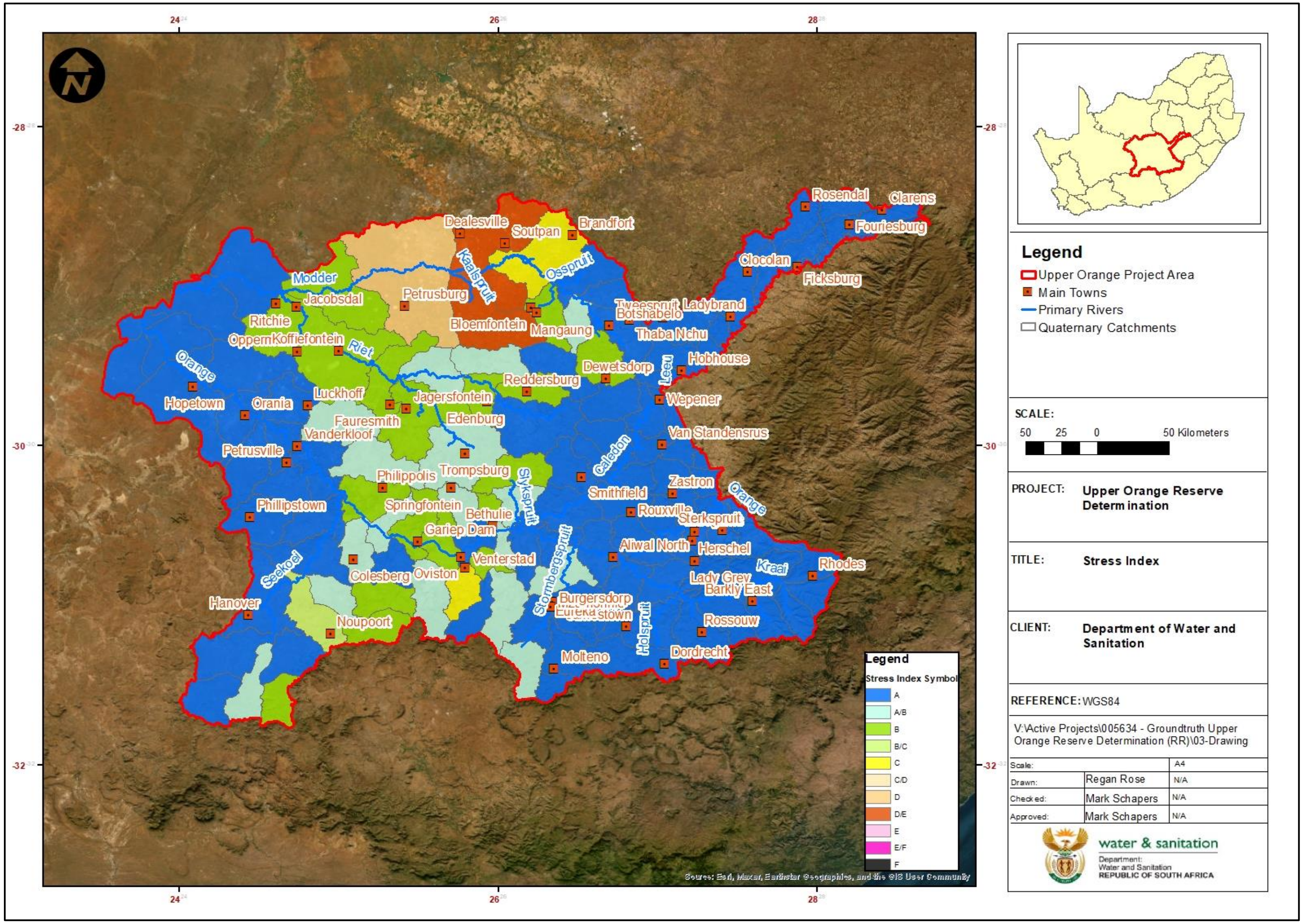


Figure 6-1: Stress index for the GRUs

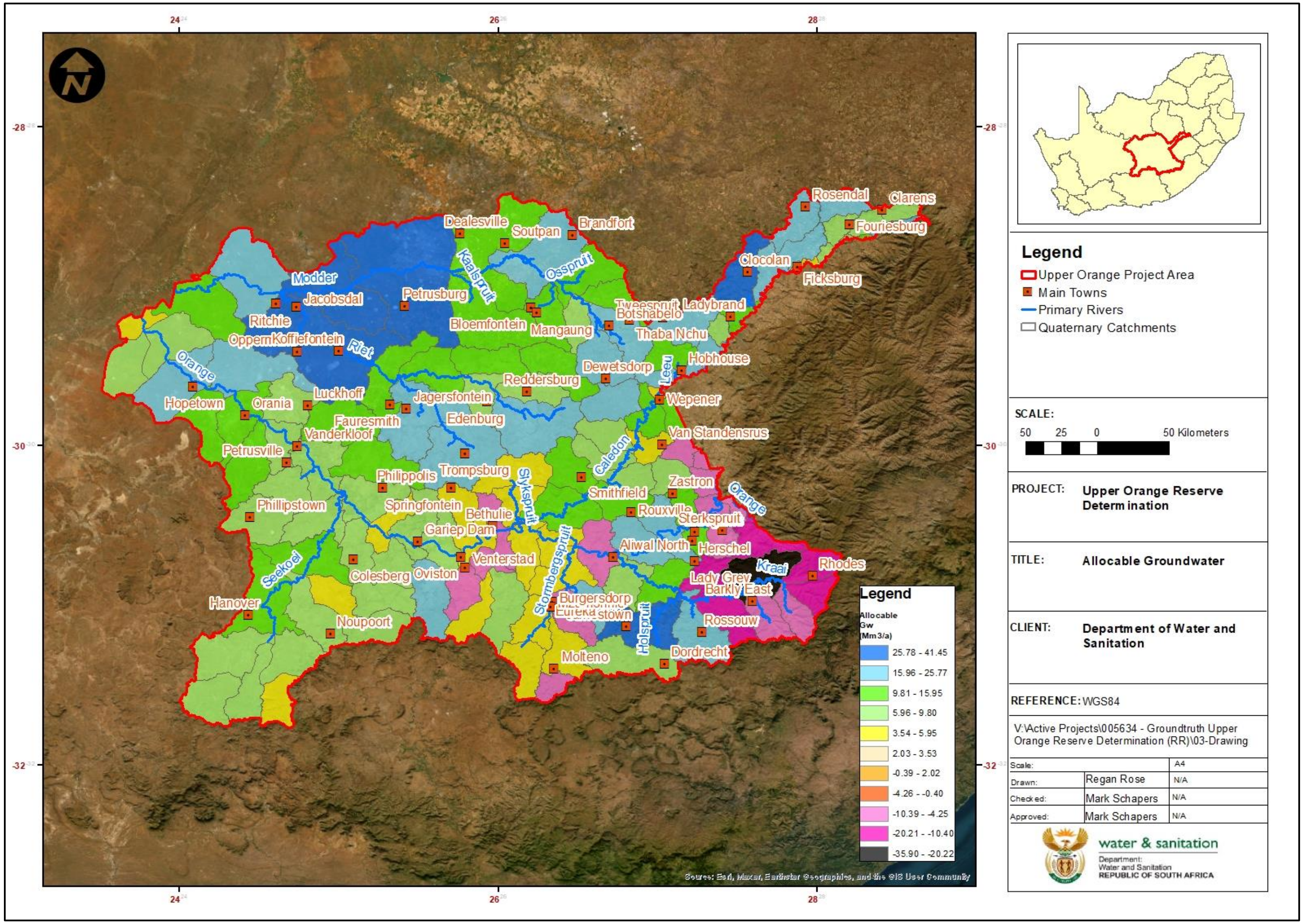


Figure 6-2: Allocable Groundwater indicating surplus or deficit in respective quaternary catchments

Table 6-4: Groundwater Reserve, Stress Index and Allocable Groundwater in the Upper Orange Catchment Area per quaternary catchment

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
2, 3	C51A	629.0	11.21	489	25	0.004	1.92	1.924	1.754	15.65	17.17	0.04%	7.527
2, 3	C51B	1579.1	24.55	804	25	0.007	3.00	3.007	1.089	4.44	12.25	0.03%	20.452
3	C51C	581.5	10.51	313	25	0.003	0.96	0.963	1.376	13.10	9.16	0.03%	8.169
2, 3	C51D	857.6	15.80	1 894	25	0.017	1.92	1.937	0.470	2.97	12.26	0.11%	13.389
3, 14	C51E	749.7	13.68	1 140	25	0.01	2.04	2.050	1.109	8.11	14.98	0.07%	10.522
3, 6, 14	C51F	815.4	13.88	528	25	0.005	1.08	1.085	1.018	7.33	7.82	0.04%	11.777
2, 3, 14	C51G	1716.0	27.11	752	25	0.007	4.68	4.687	2.072	7.64	17.29	0.03%	20.353
3, 6, 14	C51H	1662.2	27.67	1 062	25	0.01	3.48	3.490	3.354	12.12	12.61	0.04%	20.824
3, 5, 6, 14	C51J	978.3	17.59	585	25	0.005	1.20	1.205	3.128	17.78	6.85	0.03%	13.259
3, 6, 13, 14	C51K	3371.4	50.30	1 833	25	0.017	0.72	0.737	7.488	14.89	1.47	0.03%	42.076
13	C51L	1877.3	20.91	1 032	25	0.009	0.48	0.489	0.428	2.05	2.34	0.04%	19.989
13	C51M	1406.9	10.36	723	25	0.007	0.36	0.367	0.014	0.14	3.54	0.07%	9.983
1, 2, 3	C52A	871.2	24.85	906	25	0.008	3.96	3.968	2.970	11.95	15.97	0.03%	17.916
1, 3	C52B	881.5	25.98	1 394	25	0.013	2.76	2.773	0.026	0.10	10.67	0.05%	23.179
1, 3	C52C	556.3	15.87	594	25	0.005	1.44	1.445	0.216	1.36	9.11	0.03%	14.207
3	C52D	437.3	11.44	590	25	0.005	0.96	0.965	0.845	7.39	8.44	0.04%	9.630
3, 4	C52E	830.1	16.47	750	25	0.007	1.32	1.327	0.755	4.59	8.06	0.04%	14.384
3, 4	C52F	638.0	12.99	5 048	25	0.046	1.20	1.246	1.759	13.54	9.59	0.35%	9.983

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
3, 4, 14	C52G	1653.0	28.52	1 609	25	0.015	1.68	1.695	10.725	37.61	5.94	0.05%	16.096
3, 4, 14	C52H	2192.1	29.80	3 174	25	0.029	0.12	0.149	18.939	63.56	0.50	0.10%	10.707
3, 14	C52J	1783.4	34.51	7 480	25	0.068	0.36	0.428	23.287	67.48	1.24	0.20%	10.793
3, 5, 14	C52K	4007.2	56.60	2 652	25	0.024	0.24	0.264	29.382	51.91	0.47	0.04%	26.957
5, 13, 14	C52L	2226	39.18	1 690	25	0.015	0.24	0.255	5.114	13.05	0.65	0.04%	33.810
2, 7	D12A	346.5	15.38	4 237	25	0.039	13.2	13.239	0.306	1.99	86.10	0.25%	1.831
2, 7, 8	D12B	362.2	16.80	6 317	25	0.058	18.60	18.658	0.066	0.39	111.05	0.35%	-1.922
2, 7, 8	D12C	322.4	14.96	1 401	25	0.013	2.52	2.533	0.000	0.00	16.94	0.09%	12.422
2, 7	D12D	333.4	13.52	224	25	0.002	1.80	1.802	0.006	0.05	13.33	0.01%	11.715
2, 7, 8	D12E	669.1	26.82	799	25	0.007	3.48	3.487	1.057	3.94	13.00	0.03%	22.280
2, 8, 9	D12F	755.5	24.99	530	25	0.005	3.12	3.125	0.184	0.74	12.50	0.02%	21.683
7	D13A	448.1	18.60	329	25	0.003	33.24	33.243	0.135	0.73	178.73	0.02%	-14.778
7	D13B	502.1	20.21	366	25	0.003	35.52	35.523	0.006	0.03	175.78	0.01%	-15.320
7	D13C	488.4	20.38	358	25	0.003	28.80	28.803	0.000	0.00	141.36	0.01%	-8.427
7	D13D	600.3	28.93	478	25	0.004	32.04	32.044	0.881	3.05	110.77	0.01%	-3.997
7	D13E	971.6	28.90	855	25	0.008	64.68	64.688	0.113	0.39	223.8	0.03%	-35.897
7, 8	D13F	916.3	33.00	855	25	0.008	48.12	48.128	0.040	0.12	145.85	0.02%	-15.169
7, 8	D13G	1064.4	34.57	923	25	0.008	9.84	9.848	0.069	0.20	28.49	0.02%	24.651
8	D13H	1084.3	14.89	864	25	0.008	6.60	6.608	0.049	0.33	44.37	0.05%	8.235
7, 8	D13J	1103.5	34.98	747	25	0.007	7.08	7.087	0.600	1.72	20.26	0.02%	27.293

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
7, 8	D13K	374.3	11.81	358	25	0.003	23.52	23.523	0.161	1.36	199.20	0.03%	-11.875
7, 8	D13L	642.8	20.70	445	25	0.004	6.12	6.124	0.229	1.10	29.58	0.02%	14.351
8, 9	D13M	639.3	10.25	557	25	0.005	3.96	3.965	0.254	2.48	38.70	0.05%	6.027
2, 8, 9	D14A	719.4	7.83	740	25	0.007	4.08	4.087	0.323	4.12	52.17	0.09%	3.424
9	D14B	307.5	4.74	190	25	0.002	1.32	1.322	0.000	0.00	27.88	0.04%	3.419
8, 9	D14C	683.5	8.96	446	25	0.004	3.36	3.364	0.284	3.17	37.53	0.04%	5.316
9	D14D	644.5	8.14	383	25	0.003	2.04	2.043	0.499	6.13	25.10	0.04%	5.599
9	D14E	627.1	7.24	425	25	0.004	1.80	1.804	0.360	4.98	24.92	0.06%	5.075
8, 9	D14F	511.3	6.73	302	25	0.003	2.88	2.883	0.054	0.80	42.87	0.04%	3.788
8, 9	D14G	571.7	27.94	373	25	0.003	3.12	3.123	0.091	0.33	11.18	0.01%	24.730
8, 9	D14H	657	8.41	487	25	0.004	2.16	2.164	0.517	6.15	25.73	0.05%	5.729
2, 8, 9	D14J	484.4	6.22	285	25	0.003	1.56	1.563	0.286	4.60	25.14	0.05%	4.368
2, 8, 9	D14K	596.5	7.60	319	25	0.003	1.80	1.803	0.269	3.55	23.73	0.04%	5.527
2	D15G	453.6	12.83	76	25	0.001	18.60	18.601	0.000	0.00	144.96	0.01%	-5.769
2, 7	D15H	338.1	8.46	209	25	0.002	12.12	12.122	0.002	0.02	143.24	0.02%	-3.661
7	D18K	879.2	31.88	4 263	25	0.039	48.00	48.039	0.000	0.00	150.69	0.12%	-16.160
2, 7	D18L	571.4	19.65	5 401	25	0.049	25.20	25.249	0.000	0.00	128.50	0.25%	-5.600
1	D21A	285.4	22.65	280	25	0.003	0.00	0.003	0.006	0.03	0.01	0.01%	22.638
1	D21C	195.5	12.73	76	25	0.001	0	0.001	0.000	0.00	0.01	0.01%	12.728
1	D21D	231.8	13.42	795	25	0.007	6.84	6.847	0.004	0.03	51.04	0.05%	6.564

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
1	D21E	247.5	16.70	929	25	0.008	7.32	7.328	0.370	2.22	43.88	0.05%	9.003
1	D21F	441.9	25.00	1 623	25	0.015	4.56	4.575	0.350	1.40	18.30	0.06%	20.075
1	D21G	256.6	11.57	773	25	0.007	2.64	2.647	0.021	0.18	22.89	0.06%	8.898
1	D21H	351.9	20.45	279	25	0.003	13.2	13.203	0.000	0.00	64.56	0.01%	7.247
1	D22A	586.1	27.63	1 223	25	0.011	4.44	4.451	0.092	0.33	16.11	0.04%	23.082
1	D22B	422.2	25.54	997	25	0.009	3.84	3.849	0.005	0.02	15.07	0.04%	21.687
1	D22C	449.3	21.40	223	25	0.002	16.20	16.202	0.000	0.00	75.72	0.01%	5.196
1	D22D	580.8	22.65	1 034	25	0.009	4.44	4.449	0.289	1.28	19.64	0.04%	17.911
1	D22G	897.0	38.05	1 651	25	0.015	6.12	6.135	0.156	0.41	16.13	0.04%	31.754
1	D22H	501.9	20.06	612	25	0.006	4.32	4.326	0.174	0.87	21.57	0.03%	15.557
1	D22L	349.6	11.79	551	25	0.005	2.40	2.405	0.127	1.08	20.39	0.04%	9.262
1	D23A	565.5	24.25	622	25	0.006	3.24	3.246	0.058	0.24	13.39	0.02%	20.943
1	D23C	799.0	26.46	1 444	25	0.013	3.72	3.733	0.022	0.08	14.11	0.05%	22.700
1	D23D	525.3	16.38	1 218	25	0.011	2.52	2.531	0.000	0.00	15.45	0.07%	13.846
1, 3	D23E	653.8	20.35	639	25	0.006	3.12	3.126	0.000	0.00	15.36	0.03%	17.224
1, 2, 3	D23F	327.9	6.48	56	25	0.001	2.16	2.161	0.000	0.00	33.37	0.02%	4.314
1, 2	D23G	477.4	14.80	224	25	0.002	2.88	2.882	0.002	0.01	19.47	0.01%	11.920
1, 2, 3	D23H	723.7	20.48	507	25	0.005	2.76	2.765	0.429	2.09	13.50	0.02%	17.283
1, 2, 3	D23J	498.0	14.40	468	25	0.004	2.28	2.284	0.237	1.64	15.86	0.03%	11.877
2	D24A	289.8	5.97	236	25	0.002	1.92	1.922	0.033	0.56	32.18	0.03%	4.018

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
2	D24B	440.7	9.05	268	25	0.002	2.04	2.042	0.090	0.99	22.56	0.02%	6.918
2	D24C	372.3	6.90	322	25	0.003	1.20	1.203	0.252	3.65	17.43	0.04%	5.447
2	D24D	559.2	10.14	195	25	0.002	1.44	1.442	0.019	0.19	14.22	0.02%	8.679
2	D24E	457.5	8.38	151	25	0.001	1.08	1.081	0.262	3.12	12.90	0.01%	7.040
2	D24F	531.2	10.52	166	25	0.002	1.56	1.562	0.000	0.00	14.85	0.02%	8.953
2	D24G	587.3	13.51	314	25	0.003	2.52	2.523	0.000	0.00	18.67	0.02%	10.991
2	D24H	688.8	12.52	305	25	0.003	2.04	2.043	0.363	2.90	16.32	0.02%	10.111
2, 9	D24J	969.0	17.25	569	25	0.005	2.16	2.165	0.766	4.44	12.55	0.03%	14.321
2, 3	D24K	820.8	8.22	364	25	0.003	1.92	1.923	0.967	11.76	23.39	0.04%	5.333
2	D24L	479.0	7.39	167	25	0.002	1.08	1.082	0.491	6.64	14.64	0.03%	5.819
2, 6, 12, 14	D31A	1084.6	13.71	439	25	0.004	2.16	2.164	1.285	9.37	15.78	0.03%	10.264
12, 13	D31B	934.5	10.08	204	25	0.002	0.60	0.602	0.223	2.22	5.97	0.02%	9.251
12, 13	D31C	633.9	6.96	160	25	0.001	0.60	0.601	0.053	0.77	8.64	0.01%	6.305
6, 12, 14	D31D	1033.8	15.04	364	25	0.003	1.20	1.203	1.069	7.11	8.00	0.02%	12.764
12, 13, 14	D31E	906.6	10.25	290	25	0.003	1.20	1.203	0.071	0.70	11.74	0.03%	8.977
10	D32A	678.7	7.78	146	25	0.001	0.60	0.601	0.401	5.15	7.72	0.01%	6.781
10	D32B	552.1	6.48	282	25	0.003	0.72	0.723	1.104	17.04	11.16	0.05%	4.652
9, 10	D32C	804.5	10.06	297	25	0.003	0.60	0.603	0.255	2.54	5.99	0.03%	9.202
10	D32D	807.2	9.24	151	25	0.001	0.60	0.601	0.000	0.00	6.51	0.01%	8.635
10	D32E	1094.4	9.28	242	25	0.002	0.60	0.602	0.279	3.01	6.49	0.02%	8.401

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
10, 11, 12	D32F	1360.6	15.57	351	25	0.003	0.84	0.843	0.402	2.58	5.41	0.02%	14.325
9, 10, 11, 12	D32G	986.4	10.83	374	25	0.003	0.84	0.843	2.310	21.33	7.78	0.03%	7.676
9, 11, 12	D32H	539.7	5.97	216	25	0.002	0.48	0.482	0.385	6.45	8.07	0.03%	5.107
11, 12	D32J	1047.4	14.64	368	25	0.003	0.84	0.843	0.136	0.93	5.76	0.02%	13.656
11, 12	D32K	773.5	7.80	272	25	0.002	0.60	0.602	0.118	1.52	7.72	0.03%	7.075
12, 13, 14	D33A	553.5	9.02	169	25	0.002	0.36	0.362	0.120	1.33	4.01	0.02%	8.542
12, 13, 14	D33B	951.7	10.31	217	25	0.002	0.24	0.242	0.095	0.92	2.35	0.02%	9.970
13, 14	D33C	749.8	10.02	178	25	0.002	0.36	0.362	0.161	1.61	3.61	0.02%	9.492
13, 14	D33D	886.7	11.25	250	25	0.002	0.24	0.242	0.010	0.09	2.15	0.02%	10.997
13, 14	D33E	1443.9	18.60	669	25	0.006	0.12	0.126	0.550	2.96	0.68	0.03%	17.921
13	D33F	804.1	11.69	294	25	0.003	0.12	0.123	0.018	0.15	1.05	0.03%	11.545
13	D33G	1307.2	16.26	549	25	0.005	0.24	0.245	0.023	0.14	1.51	0.03%	15.995
13	D33H	977.5	9.30	446	25	0.004	0.24	0.244	0.000	0.00	2.62	0.04%	9.052
13	D33J	802.9	7.33	385	25	0.004	0.12	0.124	0.069	0.93	1.69	0.05%	7.138
13	D33K	451.8	4.65	180	25	0.002	0.24	0.242	0.000	0.00	5.21	0.04%	4.407
2, 11	D34A	745.3	9.07	288	25	0.003	0.36	0.363	1.782	19.64	4.00	0.03%	6.926
9, 11	D34B	667.2	8.00	364	25	0.003	0.12	0.123	0.819	10.23	1.54	0.04%	7.062
2, 9, 11	D34C	717.4	8.49	366	25	0.003	0.12	0.123	0.930	10.96	1.45	0.04%	7.438
2, 9, 11	D34D	564.1	6.73	271	25	0.002	0.12	0.122	0.235	3.50	1.81	0.03%	6.369

GRU	Quaternary Catchment	Area (km2)	Recharge (Mm3/a)	Population depending on groundwater as BHN	Per capita need (litres / day)	BHN GW Reserve (Mm3/a)	GW Baseflow (Mm3/a)	GW Reserve (Mm3/a)	GW Use (Mm3/a)	Stress Index	GW Reserve (as % Recharge)	BHN as % of Recharge	Allocable GW (Mm3/a)
2, 11	D34E	487.4	5.90	201	25	0.002	0.12	0.122	0.478	8.11	2.07	0.03%	5.302
2, 11, 12	D34F	650.6	7.69	403	25	0.004	0.12	0.124	0.398	5.17	1.61	0.05%	7.168
2, 11, 12, 14	D34G	890.0	10.96	341	25	0.003	0.36	0.363	1.331	12.15	3.31	0.03%	9.268
2	D35A	238.7	3.07	96	25	0.001	0.84	0.841	0.380	12.37	27.38	0.03%	1.851
2, 8, 9	D35B	244.7	3.11	124	25	0.001	0.72	0.721	0.186	5.98	23.20	0.03%	2.201
9	D35C	890.7	11.06	404	25	0.004	2.28	2.284	0.709	6.41	20.65	0.04%	8.065
9	D35D	554.0	6.82	228	25	0.002	1.20	1.202	0.235	3.45	17.63	0.03%	5.379
2, 9	D35E	293.9	3.67	112	25	0.001	0.72	0.721	0.505	13.77	19.66	0.03%	2.441
2	D35F	522.9	6.62	215	25	0.002	1.56	1.562	0.484	7.30	23.58	0.03%	4.578
2, 9	D35G	520.5	6.40	191	25	0.002	0.84	0.842	2.073	32.39	13.16	0.03%	3.484
2, 9	D35H	468.5	6.07	181	25	0.002	1.08	1.082	0.292	4.82	17.83	0.03%	4.696
2, 9, 11	D35J	945.0	19.14	362	25	0.003	1.80	1.803	1.264	6.60	9.42	0.02%	16.071
2, 9	D35K	634.0	8.19	246	25	0.002	1.08	1.082	0.909	11.09	13.20	0.02%	6.203

6.4 Groundwater Reserve: Quality

In terms of groundwater quality, the DWS WMS data was interrogated to further assess groundwater quality (chemical) parameters in the catchment in more detail. From the data set, chemical parameters including pH, EC, Calcium, Magnesium, Potassium, Sodium. Chlorine, Fluorine, Total Alkalinity, Sulphate and Nitrates were available. The objective of this exercise was to assign groundwater quality class to the Reserve by analysing the chemicals trend over time. Median Concentrations for each chemical parameter were determined to characterise the prominent groundwater quality for each quaternary catchment, where available.

The catchment area constitutes 129 quaternary catchments, of which 18 quaternary catchments have groundwater quality data, thus a noticeable shortage and lack of groundwater data through the study area, although a systemic issue for not only groundwater, but surface water data too. Refer to **Table 6-5** to **Table 6-24** for the groundwater quality Reserve for the 18 quaternary catchment. In addition, the study further compiled the quality Reserve per GRU. For GRU5, GRU6 and GRU11 no groundwater quality data was available for the relevant quaternary catchments. Groundwater quality is within the limits of a Class 1 water quality in terms of DWS Water quality guidelines (DWS 1998); however, for GRU4, GRU9, GRU10 and GRU13, the limits exceed DWS Class 1 Water quality guidelines. GRU 4 and GRU 9 has the worst groundwater quality of Class 3 and Class 4, respectively. Refer to Table 6-25 to Table 6-35 for the groundwater quality Reserve per GRU.

Table 6-5: Groundwater quality Reserve D22G

Chemical Parameter	Unit	Quaternary D22G			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	46	8.10	5.0 – 9.5	7.29 - 8.91
Electrical Conductivity	mS/m	46	44.60	<150	49.06
Calcium as Ca	mg/l	39	26.39	<150	29.03
Magnesium as Mg	mg/l	39	8.60	<100	9.46
Sodium as Na	mg/l	38	62.11	<200	68.32
Potassium as K	mg/l	38	3.42	<50	3.76
Total Alkalinity as $CaCO_3$	mg/l	40	189.07	<330	207.98
Chloride as Cl	mg/l	39	19.60	<200	21.56
Sulphate as SO_4	mg/l	39	18.50	<400	20.35
Nitrate and Nitrite as N	mg/l	38	1.77	<1.0	1.77
Fluoride as F	mg/l	1	0.83	<1.0	0.91
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-6: Groundwater Quality Reserve D21E

Chemical Parameter	Unit	Quaternary D21E			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	11	8.00	5.0 – 9.5	7.20 - 8.80
Electrical Conductivity	mS/m	11	45.40	<150	49.94
Calcium as Ca	mg/l	9	65.80	<150	72.38
Magnesium as Mg	mg/l	9	13.50	<100	14.85
Sodium as Na	mg/l	9	30.08	<200	33.09
Potassium as K	mg/l	9	1.16	<50	1.28
Total Alkalinity as $CaCO_3$	mg/l	9	259.86	<330	285.84
Chloride as Cl	mg/l	9	7.60	<200	8.36
Sulphate as SO_4	mg/l	9	24.30	<400	26.73
Nitrate and Nitrite as N	mg/l	9	0.21	<1.0	0.23
Fluoride as F	mg/l	2	0.36	<1.0	0.39
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-7: Groundwater Quality Reserve D21D

Chemical Parameter	Unit	Quaternary D21D			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–			5.0 – 9.5	5.0 - 9.5
Electrical Conductivity	mS/m	12	35.05	<150	38.56
Calcium as Ca	mg/l			<150	150.00
Magnesium as Mg	mg/l			<100	100.00
Sodium as Na	mg/l			<200	200.00
Potassium as K	mg/l			<50	50.00
Total Alkalinity as $CaCO_3$	mg/l			<330	330.00
Chloride as Cl	mg/l			<200	200.00
Sulphate as SO_4	mg/l			<400	400.00
Nitrate and Nitrite as N	mg/l			<1.0	1.00
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-8: Groundwater Quality Reserve D35J

Chemical Parameter	Unit	Quaternary D35J			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	51	8.13	5.0 – 9.5	7.32 - 8.94
Electrical Conductivity	mS/m	51	62.00	<150	68.20
Calcium as Ca	mg/l	46	28.03	<150	30.83
Magnesium as Mg	mg/l	46	7.52	<100	8.28
Sodium as Na	mg/l	44	82.46	<200	90.71
Potassium as K	mg/l	45	1.02	<50	1.12
Total Alkalinity as $CaCO_3$	mg/l	47	204.19	<330	224.61
Chloride as Cl	mg/l	46	23.49	<200	25.84
Sulphate as SO_4	mg/l	46	40.12	<400	44.14
Nitrate and Nitrite as N	mg/l	46	0.05	<1.0	0.06
Fluoride as F	mg/l	1	2.88	<1.0	2.88
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-9: Groundwater Quality Reserve D24G

Chemical Parameter	Unit	Quaternary D24G			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	6	8.06	5.0 – 9.5	7.25 - 8.87
Electrical Conductivity	mS/m	6	60.40	<150	66.44
Calcium as Ca	mg/l	6	39.90	<150	43.89
Magnesium as Mg	mg/l	6	20.35	<100	22.39
Sodium as Na	mg/l	6	60.35	<200	66.39
Potassium as K	mg/l	6	5.39	<50	5.93
Total Alkalinity as $CaCO_3$	mg/l	6	278.95	<330	306.85
Chloride as Cl	mg/l	6	13.00	<200	14.30
Sulphate as SO_4	mg/l	6	18.45	<400	20.30
Nitrate and Nitrite as N	mg/l	6	0.64	<1.0	0.70
Fluoride as F	mg/l	1	0.34	<1.0	0.37
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-10: Groundwater Quality Reserve D12D

Chemical Parameter	Unit	Quaternary D12D			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	43	8.11	5.0 – 9.5	7.30 - 8.92
Electrical Conductivity	mS/m	42	33.75	<150	37.13
Calcium as Ca	mg/l	40	37.46	<150	41.21
Magnesium as Mg	mg/l	40	9.28	<100	10.21
Sodium as Na	mg/l	38	19.95	<200	21.95
Potassium as K	mg/l	38	0.91	<50	1.00
Total Alkalinity as $CaCO_3$	mg/l	40	161.85	<330	178.04
Chloride as Cl	mg/l	39	4.90	<200	5.39
Sulphate as SO_4	mg/l	40	8.95	<400	9.85
Nitrate and Nitrite as N	mg/l	39	0.15	<1.0	0.17
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-11: Groundwater Quality Reserve C51G

Chemical Parameter	Unit	Quaternary C51G			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	17	7.98	5.0 – 9.5	7.18 - 8.78
Electrical Conductivity	mS/m	17	61.50	<150	67.65
Calcium as Ca	mg/l	15	58.22	<150	64.04
Magnesium as Mg	mg/l	16	20.95	<100	23.05
Sodium as Na	mg/l	16	36.79	<200	40.47
Potassium as K	mg/l	16	1.54	<50	1.69
Total Alkalinity as $CaCO_3$	mg/l	16	244.70	<330	269.17
Chloride as Cl	mg/l	16	17.30	<200	19.03
Sulphate as SO_4	mg/l	16	32.43	<400	35.67
Nitrate and Nitrite as N	mg/l	16	2.85	<1.0	2.85
Fluoride as F	mg/l	1	0.67	<1.0	1.00
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-12: Groundwater Quality Reserve C51A

Chemical Parameter	Unit	Quaternary C51A			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	49	8.18	5.0 – 9.5	7.37 - 9.00
Electrical Conductivity	mS/m	48	60.70	<150	66.77
Calcium as Ca	mg/l	43	65.65	<150	72.21
Magnesium as Mg	mg/l	43	20.62	<100	22.68
Sodium as Na	mg/l	41	39.00	<200	42.90
Potassium as K	mg/l	41	6.34	<50	6.97
Total Alkalinity as $CaCO_3$	mg/l	43	286.10	<330	314.71
Chloride as Cl	mg/l	43	18.30	<200	20.12
Sulphate as SO_4	mg/l	43	20.45	<400	22.49
Nitrate and Nitrite as N	mg/l	43	1.96	<1.0	1.96
Fluoride as F	mg/l	1	0.92	<1.0	1.01
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-13: Groundwater Quality Reserve C52A

Chemical Parameter	Unit	Quaternary C52A			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	9	8.00	5.0 – 9.5	7.20 - 8.80
Electrical Conductivity	mS/m	9	93.10	<150	102.41
Calcium as Ca	mg/l	8	90.20	<150	99.22
Magnesium as Mg	mg/l	8	32.45	<100	35.70
Sodium as Na	mg/l	8	75.50	<200	83.05
Potassium as K	mg/l	8	1.15	<50	1.27
Total Alkalinity as $CaCO_3$	mg/l	8	383.50	<330	383.50
Chloride as Cl	mg/l	8	58.35	<200	64.19
Sulphate as SO_4	mg/l	8	29.35	<400	32.29
Nitrate and Nitrite as N	mg/l	8	0.35	<1.0	0.38
Fluoride as F	mg/l	2	0.22	<1.0	0.24
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-14: Groundwater Quality Reserve C52H

Chemical Parameter	Unit	Quaternary C52H			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	11	8.24	5.0 – 9.5	7.42 - 9.06
Electrical Conductivity	mS/m	11	188.00	<150	188.00
Calcium as Ca	mg/l	10	55.45	<150	61.00
Magnesium as Mg	mg/l	10	15.05	<100	16.56
Sodium as Na	mg/l	10	414.95	<200	414.95
Potassium as K	mg/l	10	5.06	<50	5.56
Total Alkalinity as $CaCO_3$	mg/l	10	232.90	<330	256.19
Chloride as Cl	mg/l	10	551.20	<200	551.20
Sulphate as SO_4	mg/l	10	45.50	<400	50.05
Nitrate and Nitrite as N	mg/l	10	1.99	<1.0	1.99
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-15: Groundwater Quality Reserve D13D

Chemical Parameter	Unit	Quaternary D13D			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	41	8.03	5.0 – 9.5	7.23 - 8.83
Electrical Conductivity	mS/m	43	57.50	<150	63.25
Calcium as Ca	mg/l	37	65.21	<150	71.73
Magnesium as Mg	mg/l	37	28.45	<100	31.30
Sodium as Na	mg/l	35	14.81	<200	16.29
Potassium as K	mg/l	35	0.15	<50	0.17
Total Alkalinity as $CaCO_3$	mg/l	37	251.12	<330	276.23
Chloride as Cl	mg/l	37	12.55	<200	13.80
Sulphate as SO_4	mg/l	36	23.68	<400	26.05
Nitrate and Nitrite as N	mg/l	37	2.12	<1.0	2.12
Fluoride as F	mg/l	1	0.47	<1.0	0.52
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-16: Groundwater Quality Reserve D13H

Chemical Parameter	Unit	Quaternary D13H			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	32	7.75	5.0 – 9.5	6.98 - 8.53
Electrical Conductivity	mS/m	35	102.20	<150	112.42
Calcium as Ca	mg/l	27	89.29	<150	98.22
Magnesium as Mg	mg/l	27	42.50	<100	46.75
Sodium as Na	mg/l	27	60.00	<200	66.00
Potassium as K	mg/l	27	3.05	<50	3.35
Total Alkalinity as $CaCO_3$	mg/l	27	315.50	<330	315.50
Chloride as Cl	mg/l	27	132.69	<200	145.96
Sulphate as SO_4	mg/l	27	67.20	<400	73.92
Nitrate and Nitrite as N	mg/l	27	0.05	<1.0	0.06
Fluoride as F	mg/l	1	0.53	<1.0	0.58
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-17: Groundwater Quality Reserve D14A

Chemical Parameter	Unit	Quaternary D14A			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	51	7.59	5.0 – 9.5	6.83 - 8.35
Electrical Conductivity	mS/m	51	219.80	<150	219.80
Calcium as Ca	mg/l	45	84.00	<150	92.40
Magnesium as Mg	mg/l	45	0.63	<100	0.69
Sodium as Na	mg/l	43	332.36	<200	332.36
Potassium as K	mg/l	43	2.35	<50	2.59
Total Alkalinity as $CaCO_3$	mg/l	45	21.79	<330	23.97
Chloride as Cl	mg/l	43	638.07	<200	638.07
Sulphate as SO_4	mg/l	45	5.59	<400	6.15
Nitrate and Nitrite as N	mg/l	44	0.04	<1.0	0.04
Fluoride as F	mg/l	1	4.10	<1.0	4.10
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-18: Groundwater Quality Reserve D14E

Chemical Parameter	Unit	Quaternary D14E			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	11	7.88	5.0 – 9.5	7.09 - 8.66
Electrical Conductivity	mS/m	12	84.65	<150	93.12
Calcium as Ca	mg/l	10	63.25	<150	69.58
Magnesium as Mg	mg/l	10	28.60	<100	31.46
Sodium as Na	mg/l	10	69.65	<200	76.62
Potassium as K	mg/l	10	1.00	<50	1.09
Total Alkalinity as $CaCO_3$	mg/l	10	280.76	<330	308.83
Chloride as Cl	mg/l	10	34.95	<200	38.45
Sulphate as SO_4	mg/l	10	75.30	<400	82.83
Nitrate and Nitrite as N	mg/l	10	1.64	<1.0	1.64
Fluoride as F	mg/l	1	1.16	<1.0	1.16
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-19: Groundwater Quality Reserve D32E

Chemical Parameter	Unit	Quaternary D32E			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	11	7.96	5.0 – 9.5	7.16 - 8.76
Electrical Conductivity	mS/m	11	81.00	<150	89.10
Calcium as Ca	mg/l	11	73.60	<150	80.96
Magnesium as Mg	mg/l	11	37.80	<100	41.58
Sodium as Na	mg/l	11	34.40	<200	37.84
Potassium as K	mg/l	11	2.49	<50	2.74
Total Alkalinity as $CaCO_3$	mg/l	11	278.90	<330	306.79
Chloride as Cl	mg/l	11	32.10	<200	35.31
Sulphate as SO_4	mg/l	11	32.30	<400	35.53
Nitrate and Nitrite as N	mg/l	11	12.85	<1.0	12.85
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-20: Groundwater Quality Reserve D32G

Chemical Parameter	Unit	Quaternary D32G			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	39	8.15	5.0 – 9.5	7.33 - 8.96
Electrical Conductivity	mS/m	40	76.30	<150	83.93
Calcium as Ca	mg/l	33	74.04	<150	81.44
Magnesium as Mg	mg/l	34	22.05	<100	24.25
Sodium as Na	mg/l	33	65.82	<200	72.41
Potassium as K	mg/l	34	1.67	<50	1.84
Total Alkalinity as $CaCO_3$	mg/l	33	334.89	<330	334.89
Chloride as Cl	mg/l	33	25.50	<200	28.05
Sulphate as SO_4	mg/l	33	39.40	<400	43.34
Nitrate and Nitrite as N	mg/l	33	1.48	<1.0	1.48
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-21: Groundwater Quality Reserve D32K

Chemical Parameter	Unit	Quaternary D32K			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	47	8.20	5.0 – 9.5	7.38 - 9.02
Electrical Conductivity	mS/m	48	98.75	<150	108.63
Calcium as Ca	mg/l	42	47.70	<150	52.47
Magnesium as Mg	mg/l	41	82.75	<100	91.03
Sodium as Na	mg/l	40	38.38	<200	42.22
Potassium as K	mg/l	40	3.35	<50	3.69
Total Alkalinity as $CaCO_3$	mg/l	42	366.66	<330	366.66
Chloride as Cl	mg/l	42	77.60	<200	85.36
Sulphate as SO_4	mg/l	42	80.51	<400	88.56
Nitrate and Nitrite as N	mg/l	40	1.91	<1.0	1.91
Fluoride as F	mg/l	1	0.53	<1.0	0.58
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-22: Groundwater Quality Reserve C51M

Chemical Parameter	Unit	Quaternary C51M			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	44	8.05	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	50	165.00	<150	165.00
Calcium as Ca	mg/l	40	97.80	<150	107.58
Magnesium as Mg	mg/l	38	66.28	<100	72.91
Sodium as Na	mg/l	38	140.36	<200	154.40
Potassium as K	mg/l	38	2.11	<50	2.32
Total Alkalinity as $CaCO_3$	mg/l	40	277.00	<330	304.70
Chloride as Cl	mg/l	40	351.74	<200	351.74
Sulphate as SO_4	mg/l	40	66.25	<400	72.88
Nitrate and Nitrite as N	mg/l	40	4.55	<1.0	4.55
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-23: Groundwater Quality Reserve C51L

Chemical Parameter	Unit	Quaternary C51L			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–			5.0 – 9.5	7.33 - 8.96
Electrical Conductivity	mS/m	4	103.90	<150	114.29
Calcium as Ca	mg/l			<150	150.00
Magnesium as Mg	mg/l			<100	100.00
Sodium as Na	mg/l			<200	200.00
Potassium as K	mg/l			<50	50.00
Total Alkalinity as $CaCO_3$	mg/l			<330	330.00
Chloride as Cl	mg/l			<200	200.00
Sulphate as SO_4	mg/l			<400	400.00
Nitrate and Nitrite as N	mg/l			<1.0	1.00
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-24: Groundwater Quality Reserve C51K

Chemical Parameter	Unit	Quaternary C51K			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	59	8.15	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	58	65.50	<150	72.05
Calcium as Ca	mg/l	51	59.60	<150	65.56
Magnesium as Mg	mg/l	52	39.93	<100	43.92
Sodium as Na	mg/l	49	23.57	<200	25.93
Potassium as K	mg/l	50	2.32	<50	2.55
Total Alkalinity as $CaCO_3$	mg/l	52	246.47	<330	271.12
Chloride as Cl	mg/l	52	38.33	<200	42.16
Sulphate as SO_4	mg/l	52	32.75	<400	36.03
Nitrate and Nitrite as N	mg/l	51	3.98	<1.0	3.98
Fluoride as F	mg/l	2	0.45	<1.0	0.50
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-25: Groundwater Quality Reserve GRU1

Chemical Parameter	Unit	GRU1			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	57	8.05	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	69	44.60	<150	49.06
Calcium as Ca	mg/l	48	46.10	<150	50.71
Magnesium as Mg	mg/l	48	11.05	<100	12.16
Sodium as Na	mg/l	47	46.09	<200	50.70
Potassium as K	mg/l	47	2.29	<50	2.52
Total Alkalinity as $CaCO_3$	mg/l	49	224.46	<330	246.91
Chloride as Cl	mg/l	48	13.60	<200	14.96
Sulphate as SO_4	mg/l	48	21.40	<400	23.54
Nitrate and Nitrite as N	mg/l	47	0.99	<1.0	1.09
Fluoride as F	mg/l	3	0.59	<1.0	0.65
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-26: Groundwater Quality Reserve GRU2

Chemical Parameter	Unit	GRU2			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	100	8.11	5.0 – 9.5	7.30 - 8.92
Electrical Conductivity	mS/m	99	60.40	<150	66.44
Calcium as Ca	mg/l	92	37.46	<150	41.21
Magnesium as Mg	mg/l	92	9.28	<100	10.21
Sodium as Na	mg/l	88	60.35	<200	66.39
Potassium as K	mg/l	89	1.02	<50	1.12
Total Alkalinity as $CaCO_3$	mg/l	93	204.19	<330	224.61
Chloride as Cl	mg/l	91	13.00	<200	14.30
Sulphate as SO_4	mg/l	92	18.45	<400	20.30
Nitrate and Nitrite as N	mg/l	91	0.15	<1.0	0.17
Fluoride as F	mg/l	2	1.61	<1.0	1.61
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-27: Groundwater Quality Reserve GRU3

Chemical Parameter	Unit	GRU3			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	75	8.00	5.0 – 9.5	7.20 - 8.80
Electrical Conductivity	mS/m	74	61.50	<150	67.65
Calcium as Ca	mg/l	66	65.65	<150	72.21
Magnesium as Mg	mg/l	67	20.95	<100	23.05
Sodium as Na	mg/l	65	39.00	<200	42.90
Potassium as K	mg/l	65	1.54	<50	1.69
Total Alkalinity as $CaCO_3$	mg/l	67	286.10	<330	314.71
Chloride as Cl	mg/l	67	18.30	<200	20.12
Sulphate as SO_4	mg/l	67	29.35	<400	32.29
Nitrate and Nitrite as N	mg/l	67	1.96	<1.0	2.16
Fluoride as F	mg/l	4	0.67	<1.0	0.74
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-28: Groundwater Quality Reserve GRU4

Chemical Parameter	Unit	GRU4			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	11	8.24	5.0 – 9.5	7.42 - 9.06
Electrical Conductivity	mS/m	11	188.00	<150	188.00
Calcium as Ca	mg/l	10	55.45	<150	61.00
Magnesium as Mg	mg/l	10	15.05	<100	16.56
Sodium as Na	mg/l	10	414.95	<200	414.95
Potassium as K	mg/l	10	5.06	<50	5.56
Total Alkalinity as $CaCO_3$	mg/l	10	232.90	<330	256.19
Chloride as Cl	mg/l	10	551.20	<200	551.20
Sulphate as SO_4	mg/l	10	45.50	<400	50.05
Nitrate and Nitrite as N	mg/l	10	1.99	<1.0	1.99
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-29: Groundwater Quality Reserve GRU7

Chemical Parameter	Unit	GRU7			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	41	8.03	5.0 – 9.5	7.42 - 9.06
Electrical Conductivity	mS/m	43	57.50	<150	63.25
Calcium as Ca	mg/l	37	65.21	<150	71.73
Magnesium as Mg	mg/l	37	28.45	<100	31.30
Sodium as Na	mg/l	35	14.81	<200	16.29
Potassium as K	mg/l	35	0.15	<50	0.17
Total Alkalinity as $CaCO_3$	mg/l	37	251.12	<330	276.23
Chloride as Cl	mg/l	37	12.55	<200	13.80
Sulphate as SO_4	mg/l	36	23.68	<400	26.05
Nitrate and Nitrite as N	mg/l	37	2.12	<1.0	2.33
Fluoride as F	mg/l	1	0.47	<1.0	0.52
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-30: Groundwater Quality Reserve GRU8

Chemical Parameter	Unit	GRU8			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	32	7.75	5.0 – 9.5	6.98 - 8.53
Electrical Conductivity	mS/m	35	102.20	<150	112.42
Calcium as Ca	mg/l	27	89.29	<150	98.22
Magnesium as Mg	mg/l	27	42.50	<100	46.75
Sodium as Na	mg/l	27	60.00	<200	66.00
Potassium as K	mg/l	27	3.05	<50	3.35
Total Alkalinity as $CaCO_3$	mg/l	27	315.50	<330	347.05
Chloride as Cl	mg/l	27	132.69	<200	145.96
Sulphate as SO_4	mg/l	27	67.20	<400	73.92
Nitrate and Nitrite as N	mg/l	27	0.05	<1.0	0.06
Fluoride as F	mg/l	1	0.53	<1.0	0.58
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-31: Groundwater Quality Reserve GRU9

Chemical Parameter	Unit	GRU9			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	62	7.73	5.0 – 9.5	6.96 - 8.51
Electrical Conductivity	mS/m	63	152.23	<150	152.23
Calcium as Ca	mg/l	55	73.63	<150	80.99
Magnesium as Mg	mg/l	55	14.61	<100	16.07
Sodium as Na	mg/l	53	201.00	<200	201.00
Potassium as K	mg/l	53	1.67	<50	1.84
Total Alkalinity as $CaCO_3$	mg/l	55	151.27	<330	166.40
Chloride as Cl	mg/l	53	336.51	<200	336.51
Sulphate as SO_4	mg/l	55	40.45	<400	44.49
Nitrate and Nitrite as N	mg/l	54	0.84	<1.0	0.92
Fluoride as F	mg/l	2	2.63	<1.0	2.63
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-32: Groundwater Quality Reserve GRU10

Chemical Parameter	Unit	GRU10			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	50	8.05	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	51	78.65	<150	86.52
Calcium as Ca	mg/l	44	73.82	<150	81.20
Magnesium as Mg	mg/l	45	29.92	<100	32.92
Sodium as Na	mg/l	44	50.11	<200	55.12
Potassium as K	mg/l	45	2.08	<50	2.29
Total Alkalinity as $CaCO_3$	mg/l	44	306.89	<330	337.58
Chloride as Cl	mg/l	44	28.80	<200	31.68
Sulphate as SO_4	mg/l	44	35.85	<400	39.44
Nitrate and Nitrite as N	mg/l	44	7.16	<1.0	7.16
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-33: Groundwater Quality Reserve GRU12

Chemical Parameter	Unit	GRU12			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	47	8.20	5.0 – 9.5	7.38 - 9.02
Electrical Conductivity	mS/m	48	98.75	<150	108.63
Calcium as Ca	mg/l	42	47.70	<150	52.47
Magnesium as Mg	mg/l	41	82.75	<100	91.03
Sodium as Na	mg/l	40	38.38	<200	42.22
Potassium as K	mg/l	40	3.35	<50	3.69
Total Alkalinity as $CaCO_3$	mg/l	42	366.66	<330	366.66
Chloride as Cl	mg/l	42	77.60	<200	85.36
Sulphate as SO_4	mg/l	42	80.51	<400	88.56
Nitrate and Nitrite as N	mg/l	40	1.91	<1.0	1.91
Fluoride as F	mg/l	1	0.53	<1.0	0.58
				Water quality class	Class 1

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-34: Groundwater Quality Reserve GRU13

Chemical Parameter	Unit	GRU13			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	44	8.05	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	54	134.45	<150	147.90
Calcium as Ca	mg/l	40	97.80	<150	107.58
Magnesium as Mg	mg/l	38	66.28	<100	72.91
Sodium as Na	mg/l	38	140.36	<200	154.40
Potassium as K	mg/l	38	2.11	<50	2.32
Total Alkalinity as $CaCO_3$	mg/l	40	277.00	<330	304.70
Chloride as Cl	mg/l	40	351.74	<200	351.74
Sulphate as SO_4	mg/l	40	66.25	<400	72.88
Nitrate and Nitrite as N	mg/l	40	4.55	<1.0	4.55
Fluoride as F	mg/l			<1.0	1.00
				Water quality class	Class 2

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

Table 6-35: Groundwater Quality Reserve GRU14

Chemical Parameter	Unit	GRU14			
		No. of Samples	Ambient GW quality or median[1]	BHN Threshold[2]	Groundwater Quality Reserve[3]
pH	–	59	8.15	5.0 – 9.5	7.25 - 8.86
Electrical Conductivity	mS/m	58	65.50	<150	72.05
Calcium as Ca	mg/l	51	59.60	<150	65.56
Magnesium as Mg	mg/l	52	39.93	<100	43.92
Sodium as Na	mg/l	49	23.57	<200	25.93
Potassium as K	mg/l	50	2.32	<50	2.55
Total Alkalinity as $CaCO_3$	mg/l	52	246.47	<330	271.12
Chloride as Cl	mg/l	52	38.33	<200	42.16
Sulphate as SO_4	mg/l	52	32.75	<400	36.03
Nitrate and Nitrite as N	mg/l	51	3.98	<1.0	3.98
Fluoride as F	mg/l	2	0.45	<1.0	0.50
				Water quality class	Class 0

[1] Median value (calculated from population of samples in QC).
[2] Upper limit of Class I water quality (DWAF et al 1998) and SANS (241: 2015) drinking water limits.
[3] The median plus 10% for the Groundwater Quality Reserve.

6.5 Ecological Specifications and Monitoring Programme

Based on outcomes of the Groundwater Reserve, groundwater quantity and quality indices were derived for the study area on a quaternary catchment scale. **Table 6-36** contains the dataset for the DWS GRDM and is extended to include groundwater quantity and quality indices and directives.

The groundwater quantity directive identified three levels of potential stresses on the groundwater component in the quaternary catchments, each with a specific guideline to address further groundwater allocations as follows:

- Minimum Stress Index Level:
  - Groundwater investigation limited to local water balance estimation and hydrocensus.
- Moderate Stress Index Level:
  - Groundwater investigation more detailed in terms of hydrogeological conditions, hydrocensus, limited monitoring requirements, mapping of other abstractions and water balance.
- High Stress Index Level:
  - High-level groundwater investigation, monitoring boreholes, specific license conditions, aquifer characterisation, recharge estimates, regional potential impacts and piezometric mapping.

Ecological specifications of the groundwater resources are directly linked to these indexes, namely in the case of the groundwater component status of the Reserve in a high stress index level, the water use may be already impacting on the total Reserve of the quaternary catchment and further allocations should be carefully considered.

The groundwater quality directive describes the time series component of the quaternary catchment's groundwater quality. Of particular importance in this assessment is the long-term rising trends in salinity, i.e. EC/TDS, chloride, sodium, nitrate and nitrite, TALK and fluoride. In this case the groundwater quality Reserve should specify at least a marginal water quality in terms of the DWA (1998) Assessment Guide and further deterioration should not be allowed without very strict mitigation measures. It must further be noted that increases in salinity do not always imply an impacted source but it could also imply less favourable recharge conditions coupled with increased residence time of groundwater in the aquifer (i.e. older groundwater).

Furthermore, the recommended groundwater monitoring programme for each quaternary catchment is presented in **Table 6-37**. Additionally, it is essential to expand the groundwater monitoring program into the quaternary catchments identified in **Table 6-38**. These catchments lack sufficient data on groundwater quality and levels. Once monitoring networks are in place, the following parameters are recommended for ongoing monitoring:

- Monthly water levels. Alternatively continuous monitoring with the use of data loggers to be downloaded on a quarterly basis; and
- Bi-annual sampling and laboratory analysis for major cations, anions and selected metals (SANS 241: 2015 short analysis).

Table 6-36: Groundwater quantity and quality indices per quaternary catchment

Quaternary Catchment	Recharge Mm³/a)	BHN GW Reserve (Mm³/a)	GW Baseflow (Mm³/a)	GW Reserve (Mm³/a)	GW Use (Mm³/a)	Stress Index	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Allocable GW (Mm³/a)	GW Reserve (as % Recharge)
C51A	11.21	0.004	1.92	1.924	1.754	15.65	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	7.527	17.17
C51B	24.55	0.007	3.00	3.007	1.089	4.44	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	20.452	12.25
C51C	10.51	0.003	0.96	0.963	1.376	13.10	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	8.169	9.16
C51D	15.80	0.017	1.92	1.937	0.470	2.97	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	13.389	12.26
C51E	13.68	0.010	2.04	2.05	1.109	8.11	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	10.522	14.98
C51F	13.88	0.005	1.08	1.085	1.018	7.33	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	11.777	7.82
C51G	27.11	0.007	4.68	4.687	2.072	7.64	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	20.353	17.29
C51H	27.67	0.010	3.48	3.49	3.354	12.12	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	20.824	12.61
C51J	17.59	0.005	1.20	1.205	3.128	17.78	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	13.259	6.85
C51K	50.30	0.017	0.72	0.737	7.488	14.89	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	42.076	1.47
C51L	20.91	0.009	0.48	0.489	0.428	2.05	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	19.989	2.34
C51M	10.36	0.007	0.36	0.367	0.014	0.14	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	9.983	3.54
C52A	24.85	0.008	3.96	3.968	2.970	11.95	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	17.916	15.97
C52B	25.98	0.013	2.76	2.773	0.026	0.10	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	23.179	10.67
C52C	15.87	0.005	1.44	1.445	0.216	1.36	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	14.207	9.11
C52D	11.44	0.005	0.96	0.965	0.845	7.39	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	9.630	8.44
C52E	16.47	0.007	1.32	1.327	0.755	4.59	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	14.384	8.06
C52F	12.99	0.046	1.20	1.246	1.759	13.54	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	9.983	9.59
C52G	28.52	0.015	1.68	1.695	10.725	37.61	Moderately Modified	Marginal, Class 2	Moderate Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	16.096	5.94
C52H	29.80	0.029	0.12	0.149	18.939	63.56	Seriously Modified	Marginal, Class 2	High Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	10.707	0.50
C52J	34.51	0.068	0.36	0.428	23.287	67.48	Seriously Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	10.793	1.24
C52K	56.60	0.024	0.24	0.264	29.382	51.91	Largely Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	26.957	0.47
C52L	39.18	0.015	0.24	0.255	5.114	13.05	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	33.810	0.65
D12A	15.38	0.039	13.20	13.239	0.306	1.99	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	1.831	86.10
D12B	16.80	0.058	18.60	18.658	0.066	0.39	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-1.922	111.05
D12C	14.96	0.013	2.52	2.533	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	12.422	16.94
D12D	13.52	0.002	1.80	1.802	0.006	0.05	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	11.715	13.33
D12E	26.82	0.007	3.48	3.487	1.057	3.94	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	22.280	13.00
D12F	24.99	0.005	3.12	3.125	0.184	0.74	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	21.683	12.50
D13A	18.60	0.003	33.24	33.243	0.135	0.73	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-14.778	178.73
D13B	20.21	0.003	35.52	35.523	0.006	0.03	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-15.320	175.78
D13C	20.38	0.003	28.80	28.803	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-8.427	141.36
D13D	28.93	0.004	32.04	32.044	0.881	3.05	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-3.997	110.77
D13E	28.90	0.008	64.68	64.688	0.113	0.39	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-35.897	223.80
D13F	33.00	0.008	48.12	48.128	0.040	0.12	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	-15.169	145.85
D13G	34.57	0.008	9.84	9.848	0.069	0.20	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	24.651	28.49

Quaternary Catchment	Recharge Mm³/a)	BHN GW Reserve (Mm³/a)	GW Baseflow (Mm³/a)	GW Reserve (Mm³/a)	GW Use (Mm³/a)	Stress Index	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Allocable GW (Mm³/a)	GW Reserve (as % Recharge)
D13H	14.89	0.008	6.60	6.608	0.049	0.33	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	8.235	44.37
D13J	34.98	0.007	7.08	7.087	0.600	1.72	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	27.293	20.26
D13K	11.81	0.003	23.52	23.523	0.161	1.36	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	-11.875	199.20
D13L	20.70	0.004	6.12	6.124	0.229	1.10	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	14.351	29.58
D13M	10.25	0.005	3.96	3.965	0.254	2.48	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	6.027	38.70
D14A	7.83	0.007	4.08	4.087	0.323	4.12	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	3.424	52.17
D14B	4.74	0.002	1.32	1.322	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	3.419	27.88
D14C	8.96	0.004	3.36	3.364	0.284	3.17	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	5.316	37.53
D14D	8.14	0.003	2.04	2.043	0.499	6.13	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	5.599	25.10
D14E	7.24	0.004	1.80	1.804	0.360	4.98	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, nitrate and fluoride	5.075	24.92
D14F	6.73	0.003	2.88	2.883	0.054	0.80	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	3.788	42.87
D14G	27.94	0.003	3.12	3.123	0.091	0.33	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	24.730	11.18
D14H	8.41	0.004	2.16	2.164	0.517	6.15	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	5.729	25.73
D14J	6.22	0.003	1.56	1.563	0.286	4.60	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	4.368	25.14
D14K	7.60	0.003	1.80	1.803	0.269	3.55	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	5.527	23.73
D15G	12.83	0.001	18.60	18.601	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	-5.769	144.96
D15H	8.46	0.002	12.12	12.122	0.002	0.02	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-3.661	143.24
D18K	31.88	0.039	48.00	48.039	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-16.160	150.69
D18L	19.65	0.049	25.20	25.249	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-5.600	128.50
D21A	22.65	0.003	0.00	0.003	0.006	0.03	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	22.638	0.01
D21C	12.73	0.001	0.00	0.001	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	12.728	0.01
D21D	13.42	0.007	6.84	6.847	0.004	0.03	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	6.564	51.04
D21E	16.70	0.008	7.32	7.328	0.370	2.22	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	9.003	43.88
D21F	25.00	0.015	4.56	4.575	0.350	1.40	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	20.075	18.30
D21G	11.57	0.007	2.64	2.647	0.021	0.18	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	8.898	22.89
D21H	20.45	0.003	13.20	13.203	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	7.247	64.56
D22A	27.63	0.011	4.44	4.451	0.092	0.33	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	23.082	16.11
D22B	25.54	0.009	3.84	3.849	0.005	0.02	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	21.687	15.07
D22C	21.40	0.002	16.20	16.202	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	5.196	75.72
D22D	22.65	0.009	4.44	4.449	0.289	1.28	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	17.911	19.64
D22G	38.05	0.015	6.12	6.135	0.156	0.41	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	31.754	16.13
D22H	20.06	0.006	4.32	4.326	0.174	0.87	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	15.557	21.57
D22L	11.79	0.005	2.40	2.405	0.127	1.08	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	9.262	20.39
D23A	24.25	0.006	3.24	3.246	0.058	0.24	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	20.943	13.39
D23C	26.46	0.013	3.72	3.733	0.022	0.08	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	22.700	14.11
D23D	16.38	0.011	2.52	2.531	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	13.846	15.45
D23E	20.35	0.006	3.12	3.126	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	17.224	15.36
D23F	6.48	0.001	2.16	2.161	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	4.314	33.37

Quaternary Catchment	Recharge Mm³/a)	BHN GW Reserve (Mm³/a)	GW Baseflow (Mm³/a)	GW Reserve (Mm³/a)	GW Use (Mm³/a)	Stress Index	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Allocable GW (Mm³/a)	GW Reserve (as % Recharge)
D23G	14.80	0.002	2.88	2.882	0.002	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride	11.920	19.47
D23H	20.48	0.005	2.76	2.765	0.429	2.09	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	17.283	13.50
D23J	14.40	0.004	2.28	2.284	0.237	1.64	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	11.877	15.86
D24A	5.97	0.002	1.92	1.922	0.033	0.56	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	4.018	32.18
D24B	9.05	0.002	2.04	2.042	0.090	0.99	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	6.918	22.56
D24C	6.90	0.003	1.20	1.203	0.252	3.65	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.447	17.43
D24D	10.14	0.002	1.44	1.442	0.019	0.19	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	8.679	14.22
D24E	8.38	0.001	1.08	1.081	0.262	3.12	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	7.040	12.90
D24F	10.52	0.002	1.56	1.562	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	8.953	14.85
D24G	13.51	0.003	2.52	2.523	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	10.991	18.67
D24H	12.52	0.003	2.04	2.043	0.363	2.90	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	10.111	16.32
D24J	17.25	0.005	2.16	2.165	0.766	4.44	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	14.321	12.55
D24K	8.22	0.003	1.92	1.923	0.967	11.76	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	5.333	23.39
D24L	7.39	0.002	1.08	1.082	0.491	6.64	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.819	14.64
D31A	13.71	0.004	2.16	2.164	1.285	9.37	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	10.264	15.78
D31B	10.08	0.002	0.60	0.602	0.223	2.22	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	9.251	5.97
D31C	6.96	0.001	0.60	0.601	0.053	0.77	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	6.305	8.64
D31D	15.04	0.003	1.20	1.203	1.069	7.11	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; Elevated TALK, nitrate and nitrite	12.764	8.00
D31E	10.25	0.003	1.20	1.203	0.071	0.70	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	8.977	11.74
D32A	7.78	0.001	0.60	0.601	0.401	5.15	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	6.781	7.72
D32B	6.48	0.003	0.72	0.723	1.104	17.04	Largely Natural	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	4.652	11.16
D32C	10.06	0.003	0.60	0.603	0.255	2.54	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, nitrate and nitrite	9.202	5.99
D32D	9.24	0.001	0.60	0.601	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	8.635	6.51
D32E	9.28	0.002	0.60	0.602	0.279	3.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Slight elevated salinity; High nitrate and nitrite	8.401	6.49
D32F	15.57	0.003	0.84	0.843	0.402	2.58	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	14.325	5.41
D32G	10.83	0.003	0.84	0.843	2.310	21.33	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	7.676	7.78
D32H	5.97	0.002	0.48	0.482	0.385	6.45	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	5.107	8.07
D32J	14.64	0.003	0.84	0.843	0.136	0.93	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	13.656	5.76
D32K	7.80	0.002	0.60	0.602	0.118	1.52	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	7.075	7.72
D33A	9.02	0.002	0.36	0.362	0.120	1.33	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	8.542	4.01
D33B	10.31	0.002	0.24	0.242	0.095	0.92	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	9.970	2.35
D33C	10.02	0.002	0.36	0.362	0.161	1.61	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	9.492	3.61
D33D	11.25	0.002	0.24	0.242	0.010	0.09	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	10.997	2.15
D33E	18.60	0.006	0.12	0.126	0.550	2.96	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	17.921	0.68
D33F	11.69	0.003	0.12	0.123	0.018	0.15	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	11.545	1.05
D33G	16.26	0.005	0.24	0.245	0.023	0.14	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	15.995	1.51
D33H	9.30	0.004	0.24	0.244	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	9.052	2.62
D33J	7.33	0.004	0.12	0.124	0.069	0.93	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	7.138	1.69

Quaternary Catchment	Recharge Mm³/a)	BHN GW Reserve (Mm³/a)	GW Baseflow (Mm³/a)	GW Reserve (Mm³/a)	GW Use (Mm³/a)	Stress Index	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Allocable GW (Mm³/a)	GW Reserve (as % Recharge)
D33K	4.65	0.002	0.24	0.242	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	4.407	5.21
D34A	9.07	0.003	0.36	0.363	1.782	19.64	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	6.926	4.00
D34B	8.00	0.003	0.12	0.123	0.819	10.23	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	7.062	1.54
D34C	8.49	0.003	0.12	0.123	0.930	10.96	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	7.438	1.45
D34D	6.73	0.002	0.12	0.122	0.235	3.50	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	6.369	1.81
D34E	5.90	0.002	0.12	0.122	0.478	8.11	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.302	2.07
D34F	7.69	0.004	0.12	0.124	0.398	5.17	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	7.168	1.61
D34G	10.96	0.003	0.36	0.363	1.331	12.15	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	9.268	3.31
D35A	3.07	0.001	0.84	0.841	0.380	12.37	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	1.851	27.38
D35B	3.11	0.001	0.72	0.721	0.186	5.98	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	2.201	23.20
D35C	11.06	0.004	2.28	2.284	0.709	6.41	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	8.065	20.65
D35D	6.82	0.002	1.20	1.202	0.235	3.45	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	5.379	17.63
D35E	3.67	0.001	0.72	0.721	0.505	13.77	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	2.441	19.66
D35F	6.62	0.002	1.56	1.562	0.484	7.30	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	4.578	23.58
D35G	6.40	0.002	0.84	0.842	2.073	32.39	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity, chloride, fluoride	3.484	13.16
D35H	6.07	0.002	1.08	1.082	0.292	4.82	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	4.696	17.83
D35J	19.14	0.003	1.80	1.803	1.264	6.60	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	16.071	9.42
D35K	8.19	0.002	1.08	1.082	0.909	11.09	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	6.203	13.20

Please note:

- ***GW Quantity Directive*** *description based on the estimation of the so-called aquifer Stress Index (i.e. Use/Recharge, groundwater use divided by the local recharge), A (<0.1), B (0.10-0.20), C (0.20-0.40), D (0.40-0.60), E (0.60-0.80) and F (0.80-1.00). MAX stress should be a C. All SI's >C needs water balance assessments and categorised hydrogeological investigations for new water use applications (viz. Quantity Directive as a guideline).*
- ***Quality Index*** *description based on the DWAF et al, 1998 Domestic water quality classification and the available water quality data – which unfortunately is based on a quaternary level and outdated as well. This is just a narrative of the water quality status.*
- ***GW Quantity Directive*** *describes the actual activity required to allow additional water allocations and is based on the Quantity Index, Allocable Groundwater and Recharge (% of Recharge). The following criteria has been adopted as a guideline for future groundwater investigations to support water use license conditions:*
    - *Minimum Stress Index Level (Groundwater investigation limited to local water balance estimation and hydrocensus)*
    - *Medium Stress Index Level (Groundwater investigation more detail in terms of hydrogeological conditions, hydrocensus, limited monitoring requirements, mapping of other abstractions and water balance);*
    - *High Stress Index Level (High-level groundwater investigation, monitoring boreholes, specific license conditions, aquifer characterisation, recharge estimates, regional potential impacts and piezometric mapping)*
    - *Quaternary Catchment water balance assessment required (Current water balances for quaternary catchment does not match and Allocable groundwater is < 1 Mm³/a)); and*
    - *Groundwater allocation (or use) significantly over-allocated, means that use is potentially impacting on the Groundwater Component of the Reserve.*

GW Quality Status *describes specific groundwater quality signatures and should help as an indicator of management measure to address these water quality trends. Some of the trends are regional impacts, i.e. the EC, nitrate and nitrite, chloride, sodium, TALK and fluoride*

Table 6-37: Recommended Groundwater Monitoring Programme

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
13, 14	D33C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13, 14	D33D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13, 14	D33E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	C51M	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14A	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D14B	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D14D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 11	D34B	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D35C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D35D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4	C52E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4	C52F	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4, 14	C52G	Moderately Modified	Marginal, Class 2	Moderate Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
3, 4, 14	C52H	Seriously Modified	Marginal, Class 2	High Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
1	D21A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3	C51C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3	C52D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D18K	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
1, 2	D23G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	C52A	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	C52B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	C52C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	D23E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 14	C51E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 14	C51F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 14	C51H	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 5, 6, 14	C51J	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 13, 14	C51K	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 14	C52J	Seriously Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
3, 5, 14	C52K	Largely Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
2	D15G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11	D34A	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11	D34E	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D35A	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D35F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51A	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51B	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51D	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3, 14	C51G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D12A	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12B	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12C	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D12D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12E	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D15H	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D18L	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
2, 3	D24K	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 6, 12, 14	D31A	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11, 12	D34F	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11, 12, 14	D34G	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32A	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32B	Largely Natural	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32D	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D31E	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D33A	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D33B	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13K	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10, 11, 12	D32F	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13	D31B	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13	D31C	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
11, 12	D32J	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
11, 12	D32K	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
6, 12, 14	D31D	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; Elevated TALK, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32E	Unmodified	Good, Class 1	Minimum Stress Index Level	Slight elevated salinity; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
13	C51L	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8	D13H	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D12F	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14J	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14K	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D24J	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9, 11	D34C	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9, 11	D34D	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D35B	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35E	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35G	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
2, 9	D35H	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9, 11	D35J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35K	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
9	D14E	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, nitrate and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D13M	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14C	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14F	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
8, 9	D14G	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 10	D32C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 10, 11, 12	D32G	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
9, 11, 12	D32H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
5, 13, 14	C52L	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33F	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33G	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33J	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33K	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings

Table 6-38: Quaternary catchments with no groundwater quality data

GRU	Quaternary Catchments
GRU1	C52B, C52C, D21A, D21C, D21D, D21F, D21G, D21H, D22A, D22B, D22C, D22D, D22H, D22L, D23A, D23C, D23D, D23E, D23F, D23G, D23H, D23J
GRU2	C51D, C51G, D12A, D12B, D12C, D12E, D12F, D14J, D14K, D15G, D15H, D18L, D23F, D23G, D23H, D23J, D24A, D24B, D24C, D24E, D24F, D24H, D24J, D24K, D24L, D31A, D34A, D34C, D34D, D34E, D34F, D34G, D35A, D35B, D35E, D35F, D35G, D35H, D35K
GRU3	C51B, C51C, C51D, C51E, C51F, C51G, C51H, C51J, C52B, C52C, C52D, C52E, C52F, C52G, C52J, C52K, D23E, D23F, D23H, D23J, D24K
GRU4	C52E, C52F, C52G
GRU5	C51J, C52K, C52L
GRU6	C51F, C51H, C51J, D31A, D31D
GRU7	D12A, D12B, D12C, D12E, D13A, D13B, D13C, D13E, D13F, D13G, D13J, D13K, D13L, D15H, D18K, D18L
GRU8	D12B, D12C, D12E, D12F, D13F, D13G, D13J, D13K, D13L, D13M, D14C, D14F, D14G
GRU9	D12F, D13M, D14B, D14C, D14D, D14F, D14G, D14H, D14J, D14K, D24J, D32C, D32H, D34B, D34C, D34D, D35B, D35C, D35D, D35E, D35G, D35H, D35K
GRU10	D32A, D32B, D32C, D32D, D32F
GRU11	D32F, D32H, D32J, D34A, D34B, D34C, D34D, D34E, D34F, D34G
GRU12	D31A, D31B, D31C, D31D, D31E, D32F, D32H, D32J, D33A, D33B, D34F, D34G
GRU13	C51L, C52L, D31B, D31C, D31E, D33A, D33B, D33C, D33D, D33E, D33F, D33G, D33H, D33J, D33K
GRU14	C51E, C51F, C51G, C51H, C51J, C52G, C52J, C52K, C52L, D31A, D31D, D31E, D33A, D33B, D33C, D33D, D33E, D34G

.

7. INTERACTION BETWEEN SURFACE WATER (RIVERS AND WETLANDS) AND GROUNDWATER

An approach and method to define the interactions between surface water (wetlands and rivers) and groundwater was developed to integrate the water requirements between all the components as part of this study. This section describes the method that was developed and used to infer the interaction between the water resource components that were assessed as a part of this Reserve study.

The method is a locally novel approach[3] to assessing the probability of hydrological dependence between groundwater and surface water resources as well as the probability of hydrological dependence between discrete surface water resources (i.e., streams, wetlands, and estuaries). The necessity of this assessment was recognised particularly in areas where multiple resource units (i.e., rivers, wetlands, groundwater and estuarine resource units) overlap. Due to the known interactions and reliance between these different water resource components, it is vital that some understanding of their dependency on one another is obtained. It is particularly important to understand these dependencies in the context of this Reserve study (and other Reserve studies hereafter) because environmental authorisations that result in the degradation of one suite of resources (for example, abstraction of groundwater resources) may have an additional impact on another suite of resources (for example, groundwater-dependent wetlands). As such, the integrated assessment of all these resources should be included in authorisation processes in the areas that have inferred interactions between water resources. Refer to **Figure 7-1** for a summary of the approach adopted for this component.

The product of this process is intended to be a spatial GIS layer of the selected study area in which the probability of dependence on groundwater or surface water is inferred. Additionally, the nature of that dependence (either non-dependent, seasonally dependent or entirely dependent) has been inferred for each discrete portion of the study area.

[3] It should be noted that this approach was adapted from the approach that was developed by Serov *et al.* (2012) to assess groundwater dependence of surface water ecosystems in Australia.

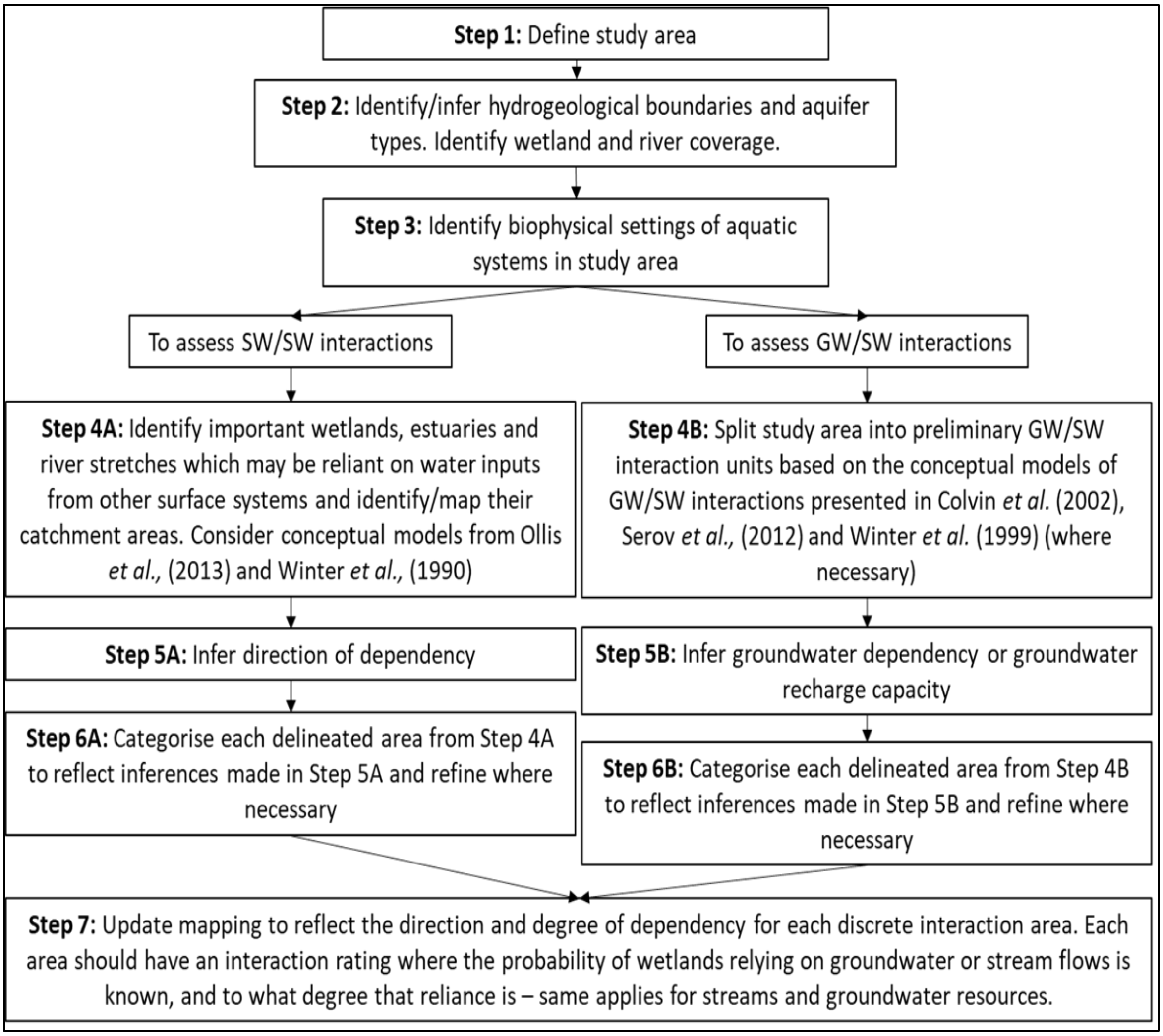


Figure 7-1: Proposed method to determine the degree and direction of dependency of different freshwater ecosystems on hydrological inputs from other freshwater ecosystem types (method adapted from Serov *et al.* (2012) and Colvin *et al.* (2002)

Data which was considered for the integration component included the following:

- Water resource coverage (wetland, river, groundwater GIS layers);
- Geological information;
- Vegetation types;
- Slope and elevation data;
- Aquifer transmissivity data;
- Borehole density and depth to ground water;
- Flow data in rivers;
- Wetland typologies; and
- The more data made available, the more confident and robust the outputs are.

Below is a high-level overview of the results for the various steps as per **Figure 7-1** for the Kraai study area.

7.1 Step 1: Define the study area

Figure 7-2 indicates the study area for the integration of the Kraai water resources. This includes the Groundwater RU 7, the river RU numbers 11, 24, 25 and 27 and the Wetland RU 6, 16 and 17.

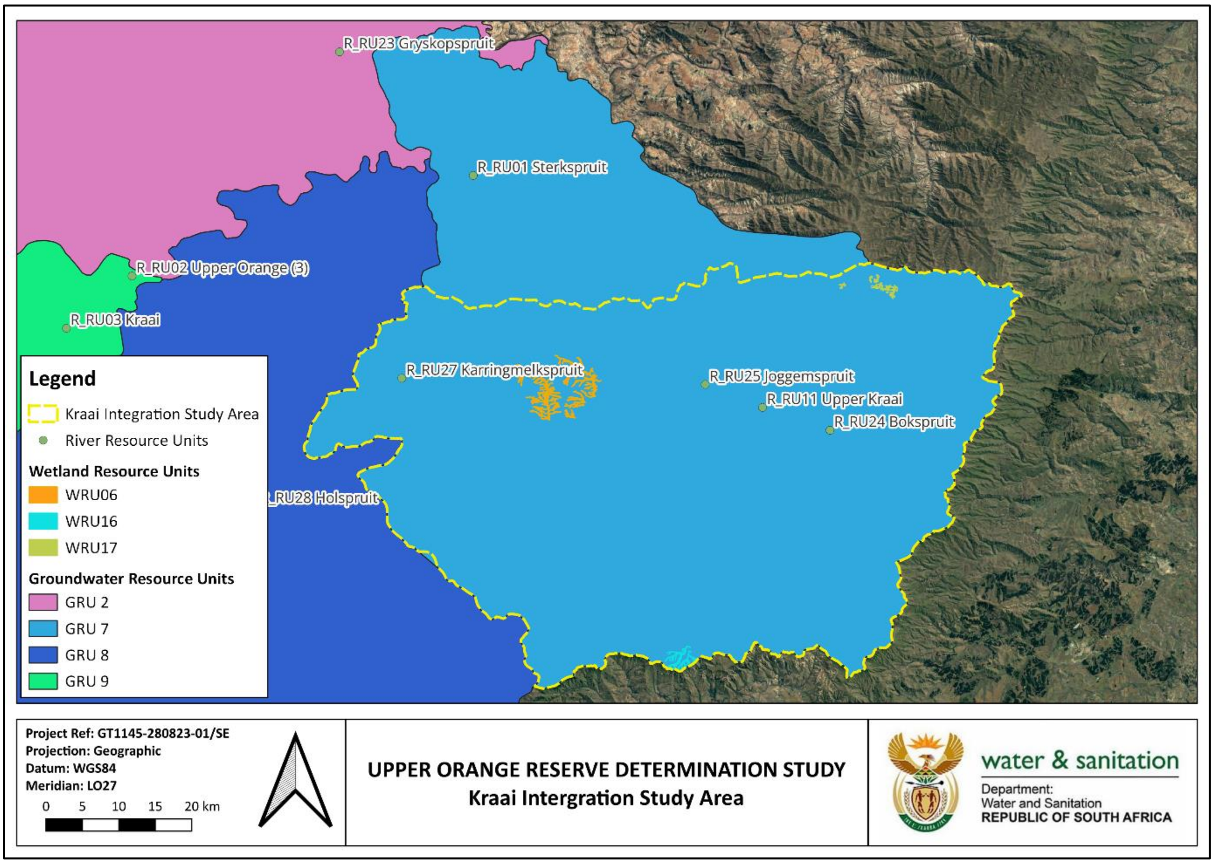


Figure 7-2: Study area for the integration of the Kraai water resources. This includes the Groundwater RU 7, the River RU numbers 11, 24, 25 and 27 and the Wetland RU 6, 16 and 17

7.2 Step 2: Identify hydrogeological boundaries, aquifer, wetland, river and estuary coverages within the study area

In the Upper Kraai, the entire study area is characterised by intergranular and fractured lithologies with varying modelled transmissivity values. Additionally, the Kraai and Bell Rivers run through the study area, both of which have extensive catchments and many feeder tributaries. Extensively mapped river reaches within steeply-sided valleys exist in the study area. Few wetlands have been mapped in the NWM5 dataset in the study area. However, the wetland data has been supplemented with field verified and expert desktop mapped wetland areas (where available). **Figure 7-3** and **Figure 7-4** depict the different data layers that were considered for Step 2.

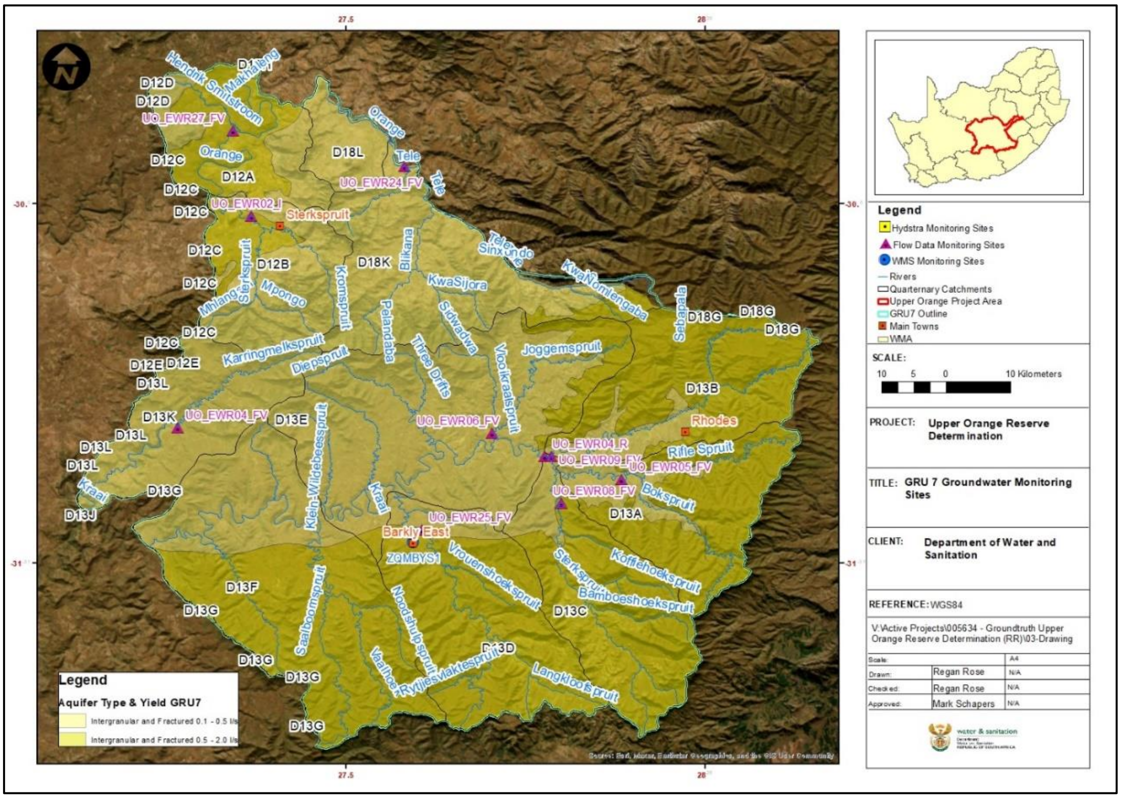


Figure 7-3: Hydrogeological map of the Upper Kraai study area

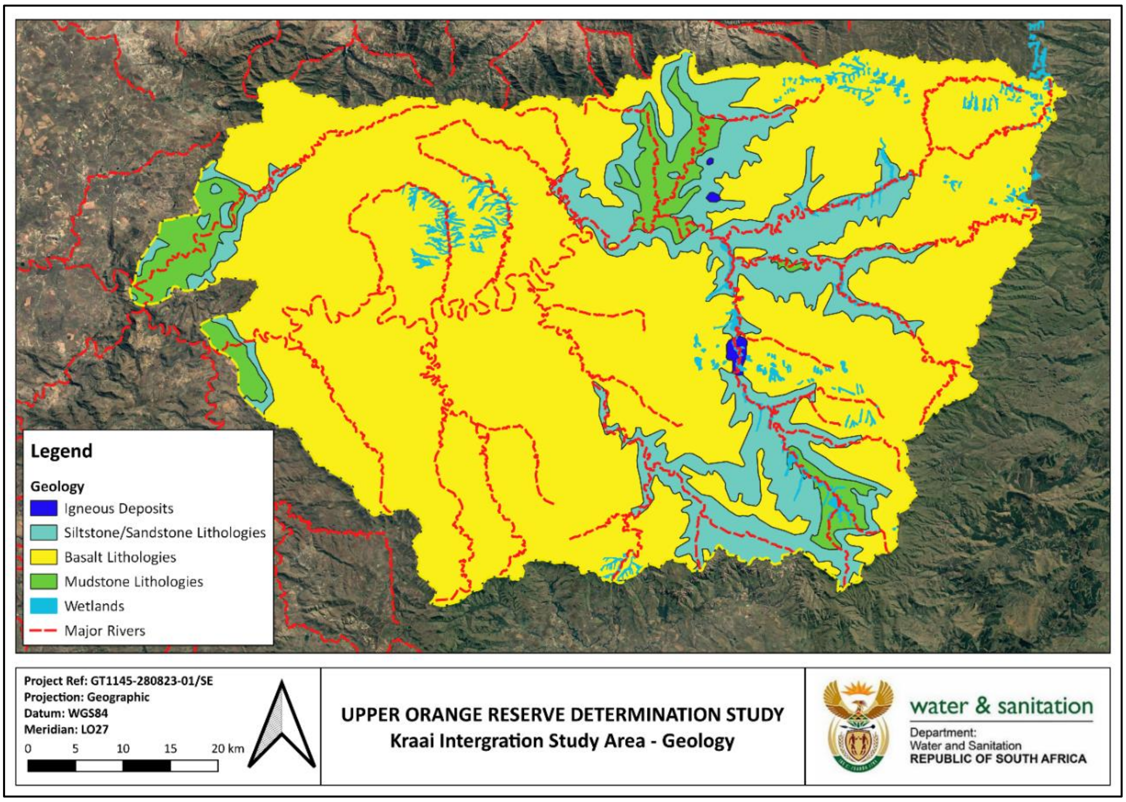


Figure 7-4: Geological, river and wetland data utilised for the Upper Kraai study area

In the Kraai study area, geological features, particularly extensive basalt lithologies, shape the interaction between surface and groundwater. Limited deep groundwater data exists, but it's suggested that deep aquifers may support the lower Kraai River in the west. Seasonal variations in surface water-surface water interactions (i.e. interactions between different surface water resources, being rivers and wetlands, wetlands and other wetlands, rivers and other rivers) are likely due to the presence of valley-bottom and seep wetlands in this study area.

7.3 Step 3: Identify biophysical settings of the surface water resources

Knowledge about soil type, vegetation type, borehole location and depth to groundwater, Flow data in streams, topographic and water quality data (both surface and groundwater data) is important for this step when identifying the biophysical settings of the surface water resource. **Figure 7-5** indicates the vegetation dataset for the study area overlaid by the available river and wetland coverages. Strong overlap between mapped wetlands and the Southern Drakensberg Highland Grassland vegetation type in the valleys and the sandstone/mudstone and siltstone lithologies. Strong overlap of mapped seep wetlands and the Lesotho Highland Basalt Grassland type in the eastern portion of the study area, which coincides with the basalt lithologies.

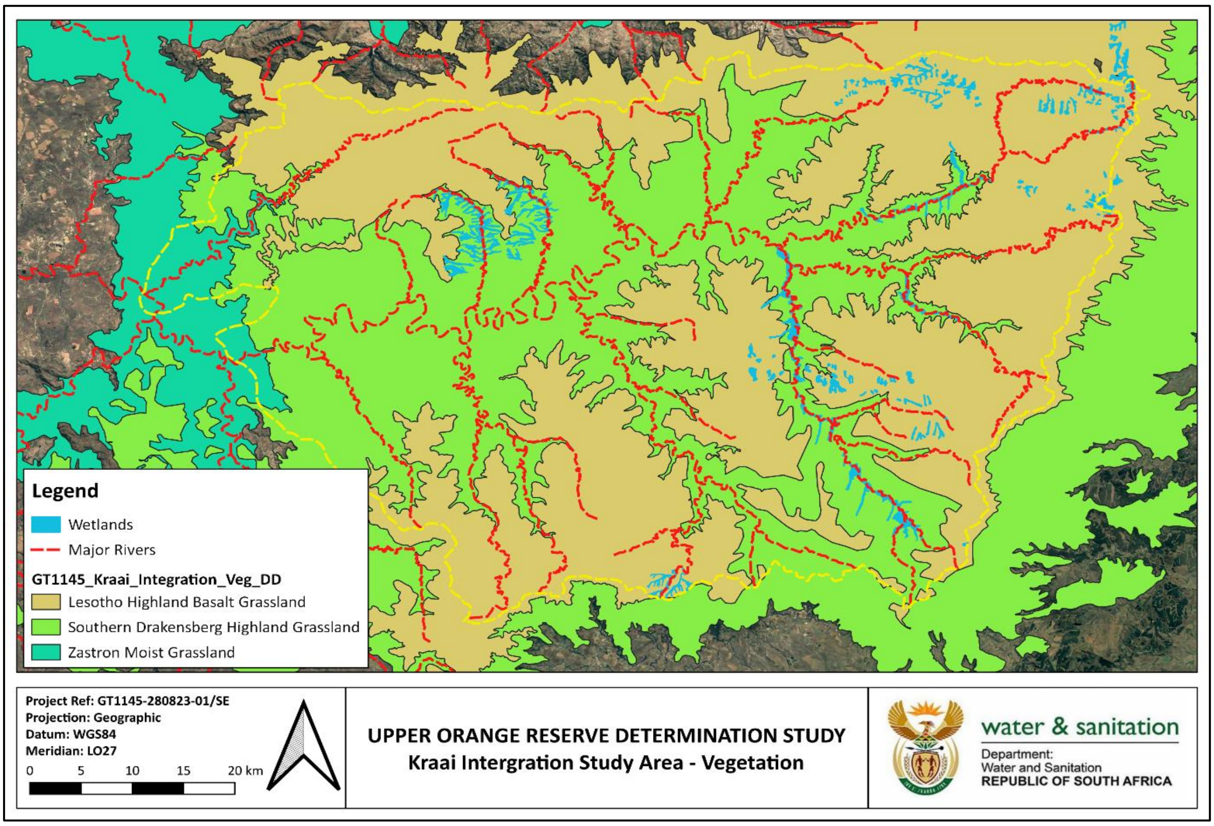


Figure 7-5: Mucina and Rutherford (2006) vegetation dataset for the study area overlaid by the available river and wetland coverages

Furthermore, the derived slope analysis for the Upper Kraai study area is illustrated in **Figure 7-6.** As a result, there is a strong correlation between average slope and vegetation type, as well as between average slope and geology. Thus, one can infer that valley-bottom wetlands will generally occur in areas where the slope is <=10% - which generally coincides with sandstone/mudstone and siltstone geologies in areas below 1800masl. This can further infer that seep wetlands occur on slopes >15%, which often coincides with basalt lithologies above 1800masl.

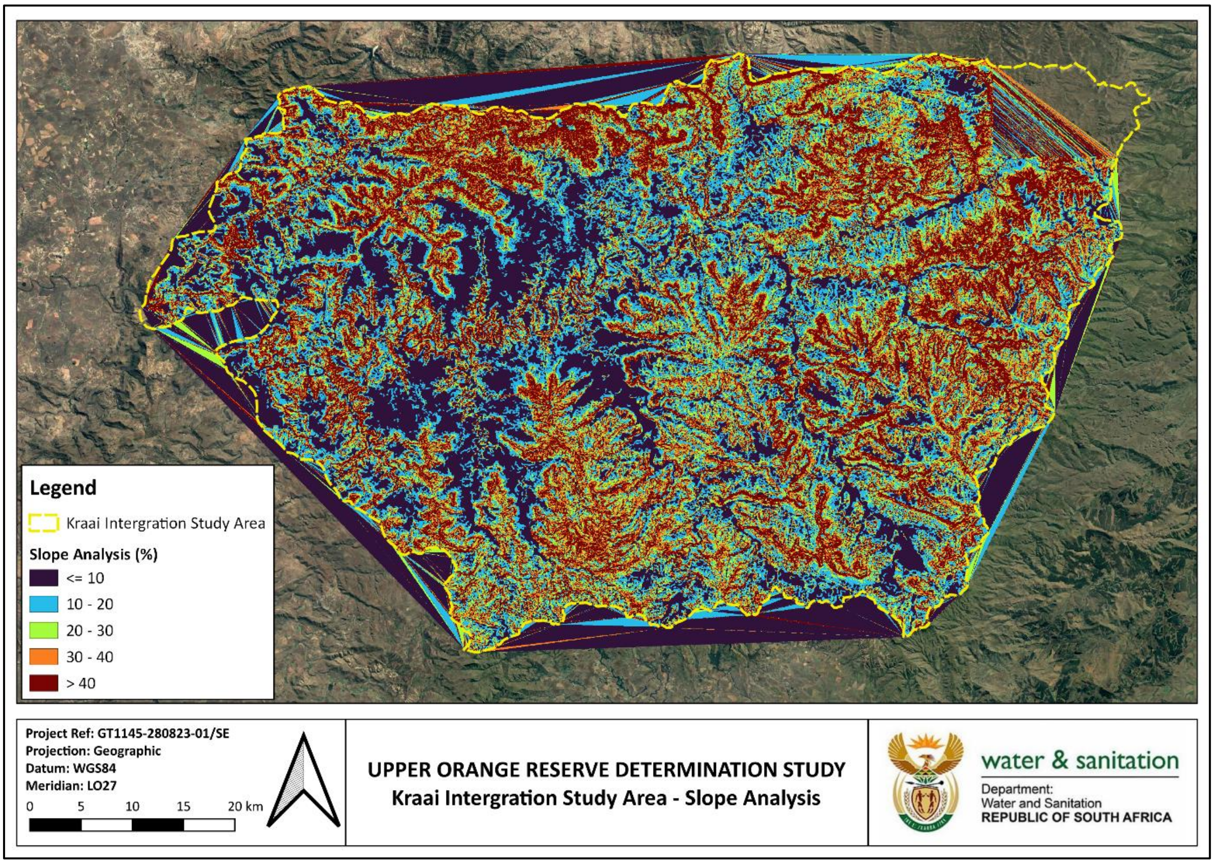


Figure 7-6: Derived slope analysis for the Upper Kraai study area

7.4 Step 4A: Split portions of the study area into preliminary groundwater-surface water interaction areas based on the conceptual models presented in Colvin et al. (2002), Winter et al (1999) and Serov et al (2012).

In the Upper Kraai study area, groundwater-surface water interactions were categorised based on geological variations. Preliminary zones considered differences in transmissivity and groundwater holding capacity. Areas with slopes less than 10%, often valley-bottom regions with wetlands or streams, showed a high likelihood of seasonal groundwater dependence and surface water-surface water interactions. Areas with slopes greater than 10% feature low-order streams and seepage wetlands, suggesting a high probability of the groundwater-surface water interaction. **Figure 7-7** provides an overview of the estimated spatial distribution of these interaction areas.

Similar to other lithologies, the Upper Kraai basalt area was divided into interaction zones based on slope, elevation, and soil type. See **Figure 7-8** for the estimated spatial distribution of these different interaction areas.

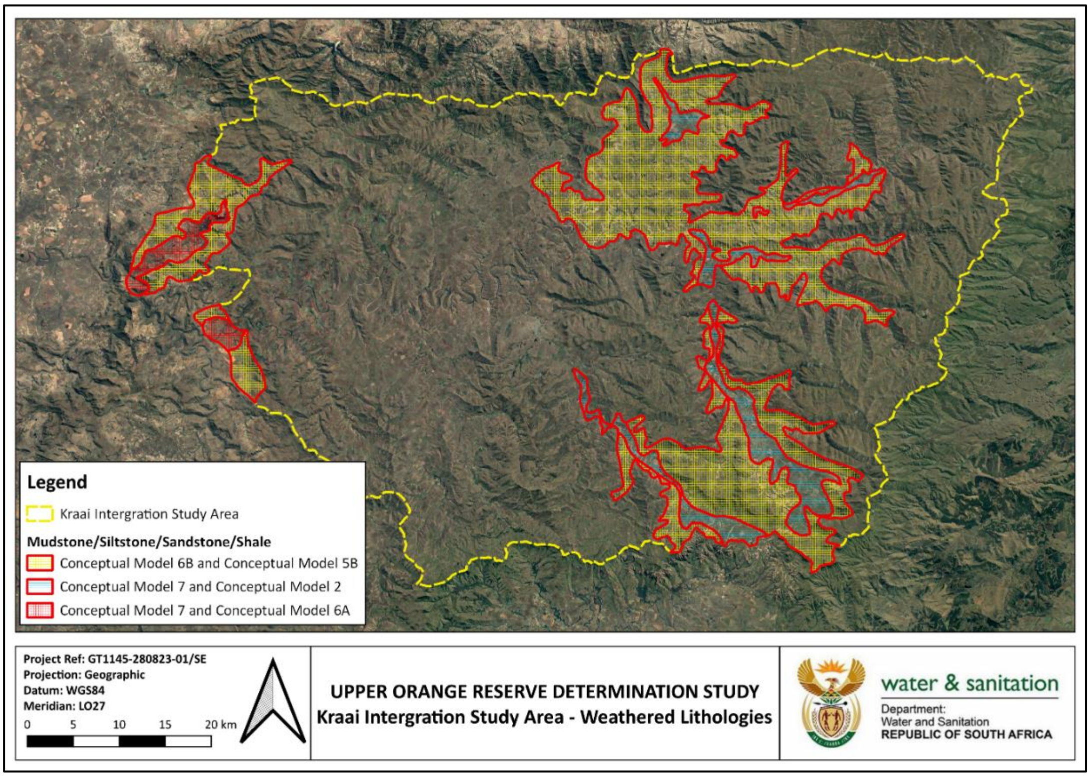


Figure 7-7: Mapped groundwater-surface water interaction units for the sandstone/mudstone and siltstone lithologies in the Upper Kraai study area

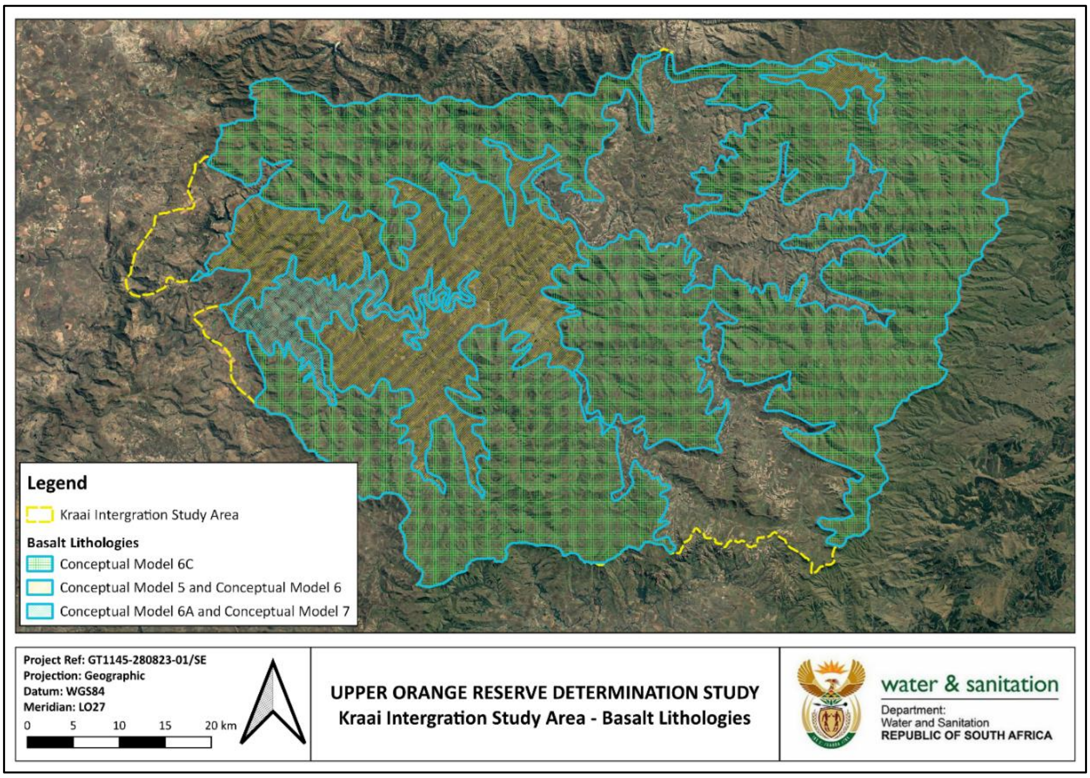


Figure 7-8: Mapped groundwater-surface water interaction units for the basalt lithologies in the Upper Kraai study area

7.5 Step 4B: Split the remaining portions of the study area into preliminary surface water-surface water interaction areas based on the conceptual models presented in Winter et al. (1999) and Ollis et al. (2013).

In the Upper Kraai study area (**Figure 7-9**), seep wetlands on east-west slopes likely feed the Klein Wildebeesspruit and Wildebeesspruit streams. Channelled valley-bottom wetlands on the valley floor probably receive seasonal overflow from these streams.

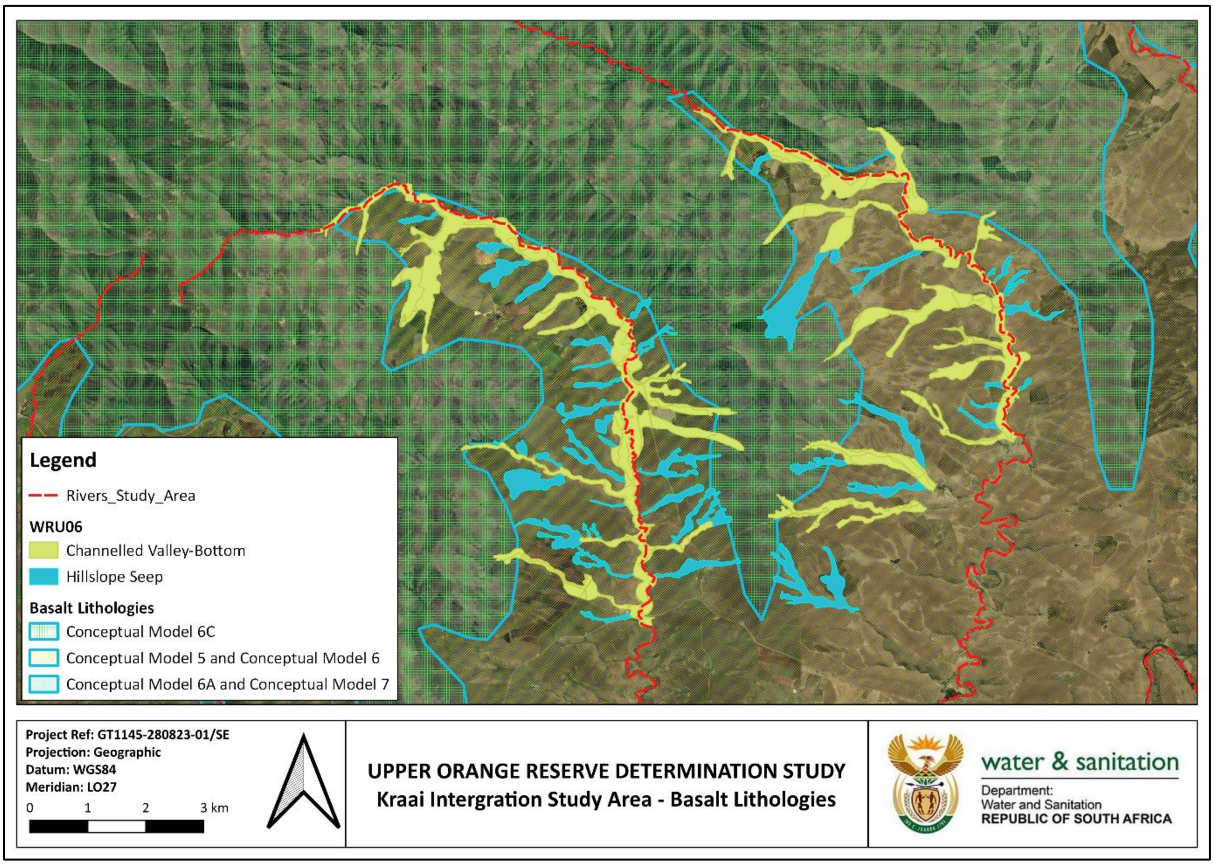


Figure 7-9: The mapped WRU 6 along with the low order streams of the Klein Wildebeesspruit and the Wildebeesspruit Rivers flowing through the WRU.

7.6 Step 5A: Infer groundwater dependency or groundwater recharge dependency

In the Upper Kraai study area, the groundwater dependency assessment involves answering sequential questions from **Table 7-1** for different conceptual interaction models. The questions consider factors like location, ecology, and ecosystem function to infer groundwater dependency. Positive answers indicate a higher probability of dependency, without specifying details about the groundwater regime. The number of positive answers corresponds to the likelihood of groundwater dependency. For systems showing dependency, a decision is made on whether it is on shallow/perched or deeper aquifers.

Table 7-1: Inferring groundwater dependency. A worked example of the basalt lithologies shown **Figure 7-9** is shown below

1. General questions for all groundwater dependent ecosystems (GDE)	Yes	No	Unknown
Is the ecosystem similar to another that is known to be groundwater dependent?	X		
Is the distribution of the ecosystem consistent with known areas of groundwater discharge?			X
Is the distribution of the ecosystem often confined to locations where groundwater is known or expected to be at a shallow depth? (Consider topography, boreholes, geology, alluvial setting of the system)	X		
Does the system withstand prolonged dry conditions without obvious signs of water stress?	X		
Does expert opinion indicate that the ecosystem is groundwater dependent?			X
2. GDE Specific Questions			
Base flow streams			
Is the stream perennial, and does streamflow increase consistently downstream during prolonged dry conditions? (Consider flow gauge data and proximal borehole data)	X		
Is the stream or sections of the stream known to be gaining; i.e., receiving water from groundwater discharge where surrounding groundwater levels are higher than the stream bed or there is groundwater up-welling?			X
Is the stream bed composed of course grained unconsolidated sediments such as sand or gravel? (Consider soil type data, geology and in-field observation)	X		
Is the aquatic invertebrate community within the surface water comprised predominantly of long lived, short range endemic species? (Consider SASS data/ infield observations)			X
Is the aquatic invertebrate community within the stream bed substrate composed of groundwater obligate (stygofauna) species?			X
Groundwater dependent wetlands			
Does the location of the wetlands suggest that they are likely to be groundwater dependent; e.g. permanent wetlands on coastal sand beds, seasonal wetlands along paleo-drainage lines, and streams with consistent flow along flow path during extended dry periods? (Consider topography, slope, geology, depth to water table, flow gauges, local knowledge)		X	
Is the wetland associated with a spring or a seep? Groundwater discharge that is concentrated and occurs adjacent or in the wetland suggests groundwater may be an important source of water (Consider wetland type, landscape position, topography, slope, geology)	X		
Is there visible water in the wetlands (especially during prolonged dry periods) and do the wetlands lack surface inflow? (Consider wetland type, landscape position, topography, satellite imagery). Some permanent wetlands that lack distinct surface water inflows can be perched on hardpan soils and are isolated from groundwater.	X		
Is the vegetation, vertebrate or invertebrate community composed of species known to require permanent saturation in situations that are not obviously fed by surface water? (Consider vegetation type, satellite imagery, infield observations)			X
Is the wetland considered seasonal? Seasonal wetlands are unlikely to receive significant, season long inputs of groundwater and are likely to be maintained by		X	

surface water inputs. **Answering No to this question indicates and increased probability for groundwater dependency.**			

7.7 Step 5B: Infer direction of surface water dependency

Table 7-2 was used to assess surface water dependency by considering factors like location and ecosystem function. Positive answers indicate potential dependency without specifying details. This process was applied to different conceptual interaction models and specific surface water ecosystem types in mapped areas. As an example, the Klein Wildebeesspruit and Wildebeesspruit rivers were evaluated, revealing seep wetlands contributing significantly to perennial flow and valley-bottom wetlands seasonally supported by river flooding, likely partially supporting the rivers during dry seasons.

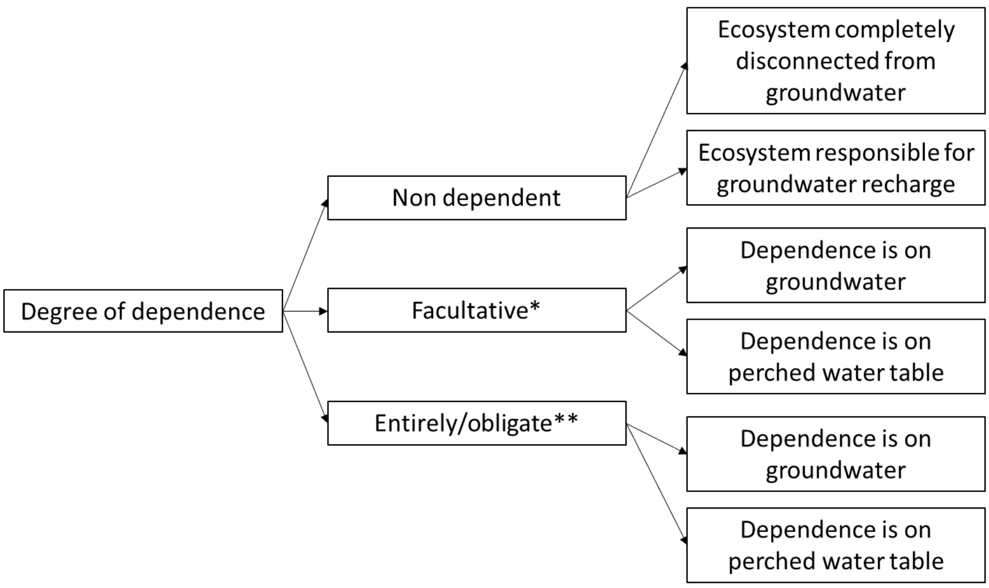
Table 7-2: Inferring surface water-surface water dependency. A worked example of the systems depicted in Figure 7-9 is shown below

1. Questions for Channelled Valley-Bottom and Floodplain Wetlands	Yes	No	Unknown
1.1 If the wetland were operating naturally, would the main source of water to the wetland be derived from the overbank flooding of the stream channel(s) running through/into the wetland? If “Yes” proceed to 1.3.	X		
1.2 If the answer to 1.1. is “No”, is the predominant source of water derived from lateral seepage inputs? Proceed to 1.3.	N/A		
1.3 Is there evidence that overbank flooding still occurs periodically within the wetland? If “Yes”, proceed to 1.5.		X	
1.4 If the answer to 1.3. is “No” is there evidence for why overbank flooding is no longer/less frequently occurring? Reasons might include inter alia: channel incision, extensive dam construction upstream, extensive flow diversions/abstraction in the catchment.	X		
1.5 Is there evidence that shows that water remains within the wetland areas adjacent to the stream channel(s) throughout the year? It is especially important to note this for the dry season when the streams might be low.	X		
2. Questions for Unchannelled Valley-Bottom Wetlands			
2.1 Is there a channel that flows into the wetland? i.e., is the wetland fed by a stream?	N/A		
2.2 Is there a channel that flows out of the wetland? i.e., does the wetland feed a stream?			
2.3 Are there significant lateral water inputs from seeps and/or springs?			
2.4 Is there evidence of water retention within the wetland particularly in the dry season?			
3. Questions for seasonal streams			
3.1 Is the stream located in an area where the MAP is >800mm?	N/A		
3.2 Is the stream a perennial stream?			
3.3 Of the total catchment area for the seasonal stream, is the proportion that is comprised of seepage and/or unchannelled valley bottom wetlands greater than 1% of the total catchment area?			

3.4 Is the stream located in a temperate or seasonal climate?			
4. Questions for perennial streams			
4.1 Is the stream located in an area where the MAP is >800mm?		**X**	
4.2 Is the stream a perennial stream?	**X**		
4.3 Of the total catchment area for the perennial stream, is the proportion that is comprised of seepage and/or unchannelled valley bottom wetlands greater than 1% of the total catchment area?	**X**		
4.4 Is the stream located in a temperate or seasonal climate?	**X**		

7.8 Step 6A: Categorise each delineated area from Step 4A to reflect inferences made in Step 5A and categorise the overall dependence of the groundwater or surface water ecosystem.

Figure 7-10 is a decision tree which was used to determine the direction and degree of dependency for each delineated area. If maps are requiring adjustment to align with the conceptual model of groundwater-surface water interaction, taking into account the identified degree and direction of dependency for each area, this step would be applied.



*Facultative refers to the seasonal or partial reliance of an ecosystem on groundwater/perched water table to maintain ecosystem function
**Entirely/obligate refers to the majority of the water inputs being derived from groundwater related inputs.

Figure 7-10: Decision tree used to categorise delineated interaction areas in terms of the degree and direction of dependence on groundwater or surface water ecosystems (adapted from Sigonyela *et al.,* 2006)

7.9 Step 6B: Categorise each delineated area from Step 4B to reflect inferences made in Step 5B and categorise the overall dependence of the surface water ecosystem on other surface water ecosystems.

Figure 7-11 provides the decision tree used to categorise degree of dependence of wetlands on groundwater (A), stream dependence on wetland inputs (B) and wetland dependence on stream inputs (C). The orange outlines indicated that the surface water systems rely on groundwater/perched aquifers – therefore groundwater abstraction may have an impact on groundwater fed wetlands and baseflow dependent streams. The blue outlines indicated that the surface water systems were less dependent on groundwater, but wetlands have higher dependence on streams – therefore streamflow modifying activities should be considered in terms of wetlands as well as streams.

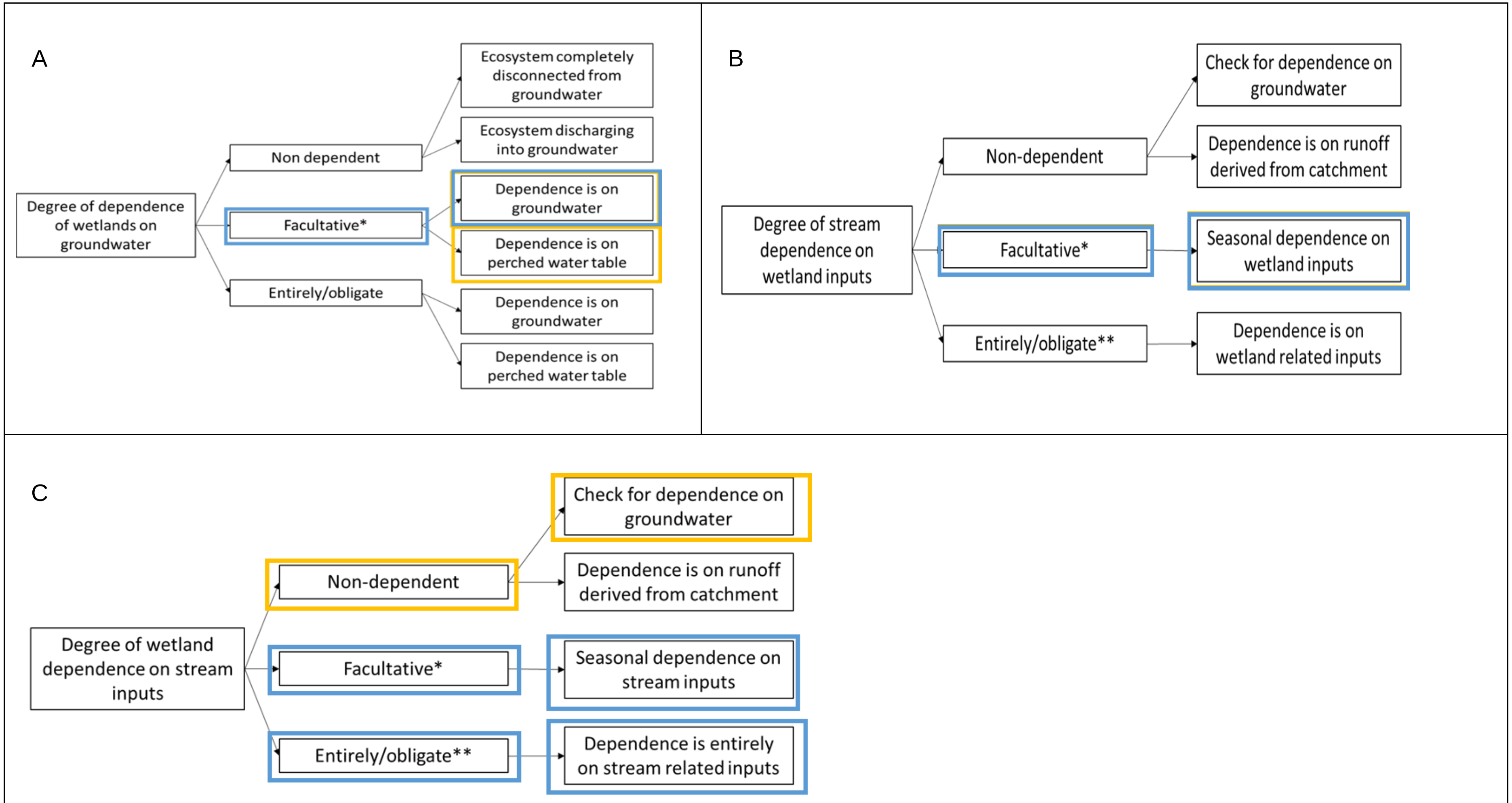


Figure 7-11: Decision tree used to categorise degree of dependence of wetlands on groundwater (A), stream dependence on wetland inputs (B) and wetland dependence on stream inputs (C) (adapted Sigonyela *et al.*, 2006)

7.10 Step 7: Update the preliminary mapping undertaken in Steps 6A and 6B to reflect the refined interaction model for the entire study area.

This approach is recommended to be taken forward into the Classification phase of the Upper Orange catchment area, so that refinements and updates of the spatial and attribute data of the GIS layer can be undertaken, to indicate the probability of groundwater or surface water dependency.

Overall, this proposed approach may yield important cross-discipline and cross water resource information for future authorisations. However, it is important to note that the quality of data can drastically impact the confidence of these models. Furthermore, stakeholders can be involved by sharing any streamflow or borehole depth data going forward.

8. CAPACITY BUILDING PROGRAMME

The study team was cognisant of the DWS's and specifically the CD: WEM imperative to build capacity and transfer skills in water resource management and protection. A capacity building programme was developed to form part of the study. This programme was based on a model well received by DWS officials on previous projects implemented by this team which included introductory training before each key workshop, and mentoring of DWS officials by specialists during field surveys, EWR and scenario workshops, etc. DWS officials were encouraged to select specialist fields where they wanted to learn more, and pair-up with that specialist during field surveys and workshops.

The capacity building was realised through the following mechanisms in this study, namely:

- **Mentorship:** Mentoring of the Upper Orange Reserve determination DWS team - which involved dedicated sessions with the identified specialists on the team addressing rivers, wetlands and groundwater as the subject matter;
- **Stakeholder Engagement/empowerment:** stakeholder empowerment sessions were linked to the stakeholder meetings. The team capacitated stakeholders through the various meetings and consultation forums that were created over the duration of the project. Each presentation ran through the process, tools/ methods applied or applicable approaches followed so that stakeholders became familiar with the methodology applied. Applicable supporting information was made available to stakeholders;
- **Specialist workshops:** Various specialist workshops were held during the course of this study, further providing a platform for identified DWS officials and/or other identified trainees:
    - A number of project phase workshops were held over the course of the study, meeting the needs of the DWS members;
    - All workshops were communicated to the Department well in advance and all held virtually,
    - During the initiation meeting held on 25 August 2021, GroundTruth requested the Department to submit the names of those officials who were interested to attend these initiatives and for which the various virtual invitations can be sent ahead of time for planning and preparation. These colleagues are included in Chapter 1.4.

- **Capacity building Training -** Participation of identified DWS officials – in nine half day to one-day dedicated training initiatives on the water resource components and Reserve determination tools which aimed to build their capacity and broaden their skills base with respect to the 8-step Reserve process, as well in terms of specific technical content;
- **In-field capacity building:** two (2) in-field river surveys, a single wetland survey and groundwater hydrocensus were undertaken. Members of the Department were invited and encouraged to attend, with the aim to obtain in-field insight, all which were incorporated into the below-mentioned tools and models that were trained upon; and
- **Citizen science –** The use of citizen science (CS) in this study was to assist during the various in-field verifications and monitoring using the selected river approach levels. Beyond the lifespan of this project, this will allow for more data to be collected at more sites, through the encouragement and community involvement in water resource management, complement data collected, and upskill community members. Where appropriate, CS tools were defined, particularly during the surveys (i.e. rivers). Ideally DWS staff, with a specific mandate to monitor and/or engage with communities, was encouraged to co-operate and co-create the opportunities for the translation and then application of CS tools into longer term monitoring programmes to achieve and meet the Reserve monitoring requirements. This negates the need for a skilled hydrologist/technician or gauging weir to measure attainment of the required Reserve requirement at that site. It also empowers local communities to engage with the Reserve process and the importance of these communities in achieving some of the Sustainable Development Gaols (SDG) targets, for example Target 6.b – Stakeholder participation - "Support and strengthen the participation of local communities in improving water and sanitation management" - 2030 Agenda for Sustainable Development (see https://www.sdg6monitoring.org/indicators/target-6b/).

A summary of all capacity building events is listed in **Table 8-1** below.

Table 8-1: Summary of capacity building events during the duration of the study

Capacity building topic	Date	Outputs

Resource Unit prioritisation workshop	31 August 2021	• Approaches per component to obtain approval from DWS:
		  • Surface water;
		  • Groundwater; and
		  • Wetlands.
		• Discussion on the identified river RUs and levels of determination; and
		• Integration of rivers RUs with groundwater and wetlands.

Resource Unit prioritisation capacity building		• Assess RUs and river level approaches, including the IWUI (resource stress) and the IEI. Assessment of the resource stress;
		• Approaches per component:
		  • Surface water;
		  • Groundwater; and
		  • Wetlands.

Wetland Technical Workshop: Approach and Refinement of Resource Units	9 December 2021	• Project background and proposed wetland approach; • Wetland study area; • Information gaps; • Prioritised wetlands; • Discussion and input from attendees on the proposed approach and on potential wetland areas for consideration; • Working for wetlands strategic planning; and • General discussion.

Wetland and Groundwater RU Capacity Building	4 February 2022	• Presentation of identified wetland RUs:
		  • Described the Wetland Reserve Determination Tools;
		  • Described the wetland prioritisation process and the multi-criteria analysis;

Capacity building topic	Date	Outputs
		◦ Took colleagues through the layers used to inform the desktop prioritisation namely: ▪ Presence of surface and/or groundwater Strategic Water Source Areas (SWSAs); ▪ Assessed the preliminary river RU quaternary catchments; ▪ Top 10% of quaternary catchments identified through the Working for Wetland strategic planning for the Eastern Cape, Northern Cape and Free State provinces; ▪ Specific important wetland areas identified by individual stakeholders; and ▪ Quaternary catchments identified with the highest recorded water uses (water quantity). ◦ Provided an overview of the final wetland RUs. • Presentation of identified groundwater RU: ◦ Discuss the groundwater approach which included the description of the groundwater RU delineation approach which included primary, secondary and tertiary delineations; ◦ Discussed the WARMS data to identify hotspots; ◦ Discussed strategic groundwater resources and major wetland systems connected to groundwater resources; ◦ Groundwater modelling (conceptual, numerical, etc.); ◦ Discussed recharge estimation per delineation; ◦ Discussed the baseflow estimation per delineation; and ◦ Determination of the groundwater component/contribution to baseflow. • Discussed the integration of components (rivers, groundwater and wetlands) at selected sites (Kraai, Lower Modder).
Site Selection – rivers, wetlands and groundwater capacity building	23 March 2022	• Rivers: ◦ Site selection and specific consideration:

Capacity building topic	Date	Outputs
		◦ Locality of priority RUs (stressed areas, hotspots), gauging weirs with good quality hydrological data, characteristics of tributaries); ◦ Representivity of the river reach, ecoregions, geomorphic zones; ◦ Sampling suitability (i.e. hydrology, habitats, accessibility, safety); and ◦ Hydraulic profiles i.e. discharge calculations at the site, assessment of bends, islands, bridges, bars, slope which affects the confidence in the results or whether the channel is straight (high confidence results). • Wetlands: ◦ Wetland complexes; ◦ Assessment of the different hydrogeomorphic unit (HGM) categorisations of wetlands; ◦ Representivity of the wetland system to be assessed; and ◦ Critical habitats within wetlands. • Groundwater: ◦ Existing DWS monitoring points – WMS data and Hydstra data; ◦ Site selection mainly based on active sites, representative of aquifer or part of aquifer; ◦ Long term historical data an advantage; ◦ Spatial distribution within the catchment; and • Unimpacted vs impacted condition, ideally need to have a bit of both.
Wetland Resource Unit In-field Survey and on-site capacity building	10 – 14 April 2022	• An important component of the wetland resource unit survey was to share expert knowledge and wetland survey methodologies with members of the DWS; • During the field survey, the DWS colleagues went through the WET-Health (MacFarlane et al. 2020) assessment tool field datasheets with the survey team, which formed the primary form of data captured for these wetland resource unit surveys;

Capacity building topic	Date	Outputs
		• In addition, the survey team shared a number of wetland delineation tips and tricks with the DWS officials using soils, vegetation and landscape position to quickly be able to tell if one is standing within or outside the wetland boundary; • Furthermore, general discussions were had about groundwater/surface water interactions in depression wetlands, different hydroperiods of wetlands across the study area, defining HGM units, vegetation classification in wetlands, soil chemistry in wetlands and the different assessment techniques that will be used for the wetland component of the reserve study; and • Overall, the enthusiasm and willingness to learn and ask questions made for a positive learning experience for all involved.

Groundwater Hydrocensus capacity building	25 – 29 April 2022	• An important component of the Groundwater Hydrocensus was to engage with DWS personnel from the regions and head office, share expert knowledge and groundwater survey methodologies with the members;
		• The objectives of the capacity building initiative was to:
		  • Describe the groundwater Reserve process;
		  • Gain an understanding of institutional arrangements and challenges; and
		  • Seek ways to synergize activities between the regions and service provider for mutual benefit.
		• The engagement with DWS personnel allowed for detailed discussions relating to the High Confidence Reserve Determination Study. The discussions focussed on several key elements as follows:
		  • Data requirements and future data collection;
		  • Regional Office duties and database management;
		  • Existing and future groundwater licenses and compliance monitoring; and
		  • Groundwater supply at towns and the responsibility of the Water Services Provider to comply with groundwater monitoring and reporting.
		• Overall, the enthusiasm and willingness to learn, ask questions, guidance as to where to obtain groundwater data made for a positive learning experience for all involved.

Capacity building topic	Date	Outputs

Rivers Survey 1 capacity building	4 to 15 July 2022	• An important component of the river survey 1 was to share expert knowledge and river survey methodologies with members of the DWS;
		• The DWS teams were taken through the detail behind what is involved in Intermediate, Rapid 3 and field verification river level approaches;
		• Discussions were had around the characteristics of each site, the associated reach features namely, erosion, available biotopes/habits for the biota, flow velocities, algae/eutrophication, surrounding land use practices, sediment loading, hydraulic features, impediments amongst others;
		• Vital components around how sites are selected were discussed. It was reiterated that those selected sites were those that would provide the information regarding the variety of conditions in a river reach related to the available habitats;
		• Considerations were further discussed namely, their location within the identified priority RU (stressed areas, hotspots), whether there were gauging weirs in close vicinity with good quality hydrological data, coupled with characteristics of tributaries;
		• Each specialist then further took the members through their individual components, for this survey, these included:
		  • Water quality (i.e. diatoms);
		  • Aquatic macroinvertebrates - the South African Scoring System version 5 (SASS5) and the associated methods and habitats were described and illustrated. Furthermore, the identification of the macroinvertebrates through their families, body and movement characteristics, was shown and trained upon;
		  • Fish - the various flow-velocity-depth classes were discussed and examples illustrated on site. Fish identification exercises were held;
		  • Geomorphology – features, zones, sediment regime, various geomorphological drivers were deliberated and examples at the sites shown; and
		  • Furthermore, the suitability of the sites for accurate hydraulic modelling, where the range of possible flows, especially low flows, was discussed and how discharge is measured.

Capacity building topic	Date	Outputs
		• Overall, the enthusiasm and willingness to learn and ask questions made for a positive learning experience for all involved.

Rivers Eco-categorisation Capacity Building: Part 1	28 July 2022	• Provided an overview of the background to the rives eco-categorisation process
		• Described the approach in accordance with the 8-step Reserve determination process and Step 3 as outlined in the Establishment of a WRCS as per Regulation 810 (Government Gazette 33541) dated 17 September 2010
		• Example used for the capacity building session was the Lower Kraai (UO_EWR08_I) whereby the following was guided upon:
		  • Site location and site characteristics
		  • Index of habitat integrity (IHI): instream and riparian criteria were described and the thought process when rating each criteria;
		  • The significance of incorporating aquatic macroinvertebrates within the eco-categorisation process and how these organisms provide valuable insights into the health and ecological dynamics of the river system.
		  • Macroinvertebrate response assessment index (MIRAI)
		  • DWS were taken through the excel model with each metric described
		  • The importance of assessing fish and their valuable input in understanding the health and integrity of a river system
		  • Fish response assessment index (FRAI)
		  • DWS were taken through the excel model with each metric described
		  • Eco-Status Level 4: using the ecological category results from the MIRAI, FRAI and the riparian score from the IHI as a surrogate to the Riparian Vegetation Response Assessment Index (VEGRAI); and
		• Overall results and conclusion of the Lower Kraai

Rivers Eco-categorisation Capacity Building: Part 2	28 November 2022	• Overview of the river surveys that were/to be conducted and the different Reserve levels (Intermediate, Rapid 3 and field verification), including the driver and response components surveyed for the different levels;

Capacity building topic	Date	Outputs

		• Re-capped on the background to the rives eco-categorisation process
		• Example used for the capacity building session was the Lower Kraai (UO_EWR08_I) whereby the following was guided upon:
		  ◦ Hydrological Driver Assessment Index (HAI)
		  ◦ Geomorphology Driver Assessment Index (GAI);
		  ◦ Physical-chemical Driver Assessment Index (PAI):
		    ▪ Although the PAI was not run for this study owing to a considerable lack of surface water quality data in the catchment – the model was trained upon and illustrated;
		  ◦ Approach/guidance how to address catchment wide water quality issues;
		  ◦ Presentation on background to diatoms, the laboratory technique in identifying the species, and their associated response to water quality, providing the study with valuable insight into the water quality of the river systems; and
		• The VEGRAI.

Rivers Survey 2 capacity building	29 May to 4 June 2023	• All topics included in Section 3.7 were revisited and recapped during this second survey;
		• In addition to this survey, the riparian vegetation specialist and engineers were on site, providing many opportunities to discuss the following in more detail, compared to the first survey:
		  ◦ Riparian vegetation and the different zones associated with the assessment;
		  ◦ Riparian vegetation identification exercises; and
		  ◦ Further detail around accurate hydraulic modelling, site selection purely from a hydraulic perspective and the characteristics of the cross-sections.
		• Similarly to the first river survey, the overall enthusiasm and willingness to learn made for another positive learning experience for all involved. Thank you to those DWS members for your participation, involvement and more importantly, your support.

Capacity building topic	Date	Outputs
EWR workshop for all Intermediate EWR sites	19 July 2023	• Quantification of the EWR for all Intermediate EWR river sites within the Upper Orange Catchment area; • Presentation and discussion on the Habitat Flow Model (HabFlo); • Discussion on the Flow-Stressor Response model; • With a focus on the Lower Kraai EWR site, discussion around the responses form a geomorphological, riparian vegetation and instream biota perspective; • Illustration of the Desktop Reserve Model (DRM) within SPATSIM which was used for the integration of data produced from the surveys and the eco-categorisation to quantify the EWRs (as what was done for the Rapid 3 EWR sites quantification); and Presentation on the hydraulic modelling (cross-sectional profile and discharge) will also be used to evaluate the DRM requirements.

Scenario and Consequences capacity building	29 November 2023	• Purpose of assessing the scenarios and consequences;
		• The process whereby the operational scenarios are defined;
		• The approaches of assessing the ecological consequences of these scenarios for the rivers:
		  • Hydrological modelling and interpretation;
		  • Water quality;
		  • Geomorphology;
		  • Riparian vegetation;
		  • Instream Biota (fish and macroinvertebrates), including taking DWS colleagues through the Fish, Invertebrate, Flow, Habitat Assessment Model (FIFHA); and
		  • The qualitative approach to assessing the socio-economic consequences of the defined scenarios.
		• Determining and ranking of scenarios per EWR site; and
		• Working example: Upper Orange (UO_EWR03_I).

Capacity building topic	Date	Outputs

Final Capacity Building – Holistic Overview of the Reserve Determination Process for all water resources	30 January 2024	• The objective of this holistic capacity building event was to provide an overview of the main approaches, steps and activities undertaken during the Reserve determination for rivers, wetlands and groundwater components for the Upper Orange catchment area
		• The *rivers* presentation provided an overview of the following:
		  • The delineation and prioritisation of resource units;
		  • The considerations taken into account when selecting an EWR site and conducting surveys;
		  • Eco-categorisation and the tools showcase;
		  • Quantification of Ecological Water Requirements;
		  • Process to define the operational scenarios;
		  • Evaluation of scenarios and ecological/socio-economic consequences; and
		  • Ecological specifications and monitoring programme.
		• The *wetlands* presentation provided an overview of the following:
		  • The delineation and prioritisation of wetland resource units;
		  • Eco-categorisation and the wetland tools showcase;
		  • High focus was placed on the eco-categorisation process (step 3) as most of the work went into this step from a wetland perspective
		  • The context to the Decision Support System, in relation to the Ecological Water Requirements quantification; and
		  • Ecological specifications and monitoring programme.
		• The *groundwater* presentation provided an overview of the following:
		  • The delineation and prioritisation of groundwater resource units;
		  • Present Ecological State (defined by the Stress Index) of prioritised groundwater resource units
		  • Quantification of the Reserve
		    • Groundwater quantity Reserve, which entails:
		      • Recharge;

Capacity building topic	Date	Outputs
		• Basic Human Needs; and • Groundwater baseflow contribution. • Groundwater quality Reserve; • Groundwater ecological specifications and the monitoring programme.

9. CONCLUSION

The CD: WEM of the DWS initiated a high confidence Reserve Determination study for the Upper Orange catchment area in WMA 6. The study covered surface water, including rivers and wetlands, as well as groundwater resources. The objectives were to safeguard against potential hydraulic fracturing activities, assess various Water Use License Applications (WULA), and evaluate the impacts of current and proposed developments on water availability.

The study identified and surveyed 10 Intermediate and six Rapid level 3 EWR sites, along with 25 additional field verification sites for the rivers. The assessment involved calculating the PES, deriving the REC, quantifying EWRs, determining operational scenarios, and evaluating ecological and socio-economic consequences. Wetlands and groundwater were also prioritized, with EcoSpecs assigned for effective monitoring. However, the study faced challenges due to a lack of historical and current water quality data, affecting confidence levels in the results.

Despite limitations, the team is confident that the EcoSpecs outlined for all water resources will maintain or enhance water quality. Monitoring programs aligned with adaptive management principles are recommended, ensuring adjustments to practices if EcoSpecs are not met. These EcoSpecs will contribute to RQOs in the ongoing Classification study, aiming to ensure the maintenance or improvement of water resources in the Upper Orange catchment area.

The study further incorporated two additional elements: a conceptual FMP for the areas between Gariep and Vanderkloof dams, and downstream of the latter dam, and a novel concept designed to evaluate the synergy between surface and groundwater resources, focusing on the Kraai River water resources. This concept is suggested to be further developed and integrated into the ongoing Classification study, aiming for improvements and updates in GIS data to indicate the likelihood of groundwater or surface water dependency.

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