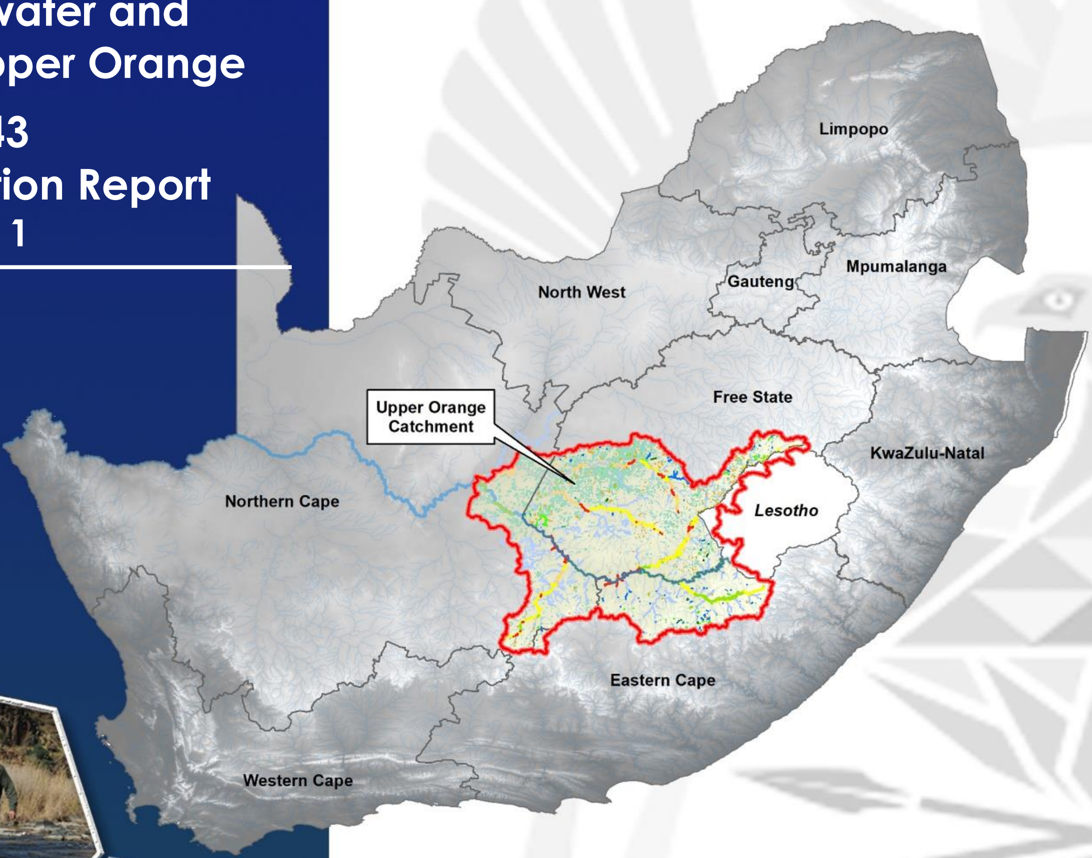
DEPARTMENT OF WATER AND SANITATION

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

WP11343
Eco-Categorisation Report
VOLUME 1



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LIST OF ACRONYMS

AEC	Alternative Ecological Category
BHN	Basic Human Needs
CVB	Channelled valley bottom
CD: WEM	Chief Directorate: Water Ecosystems Management
CR	Critically endangered
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EcoRegions	Ecological Regions
EIS	Ecological Importance and Sensitivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Area
FMP	Flow Management Plan
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
GRDM	Groundwater Resource Directed Measures
HF	Hydraulic Fracturing
HGM	Hydrogeomorphic
IBA	Important Bird Areas
IEI	Integrated Ecological Index
IHI	Index of Habitat Integrity
IWUI	Integrated Water Use Index
JBS	Joint Basin Survey
LT	Least Threatened
MCA	Multi-criteria analysis
MIRAI	Macroinvertebrate Response Assessment Index
NFEPA	National Freshwater Ecosystem Priority Areas
NT	Near Threatened
NWM5	National Wetlands Map 5
NWA	National Water Act
PES	Present Ecological State
RDM	Resource Directed Measures

RU	Resource Units
SCI	Social Cultural Importance
SWSA	Strategic Water Source Area
UCVB	Unchanneled valley bottom
VEGRAI	Riparian Vegetation Response Assessment Index
VU	Vulnerable
WARMS	Water use Authorization & Registration Management System
WRC	Water Research Commission
WMA	Water Management Area
WR2012	Water Resources 2012
WRCS	Water Resources Classification System
WWTW	Wastewater Treatment Work

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EXECUTIVE SUMMARY

Background and Purpose

This phase forms part of the following study: A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange. 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 of Water and Sanitation (DWS) 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 River Catchment, specifying the Ecological Water Requirements (EWR) and ecological specifications/conditions for the management of the priority rivers, wetlands and groundwater areas.

The initial phase of this study included the identification of "hotspots" which indicated the areas where EWRs would be required to be quantified for the rivers. Consequently, the main rivers within these areas were selected and delineated in Management Resource Units (RU) (Report No. RDM/WMA13/00/CON/COMP/0422). It was these RU's where EWRs would be quantified. The primary focus of ***this report*** is the ecological categorisation (eco-categorisation) of all identified EWR sites within the RUs (Intermediate, Rapid 3 or field verification sites). Scientific data was collected on both the driver components (geomorphology, hydraulics, water quality derived from diatoms) and the response components (fish, aquatic macroinvertebrates, riparian vegetation/instream-riparian habitat integrity, during two (2) river surveys conducted in July 2022 and May/June 2023. The use of the present data collected for this high confidence study, compared with existing and reference data, was subsequently analysed, with the aim to update the eco-categorisation of all EWR sites. The next report will be then the EWR quantification, setting of flow regimes to maintain different ecological states.

Study Area and location of EWR sites

The locality of all EWR sites within the RU as identified during this study, is provided in Table below.

RU	EWR site code	River	Quat	Co-ordinates	
INTERMEDIATE EWR SITES					
R_RU04	UO_EWR01_I	Middle Caledon	D22D	-28.909102	27.784924
R_RU01	UO_EWR02_I	Sterkspruit	D12B	-30.51784446	27.36907996
R_RU02a	UO_EWR03_I	Upper Orange	D12F	-30.65288889	26.82304963
R_RU05	UO_EWR04_I	Lower Caledon	D24J	-30.28011493	26.65306029
R_RU06	UO_EWR05_I	Seekoei	D32J	-30.53390069	24.96253678
R_RU08	UO_EWR06_I	Upper Riet	C51F	-29.53478727	25.52449567
R_RU09a	UO_EWR07_I	Upper Modder (Sannaspos)	C52G	-29.160017	26.572492
R_RU03	UO_EWR08_I	Lower Kraai	D13M	-30.69007	26.74157
R_RU10	UO_EWR09_I	Lower Riet	C51L	-29.026963	24.512919
R_RU07	UO_EWR10_I	Lower Orange	D33K	-29.1448547	23.69140399
RAPID 3 EWR SITES					

RU	EWR site code	River	Quat	Co-ordinates	
R_RU13	UO_EWR01_R	Little Caledon	D21D	-28.557796	28.405709
R_RU14	UO_EWR02_R	Brandwater (Groot)	D21G	-28.68034	28.139926
R_RU16	UO_EWR03_R	Mopeli	D22G	-29.101205	27.570751
R_RU11a	UO_EWR04_R	Upper Kraai	D13E	-30.85179	27.77689
R_RU12	UO_EWR05_R	Wonderboomspruit	D14E	-31.005262	26.341938
R_RU09b	UO_EWR06_R	Middle Modder (Soetdoring)	C52H	-28.807191	26.109695
FIELD VERIFICATION SITES					
R_RU04	UO_EWR01_FV	Middle Caledon	D23A	-29.368925	27.405189
R_RU30	UO_EWR02_FV	Meulspruit	D22B	-28.885731	27.834944
R_RU31	UO_EWR03_FV	Witspruit	D24C	-30.00826	26.928315
R_RU22	UO_EWR04_FV	Gryskopspruit	D12D	-30.339629	27.176878
R_RU26	UO_EWR05_FV	Karringmelkspruit	D13K	-30.811765	27.264973
R_RU23	UO_EWR06_FV	Bokspruit	D13A	-30.88469	27.884557
R_RU27	UO_EWR07_FV	Holspruit	D13J	-30.995316	27.056639
R_RU11b	UO_EWR08_FV	Sterkspruit (trib. of Bell/Kraai)	D13C	-30.917621	27.800753
R_RU11c	UO_EWR09_FV	Bell	D13B	-30.852601	27.786557
R_RU32a	UO_EWR10_FV	Groenspruit	D24H	-30.24119	26.5613
R_RU32b	UO_EWR11_FV	Skulpspruit	D24H	-30.23444	26.51134
R_RU18	UO_EWR12_FV	Fouriespruit	C51A	-29.671211	26.074393
R_RU37	UO_EWR13_FV	Renoster	C52F	-29.11632	26.328701
R_RU21	UO_EWR14_FV	Os-spruit	C52E	-28.93917	26.511411
R_RU33	UO_EWR15_FV	Hondeblaf	C31C	-30.205138	24.71803
R_RU40	UO_EWR16_FV	Trib. van Zyl	C51G	-30.031203	25.786463
R_RU04	UO_EWR17_FV	Slykspruit	D24L	-30.393003	26.120925
R_RU11d	UO_EWR18_FV	Langkloofspruit	D13D	-30.954126	27.606129
R_RU25	UO_EWR19_FV	Wasbankspruit	D13G	-31.15554	27.284442
R_RU39	UO_EWR20_FV	Lower Modder	C52K	-28.89166	25.656445
R_RU19a	UO_EWR21_FV	Upper Kromellenboog	C51G	-30.066282	25.681056
R_RU19b	UO_EWR22_FV	Lower Kromellenboog	C51H	-29.6536	25.43507
R_RU41	UO_EWR23_FV	Tele	D18K	-30.448588	27.582337
R_RU02b	UO_EWR24_FV	Orange	D12A	-30.398757	27.342987
R_RU42	UP_EWR25_FV	Maghaleng	D15H	-30.16412	27.398251

Approach and Methodology

The eco-categorisation process was followed according to the methods of Kleynhans and Louw (2007). Eco-categorisation refers to the determination and categorisation of the Present Ecological State (PES) (health and integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference conditions. The state of the river is expressed in terms of the following biophysical components:

- Drivers: *In situ* water quality and diatoms (inferred information to derive physical-chemical conditions); Geomorphology; Hydraulics; and Hydrology, which provide a particular habitat template; and

- Biological responses: fish, aquatic macroinvertebrates and riparian vegetation/instream-riparian habitat integrity.

Various processes and models were followed to assign an ecological category (A-F with A=Natural and F=Critically modified) for each component. Ecological evaluation in terms of expected reference conditions, followed by the integration of these components, represents the Ecological State (EcoStatus) of a river. The Recommended Ecological Category (REC) was further deliverated amongst the specialist team, taking cognisance of the driver component, as well as the revised Ecological Importance and Sensitivity (EI-ES). An Alternative Ecological Category (AEC) was further categorised for all intermediate EWR sites only.

Eco-categorisation results summary

The results for the Intermediate and Rapid 3 EWR sites are summarised in the tables below.

INTERMEDIATE EWR SITES

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
AEC	C

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 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 discharge upstream in Ficksburg.

Present EI-ES*

- Both remained Moderate.

REC**

- The system has perennial flows – limited to no zero flows as per the HAI. The month of October generally have these zero flows.

AEC***

- Improvement to the system through the transfer to the Hlotse Dam and e-flows downstream to meet Caledon River requirements;
- Clearing and removal of alien invasive plants within the riparian zone and ensuring maintenance thereof, with the aim to avoid to re-establishment of these plants; and
- Overall land management and improvement (cattle overgrazing and trampling).

**EI-ES: Revised Ecological Importnace and Ecological Senstivity using the DES (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)*
****AEC: Alternative Ecological Category identified and which may be achieved through, mitigation, management and rehabilitation measures proposed and implemented*

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
AEC	C

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

- 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, this will provide an opportunity to improve the biotic state of the system, coupled with adequate flows; and
- Maintenance and upgrade of WWTW infrastructure, including the upgrade and functioning of the adjacent maturation pond.

AEC

- Overall improvement and functionality of land and catchment management practices;
- Maintenance and upgrade of WWTW infrastructure, including the upgrade and functioning of the adjacent maturation pond;
- Informal and illegal sand mining practices to be halted and fines issued to the company partaking in such activities immediately;
- Sediment traps needed to prevent excessive sediment run-off into the river;
- Control and plan surrounding urban development and informal settlements;
- Better management of rubbish dumping facilities and the complete prevention of rubbish dumping within the river;
- Planning design for road network, catchment sediment drains; and
- Town clean up (local municipality to take accountability and responsibility).

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
AEC	C/D

Reasons for EcoStatus

- Poor habitat availability for both fish and aquatic macroinvertebrates;
- Widespread overgrazing and soil erosion in the catchment (largely 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.

AEC

- This reach is not driven by water quality, but more so from sediment loads stemming from upstream activities;
- Catchment and land management improvement (sand mining, upstream practices within Lesotho); and
- Lesotho to consider implementation of environmental flows.

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
AEC	C/D

Reasons for EcoStatus

- Widespread overgrazing and soil erosion in the upper catchment (largely 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.

AEC

- No change from REC

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
AEC	B/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 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.

AEC

- Removal of redundant weirs; and
- This may mobilise sediment/gravel bars further downstream (additional potential habitat for fish spawning opportunity and macroinvertebrates).

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
AEC	B/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.

AEC

- Increase in flows;
- Aim to increase and improve the riparian vegetation;
- Aim to enhance fish movement (fishways) and spawning; and
- Wate quality improvement through better management of return flows from irrigation and upstream town management and effluent releases.

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
AEC	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 barrier (upstream weir); 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).

AEC

- No change from REC.

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
AEC	B

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 and flow modification;
- Localised erosion along left bank due to the weir. 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.

AEC

- Removal of alien alien vegetation along the riparian zone and continual management; and
- Catchment management (buffer zones for irrigation, overgrazing, trampling).

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
AEC	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).

AEC

- No change from REC.

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
AEC	B/C

Reasons for EcoStatus

- Flow modification from upstream hydropower discharges;
- 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.

AEC

- A conceptual FMP is currently being compiled for the sacrificial zone between the 2 dams and just downstream of Vanderkloof Dam;
- Land management (alien invasive vegetation clearing, buffer zones for irrigation); and
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways).

RAPID 3 EWR SITES

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;
- 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.

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;
- 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.

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;
- 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.

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
- Present 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.

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, extensive 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.

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.

The results for the field verification sites are summarised in the tables below.

EWR site code	River	Quat	PES (DWS, 2014)	EcoStatus (2023)	REC
UO_EWR01_FV	Meulspruit	D22B	D	D	D
UO_EWR02_FV	Witspruit	D24C	D	C/D	C
UO_EWR03_FV	Gryskopspruit	D12D	D	C	C
UO_EWR04_FV	Karringmelkspruit	D13K	B	B	B
UO_EWR05_FV	Bokspruit	D13A	C	B/C	B
UO_EWR06_FV	Holspruit	D13J	B	C	C
UO_EWR07_FV	Sterkspruit (trib of Bell/Kraai)	D13C	C	C	B/C
UO_EWR08_FV	Bell	D13B	C	B/C	B
UO_EWR09_FV	Groenspruit	D24H	C	C/D	C
UO_EWR10_FV	Skulpspruit	D24H	C	C	C
UO_EWR11_FV	Fouriespruit	C51A	D	C	C
UO_EWR12_FV	Renoster	C52F	C	D/E	D
UO_EWR13_FV	Os-spruit	C52E	C	B/C	B/C
UO_EWR14_FV	Hondeblaf	C31C	C	B	B
UO_EWR15_FV	Trib van Zyl	C51G	C	C	C
UO_EWR16_FV	Slykspruit	D24L	C	B/C	B/C
UO_EWR17_FV	Langkloofspruit	D13D	C	B/C	B
UO_EWR18_FV	Wasbankspruit	D13G	D	C	B/C
UO_EWR19_FV	Lower Modder	C52K	D	C/D	C
UO_EWR20_FV	Upper Kromellenboog	C51G	C	B	B
UO_EWR21_FV	Lower Kromellenboog	C51H	C	C	B/C
UO_EWR22_FV	Tele	D18K	C	C	C
UO_EWR23_FV	Orange	D12A	B	C/D	C
UP_EWR24_FV	Maghaleng	D15H	C	C/D	C/D
UO_EWR25_FV	Middle Caledon	D23A	D	D	C/D

Overall, the EcoStatus of the Upper Orange catchment area is primarily moderate to seriously 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. Should water quality within the catchment be improved, the REC can be achieved. The specified flow regimes to maintain different ecological states will form part of the next phase of this high confident study.

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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 from (i) possible hydraulic fracturing (HF) activities, (ii) assessment of various water use license applications, 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 PES and the ecological importance (EI) and ecological sensitivity (ES) of each sub-quaternary reach. This results in the identification of priority resource units 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 will be 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 will also be 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 document the results from the Ecological Categorisation (Eco-Categorisation), of all EWR sites within the Upper Orange catchment, forming part of the Orange WMA6, based on the information and data that is currently available through various previous studies and current surveys undertaken. The following information has been documented per EWR site:

- Site name, river and co-ordinates;
- Site photos;
- Quaternary catchment and sub-quaternary reach;
- Ecoregion;
- Geomorphic zone;
- Gauging weirs at or near the site;
- Total catchment area;
- Natural Mean Annual Runoff (MAR) at the EWR site;
- Altitude;
- Resource Units (RU);
- Present Ecological State (PES)/ EcoStatus for the EWR site and for each component. Where no site was selected for a priority RU (desktop level) or limited surveys undertaken (field verification), these are mainly based on the results per sub-quaternary reach (SQR) from the 2014 (DWS, 2014) desktop assessment of the PES, EI and ES. Where an existing EWR site have been re-surveyed, the results from the previous study have been included as well;
- Trends per component;
- Ecological Importance and Sensitivity (EIS);
- The overall EcoStatus, and
- The overall Recommended Ecological Category (REC) as well as alternative ecological categories (AEC) that could be considered.

The specialist components consist of the physical drivers (geomorphology, physical-chemical variables and hydrology) and the ecological responses (instream vegetation, riparian vegetation, fish and macroinvertebrates).

The Eco-Categorisation forms part of Step 3 of the integrated steps for the determination of the Reserve (see Figure 1-1 below). Please refer to the EWR Quantification Report (Report No. RDM/WMA13/00/CON/COMP/1123) for the quantification of the EWRs for the REC at each site.

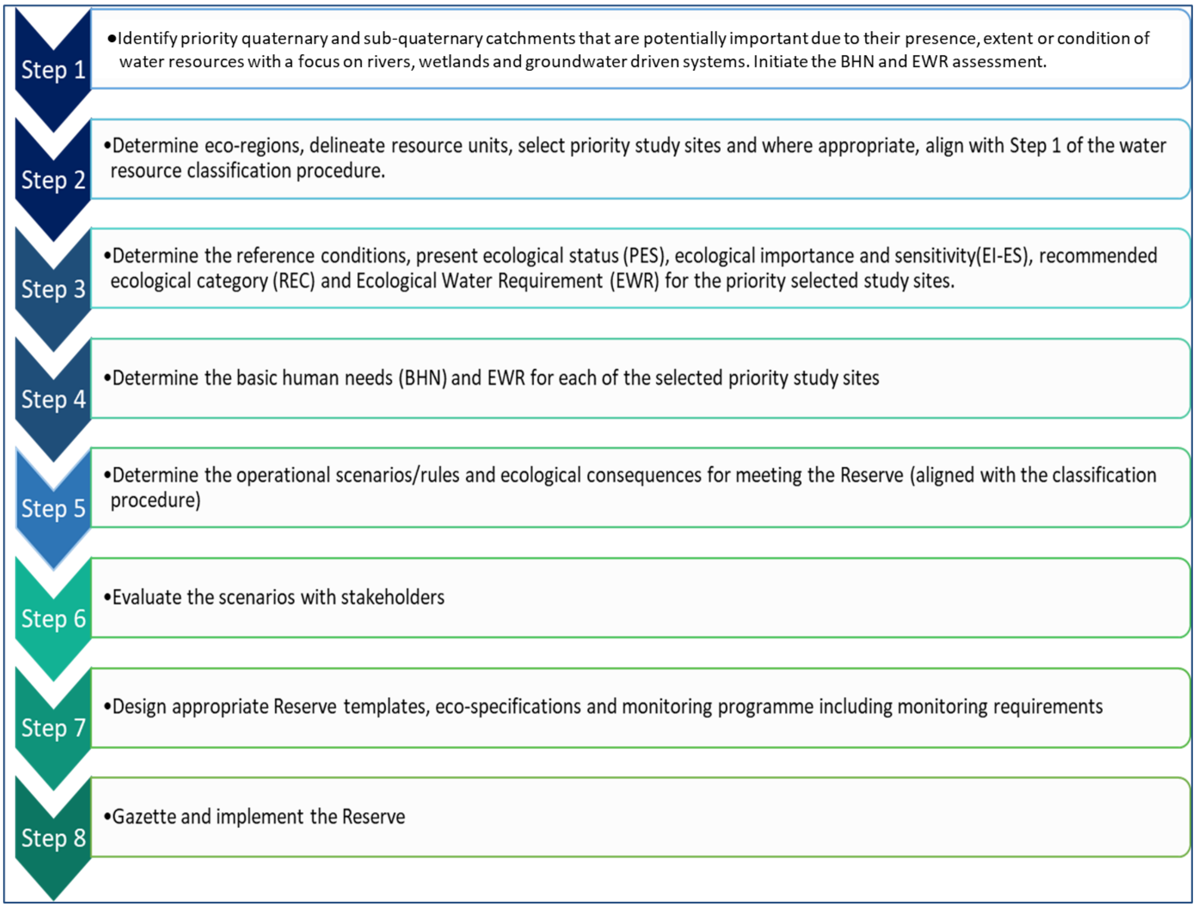


Figure 1-1: Integrated steps for the determination of the Reserve (DWS, 2017)

2. OVERVIEW OF THE STUDY AREA

The study area of the Upper Orange Catchment forms part of the Orange WMA6 (Figure 2-1) 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. The Modder-Riet River drains into the Vaal River and 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.

In accordance with DWS (2014) desktop PES/EI/ES, the data revealed that 64% of the sub-quaternary reaches assessed in the catchment were in a moderately to largely modified state (category C and D respectively), congruent with conditions seen in the catchment.

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 regional geology is dominated by the Karoo Supergroup that was deposited in the Karoo Basin with a surface area of 200,000 km^2 (Aarnes *et al.,* 2011). The Karoo Supergroup was formed through sedimentation within an intracratonic, foreland basin on Gondwanaland, during the Carboniferous, Permian, Triassic and early Jurassic ages, about 300 Ma to 160 Ma ago (Truswell, 1970). The main Karoo Basin covers a large part of the central and eastern parts of South Africa, and according to Du Toit (1954), the Karoo Basin has a maximum thickness in the southern parts of the Northern Cape Province and Lesotho.

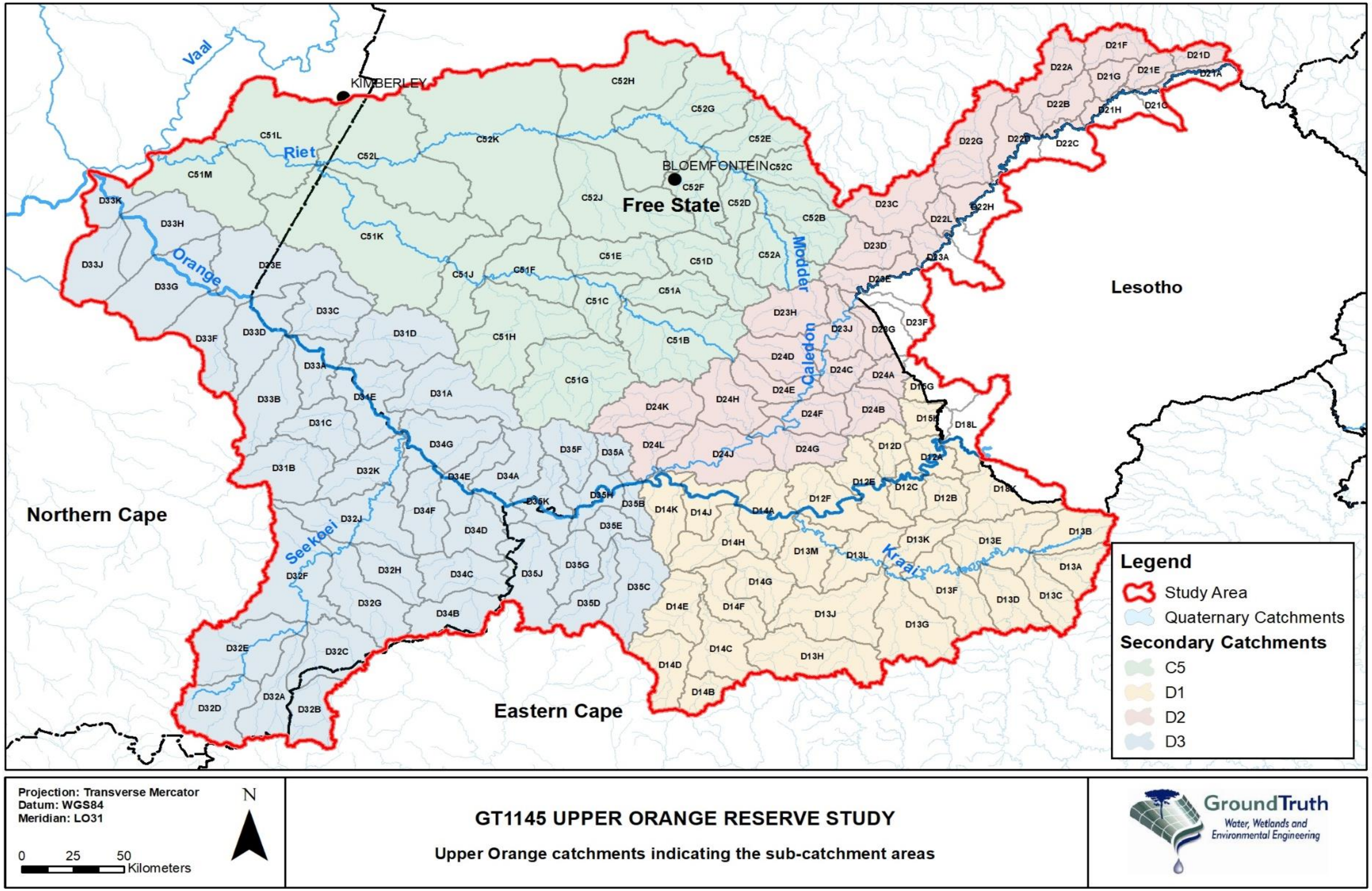


Figure 2-1: Upper Orange Catchment

3. SUMMARY OF PRIORITY RIVER RESOURCE UNITS

An assessment of the system was undertaken during the inception, gap analysis and resource units phases of the study to identify and confirm the priority water resources, quaternary and sub-quaternary catchments, Ecological Water Requirement (EWR) sites, wetlands and groundwater driven systems where ecological gaps exist and needed to be addressed. These have been supported by the determination of hotspot areas based on an Integrated Ecological Index and Water Resource Use Index. The hotspot assessment identified the level of Reserve determination that was required (see Gap Analysis and Resource Units Reports (Report Numbers: RDM/WMA13/00/CON/COMP/0321 and RDM/WMA13/00/CON/COMP/0422 respectively) for further information).

Priority quaternary catchments (with associated river reaches) within the Upper Orange catchment was 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 by 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 Present Ecological State (PES) using the EcoStatus Level 4 model, Ecological Importance and Ecological Sensitivity (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 will be followed to determine the EWRs where applicable. The Fish Invertebrate Flow Habitat Assessment Model (FIFHA) will be 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), will be 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.

Approached for each of the components and models mentioned above are detailed in Chapter 5 below.

A summary of the final priority RUs identified, including the selected EWR sites (Intermediate, Rapid 3, Field Verification sites) are presented in Table 3-1 and Figure 3-1. The rationale for the selection is also provided.

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 Flow Management Plan (FMP) was proposed. The aim of this plan is to identify the impacts on the ecological functioning of the river and to optimise the releases (see Chapter 4).

Table 3-1: Summary of the priority Resource Units (RUs) for the study area

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
INTERMEDIATE EWR SITES*						
R_RU04	UO_EWR01_I	Middle Caledon	D22D	-28.909102	27.784924	• High priority • Impacts from water use in the tributaries • Increased sediment due to erosion and downstream Ficksburg
R_RU01	UO_EWR02_I	Sterkspruit	D12B	-30.51784446	27.3690799	• Dam in upper reaches (Mhlangeni River) • Increased sedimentation • Sand mining • Water quality issues concerning WWTW and hospital return flows • Although a small system, high runoff • Site selected and hydraulics survey undertaken in October 2021
R_RU02a	UO_EWR03_I	Upper Orange	D12F	-30.65288889	26.8230496	• Orange River just downstream of Lesotho border with the impacts of the proposed Polihali Dam and other developments in Lesotho
R_RU05	UO_EWR04_I	Lower Caledon	D24J	-30.28011493	26.6530603	• Impacts of upstream water use (irrigation, domestic) • High levels of sedimentation • Welbedacht Dam upstream of the site and the transfer from Caledon to Modder system at Knellpoort Dam • Existing EWR site (D24J) from ORASECOM EFR study, 2010 • JBS3 ORASECOM site OSAEH 26_08** and DWS REMP site D2CALE-TUSSE
R_RU06	UO_EWR05_I	Seekoei	D32J	-30.53390069	24.9625368	• Reach designated as a fish sanctuary and regarded as a Fish Support Area with vulnerable or NT fish populations • Priority wetlands located in the middle reaches
R_RU08	UO_EWR06_I	Upper Riet	C51F	-29.53478727	25.5244957	• Agricultural activities • Small dams in upper reaches and tributaries • Extensive water use

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
						• JBS3 ORASECOM site OSAEH 26_10 and DWS REMP site C5RIET-IFR03
R_RU09a	UO_EWR07_I	Upper Modder (Sannaspos)	C52G	-29.160017	26.572492	• Extensive water use • Dams on mainstem and tributaries • WWTWs from Bloemfontein and surrounding areas discharges into upstream tributaries • JBS3 ORASECOM site OSAEH 11_18 and DWS REMP site C5RIET-IFR03
R_RU03	UO_EWR08_I	Lower Kraai	D13M	-30.69007	26.74157	• The entire upstream reach of the mainstem is a designated Freshwater Ecosystem Priority Area (FEPA) for fish species with vulnerable or Near Threatened (NT) fish populations • Classed as a flagship river • Upper parts of the Kraai River and tributaries forms part of the SWSAs • Site selected downstream of possible dam on the lower reaches of the Kraai River • JBS3 ORASECOM site OSAEH 26_11** and DWS REMP site D1KRAA-ALIWA • Site downstream of proposed dam
R_RU10	UO_EWR09_I	Lower Riet	C51L	-29.026963	24.512919	• All impacts of upstream water use • Discharges and infrastructure from both the Modder and Riet Rivers and before the impacts of the extensive irrigation of the lower Riet River • Hydraulic data from Vaal comprehensive study (Vaal_EWR19) • JBS3 ORASECOM site OSAEH 29_5 and DWS REMP site C5RIET-DEKRA
R_RU07	UO_EWR10_I	Lower Orange	D33K	-29.1448547	23.6914039	• Lowest site on the Upper Orange River before the Vaal confluence

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
						• Includes all the impacts of water use and infrastructure (Gariep and Vanderkloof Dams with hydropower and irrigation releases) • Water also transferred at Marksdrift Weir to the lower Riet and Vaal Rivers at Douglas • Reach designated as a fish sanctuary and regarded as a Fish Support Area with vulnerable or NT fish populations • Priority wetlands located in the middle reaches • JBS3 ORASECOM site OSAEH 26_03 and DWS REMP site D3ORAN-MARKS
RAPID 3 EWR SITES*						
R_RU13	UO_EWR01_R	Little Caledon	D21D	-28.557796	28.405709	• Forms part of the SWSAs • Priority wetlands located along reach • WWTW • Irrigation • Recent diatom results (October 2021) indicated poor ecological water quality • SCI area • Part of the reach within D21D is designated as a fish sanctuary • Site selected during Oct 2021. Also previous rapid site (2003) lower down at S28.61139, E28.30194
R_RU14	UO_EWR02_R	Brandwater (Groot)	D21G	-28.68034	28.139926	• Priority wetlands located along reach • Extensive irrigation • Site from 2003 rapid study
R_RU16	UO_EWR03_R	Mopeli	D22G	-29.101205	27.570751	• Priority wetlands located along reach • Extensive irrigation
R_RU11a	UO_EWR04_R	Upper Kraai	D13E	-30.85179	27.77689	• Forms part of the SWSAs • Priority wetlands located along reaches • Irrigation along rivers

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
						• Social Cultural Important (SCI) area • The entire upstream reach of mainstem designated as a FEPA for fish species • Classed as a flagship river • Site selected downstream of Sterkspruit confluence
R_RU12	UO_EWR05_R	Wonderboom-spruit	D14E	-31.005262	26.341938	• Numerous dams • Irrigation • Non-functional / unmaintained WWTW • SCI area
R_RU09b	UO_EWR06_R	Middle Modder (Soetdoring)	C52H	-28.807191	26.109695	• JBS3 ORASECOM site OSAEH 11_19
Field Verification*						
R_RU04	UO_EWR01_FV	Middle Caledon	D23A	-29.368925	27.405189	• Impacts from water use in the tributaries • Increased sediment due to erosion and downstream Ficksburg and Maseru
R_RU30	UO_EWR02_FV	Meulspruit	D22B	-28.885731	27.834944	• Wetlands • Dams • Irrigation • SCI area
R_RU31	UO_EWR03_FV	Witspruit	D24C	-30.00826	26.928315	• Numerous dams • Irrigation • SCI area
R_RU22	UO_EWR04_FV	Gryskopspruit	D12D	-30.339629	27.176878	• Dams • WWTW
R_RU26	UO_EWR05_FV	Karringmelk-spruit	D13K	-30.811765	27.264973	• Forms part of the SWSAs • Wetlands • SCI area
R_RU23	UO_EWR06_FV	Bokspruit	D13A	-30.88469	27.884557	• SWSA • Part of upper Kraai wetlands cluster

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
R_RU27	UO_EWR07_FV	Holspruit	D13J	-30.995316	27.056639	• Numerous small dams in catchment • Irrigation
R_RU11b	UO_EWR08_FV	Sterkspruit (trib of Bell/Kraai)	D13C	-30.917621	27.800753	• Forms part of the SWSAs
R_RU11c	UO_EWR09_FV	Bell	D13B	-30.852601	27.786557	• Forms part of the SWSAs
R_RU32a	UO_EWR10_FV	Groenspruit	D24H	-30.24119	26.5613	• Dams and irrigation • Water quality (Smithfield WWTW)
R_RU32b	UO_EWR11_FV	Skulpspruit	D24H	-30.23444	26.51134	• Dams and irrigation
R_RU18	UO_EWR12_FV	Fouriespruit	C51A	-29.671211	26.074393	• Representative of upper tributaries of the Riet River • Extensive irrigation
R_RU37	UO_EWR13_FV	Renoster	C52F	-29.11632	26.328701	• Water quality • Large urban areas • Irrigation • WWTWs
R_RU21	UO_EWR14_FV	Os-spruit	C52E	-28.93917	26.511411	• Irrigation • Small dams • Priority wetlands located along reach
R_RU33	UO_EWR15_FV	Hondeblaf	C31C	-30.205138	24.71803	• Small, almost ephemeral system • Wetlands interaction
R_RU40	UO_EWR16_FV	Trib van Zyl	C51G	-30.031203	25.786463	• Priority wetlands located along reaches • WWTWs • Irrigation
-	UO_EWR17_FV	Slykspruit	D24L			• Irrigation
R_RU11d	UO_EWR18_FV	Langkloofspruit	D13D	-30.954126	27.606129	• Irrigation • Part of SWSA
R_RU25	UO_EWR19_FV	Wasbankspruit	D13G	-31.15554	27.284442	• SWSA • Wetlands interaction • Numerous dams • Irrigation

RU	EWR site code	River	Quaternary catchment	Co-ordinates		Rationale for selection
R_RU39	UO_EWR20_FV	Lower Modder	C52K	-28.89166	25.656445	• Water quality • Large urban areas • Irrigation • WWTWs
R_RU19a	UO_EWR21_FV	Upper Kromellenboog	C51G	-30.066282	25.681056	• Priority wetlands located along reaches • Irrigation • SCI area (Prosesspruit)
R_RU19b	UO_EWR22_FV	Lower Kromellenboog	C51H	-29.6536	25.43507	• Priority wetlands located along reaches • WWTW • Irrigation • SCI area (Prosesspruit) • D51G and C51H designated as a fish sanctuary area with vulnerable or NT fish populations in the upper reaches of Kromellenboogspruit
R_RU41	UO_EWR23_FV	Tele	D18K	-30.448588	27.582337	• Shared with Lesotho • High sediment loads
R_RU02b	UO_EWR24_FV	Orange	D12A	-30.398757	27.342987	• Extensive sand mining • Cattle grazing and trampling • Extensive bank erosion • Dams in Lesotho changing flow regime • Riparian zone completely modified
R_RU42	UP_EWR25_FV	Maghaleng	D15H	-30.16412	27.398251	• Shared with Lesotho • High sediment loads • Possible future water transfer from river in Lesotho

* As determined during Resource Unit prioritisation process

**ORASECOM, 2023a

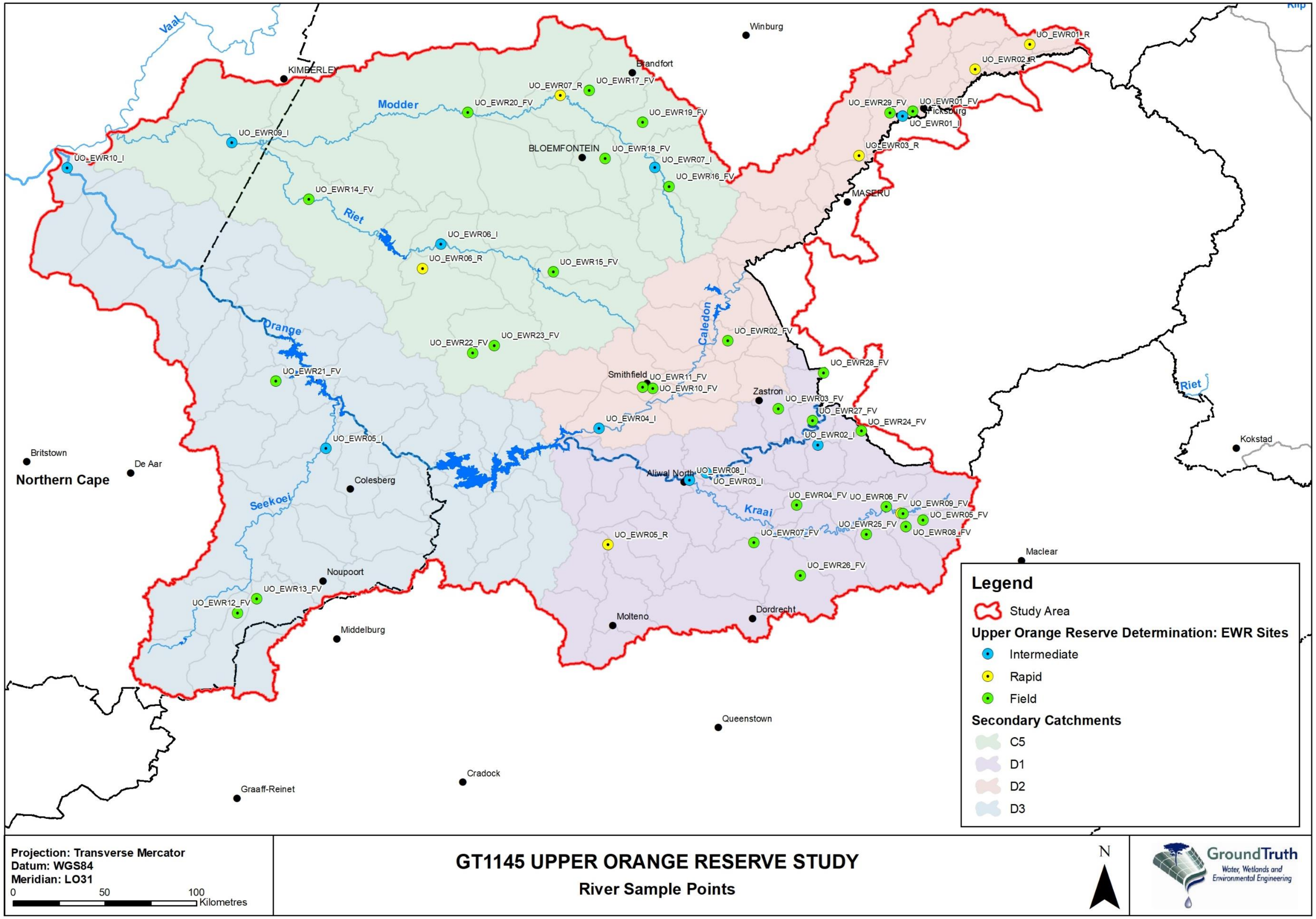


Figure 3-1: EWR sites for the Upper Orange Reserve study

4. CONCEPTUAL FLOW MANAGEMENT PLAN FOR MIDDLE REACHES OF THE ORANGE RIVER

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, 2023a).

Downstream of the Gariep and Vanderkloof dams, at the Marksdrift gauging station (D3H008), 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 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 4-1). Both dams have been used near-continuously for hydroelectric power generation, causing daily hydropeaking (Figure 4-2).

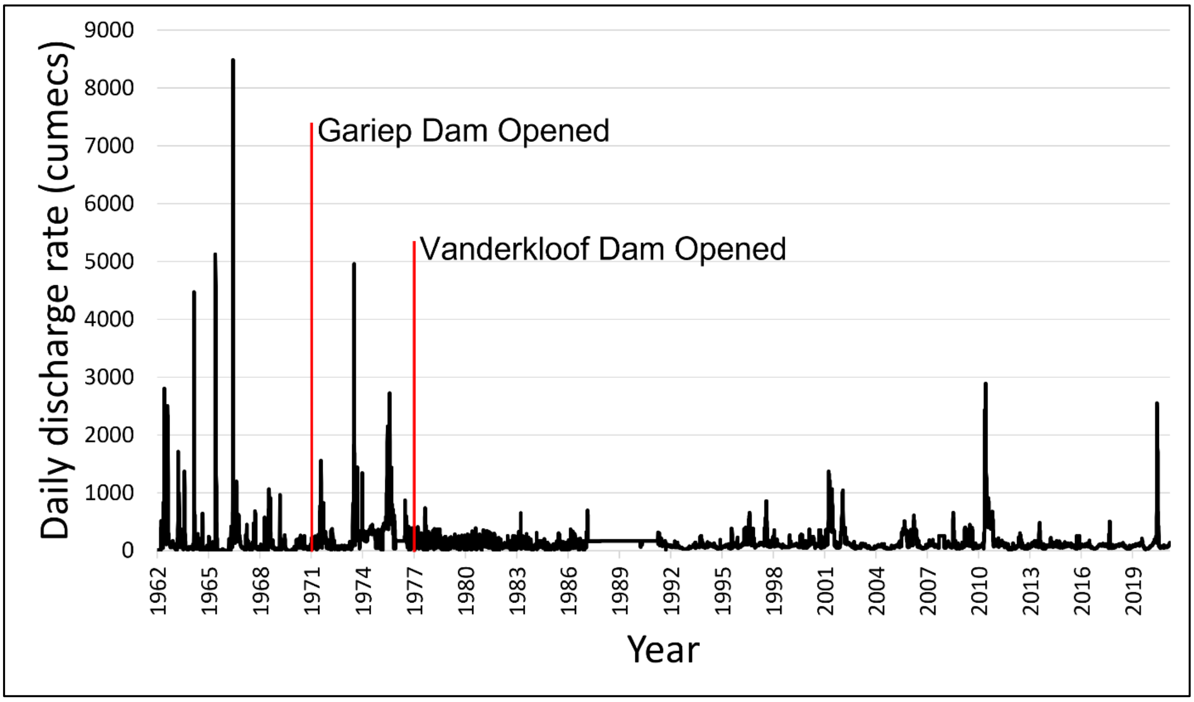


Figure 4-1: Daily discharge rate from 1962 – 2021 measured at Marksdrift gauging station (station D3H008; -29.16201, 23.69594), upstream the confluence of the Orange and Vaal rivers. Opening dates of the Gariep and Vanderkloof dams shown as solid red lines. Gauging station malfunction between 1987 – 1991.

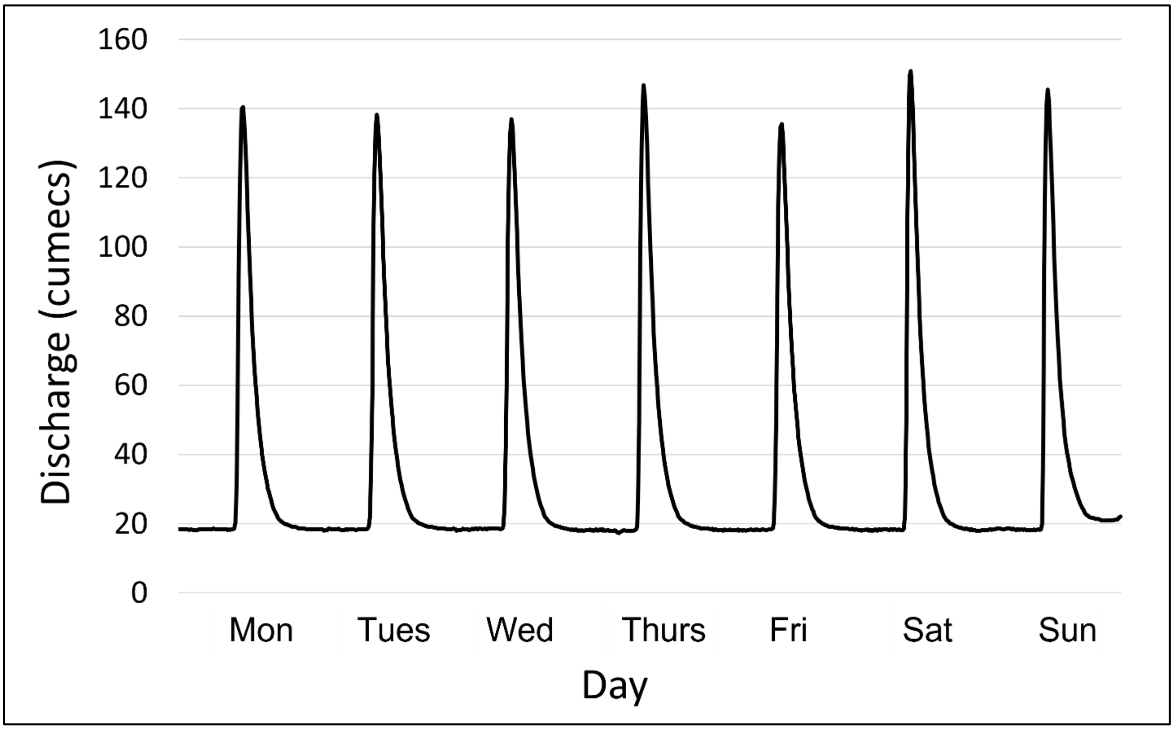


Figure 4-2: Discharge recorded from Vanderkloof Dam at gauging station (D3R003; -29.99149, 24.73189) over a one-week period (01/01/2020 – 08/01/2020). Pattern shows the daily hydropeaking resulting from hydroelectric power generation releases.

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, 2023a) 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 plastic) and erosion from poor agricultural/ land use practices causing high sedimentation. Furthermore, extensive impacts on flows (low flows as well as to a certain extent floods) due to Katse and 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). All the associated and extensive impacts are illustrated in the longitudinal profiles of the Upper Orange River from the Lesotho border to the Vaal confluence in Figure 4-3 below.

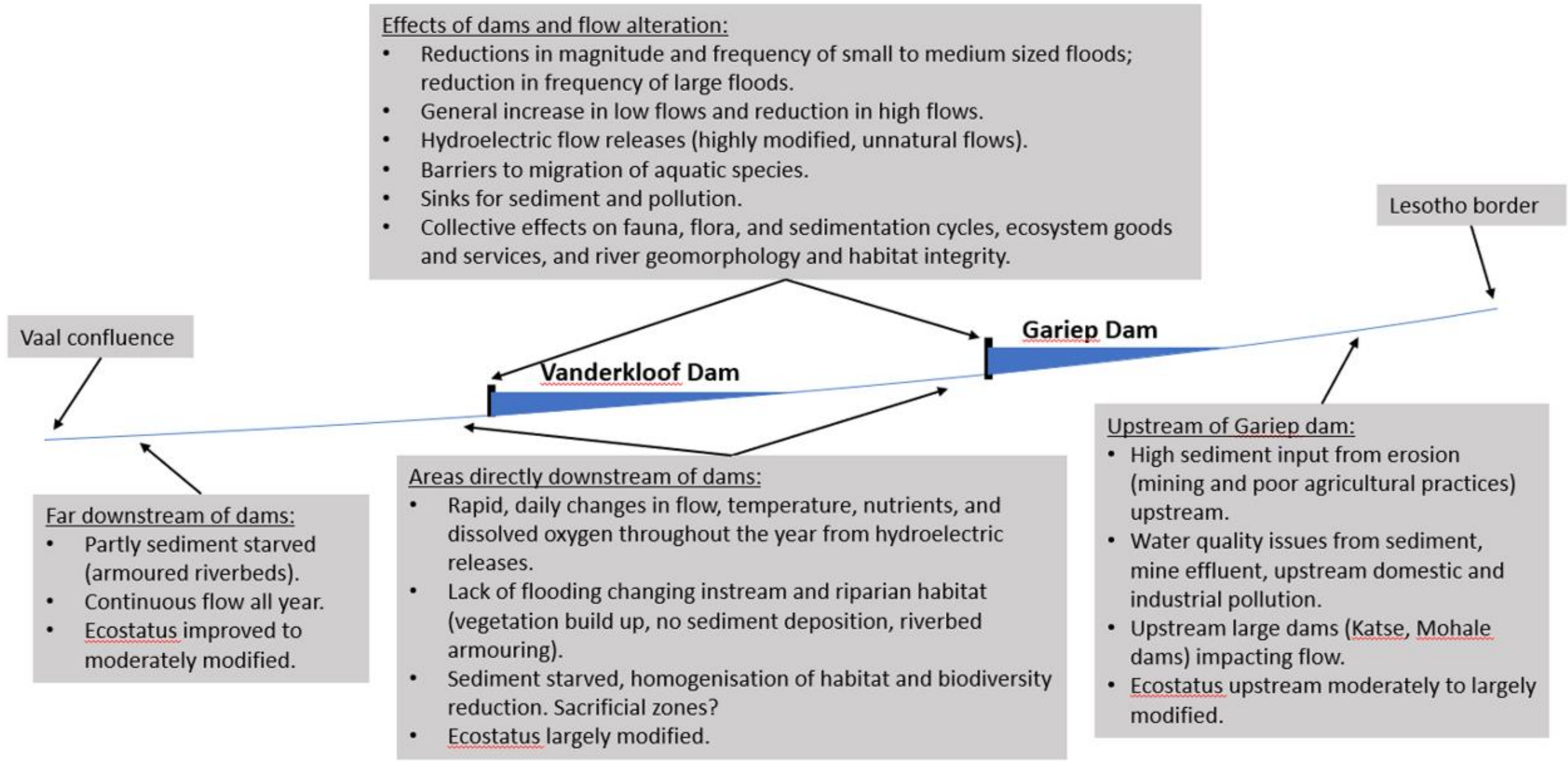


Figure 4-3: Preliminary longitudinal profile of the Upper Orange River from the Lesotho border to the Vaal confluence. The two major impoundments on this reach are shown; the Vanderkloof and Gariep Dams.

At the conclusion of the third Joint Basin Survey (JBS3) in 2022 (ORASECOM, 2023a), the sites immediately downstream of the dams were assessed to be in largely modified states, with degraded fish, macroinvertebrate, and vegetation communities (Figure 4-4). This decline suggests there is a need to evaluate if there are any geomorphological, hydrological, or biological thresholds that are about to be crossed with critical, irredeemable negative consequences which need to be presently mitigated. The ecological condition improved progressing further downstream as the impacts of the flow alterations are slowly ameliorated (Choi *et al.,* 2005; 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 4-4; ORASECOM, 2023a).

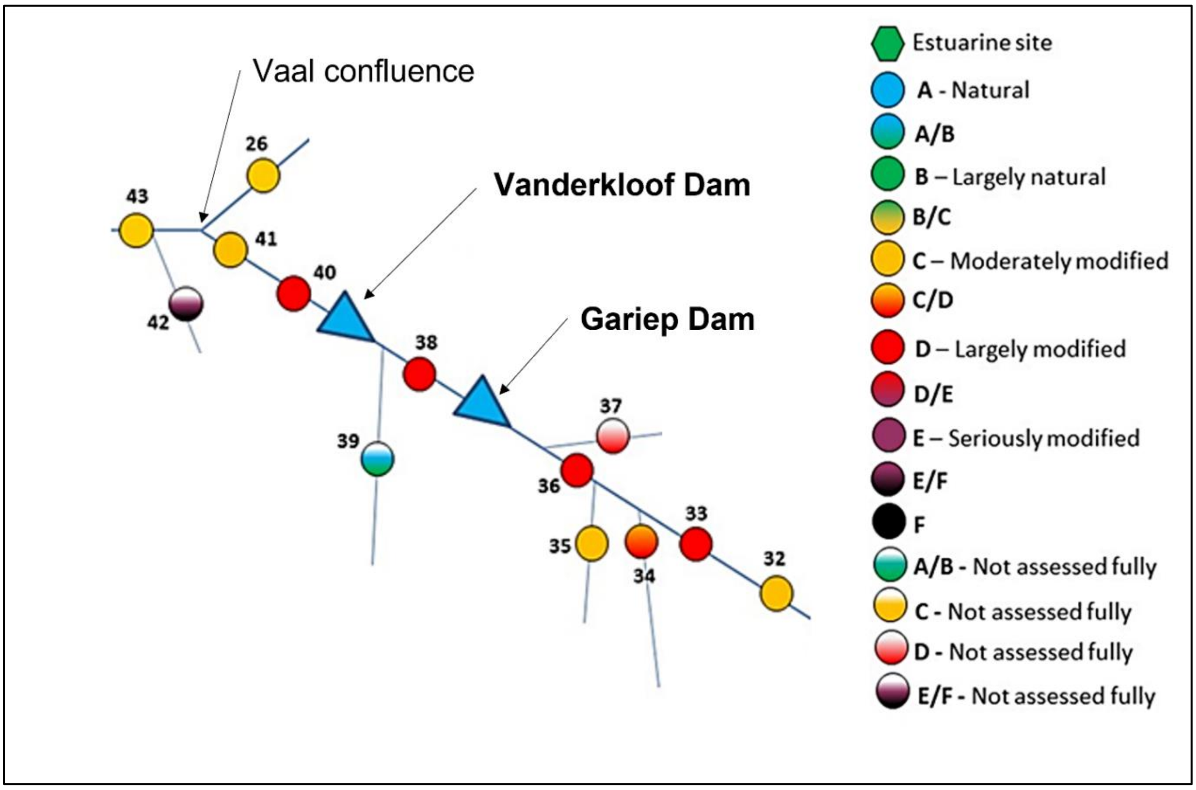


Figure 4-4: Schematic representation of the overall ecological status (key on right hand side) of relevant sample sites from the third Joint Basin Survey (JBS3) aquatic ecosystem health assessment by the Orange-Senqu River Commission (ORASECOM, 2023a).

In February 2023, a meeting was held with representatives from DWS, Eskom, WRP Consulting and the PSP to discuss the current operational rules of the two dams, and whether there was any potential opportunity to revise or refine these rules. We understand the significant negative environmental consequences of the current flow regimes and the potential social and economic implications if these flows should change to provide optimised ecological functioning. Though, through improving the environmental flows, that maintains some of the core functionality of the dams, – this may allow the improvement of the aquatic ecosystem health and boost ecological goods and services. However, based on the current social, economic and energy climate of South Africa, these dams fulfil a critical role in providing water and power generation. Thus, Eskom confirmed that this cannot be avoided, or flows altered now.

Consequently, for the purpose of this study, intermediate river field surveys were not conducted between the two dams, or just downstream of Vanderkloof Dam. However, an intermediate site (UO_EWR10_I) was selected on the Orange River at Marksdrift (just before confluence of Vaal River) and surveyed in May 2023. Subsequently, the PES, REC and AEC have been determined for this site, and the EWR will be quantified for this reach, taking cognisance of water demands of users (both in South Africa and Namibia) and the water requirements of the Orange River Mouth Estuary in the Lower Orange catchment area.

A consensus was reached, and a conceptual Flow Management Plan (FMP) has thus been compiled for the purpose of this study (Table 4-1). 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. This component will form part of the EWR Quantification Report. For more detail on the conceptual FMP, please refer to the EWR Quantification Report number RDM/WMA13/00/CON/COMP/1323).

Table 4-1: 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 will be used to guide the surveys in terms of the components to be included to be able to specify specific changes to the flow releases*

5. SURVEY LIMITATIONS

Dry season survey (July 2022)

The current La Niña weather pattern resulted in flooding events that has taken place in South Africa in the past two years. The impacts from this event are likely to last several years, when southern African summer rainfall regions experienced a generally wetter and cooler than normal wet season.

The catchment experienced heavy rainfall events during October 2021 and again in April 2022, triggering floods, high water levels and increased flow rates within the Upper Orange study area. The second round of considerable heavy rainfall events that took place in the Upper Orange River catchment in April 2022, causing further flooding events throughout the system with associated high-water levels and once more raised flow rates. During the dry season survey (4 to 15 July 2022), evidence of the continued high baseflows, as a result of these high rainfall events, were observed. The main stem Orange River and its main tributaries flowed with high baseflows, consequently not representative of normal dry season flows, and consequently not very useful for EWR when stress conditions (including droughts) often prevail. Ephemeral systems namely the Seekoei River, continue to flow during this time of year, deviant from its natural conditions. Furthermore, the lower reach of the Orange River, upstream of its confluence with the Vaal River, was not accessible in July 2022 owing to continuous high flows (>130 m^3/s) and velocities, compromising safety. Nonetheless, this site was surveyed successfully during the second river survey in May 2023.

6. ECO-CATEGORISATION APPROACH

The dry season river survey was conducted from the 4 to 15 July 2022 (first river survey) whereby the specialist team conducted all three Reserve level assessments (Intermediate, Rapid 3 and field verification) for the identified priority RUs throughout the Upper Orange catchment.

The post-wet season survey (second survey) was undertaken from 29 May to 4 June 2023, whereby only the intermediate sites were re-surveyed. For further information regarding the two river surveys, please refer to Report number RDM/WMA13/00/CON/COMP/0722 and RDM/WMA13/00/CON/COMP/1223 respectively for more details on the surveys undertaken. Below is a summary of the methods adopted for the various components for the purpose of the eco-categorisation of the rivers.

The Ecological Categorisation[1] (Eco-Categorisation) approach is used to determine and categorise the PES and REC based on the health and integrity of the biophysical attributes of a river ecosystem, relative to the natural reference condition of that system (Kleynhans & Louw 2007). It forms an integral part of the Ecological Reserve determination methods. Flows and water quality conditions cannot be recommended without information on the predicted resulting state, the Ecological

[1] *The new terminology of eco-categorisation instead of ecoclassification is being used to differentiate between the process that is followed to categorise the ecological categories as part of the Reserve determination and the approach to determine the Water Resource Classes as part of the Water Resource Classification System.*

Category (EC) (Kleynhans & Louw 2007). The primary objective of the eco-categorisation process is to recognise the causes and sources of the deviation of the derived PES through the various models, in relation to the reference condition of that river's biophysical attributes. The result is to ultimately gain information to derive future desirable and attainable ecological objectives for the river (Kleynhans & Louw 2007).

The various components required for the Eco-Categorisation process to determine the integrated state or PES, through the EcoStatus Level 4 model (Kleynhans & Louw 2007) include the following:

- Drivers:
  - Physical-chemical variables/diatoms;
  - Geomorphology; and
  - Hydrology
- Biological Responses:
  - Fish;
  - Riparian vegetation; and
  - Aquatic macroinvertebrates

Below a detailed outline of the various components conducted during the surveys for the eco-categorisation of the various EWR sites.

6.1 Drivers

6.1.1 Water quality: In situ water quality

A suite of ancillary *in-situ* water quality was measured in-field at all EWR sites during both surveys. The variables measured included pH, Electrical Conductivity (EC) / Total Dissolved Solids (TDS), Dissolved Oxygen (DO), oxygen saturation (DO%), temperature, salinity and clarity. Equipment was calibrated before the site survey to ensure accurate and reliable measurements. All *in situ* water quality were referenced against the South African Guidelines for Freshwater Ecosystems, Volume 7 (DWAF, 1996).

6.1.2 Water quality: Benthic diatoms

Sampling of diatoms was done according to the prescribed protocols in Taylor *et al.* (2007). Typically, this entailed collecting five smallish rocks at each sample site from random positions across the river where there was flow of water. The top surface of all the rocks that were exposed to the water column were then scraped using a toothbrush, which removed diatoms attached to the rock surface into a container with a small volume (<100 ml) of river water. Once the rocks had been adequately scraped, the water in the container that has the five subsamples was then transferred to a small sample bottle. A small amount of 95% ethanol (~10% of the sample bottle volume) was then added to the bottle to preserve the diatom sample. Sample bottles were then labelled, and submitted to the Northwest University for preparation and analysis. The results from the laboratory were then interpreted according to the Specific Pollution sensitivity Index (SPI) to determine river "health status" (CEMAGREF, 1982). Other useful diatom indices used to further infer water quality conditions were the Percentage of pollution Tolerant Valves (% PTV), which was the proportion of diatoms in the sample that are tolerant to pollution, and the percentage of deformed cells, which was the proportion of diatoms in the sample which were deformed as a result of toxicants in the water.

For this study, diatoms were used as a surrogate to the Physical-chemical driver Assessment Index (PAI). The desktop assessment of water quality data revealed gaps in data available for reference and recent conditions at the EWR sites or the Sub-Quaternary (SQ) reach within which the sites are located. Several data sources were used to collate information of the current and historical Physical-chemical state of the assessed river systems and associate 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 (see Table 6-1 for DWS site information and RQIS data obtained during desktop assessment). Additional data received from the DWS Free State Regional Office was also interrogated to obtain more recent information. Other data sources were also sought for information including local conservation bodies, literature and experts who have done work in the area.

Table 6-1: DWS site information and RQIS data obtained during desktop assessment for water quality

River	DWS Site ID	Latitude	Longitude	No of entries	Start Year - Year End
Seekoei (I)*	D32_101829	-30.5342	24.96194	465	1981-2019
Upper Riet** (I)	C51_189023	-29.5759	25.71075	30	2011-2015
Upper Modder (I)	C52_90811	-29.1603	26.57333	788	1987-2018
Upper Modder (I)	MS2/SW08/C5C5MODD-SANNA	-29.1603	26.57333	13	2017-2023
Lower Riet (I)	C51_189020	-29.0378	24.62481	28	2012-2015
Lower Riet (I)	C51_90835	-29.0333	23.98333	986	1990-2018
Lower Riet (I)	RS5	-29.0412	24.59838	8	2017-2023
Lower Orange (I)	D33_101824	-29.1617	23.69639	1397	1966-2018
Wonderboomspruit (R)***	D14_101788	-31.0008	26.35306	966	1967-2018
Little Caledon (R)	D2LCAL-EWR02	-28.6114	28.30194	5	2021-2022

River	DWS Site ID	Latitude	Longitude	No of entries	Start Year - Year End
Brandwater/Groot (R)	D2GROO-FARM1	-28.6806	28.13972	4	2022

*(I): Intermediate
** Site 25km upstream in different SQ Reach
***(R): Rapid Level 3

The porosity in data limited the ability to assess site reference conditions confidently and accurately. Additionally, the PAI could not be used for determining the physical-chemical category as it is data dependent. The diatom results obtained from the 2022 and 2023 river surveys were used to infer the reference condition and the current status of the river systems in question. The use of diatoms in the monitoring of water quality is well documented. In this study, the diatoms were used to infer the reference and current physical-chemical status of the system for the following reasons:

- Long environmental memory – analyses of diatom fossil records allow for the reconstruction of the history of water quality in an area. This is useful in assessing the changes in water over time and possibly infer the reference/natural state of the system in question;
- Diverse species composition – diatom communities exhibit extensive species diversity. Each species has unique preferences and tolerances to specific physical-chemical property changes. By quantifying diatom communities, it is possible to identify which physical-chemical properties have deviated from natural and are driving the physical-chemical status currently observed in the system in question;
- Indicators of nutrient enrichment – nutrient enrichment is one of the leading contributors to impaired water quality in the catchment. This is largely due to the mismanaged wastewater treatment works, which discharge poorly and, in some cases, untreated wastewater into watercourses. Certain diatom species are known to be good indicators of eutrophic water bodies and identifying river systems with elevated nutrient concentrations and prone to algal blooms;
- Sensitivity to pollutants – diatoms are also good indicators of inorganic pollution. This is especially important in identifying heavy metal pollution in river systems; and
- Rapid assessment and monitoring – diatom sampling and analyses are relatively easy, quick and cost effective. This allows for an effective and holistic assessment of water quality.

In the absence of an adequate dataset to assess reference and current physical-chemical state, diatoms proved to be an adequate replacement from which information on the physical-chemical status of the systems can be drawn. Satellite imagery, Geographic Information System (GIS) and Green Drop data were used to assess the changes and to identify the catchment drivers of the physical-chemical state of the systems in question. Combined these sets of data provided a picture of the natural state of each EWR site and how the current state has deviated from reference conditions.

6.1.3 Geomorphology

The geomorphology was assessed at all Intermediate EWR sites, using the GAI method that was developed by Rowntree (2013), with Level 4 assessments carried out for each site. This included the following general steps for undertaking a Level 4 GAI field assessment:

- Classify and describe the site using river planform, valley confinement, reach type; slope, morphological features and sediment composition;
- Define the reference state to describe the natural/pristine condition of the geomorphology at each site to benchmark changes in geomorphology at the time of Intermediate surveys (i.e., the present ecological state). This was largely based on historical air photos and the geomorphic zone classification;
- Assess the changes to connectivity (hillslope-channel, longitudinal, lateral and vertical);
- Describe and assess the changes to the sediment balance for the reach (catchment erosional processes, channel erosion and channel mining);
- Describe and assess the impacts on the stability of the bed, banks and flood zones (changes to vegetation cover, trampling, excavation); and
- Describe and assess the impacts on the morphological condition and habitat (changes to channel dimensions, sediment composition, and extent of habitat).

These data were used in the GAI level 4 model to derive a PES score with flow relation and confidence scores.

6.1.4 Hydrology

The Hydrological Assessment Index (HAI) has been developed as part of the methodologies for the determination of the Ecological Water Requirements. The approach provides an indication of the changes in hydrology from reference/ natural to present day at each selected intermediate EWR site and is based on monthly long term natural and present-day flow time series. The results of HAI are used by ecologists to interpret changes in habitats using the hydraulics (depths, velocities, wetted perimeter, etc.) and to explain some changes in the response components (fish, macroinvertebrates, and vegetation).

The assessment is based on the long-term changes from natural to present with 0, no change to 5, extreme change from natural in five metrics, namely:

- Low flows – changes to baseflows and can be either less or more flows than natural or the introduction of constant flows due to dam releases;
- Introduction of zero flows/ duration – Changing a perennial system (no zero flows) to a more seasonal or even ephemeral system due to no flows or the duration of the zero flow months increase in a seasonal stream;
- Seasonality – changes due to reduced flows during wet months (storing of excess runoff in dams) and releases from these dams during dry months for water use downstream. The so called “swopping of seasons”;
- Moderate events – changes to moderate floods/ freshets due to delayed spilling of dams after dry season (dam need to fill with first rains), thus delaying the early season cleaning of the rivers from algae and sediment build-up; and
- Event hydrology (floods) – reduction in the peaks of flood events or less frequent flooding (less spilling due to large dams capturing most of the catchment runoff).

Ecologists rank these metrics according to the impact that changes will have on the available habitats, thus affecting the overall habitats.

6.2 Responses

6.2.1 Ichthyofauna

Fish samples were collected using different techniques, including electrofishing, cast netting as well as from visual observations at all Rapid 3 and Intermediate EWR sites. Fish sampling techniques were deployed in a variety of depth and flow classes to sample each habitat to show fish species preferences for each. Electrofishing is regarded as the most effective single method for sampling fish communities in wade-able streams (Plafkin *et al.*, 1989). Fish were identified in the field, photographed and released at the point of capture. Fish species were identified using the guide Freshwater Fishes of Southern Africa (Skelton, 2001).

The FRAI method developed by Kleynhans (2007) for application in South Africa was used to assess the response of the reference fish assemblage to changing environmental conditions based on the observations made during the two river surveys. Fish species are categorised in the FRAI model according to an intolerance rating that take trophic preferences and specialisation into account, as well as all the flow, habitat, and water quality requirements. The ratings are then formulated into a relative FRAI index value, which is grouped into one of six descriptive fish assemblage integrity index classes.

The expected and observed Frequency of Occurrence (FROC) of fish species were compiled using the reference frequency of occurrence for fish species in South Africa (Kleynhans *et al.,* 2007). Data from the 2014 Present Ecological State (PES) - Ecological Importance and Ecological Sensitivity (EIS) dataset (DWS, 2014) was also consulted with the derivation of FROC. These FROC values were used to interrogate the FRAI model to evaluate changes from reference conditions. FRAI is a rule-based model developed by DWA (Kleynhans, 2007) that assesses environmental intolerances and preferences of the reference fish assemblage, as well as the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers. These intolerance and preference attributes are categorised into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.

Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually, the FRAI is based on a combination of fish sample data and available habitat for fish. Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation and to determine the Present Ecological Category of the fish assemblage.

6.2.2 Fish Taxonomy Clarification

It should be noted that, following recent taxonomic studies, the taxonomy of several species expected to occur within the study area has changed. For example, Kambikambi et al. (2021) uncovered the presence of four distinct lineages or operational taxonomic units (OTUs) within *Enteromius* (previously *Barbus) anoplus* complex through the use of a comprehensive data set of mitochondrial (mtDNA) cytochrome *b* (cyt *b*) sequences. The study further described a new species from the Orange River catchment, namely *Enteromius oraniensis.* The taxonomy as presented within this report is therefore representative of the scientific name valid at the time of writing.

6.2.3 Riparian Vegetation

Riparian vegetation was assessed at all Intermediate EWR sites only, using the VEGRAI method that was developed by Kleynhans et al. (2007), with Level 3 assessments carried out for each site. This included the following general steps for undertaking a Level 3 VEGRAI:

- Define the reference state to describe the natural/pristine condition of riparian vegetation at each site to benchmark changes in riparian vegetation at the time of Intermediate surveys (i.e.,, the present ecological state);
- Establish the extent of the riparian zone and divide into two zones (i.e.,, marginal and non-marginal zones) based on signs of zone interfaces (i.e.,, topographical/elevation changes, plant composition/community changes, terrestrial vegetation, etc.);
- Assess the condition of marginal and non-marginal zones taking note of key drivers and pressures;
- Describe the native woody (i.e.,, trees and shrubs) and non-woody vegetation (i.e.,, grasses, sedges, reeds, forbs, etc.) within each zone, taking note of key/indicator/dominant species;
- Obtain estimates of the cover, abundance and composition of woody and non-woody vegetation; and
- Evaluate and interpret any impacts observed at each site that are affecting riparian vegetation in terms of vegetation removal, alien vegetation invasion, and water quantity and water quality, and assess the intensity and extent of each impact.

6.2.4 Index of Habitat Integrity

This index was conducted at all Rapid 3 EWR sites and field verification sites, as prescribed in Kleynhans et al. (2009). The Index of Habitat Integrity (IHI) assessed indicators of instream and riparian habitat modification. Furthermore, it essentially considered the deviations/changes of habitat from natural conditions with reference to intensity and extent of human-induced impacts that have affected habitat integrity within river catchments. The assessments were achieved through determining the condition of each site by incorporating biological responses to driver changes (e.g., hydrological, geomorphological, physical-chemical, etc.) as well as through an integration of driver state or condition. The instream criteria assessed included water abstraction, flow modification, bed and channel modification, physical-chemical, inundation, alien macrophytes, introduced aquatic fauna and rubbish dumping. The riparian integrity took cognisance of vegetation removal, alien vegetation, bank erosion, channel modification, water abstraction, inundation, flow modification and physical-chemical conditions. The riparian score from this index was consequently used as a surrogate to the VEGRAI score for Rapid 3 sites when running the EcoStatus Level 4 model.

6.2.5 Aquatic Macroinvertebrates

Aquatic macroinvertebrate sampling was done using the South African Scoring System (SASS) version 5 protocol, as developed and refined by Dickens & Graham (2002). This index measures aquatic macroinvertebrate presence data at a family taxon level. Each taxon is allocated a sensitivity value between 1 and 15 according to its perceived sensitivity to water quality changes (with 1 being the least sensitive and 15 the most sensitive). Results are expressed as index scores: the SASS Score and the Average Score per Taxon (ASPT). This SASS5 technique has been accredited to ISO 17025 standards and forms part of one of the DWS river eco-categorisation models for EcoStatus determination. The SASS5 sampling was undertaken by an accredited SASS5 practitioners at all Rapid 3 and Intermediate EWR sites during both river surveys. The prescribed DWS MIRAI (Thirion, 2007) uses SASS5 and pre-determined reference condition data to determine the macroinvertebrate Ecological Condition of a site. The model considers three main drivers influencing macroinvertebrate community composition, namely: i) flow, ii) habitat and iii) water quality. These drivers create the instream habitats that affect instream biotic communities. Therefore, the Ecological Category generated by the MIRAI reflects the influence of each driver on the site and the macroinvertebrate community.

Additional aquatic macroinvertebrate data was gathered from Dr Christa Thirion and Ms Keamogetse Molefe from DWS, who conducts the SASS5 biomonitoring at all REMP sites throughout the Upper Orange study area. These sites were aligned to some of this studies EWR sites. This enabled the specialist to supplement the macroinvertebrate database, and which was added to the MIRAI model, supporting both reference conditions and/or macroinvertebrate data recorded for the last hydrological year.

6.3 Ecological Categories

Varying procedures are followed for each component to assign an Ecological Category (EC) ranging from A to F (where A represents a natural state and F a critically modified state) (Figure 6-1). It must be noted that the ecological category scale represents a continuum whereby the boundaries between categories, along the continuum, are descriptive, notional and arbitrary defined points. Subsequently, there may be circumstances where there could be ambiguity as to which category a particular entity belongs to. This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both categories (Robertson *et al.*, 2004). This is therefore referred to as boundary categories and assigned a B/C, C/D category etc. (Figure 6-1).

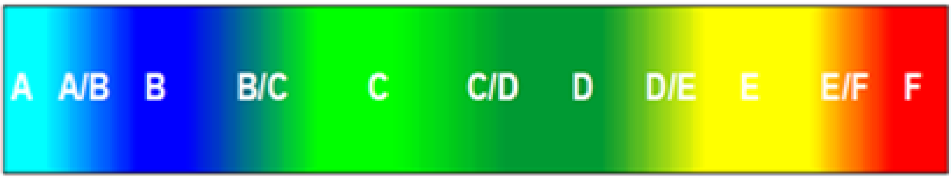


Figure 6-1: Illustration of the distribution of ecological categories on a continuum

6.4 EcoStatus and Recommended Ecological Categories

Ecological evaluation against the expected reference conditions, followed by integration of the categories of each component, provides a description of the Ecological Status or *EcoStatus* of a river. Consequently, the EcoStatus is defined as the integration of the river's features (instream and riparian zones) which influences its ability to support appropriate biota (Kleynhans & Louw 2007). This ability relates directly to the capacity of the system to provide a variety of ecosystem services.

The trends in the PES are then evaluated. A trend is viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a hanged state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux. Generally, such an assessment can be approached from a driver perspective. This means that there can be a positive or negative trend response from the biota if the drivers (specifically geomorphology and water quality) are still in a directional state of change (+ or -).

It must be noted that cognisance was taken when comparing the PES, 2014 and the EcoStatus 2023. The PES, 2014 was based on various components, while the EcoStatus 2023 was based on fish, macroinvertebrates and riparian vegetation, or for Rapid 3 sites, the riparian habitat integrity was used as a surrogate. The reason for deviation is thus provided.

Furthermore, the evaluation/comparison of the following 9 ecological importance and 8 ecological sensitivity metrics were evaluated for each EWR sub-reach using the PES/EIS (2014) study, along with in-field results from the surveys to determine the overall EIS at the EWR site:

(i) Ecological Importance
- Fish representivity and rarity
- Macroinvertebrate representivity and rarity
- Riparian-wetland-instream: vertebrates
- Riparian-wetland-instream: natural vegetation
- Habitat diversity
- Habitat size
- Habitat integrity
- Riparian-wetland habitat integrity
- Instream and riparian migration

(ii) Ecological Sensitivity
- Physical-chemical sensitivity:
- Fish and macroinvertebrates
- Fish: no flow
- Macroinvertebrates: velocity
- Riparian-wetland-instream – vertebrates: flow or water level changes
- Riparian-wetland – vegetation:
- water level changes

   - Stream size (flow/water level changes)

This updated information was then used when assessing the Recommended Ecological Category (REC) for the EWR site. The *modus operandi* followed by DWS's Directorate: Resource Directed Measures (RDM) is that, if the EIS is high or very high, the ecological aim should be to improve the condition of the river. However, the causes related to a particular PES should also be considered to determine if improvement is realistic and attainable. This relates to whether the problems in the catchment can be addressed and mitigated. If the EIS evaluated as moderate or low, the ecological aim should be to maintain the river in its PES. Within the Ecological Reserve context, Ecological Categories A to D can be recommended as future states (the REC) depending on the EIS and PES. Ecological Categories E and F - the PES is regarded as ecologically unacceptable, and a REC of a D should be used, and remediation is required.

6.5 Eco-categorisation Workshop

Following both seasonal surveys undertaken in July 2022 and May/June 2023, an Eco-Categorisation specialist workshop was held on 26 and 27 July 2022 and 13 and 14 June 2023, to determine the EcoStatus of the Rapid 3 and Intermediate EWR sites respectively. The process included the following for the EWR and field verification sites:

- Description of site localities within the catchment (EWR and field verification sites);
- Type of historical and existing information availability for each site (EWR and field verification sites);
- Characterisation and evaluation of each site in terms of both the drivers and responses identified (*i.e.,* habitat availability, aquatic biota, water quality) and associated advantages and disadvantages of each component (EWR and field verification sites);
- Reference conditions for the aquatic biota (EWR sites only);
- Description of both site and upstream impacts (EWR and field verification sites);
- Completion of the EcoStatus 4 model resulting in an overall PES category and score coupled with an explanation for each component (EWR sites only);
- A comparison using the previous PES results from preceding Reserve studies (mentioned above) was undertaken to compare the final selected PES identified during this study from the EcoStatus Model 4 and reasons for the potential deviations;
- Assessment of the PES ecological trends from 2014 for each component (aquatic biota and riparian and instream habitat integrity) (EWR sites only);
- Evaluation/ comparison of the EIS;
- Discussion and finalisation of the REC (for all Rapid 3 and Intermediate EWR sites), as well as an Alternative Ecological Category (AEC) or possible Target Ecological Category (TEC) (for Intermediate sites only) than could be used during the Water Resources Classification study.

6.6 Eco-categorisation Volume 2 (pre-requisite for this volume 1 report)

Please note that the following Report number *RDM/WMA13/00/CON/COMP/1223 (b): Eco-*

Categorisation Report – Volume 2 must be read in conjunction to this report. The Volume 2 includes all summaries of models and results/data for all EWR sites for the various components as follows:

- Appendix A: Diatom summary results;
- Appendix B: Fish inventory for all EWR sites and FRAI models;
- Appendix C: SASS5 Datasheets for macroinvertebrates for all EWR sites and MIRAI models;
- Appendix D: Riparian vegetation inventory for all Intermediate EWR sites and VEGRAI models;
- Appendix E: Summary of IHI Models;
- Appendix F: EcoStatus Level 4 models for all EWR sites;
- Appendix G: Summary of revised EI-ES;
- Appendix H: GAI models; and
- Appendix I: HAI models.

Please note, that all completed electronic models (MIRAI, FRAI, VEGRAI, GAI and HAI) have been packaged and submitted to DWS for their records within a folder.

7. ECO-CATEGORISATION: INTERMEDIATE SITES IN THE UPPER ORANGE CATCHMENT

7.1 UO_EWR01_I: MIDDLE CALEDON

Sample Date	29 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR01_I	**Prioritised RU**	R_RU04
River	Middle Caledon	**Altitude (m.a.s.l.)**	1526
Latitude	-28.909102	**Longitude**	27.784924
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D22D-03415
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	F (Lowland)		
Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology			

MAP ILLUSTRATION (Figure 7-1) AND SITE PHOTOGRAPHS (Figure 7-1)

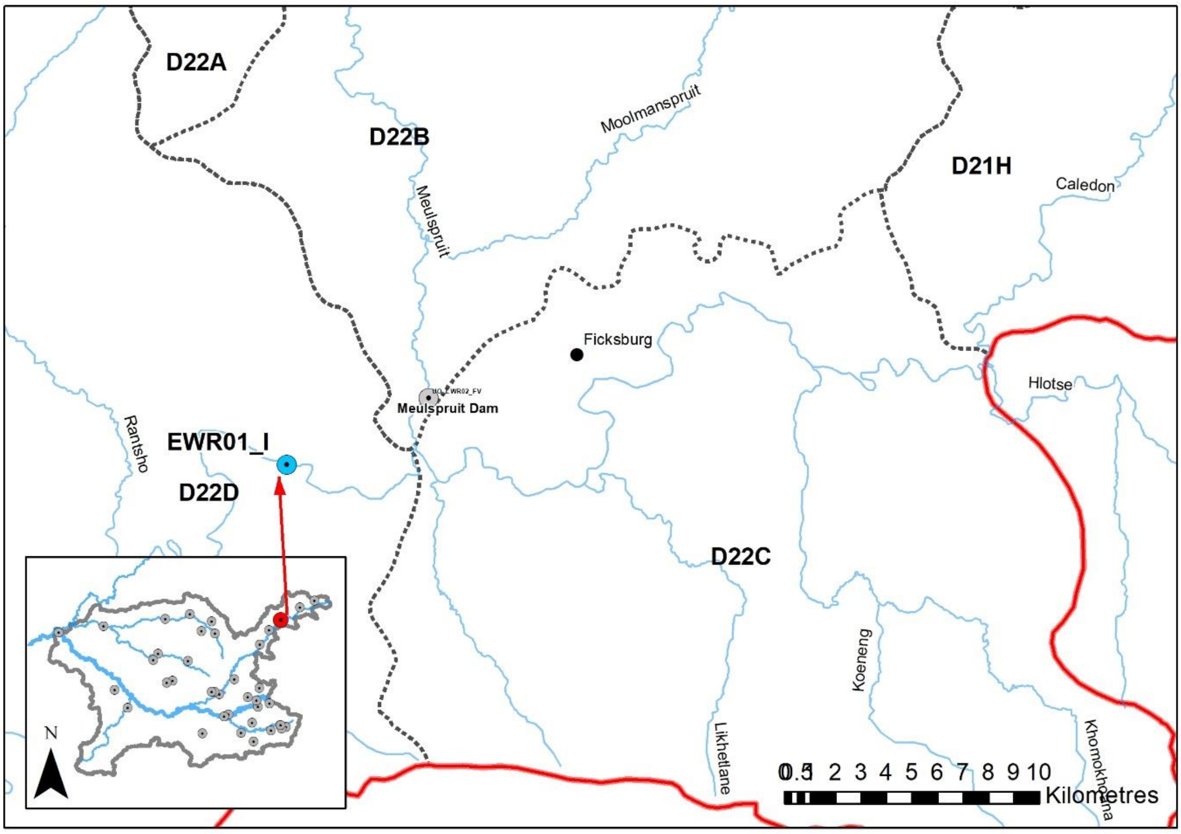


Figure 7-1: Location of site UO_EWR01_I (Middle Caledon) in relation to the study area

Site Photographs: Survey 2 (May 2023)

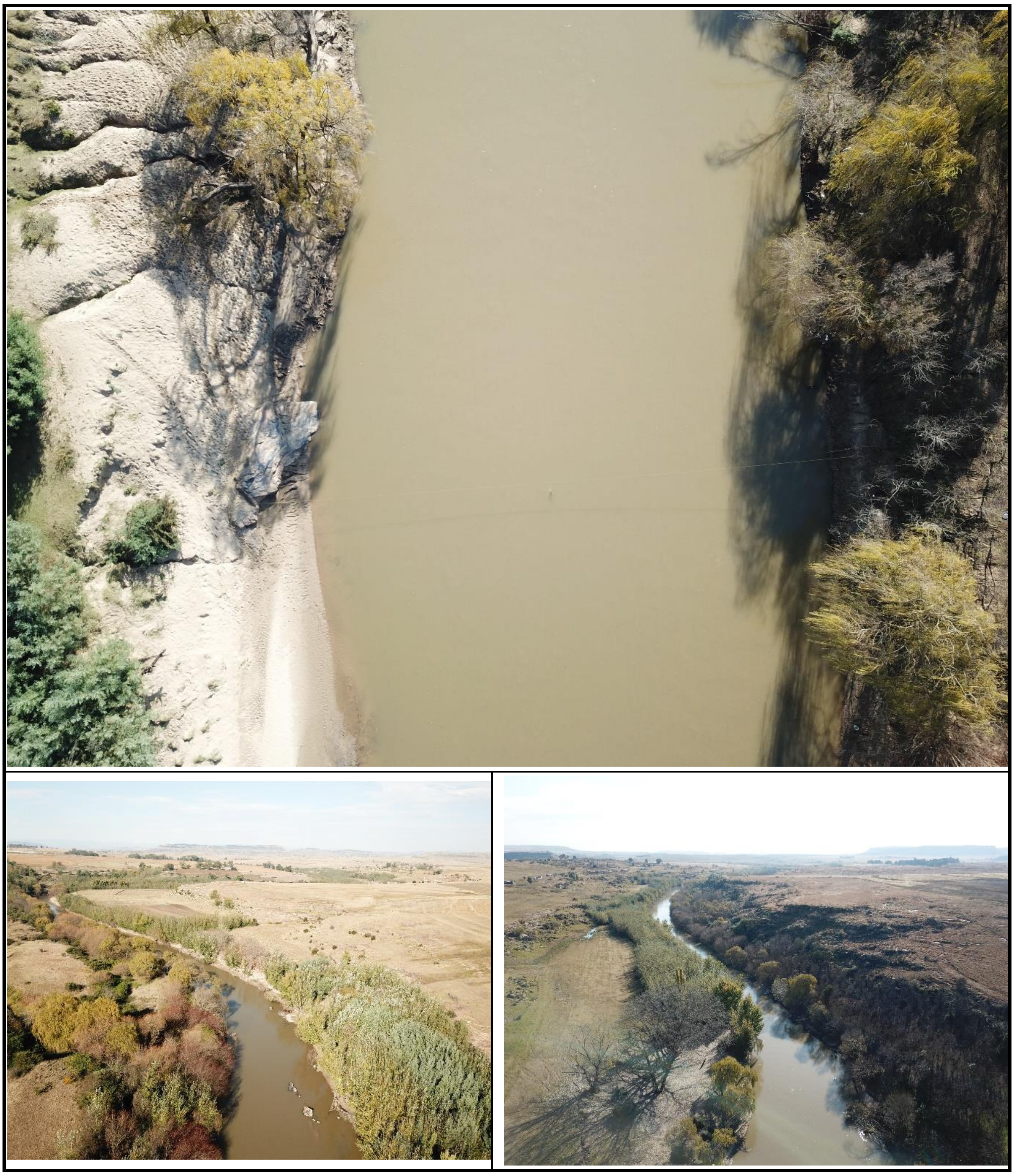


Figure 7-2: Site photographs of the Middle Caledon EWR site

Upstream	Downstream

Site Description:

This EWR site is located just upstream and downstream of the confluence with the Rantsho and Meulspruit rivers respectively near Ficksburg.

The reach is partly confined with a deeply incised channel. The width is approximately 50m, homogenous with some inundated sandbars along the channel. The riverbed is composed largely of sand and silt and both banks are sandy, steep and highly erodible. Habitat diversity for biota is poor and the water is often very turbid when not low baseflows. The surrounding area is a mix of settlements, grazing areas and small-scale croplands. The Lesotho side is heavily overgrazed and eroded contributing to the already high fine sediment load and evidence of sediment deposition.

Biotopes available for macroinvertebrates were dominated by sand and silt, with small gravel deposits over the sandy substrate. Marginal vegetation was relatively absent owing to erosion of inset benches and lower banks along both banks. There are no Stones-in-Current (SIC) or Stones-Out-Of-Current (SOOC). For fish, the flow-depth velocity classes available were only Fast-Deep (FD) and Fast-Shallow (FS) habitats.

The riparian zone is defined by a deeply incised macro-channel with steep banks that are infested by invasive alien trees (IAPs), notably Black Locust (*Robinia pseudoacacia*) on the right bank and Polular (*Populus candescens*) and Wattle (*Acacia deacurrens*) on the left bank, interspersed by Weeping Willow (*Salix babylonica*). Few indigenous species (~6 spp.) were recorded. The marginal zone was largely inundated by high baseflows, and the lower banks are devoid of vegetation. The riparian vegetation is also heavily impacted by bank erosion, footpaths and livestock trampling, and litter snagged in vegetation and scattered along the banks highlights a solid waste problem upstream.

Site impacts:

- Settlements
- Cattle grazing areas
- Small-scale croplands
- Alien invasives (*Acacia dealbata, Salix sp., Populus sp., Robinia pseudoacacia)*
- Cultivation

- Vegetation removal
- Macrophytes (plastics/litter) along both banks

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 8.0
- EC: 218.6 µS/cm
- TDS: 0.19 g/l
- DO: 9.1 mg/l
- DO%: 84.2%
- Clarity: 26cm
- Temperature: 11.7°C
- Salinity: 0.14
- Discharge: 17.190 m^3/s and 1.73 m^3/s (July 2021, from a previous study)

Diatoms*

No. species	**SPI****	**Categorisation (quality)**	**%PTV*****	**%Deformed cells******
58	8.6	D (Poor)	24.9	2.25

Dominant Species	1. *Achnanthidium sp.*
	2. *Craticula molestiformis (Hustedt) Lange-Bertalot*
	3. *Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*
	4. *Navicula symmetrica Patrick*
	5. *Nitzschia sp.*
Preference	1. Moderate to good quality waters
	2. A cosmopolitan species generally found in electrolyte rich and often heavily polluted water (including sewage effluent).
	3. Tolerant of strong pollution, indicator of industrial organic pollution
	4. A cosmopolitan sp. in eutrophic and electrolyte-rich water. Tolerant of strongly organically polluted water.
	5. Generally, siltation and moderate pollution

**Refer to Appendix A of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2*

***Specific Pollution sensitivity Index (>17: A-high water quality; 13-17: B-good water quality; 9-13: C-moderate water quality; 5-9: poor water quality; and <5: E seriously modified water quality) (adapted from Eloranta & Soininen, 2002)*

****The percentage of pollution tolerant valves (<20: site free from organic pollution; 21-40: some evidence of organic pollution; 41-60: Organic pollution likely to contribute significantly to eutrophication; and >61: Site is heavily contaminated with organic pollution (adapted from Kelly, 1998)*

*****Deformed cells: a red flag (>2%) showing potential harmful pollutants within the water column. These toxins have the potential to disturb the cell walls morphogenesis and the silica which is then laid down incorrectly in the cell wall causing changes in the cell outline or in the striae patterns of the species. Therefore, a lack to no deformed cells suggests heavy metals are not a consistent issue at the site.*

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Straight and simple channel form • Two observations	• Mobile bed, so possible changes to cross sectional area. • Observed flows for relatively low discharges.
Fish	1	• None	• Alluvial reach with limited cover features. • Limited collection records • Seasonal & sampling limitations.
Macroinvertebrates	2	• None	• Wide homogenous channel. • Limited aquatic biotopes – dominated by muddy substrate. • No marginal vegetation. • Excessive bank erosion and undercut banks. • High suspended sediment concentration (highly turbid waters).
Riparian vegetation	3	• Reasonably good access to site, and across the site. • Riparian vegetation is representative for the reach.	• Incised channel with steep banks limit vegetation structuring. • Marginal zone inundated, with highly limited opportunities for vegetation to establish. • Dense alien vegetation and bank collapse. • Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	3	• Good access to the site, clear flows during winter visit • Several visits to reach	• Disturbances along banks due to grazing, river crossings and alien vegetation harvesting.

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• Two observations for relatively low flows

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
						• Highly mobile bed
Fish						• FROC (Kleynhans et al., 2008) • PESEIS (2014) • Previous study conducted at this site on the Caledon in 2021 - Cal_EWR2** • May 2023 survey
Macroinvertebrates						• PESEIS (2014) • Previous study conducted on the lower Caledon in 2021 - Cal_EWR2** • May 2023 survey
Hydrology						• Monthly modelled natural and present day hydrology • Daily flows from gauge D2H035 in Ficksburg to provide guidance with setting freshets and floods
Geomorphology						• Historical and recent aerial images • Basic descriptions of river from old explorers
Riparian vegetation						• Historical and recent aerial images • May 2023 survey • Previous study conducted on the lower Caledon in 2021 – Cal_EWR2**
Diatoms						• May 2023 diatom sample
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • 2023 Diatom data • NCMP data DWS Site C2 2017 to 2023, n=6.

** 0 (no information) to 4 (large amount of data available)*
***Stassen et al., 2021*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Enteromius paludinosus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Reference taxa based on assessments of other rivers in the EcoRegion Level 2 include: Aeshnidae, Ancylidae, Baetidae, Caenidae, Ceratopogonidae, Chironomidae, Coenagrionidae, Corixidae, Dytiscidae/Noteridae, Elmidae, Gomphidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Leptophlebiidae, Libellulidae, Muscidae, Naucoridae, Notonectidae, Planorbinae, Pleidae, Potamonautidae, Simuliidae, Tipulidae, Tricorythidae, Veliidae/Mesoveliidae

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Riparian vegetation	Within the Grassland Biome (Mesic Highveld Grassland Bioregion). Dominated by non-woody vegetation with various grasses and herbs from surrounding Eastern Free State Clay Grassland extending into the riparian zone, which would have been dominated by *Cynodon dactylon* on the lower banks, with sedges along the river margins and emergent *Salix mucronata* trees scattered along the banks.
Hydrology	Natural flows at the EWR site were available for the period 1920 to 2004.
Geomorphology	Low gradient alluvial fine bed channel with limited lateral migration along unconfined reaches, resulting in a straight to wandering channel, with a braided pattern at very low flows. Deeper channels, pools and vegetated or bare (recently deposited) inset benches provide habitat along the margins. The banks will have a moderate gradient and will have a narrow active floodplain, set between the higher-lying terraces. The lower banks will be largely treeless.
Physical-chemical	Reference data for the site could not be obtained as the only physical-chemical data available was from 2017 to 2023. Diatom results were used to infer the reference physical-chemical condition of the system. Diatom results indicated poor water quality owing to dominant species being recorded with a preference for strong moderate to strong, including industrial organic pollution, all of which likely sourced from Ficksburg located upstream. Under reference conditions lower organic pollutant concentrations are evidently expected to be prevalent in the system.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)[a]	D (44.1%)	F/NF	• Alluvial bed with high mobility. • Loss of cover features within channel. • Hydrological and water quality modification due to catchment activities (high erosion rates due to loss of basal cover leading to high sediment loads, increased catchment development).
Macroinvertebrates (MIRAI)[b]	C (64.6%)	F/NF	• Water quality modification due to high sedimentation loads (upstream catchment activities, highly erodible soils and steep eroded banks). • Habitat modification – no marginal vegetation owing to eroded banks and sediment deposition. • The site is primarily alluvial with the dominant macroinvertebrate habitat being comprised of mud, and pockets of gravel.
Riparian vegetation (VEGRAI)[c]	E (22.6%)	NF	Site is severely impacted by alien trees resulting in widespread removal of ground cover and serious bank

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
			destabilisation leading to significant erosion of banks and sediment deposition on the banks and into the channel.
Geomorphology (GAI)	D (51.0%)	NF (18% F related)	• The main driver of the poor habitat and degraded site lies with elevated sediment yields from the degrading catchment, trampling along the banks and alien vegetation changing the bank stability and shape.
Hydrology (HAI)	C (72.5%)	F	• Reduced low flows due to water abstractions for irrigation and domestic use. • Reduced freshets as a result of numerous small dams on tributaries (SA side).
Physical-chemical Diatoms [d]	D	NF	• Due to the lack of sufficient monitoring data, diatoms were used to infer the present physical-chemical state of the system. • Largely driven by pollution related to untreated effluent discharge upstream in Ficksburg.
ECOSTATUS[e]	**D/E (34.4%)**		

[a]*Refer to Appendix B of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for the fish species inventory for all EWR sites*
[b]*Refer to Appendix C of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for theSASS5 datasheets for all EWR sites*
[c]*Refer to Appendix D of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for the riparian vegetation species inventory inventory for all EWR sites*
[d]*Refer to Appendix A of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for the diatom results*
[e]*Refer to Appendix F of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for the EcoStatus model results*

PES and causes	
Component	**Causes Present/Absent**
Fish[a]	This reach of the Caledon River is characterised by laminar flow over an alluvial bed, with limited cover elements present. Fish species expected under reference conditions are all considered to be eurytopic and moderately tolerant to water quality impairment, with varying velocity-depth and cover preferences. During the May 2023 survey, only four (4) juvenile Cyprinidae (cf. *Labeo capensis*) were collected. Although the reach was expected to act as a migratory conduit for species moving upstream during seasonal summer flows, the lack of cover features as well as the increased sediment input

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
from upstream catchment erosional processes (due to decreased basal cover) as well as solid waste presence has resulted in a decrease in the frequency of occurrence of most of the expected fish species. In addition, the presence of various dams within the catchment including Gariep Dam (Orange River) and Welbedacht Dam (Caledon River) within the system has created barriers for the movement of fish species from the lower reaches of the system while also creating artificially elevated source populations for several fish that thrive in lentic environments, including alien fish species.
<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>100.00</td><td>98.20</td></tr>
<tr><td>COVER</td><td>98.24</td><td>100.00</td></tr>
<tr><td>FLOW MODIFICATION</td><td>62.84</td><td>74.49</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>36.70</td><td>59.77</td></tr>
<tr><td>MIGRATION</td><td></td><td>72.64</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>13.97</td></tr>
<tr><td>FRAI</td><td colspan="2">PRESENT</td></tr>
<tr><td>FRAI (%)</td><td colspan="2">44.1</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">D</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates[b]</td><td>
This expansive and uniform river stretch exhibits limited biotopes for aquatic macroinvertebrates, largely due to substantial fine sediment loads and deposition. The prevailing biotope primarily consists of mud and sand, interspersed with small pockets of gravel. Marginal vegetation is notably scarce due to erosion of inset benches and lower banks, with only a few accessible roots for sampling. However, despite these limitations, the available biotopes along this stretch are relatively natural and comparable to reference conditions, except for the excessive sediment loads and deposition. The presence of highly erodible soils and steep eroded banks contributes to the significant sediment accumulation, resulting in elevated turbidity levels and compromised water quality throughout the river.
During the May 2023 survey, a total of 10 taxa were recorded, with most of them exhibiting a preference for slow-flowing to standing water and the GSM biotope. These taxa also demonstrate low to very low requirements for unmodified Physical-chemical conditions. The key taxa that characterise this site in terms of abundance and sensitivity included Baetidae >2spp, Caenidae, Chironomidae, and Hydropsychidae 1 spp. Except for Baetidae >2spp, all these taxa have an association with poor water quality, further supporting the previous statement.
</td></tr>
</table>

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><th colspan="2">INVERTEBRATE EC METRIC GROUP</th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>FLOW MODIFICATION</td><td>FM</td><td>70.2</td><td>0.321</td><td>22.5643</td><td>2</td><td>90</td></tr>
<tr><td>HABITAT</td><td>H</td><td>81.0</td><td>0.357</td><td>28.9116</td><td>1</td><td>100</td></tr>
<tr><td>WATER QUALITY</td><td>WQ</td><td>38.9</td><td>0.304</td><td>11.8233</td><td>3</td><td>85</td></tr>
<tr><td>CONNECTIVITY & SEASONALITY</td><td>CS</td><td>70.0</td><td>0.018</td><td>1.25</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>280</td></tr>
<tr><td>INVERTEBRATE EC</td><td></td><td></td><td></td><td>64.5492</td><td></td><td></td></tr>
<tr><td>INVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>C</td><td></td><td></td></tr>
</table>
Overall, the community represents moderately modified conditions (Ecological Category C, 64.55%), with water quality being the primary driver (38.9%), as explained earlier. Flow modification and habitat are the secondary and tertiary drivers, with scores of 70.2% and 81.0%, respectively. These modifications arise from reduced flows caused by upstream impoundments and water abstraction.
</td></tr>
<tr><td>Riparian vegetation[c]</td><td>
The riparian zone has become almost completely infested with alien trees (notably Acacia dealbata, Populus canescens, Robinia pseudoacacia, Salix babylonica), especially along the right bank. As a consequence, important indigenous woody species (i.e., Salix mucronata) have become largely absent and unable to recruit. Non-woody vegetation that once dominated the site has been removed through shading, and banks have become heavily degraded with a few gullies/dongas cutting down the banks into the channel. In addition, the riparian vegetation is also impacted by livestock grazing, harvesting of firewood, and large quantities of solid waste formed debris on banks and caught in the trees. Slight changes in water quality and quantity, from reference state, are also noted.
Although the marginal zone played a secondary role in riparian functions, it has become very narrow and confined due to changes in valley form and bank profile (i.e., steep banks lead directly down into the flat and wide channel that is completely sedimented). The lower bank would have played the most significant role in stabilizing banks and buffering impacts to the river, while the upper banks would have provided important functions such as fire continuity into the riparian zone from surrounding terrestrial grasslands.
Overall woody vegetation was secondary to non-woody vegetation which played the dominant role of maintaining the instream habitat integrity under natural conditions. However, the alien infestation resulted in a significant reduction in non-woody vegetation cover, abundance and species composition (mainly grasses).
</td></tr>
</table>

PES and causes

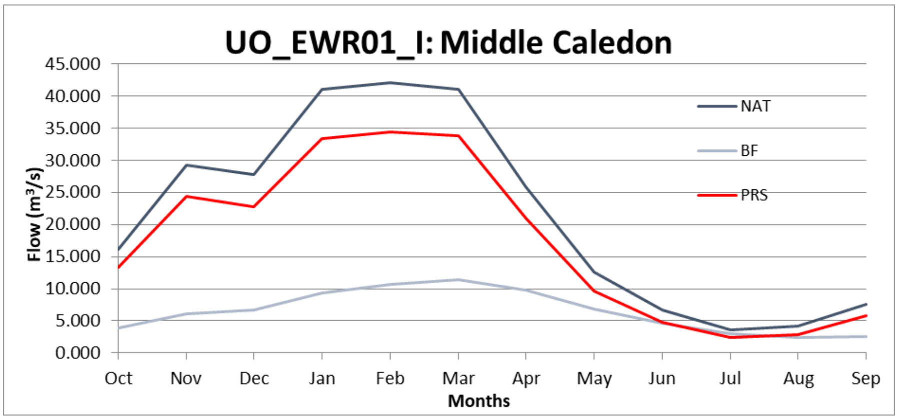
Component	Causes Present/Absent
	It was noted that large areas of exposed sand banks and alluvium would have characterised the site.

LEVEL 4 ASSESSMENT	EWR01_I: Caledon/Mohokare River (Middle)					29 May 2023
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	41.3	4.9	3.0	2.0	11.8	Weighted according to extent
Lower zone	23.4	6.9	3.0	1.0	29.4	Weighted according to extent
Upper zone	18.5	10.9	3.0	3.0	58.8	Weighted according to extent
LEVEL 4 VEGRAI (%)						22.6
VEGRAI Ecological Category						**E**
AVERAGE CONFIDENCE						3.0

	Sub-zone		
	Marginal zone	**Lower zone**	**Upper zone**
VEGRAI % (Zone)	41.3	23.4	18.5
EC (Zone)	**D/E**	**E**	**E/F**
Confidence (Zone)	3.0	3.0	3.0

Component	Causes Present/Absent
Hydrology[e]	The main change to the hydrology at this site is reduced low/ baseflows and moderate event (freshets). Some zero flows are recorded during very dry years.

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFI-DENCE**
LOW FLOWS	2	90	3.00	3
ZERO FLOW DURATION	1	100	2.00	2
SEASONALITY	2	80	0.00	2
MODERATE EVENTS	3	60	1.00	3
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	4	55	0.00	2
HYDROLOGY SCORE	**72.5**			
HYDROLOGY ECOLOGICAL CATEGORY	**C**			

PES and causes	
Component	**Causes Present/Absent**
	
Geomorphology[d]	The broad geomorphology, as classified by the geomorphic zone, of the middle Caledon has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the coarser habitats. Sandmining drives resuspension of fine sediment and forms low points along the bed profile that drives bed sediment redistribution. The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Alien vegetation shades out smaller growth forms, reducing ground cover and species diversity. The aliens can drive bank erosion through forming dense superficial root structures that are undercut and subsequently falls over and destabilises the banks. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently low habitat diversity and geomorphic stability within the channel and along the channel margins.

PES and causes	
Component	**Causes Present/Absent**

GEOMORPHOLOGY DRIVERS							
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.70	0.40	0.68	25.51	3.19
Sediment balance	3.00	70.00	3.15	0.28	0.88	14.55	3.15
Bed & bank stability	2.00	80.00	2.56	0.32	0.82	11.48	2.52
TOTALS		250.00		1.00	2.38		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					52.43		
HABITAT DRIVER CATEGORY					D	17.95	2.96
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					2.50	24.59	3.00
HABITAT CHANGE STATUS					50		
HABITAT CHANGE CATEGORY					D		

[a]Refer to Appendix B for the FRAI model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2
[b]Refer to Appendix C for the MIRAI model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2
[c]Refer to Appendix D for the VEGRAI model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2
[d]Refer to Appendix H for the GAI model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2
[e]Refer to Appendix I for the HAI model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	Given the degree of catchment-level impacts present, and assuming catchment impacts remain unchanged and no additional impacting factors are present, the ecological state of the fish assemblage is likely to remain unchanged.	2
Macroinvertebrates	Stable	Water quality modification is the primary driver influencing macroinvertebrate community health. However, further influenced by habitat modifications (sediment loads, eroded banks) and flow modification due to upstream impoundments and changes in flow regimes in the catchment from	2

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
		catchment-scale farming/agricultural activities. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time bcause of the proposed abstraction. Subject to EWR flows being met.	
Riparian vegetation	Stable	It is unlikely that the vegetation will degrade more than its current highly degraded state unless added pressures developed adjacent to the river as well as from upstream.	3
Hydrology	Stable	No recent changes to upstream water use or infrastructure developments	3
Geomorphology	Stable	The drivers have been altered several decades ago, so the reach has adapted to the new equilibrium. Further degradation will take place as the water resources are further developed.	3
Physical-chemical	Stable	The physical-chemical state of the system was changed from natural with the introduction of developments upstream, which have been around for a long time. The impacts of the Ficksburg WWTW have also been reported as a problem in 2011, suggesting that issue has been existing since before then.	3
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation *				
COMPONENT	**PES 2014**	**Cal_ EWR02, 2021**	**EcoStatus 2023[a]**	**REASON FOR DEVIATION**
ECOSTATUS	D	D	D/E	• Driven by the riparian vegetation owing to severe alien infestation and encroachment. • Exposed sand banks – lack of stability and opportunity for alien invasive encroachment. • Excessive sedimentation loads. • High sedimentation loads from upstream activities and highly erodible soils and steep eroded banks. • Cattle trampling and over grazing (unmanaged).

Overall change and reason for deviation *				
COMPONENT	**PES 2014**	**Cal_ EWR02, 2021**	**EcoStatus 2023[a]**	**REASON FOR DEVIATION**
				• High degradation resulting in compromised baseflows.

*It must be noted that cognisance was taken when comparing the PES, 2014 and the EcoStatus 2023. The PES, 2014 was based on various components, while the EcoStatus 2023 was based on results from surveys for fish, macroinvertebrates and riparian vegetation, or for Rapid 3 sites, the riparian habitat integrity was used as a surrogate. The reason for deviation is thus provided.
[a]Refer to Appendix F for the EcoStatus model of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023***
Moderate, Moderate	Moderate, Moderate

** Refer to Appendix G of Report number RDM/WMA13/00/CON/COMP/1123 (b): Eco-categorisation Report-VOLUME 2 for the EI-ES re-evaluation*

Physical-chemical state of the system
Impacts on the physical-chemical state of the system are largely a result of the Ficksburg WWTW that discharges raw sewage into the river upstream. The WWTW received a green drop score of 28% in 2021 and is currently classified as critical risk.

PES	REC		AEC	
D/E	D	• The E category for the PES is mainly due to the state of the riparian vegetation that is non-flow related. • As per DWS, if system degraded and in a category lower than a D, the REC should be a D.	C	• Clearing of alien vegetation along the riparian zone and ensuring the establishment of indigenous plants in the riparian zone and maintenance thereof through controlled grazing and trampling. • Overall land management (cattle overgrazing and trampling). • Improvement of the water quality by proper management of the Ficksburg WWTW.

OVERALL ASSESSMENT

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
AEC	C

Figure 7-3: Overall EcoStatus assessment for UO_EWR01_I (Middle Caledon)

The overall EcoStatus for this EWR site was categorised as a E, with the system in a serious to largely modified condition and the resilience of the system is often under severe stress (Figure 7-3). The degradation of the catchment is elevating suspended sediment loads, sedimentation of the channel and a reduction of habitat diversity as coarser habitats are covered by fine sediment. At the site, disturbance along the channel and margins (notably alien infestations and bank erosion) degrade the habitat associated with inset benches and banks. This is ultimately having a knock-on effect on the biota (fish and macroinvertebrates) of the system owing to altered system dynamics in the form of catchment-scale impacts. These result in a lack of diverse substrate/biotopes within the reach. Furthermore, the presence of impoundments within the system that act as a migratory barrier for fish species moving upstream from the Orange River system during seasonal migrations.

Alien trees in the riparian zone present a serious problem for the Caledon River, which will require significant investment of capital and resources to effectively manage the situation. Solid waste and failing sewer systems present a growing problem for the water quality of the system.

It is suggested that a REC and AEC of a D (largely modified) and a C (moderately modified) respectively can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Control of alien vegetation and associated rehabilitation of river banks is critically important for improving the future wellbeing of this water resource;
- DWS to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance;
- Ensure overall land management of upstream activities from both South Africa and Lesotho with regards to cattle overgrazing, trampling and overstocking;
- Land use activities within upstream 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
- Transboundary RQOs to be implemented per transboundary resource unit as per the ORASECOM RQO study currently being conducted (Report No.: ORASECOM RQO 004/2023_Draft) (ORASECOM, 2023b).

7.2 UO_EWR02_I: STERKSPRUIT

Sample Date	6 July 2022 30 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR02_I	**Prioritised RU**	R_RU01
River	Sterkspruit	**Altitude (m.a.s.l.)**	1429
Latitude	-30.51784446	**Longitude**	27.36907996
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D12B-05232
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	D (0.005; Upper Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-4) AND SITE PHOTOGRAPHS (Figure 7-5)

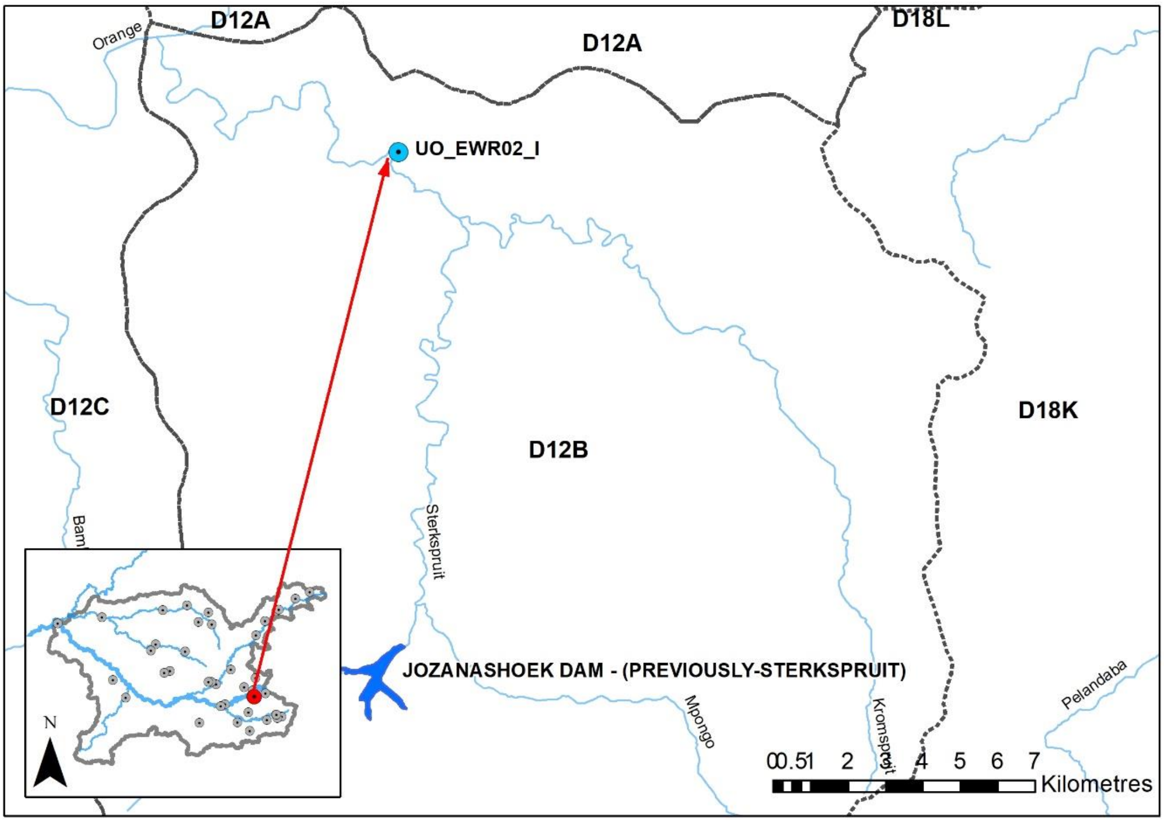


Figure 7-4: Location of site UO_EWR02_I (Sterkspruit) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)

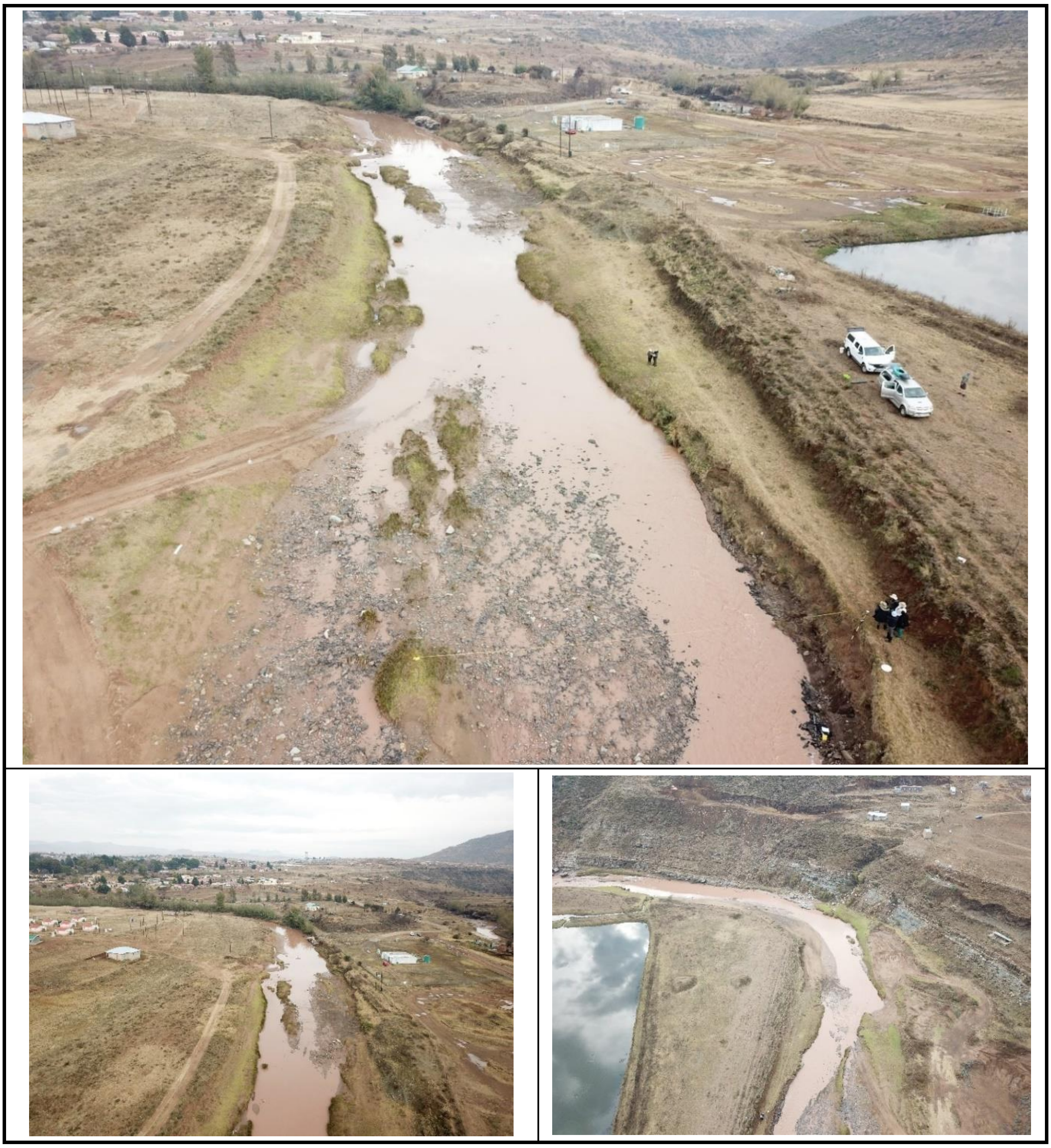


Figure 7-5: Site photographs of the Sterkspruit EWR site

Upstream	Downstream

Site Description:

The site is located downstream from the town of Sterkspruit and Hershell, but just upstream of the Sterkspruit sewage maturation pond (see inlet and overflow into the Sterkspruit in the above image). The valley setting is confined, with cobbles, boulder and bedrock forming riffles and pools. The river is ~5m to 10m wide (macro channel 30m wide) with some bed and channel modifications, erosion on both banks, and cattle trampling and grazing. Biotopes available for macroinvertebrates included SIC, SOOC and slated/fractured bedrock, along with Gravel, Sand, Mud (GSM) and limited marginal vegetation, owing to undercut banks and vegetation die-back during both surveys. For fish there was Slow-Deep (SD), Slow-Shallow (SS) and FS. Various sections of riffles and runs present. Moderate algae content and very high macroplastics in-stream, including domestic plastic (nappies).

During the May 2023 survey, the water was considerably turbid, likely owing to recent rainfall events resulting in sediment loading downstream. Furthermore, there is extensive sand mining taking place, particularly at the EWR site itself, in-channel (Figure 1), and just above the site, mountain cutting activities are taking place to clear foundations for settlements (Figure 2). All having a detrimental impact on the functioning of this ecosystem.

Both marginal and non-marginal zones have been severely impacted by sand mining operations at various points across the site, with additional impacts from rubbish dumping, livestock grazing/tramping, invasive alien plants (IAPs), bank erosion/collapse and sediment deposition.

Nevertheless, the riparian zone appears intact, with some encroachment from terrestrial plant species. Areas not directly impacted by sand mining support good marginal vegetation dominated by *Cyperus marginatus*. The non-marginal zone is dominated by the grass *Cynodon dactylon* and has a higher number of IAPs, notably Kikuyu (*Pennisetum clandestinum*), Tall Khaki Weed (*Tagetes minuta*) and Blackjack (*Bidens pilosa*).

Site impacts:

- Upstream construction and bridge collapse
- Localised and upstream sand mining
- The town of Sterkspruit and Hershell (possible water quality impacts)

- Cattle trampling and grazing
- Macroplastics

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023) at EWR site	Survey 2 (May 2023) downstream of maturation pond
pH	8.7	7.8	7.8
EC (µS/cm)	168	102.6	97.8
TDS (g/l)	0.138	0.09	0.08
DO (mg/l)	11.1	9.7	9.7
DO% (%)	108.7	102.6	88.1
Clarity (cm)	60	2.5	2.5
Temperature (°C)	14.2	10.9	10.9
Salinity (ppt)	0.10	0.07	0.06
Discharge (m3/s)	0.618	0.996	-

Diatoms:

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
July 2022 results				
17	12.1	C (Moderate)	19.8	0.75
Dominant Species		*Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
Preference		Nutrient and salinity increases (eutrophication)		
May 2023 results (diatom results at the EWR site to compare with the above)				
33	11.8	C (Moderate)	22.0	1.25
Dominant Species		*1. Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
		2. Navicula amphiceropsis Lange-Bertalot & Rumrich		
Preference		1. Nutrient and salinity increases (eutrophication)		
		2. Associated with anthropogenic pollution such as nutrients and electrolytes, largely related to cattle ranching near the studied water bodies.		

May 2023 results (diatom results downstream of the evaporation pond adjacent to the EWR sites)				
29	13.9	C (Moderate)	13.3	1.75
Dominant Species		*Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
Preference		Nutrient and salinity increases (eutrophication)		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Stable site with straight channel	• High roughness during low flows.
Fish	2	• FS, FD, SS, SD velocity-depth classes present	• None.
Macroinvertebrates	3	• SIC, SOOC and GSM available • Varying flow velocities	• Limited marginal vegetation owing to undercut banks and no instream aquatic vegetation. • Some bank erosion.
Riparian vegetation	3	• Good access to site, and across the site. Riparian vegetation is representative for the reach.	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	2.9	• Good access and no alien vegetation at the site. Water relatively clear	• At a transitional area just upstream of a steeper gorge.

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with two low flow observations
Fish		■				• PESEIS (2014) • July 2022 and May 2023 surveys
Macroinvertebrates			■			• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • July 2022 and May 2023 surveys
Hydrology		■				• Only monthly modelled data available for the period 1920-2004
Geomorphology			■			• Historical air photos and some literature on overgrazing and sediment dynamics

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Riparian vegetation			■			• Historical and recent aerial images • Single survey (May 2023)
Diatoms		■				• July 2022 and May 2023 diatom samples
Physical-chemical			■			• Green Drop Reports 2011, 2013 and 2021 on the Sterkspruit WWTW that discharges downstream but within same SQ reach as the monitoring site. • 2022 diatom results.

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Labeobarbus aeneus, Clarias gariepinus* and*Labeo capensis*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae 1sp, Baetidae 2spp, Caenidae, Leptophlebiidae, Oligoneuridae, Coenagrionidae, Lestidae, Aeshnidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae 1sp, Pisuliidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Muscidae, Simuliidae, Tabanidae, Ancylidae, Lymnaeidae, Physidae, Corbiculidae, Sphaeridae, Unionidae.
Riparian vegetation	Nested within the Grassland Biome and forms part of the Mesic Highveld Grassland Bioregion with two associated grassland types, namely Zastron Moist Grassland and Senqu Montane Shrubland. As a result, the riparian zone should support a grassland dominated community with *Cynodon dactylon* lawns incorporating various species of grasses and herbs from surrounding terrestrial grasslands. Woody shrubs and trees (e.g., *Diospyros lycioides*, *Sersia pyroides* and *Salix mucronata* subsp. *mucronata*) would occupy a small portion of the riverbanks with sedges and aquatic herbs occurring along the river margins.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Geomorphology	In its reference condition, the Sterkspruit site is likely to be a moderately steep cobble bed or mixed bedrock-cobble bed channel with pool-riffle or pool-rapid reach types. Sand and gravel bars can be present in pools. A narrow floodplain of sand, gravel and cobble could be present.
Physical-chemical	Reference physical-chemical data for the site could not be obtained. Diatom data were used to infer the reference condition at the site. The diatom results indicated periodic nutrient and salinity increases at the site. Lower

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
	nutrient concentrations and salinities are expected to prevail at the site under reference conditions

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	D/E (39.5%)	NF	• High degree of sediment input due to loss of basal cover within catchment. • Water quality impairment due to failing/non-functional sewage treatment works.
Macroinvertebrates (MIRAI)	D (49.4%)	NF	• Water quality impairment due to failing/non-functional sewage treatment works, high sediment inputs. • Algae smothering the SIC and SOOC biotope (nutrients) • Bank erosion thus hampering marginal vegetation biotope.
Riparian vegetation (VEGRAI)	D (49.9%)	NF	• Sand mining resulting in removal of vegetation cover, and increased bank collapse. • Grazing pressure resulting in reduced grass cover, increasing bank erosion and collapse. Alien infestation, notably Kikuyu grass.
Geomorphology (GAI)	D (47.0%)	32% F related	• Localised weirs and the Josana's dam that trap coarser bedload. Some storage of flood waters in Jozanashoek's Dam, possibly offset by increased runoff from severely overgrazed and gullied hillslopes. • 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. Bank and bench erosion along the left bank, erosion of inset bench along right bank.
Hydrology (HAI)	C (70.1%)	F	• Mainly domestic water use. • Large dam in upper reaches Jozanashoek Dam (D1R001) to provide water to towns of Sterkspruit/ Hershell.
Physical-chemical (Diatoms)	C	NF	• As a result of the lack of Physical-chemical data for the sites, diatoms were used to infer the present Physical-chemical state.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
			• Diatom results indicated periodic nutrient and salinity increases at the site leading to eutrophication. • Downstream of the EWR site but within the same SQ Reach as the Sterkspruit WWTW, which is currently discharging untreated wastewater into the Sterkspruit River, largely impairing the Physical-chemical state of the system.
ECOSTATUS	D (47.3%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	Due to the stream size, much of the fish presence within the reach under reference conditions was expected to be seasonal, with larger species moving into the reach from the Orange River during seasonal summer migrations for breeding purposes. However, loss of basal cover within the catchment which results in significant turbidity during rainfall events as well as water quality impacts (primarily from input of untreated sewage from failing/non-operational sewage treatment works) have resulted in the presence of a physical-chemical barrier to upstream migration, reducing the frequency of occurrence for resident as well as seasonal migrant species within the reach.
Macroinvertebrates	The biotopes of the Sterkspruit were dominated by a combination of GSM bedrock and SIC. The marginal vegetation was limited during both surveys

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	100.00	100.00
COVER	98.12	98.92
FLOW MODIFICATION	64.31	79.52
PHYSICAL-CHEMICAL	34.82	56.92
MIGRATION		62.53
IMPACT OF INTRODUCED		28.42
FRAI	PRESENT	
FRAI (%)	39.5	
EC: FRAI	D/E	

PES and causes	
Component	**Causes Present/Absent**
	owing to undercut banks. During the July 2022 and May 2023 surveys, a total of 15 and 14 taxa were recorded respectively, resulting in a community of 19 taxa. The aquatic macroinvertebrate community collected was determined to be representative of being largely modified conditions (Ecological Category D, 49.31%). Thus, there has been substantial change or loss of natural habitat, biota and basic ecosystem functions have occurred. The community mostly comprised those taxa with a preference for standing water, stones biotope and which have requirements for low to very low requirement for unmodified physical-chemical conditions. Taxa sensitive to flow and water quality which were recorded in July 2022 included, Perlidae, Baetidae >2spp and Trichorythidae. None of these taxa were recorded in May 2023, only Baetidae 2spp was recorded, as well as one individual of Athericidae. A high number of taxa expected to be present, and with a high expected frequency of occurrence, were absent from the macroinvertebrate assemblage for this site. These mostly had a preference for moderately fast flowing water and the stones biotope. Absent sensitive taxa included Heptageniidae, Leptophlebiidae, Hydropsychidae >2spp, Helodidae and Dixidae, all of which are sensitive to water quality, flow, and habitat. Comparing the structure of the macroinvertebrate community between the two surveys (July 2022/May 2023), the latter survey identified that the macroinvertebrate community appeared to have responded to water quality impairments. The majority of the assemblage had a preference for low to very low requirement for unmodified physical-chemical conditions. During the July 2022 survey, sensitive taxa viz Perlidae, Baetidae>2spp and Trichorythidae, were recorded. Except for Baetidae 2spp, all of these were absent in May 2023. During the May 2023 survey, in-channel sand mining appears to be increasing, while just upstream of this site turning into a dumping area for the town. The town of Sterkspruit occurs immediately upstream and a Wastewater Treatment Works directly adjacent to the site, but with its outlet downstream of the site. Consequently, the change in the macroinvertebrate community is indicative of deteriorating water quality

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><th>INVERTEBRATE EC METRIC GROUP</th><th></th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>FLOW MODIFICATION</td><td>FM</td><td>60.7</td><td>0.327</td><td>19.8778</td><td>2</td><td>90</td></tr>
<tr><td>HABITAT</td><td>H</td><td>49.5</td><td>0.291</td><td>14.4091</td><td>3</td><td>80</td></tr>
<tr><td>WATER QUALITY</td><td>WQ</td><td>38.3</td><td>0.364</td><td>13.9321</td><td>1</td><td>100</td></tr>
<tr><td>CONNECTIVITY & SEASONALITY</td><td>CS</td><td>60.0</td><td>0.018</td><td>1.09091</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>275</td></tr>
<tr><td>INVERTEBRATE EC</td><td></td><td></td><td></td><td>49.3099</td><td></td><td></td></tr>
<tr><td>INVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>D</td><td></td><td></td></tr>
</table>
Inclusive, in the last hydrological year (2022-2023), the community was primarily driven by water quality (38.3%), habitat modification was the subsequent driver of the system (49.5%), likely owing to marginal vegetation being very limited at this site owing to undercut banks and the SIC biotope include bedrock and the flow modification (60.7%). The Average Score Per Taxon (ASPT) for the communities identified in July 2022 and May 2023 was 5.7 and 5.1, respectively, indicating that the community was mostly composed of tolerant taxa (Dickens and Graham, 2002).
</td></tr>
<tr><td>Riparian vegetation</td><td>
The site is relatively uniform in terms of vegetation structure and composition. The marginal zone has relatively good cover made up predominantly of Cyperus marginatus with the occasional Gomphostigma virgatum. There was increased bank erosion, and illegal sand mining is having the greatest impact on riparian vegetation across all zones. Similarly, the banks are heavily grazed by livestock resulting in loss of cover and opportunities for weedy and invasive species to establish, notably Pennisetum clandestinum (Kikuyu). On the upstream side, and mainly on the left bank, there is dense woody vegetation comprising mostly Populus canescens (Grey Popular).
The marginal zone plays a primary role in support of riparian functions, mainly through stabilizing the banks during high flows, and this zone would have been more structurally varied across the channel in response to the formation of gravel beds and sand bars under natural conditions. The lower and upper bank would assist in buffering impacts to the river.
Overall, the riparian vegetation was almost entirely maintained by non-woody vegetation with woody vegetation playing a small role. It was noted that the site would have been characterized by large areas of exposed sand banks and alluvium.
</td></tr>
</table>

PES and causes

Component	Causes Present/Absent
	(see table below)

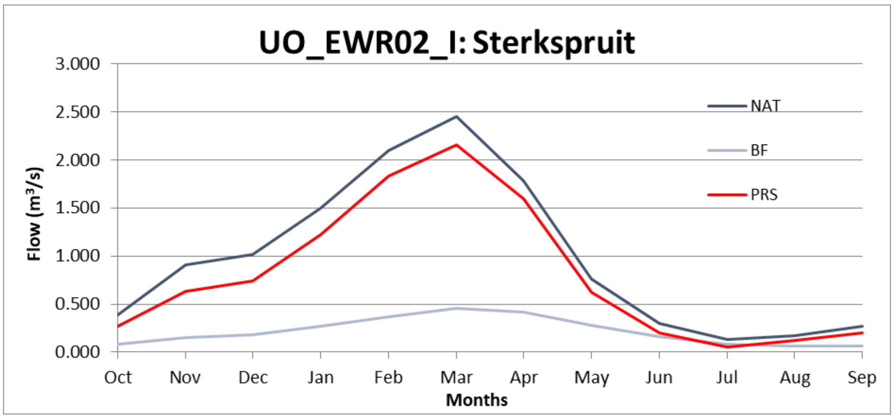
LEVEL 4 ASSESSMENT	EWR02_I: Sterkspruit River					30 May 2023
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	61.5	3.8	3.0	1.0	6.3	Weighted according to extent
Flood bench	45.0	28.1	3.2	2.0	62.5	Weighted according to extent
MCB	57.3	17.9	4.7	3.0	31.3	Weighted according to extent
0.0	not assessed			4.0		
0.0	not assessed			5.0		
0.0	not assessed			6.0		
	3.0				100.0	
LEVEL 4 VEGRAI (%)						49.9
VEGRAI Ecological Category						D
AVERAGE CONFIDENCE						3.6

	Sub-zone					
	Marginal zone	**Flood bench**	**MCB**	**0.0**	**0.0**	**0.0**
VEGRAI % (Zone)	61.5	45.0	57.3	not assessed	not assessed	not assessed
EC (Zone)	**C/D**	**D**	**D**			
Confidence (Zone)	3.0	3.2	4.7			

Hydrology

The low flows were impacted most due to upstream water abstractions. Freshets have been reduced with Jozanashoek Dam in the upper reaches of the Sterkspruit.

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFI-DENCE**
LOW FLOWS	2	90	3.0	3
ZERO FLOW DURATION	1	100	1.0	3
SEASONALITY	4	65	0.0	4
MODERATE EVENTS	3	80	2.0	4
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	5	60	1.0	4
HYDROLOGY SCORE	**70.1**			
HYDROLOGY ECOLOGICAL CATEGORY	**C**			

PES and causes	
Component	**Causes Present/Absent**
	
Geomorphology	The broad geomorphology, as described by the geomorphic zone, of the Sterkspruit has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the coarser habitats. Localised sandmining drives resuspension of fine sediment and forms low points along the bed profile that drives bed sediment redistribution and instability. Bedload has also been reduced by the Jozanashoek Dam in the upper catchment. The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently low habitat diversity and geomorphic stability within the channel and along the channel margins.

PES and causes

Component	Causes Present/Absent
	GEOMORPHOLOGY DRIVERS (see below)

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	2.63	0.43	1.14	40.00	2.88
Sediment balance	2.00	70.00	3.09	0.30	0.94	25.65	3.04
Bed & bank stability	3.00	60.00	2.18	0.26	0.57	27.06	2.74
TOTALS		230.00		1.00	2.65		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					47.03		
HABITAT DRIVER CATEGORY					D	32.26	2.89
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					2.70	43.94	3.00
HABITAT CHANGE STATUS					46.06061		
HABITAT CHANGE CATEGORY					D		

Ecological trends for the EWR site (include components that were assessed)

Component	Trend (stable, decline, improvement)	Reason	Confidence (0-5)*
Fish	Decline/stable	• Increased catchment development • Failing sewage infrastructure	3
Macroinvertebrates	Decline/stable	• Increased catchment development • Water quality continues to be compromised due to unmaintained upstream and adjacent sewage infrastructure	3
Riparian vegetation	Decline	• Sand mining operations have been increasing over the last five to ten years. • Expected that water quality impacts will affect riparian vegetation given the indications of failing sewer infrastructure from the town.	2
Hydrology	Stable	• No new large scale water developments in catchment	3
Geomorphology	Decline/stable	• Already degraded with ongoing pressures, so possibly stable	3
Physical-chemical	Decline	• Increased catchment development • Water quality continues to be compromised due to unmaintained	3

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
		upstream and adjacent sewage treatment infrastructure • In-stream sand mining	
ECOSTATUS	Decline		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**

ECOSTATUS	C	D	• Seriously compromised water quality owing to the following:
			  • Raw sewage input from adjacent maturation pond
			  • Malfunctioning and unmaintained WWTW
			  • Upstream town of Sterkspruit - medical waste inputs
			  • Rubbish dumping within the riparian zone and in-stream
			  • Sediment run-off (expansion on rural settlements/complexes) and extensive sand mining activities
			• Poor land management practices (i.e., localised sand mining, rubbish dumping, urban growth, maturation pond mal-functioning)

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023***
Moderate, High	Moderate, Moderate

Physical-chemical state of the system
The Physical-chemical state of the system is likely to be adversely impacted by the surrounding residential and industrial areas the river flows through upstream. The Sterkspruit WWTW that discharges into this river reach also has an impact on the system. Although the WWTW discharges downstream of the EWR site, it is still within the same SQ reach. The WWTW has been dysfunctional as far back as 2011 (earliest record of impacts potentially predate this record). The WWTW is currently classified as critical risk, with an effluent compliance of 15%, likely to alter the Physical-chemical state of the receiving water resource. The *in situ* water quality results appear to be within TWQR limits with elevated pH. This is likely to change downstream after the WWTW discharges into the river.

PES	REC		AEC	
D	C/D	• 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, this will provide an opportunity to improve the biotic state of the system, coupled with adequate flows; and • Maintenance and upgrade of WWTW infrastructure, including the upgrade and functioning of the adjacent maturation pond.	C	• Overall improvement and functionality of land and catchment management practices: • Maintenance and upgrade of WWTW infrastructure, including the upgrade and functioning of the adjacent maturation pond; • Informal and illegal sand mining practices to be halted, the necessary approvals sought, and management methods required for this activity; • Sediment traps to prevent excessive sediment run-off into the river; • Controlled surrounding urban development and informal settlements; • Better management of rubbish dumping facilities and the complete prevention of rubbish dumping within the river; • Planning design around road network, catchment sediment drains; and • Town clean up (local municipality to take accountability and responsibility).

OVERALL ASSESSMENT

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
AEC	C

Figure 7-6: Overall EcoStatus assessment for UO_EWR02_I (Sterkspruit)

The overall EcoStatus for this EWR site was categorised as a D, with the system being largely modified (Figure 7-6). A large change or loss of natural habitat, biota and basic ecosystem functions have occurred. The degradation of the catchment is elevating suspended sediment loads, sedimentation of the channel and a reduction of habitat diversity as coarser habitats are covered by fine sediment. At the site, disturbance along the margins degrades the habitat associated with inset benches and banks.

Water quality is highly compromised along this reach, primarily owing to dysfunctional and unmaintained WWTW, including the adjacent maturation pond with a direct outlet into the river, just downstream of this EWR site. Thus, all the above, compromising the health and integrity of the biotic community.

Macroinvertebrates are evidently responding to poor water quality, despite adequate habitat availability and hydraulic features. From a fish perspective, although the reach is not expected to support a diverse assemblage of fish under reference conditions and fish expected to be present are considered to be moderately tolerant to water quality impacts, current catchment practices and failing sewage infrastructure has resulted in lower frequencies of occurrence of some of the expected species as well as the expected loss of several species from the reach. Riparian vegetation has been impacted by livestock for many years resulting in overgrazing, trampling, and even bank erosion/collapse. Illegal sand mining activities in more recent years has resulted in extensive degradation of the riparian habitats.

It is suggested that a REC and AEC of a C/D (close to moderately modified) and a C (moderately modified) respectively can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-6).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- DWS to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance, including the adjacent maturation pond;
- Upstream municipal infrastructure to be reviewed and maintained/upgraded; and
- Land use activities within upstream 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 better management of the sand mining activities.

7.3 UO_EWR03_I: UPPER ORANGE

Sample Date	7 July 2022 30 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR03_I	**Prioritised RU**	R_RU02a
River	Upper Orange	**Altitude (m.a.s.l.)**	1302
Latitude	-30.652888889	**Longitude**	26.82304963
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D12F-05348
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	F (0.001; Lowland)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-7) AND SITE PHOTOGRAPHS (Figure 7-8)

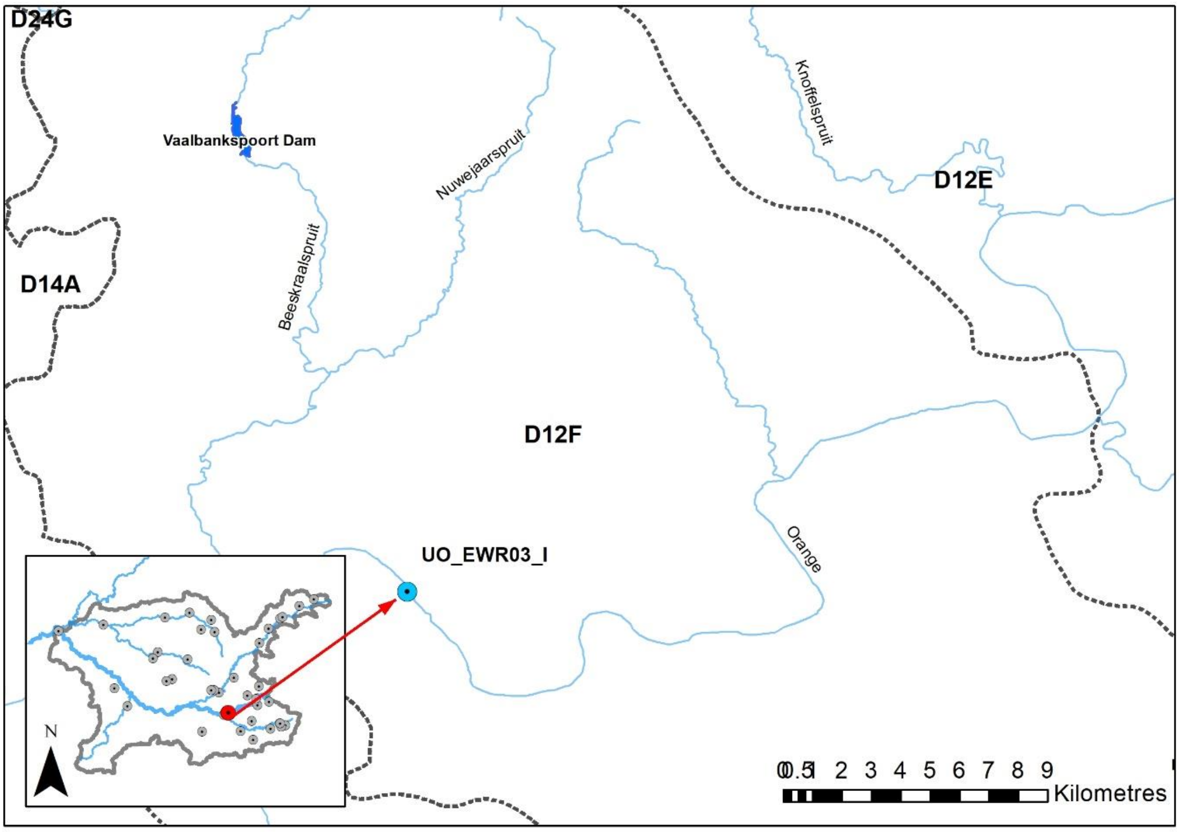


Figure 7-7: Location of site UO_EWR03_I (Upper Orange) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)
(Drone pics could not be taken owing to rainfall during the survey and lightning)

Figure 7-8: Site photographs of the Upper Orange EWR site

Upstream	Downstream

Site Description:

The site is located along a partly confined valley setting with terraces and narrow flood benches along both banks with an incised channel. The river is ~120m wide and homogenous sand bed channel with limited habitat diversity and exposed sand bars along the right bank. The site is located ~8 km upstream from the confluence of the Kraai River. The surrounding area is mostly agriculture with small-scale croplands and grazing areas. Intense in-stream sand mining both downstream and upstream of the site. The macrochannel is sandy and the steep fine sand and silt banks prove to be highly erodible. Both banks show recent erosion along the lower margins, removing inset benches. Thickets of heavy infestation of alien *Salix sp*. and Populus sp. on both sides of the riverbanks. However, it is likely these trees are aiding in stabilising the macro channel banks to limit lateral migration. The water is turbid, and the riverbed is dominated by a featureless sand bed.

Biotopes available for macroinvertebrates was only sand and mud, there was no gravel or any stones biotope. Marginal vegetation comprised fallen down tree debris. Banks are undercut and eroded, owing to previous floods with limited inset bench development or marginal vegetation establishment. For fish there was FD and SS habitats.

The incised Orange River Channel has steep banks with a relatively narrow band of riparian vegetation, which is infested by alien Popular (*Populus candescens*), particualrly of the right bank, as well as Weeping Willow (*Salix babylonica*), Tall Fleabane (*Erigeron sumatrensis*), Tall Khaki Weed (*Tagetes minuta*) and Blackjack (*Bidens pilosa*). The marginal zone is inundated by high baseflows, and the lower banks are devoid of vegetation with bare, exposed soils beneath a largely woody canopy. The upper banks also include some indigenous thicket dominated by Wild Olive (*Olea europeae africana*), Common Currant (*Searsia pyroides*), Star Apple (*Diospyros lycioides*) and River Honey-thorn (*Lycium hirsutum).*

Site impacts:

- Upstream intense sand mining
- Future influence: proposed dam upstream
- Small-scale croplands
- Cattle grazing and trampling
- Reduced flows (all components) due to dams in Lesotho and abstractions for irrigation

SUMMARY RESULTS

WATER QUALITY AND FLOW

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.8	8.3
EC (µS/cm)	155	139.4
TDS (g/l)	0.15	0.12
DO (mg/l)	10.7	8.9
DO% (%)	93.0	82.1
Clarity (cm)	27	12
Temperature (°C)	9.0	11.7
Salinity (ppt)	0.11	0.09
Discharge (m^3/s)	41.000	81.596

Diatoms:

No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
July 2022 results				
16	*9.2*	C (Moderate)	*83.1*	*0.5*
Dominant Species		6. *Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
		7. *Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot*		
Preference		1. Tolerant of strong pollution and an indicator of industrial organic pollution		
		2. Very pollution tolerant - organic pollution		
May 2023 results				
30	**10.9**	C (Moderate)	36.5	0
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of strong pollution, indicator of industrial organic pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2.5	• Simple straight channel form	• Highly mobile bed, changes to channel form likely
Fish	2	• None	• Alluvial reach with limited cover features • Limited collection records • Seasonal & sampling limitations
Macroinvertebrates	3	• None	• Wide, deep, homogenous channel • Limited aquatic biotopes – dominated by mud • No marginal vegetation, high erosion and undercut banks • High suspended sediment concentration (high turbid waters)
Riparian vegetation	2	None	• Only the right bank was accessed, which is steep with collapsing banks. • Both banks have dense stands of alien trees.

			• Challenging weather conditions – heavy rainfall and thunder. • Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	2.9	• Distant from any channel modifications	• Fairly high flows and turbid water reduces bed observations

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with one flow observation during moderate flow level
Fish		■				• FROC (Kleynhans et al., 2008) • PESEIS (2014) • July 2022 survey
Macroinvertebrates			■			• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • July 2022 survey
Hydrology		■				• Monthly modelled hydrology for the period 1920-2004. • Gauge D1H009 at Oranjedraai could be used as a guide for the setting of freshets and floods.
Geomorphology			■			• Historical aerial images and literature on changes to land cover and sediment dynamics
Riparian vegetation			■			• Historical and recent aerial images • May 2023 survey (with limitations)
Diatoms		■				• July 2022 and May 2023 diatom samples
Physical-chemical			■			• Green Drop Reports 2011, 2013, 2021 and 2022. • July 2022 and May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Atyidae, Perlidae, Baetidae 2spp, Caenidae, Leptophlebiidae, Trichorythidae, Coenagrionidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Hydrometridae, Naucoridae, Hydropsychidae 2spp, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Muscidae, Simuliidae, Tabanidae.
Riparian vegetation	The site is primarily defined by Upper Gariep Alluvial Vegetation comprising well-defined riparian thickets along the edge of the broad and flat alluvial terrace of the Orange River. Riparian thickets would be dominated trees and shrubs: *Vachellia karroo*, *Celtis africana*, *Diospyros lycioides*, *Lycium hirsutum*, *Olea europaea* subsp. *africana*, *Salix mucronata* subsp. *mucronata*, *Searsia pyroides* and *Ziziphus mucronata*. The river margins would have supported reedbeds and flooded grasslands on exposed alluvium. The surrounding terrestrial vegetation transitions from Dry Highveld Grassland (of the Grassland Biome) into Upper Karoo (of Nama-Karoo Biome) and comprises a mosaic of Aliwal North Dry Grassland and Besemkaree Koppies Shrubland.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Geomorphology	Low gradient alluvial fine bed channel with limited lateral migration along unconfined reaches, resulting in a straight to wandering channel, with a braided pattern at very low flows. Deeper channels, pools and vegetated or bare (recently deposited) inset benches provide habitat along the margins. The bank will have a moderate gradient and will have a narrow active floodplain, set between the higher lying terraces. The lower banks will be largely treeless.
Physical-chemical	Reference Physical-chemical data for the site could not be obtained. Diatom results were used to infer the reference condition at the site. The diatom results indicated heavy organic pollution at the site. Lower nutrient concentrations are expected to be prevalent under reference condition at the site, and with no input from upstream sources, especially the Sterkspruit WWTW.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	D (54.0%)	F/NF	• Alluvial bed with high mobility • Limited cover features within channel • Hydrological and water quality modification due to catchment activities (high erosion rates due to loss

			of basal cover, increased catchment) and upstream impoundments within Lesotho
Macroinvertebrates (MIRAI)	C/D (60.6%)	NF	• Large, deep homogenous system with limited to no aquatic biotopes (dominated by mud owing to alluvial bed) • Bank erosion and cattle trampling and grazing – hampering marginal vegetation aquatic biotope • Considerable fine sediment loads through the system (water quality)
Riparian vegetation (VEGRAI)	D (57.3%)	NF	Site is heavily impacted by alien trees, notable *Populus canescens*, resulting in widespread removal of non-woody cover and bank destabilisation, especially along marginal and lower zones.
Geomorphology (GAI)	C (61.0%)	19% F related	• Low density of smaller farm dams and weirs along the tributaries that trap coarser bedload. Katse and Mohale Dams reduce longitudinal transport of suspended and bed material from parts of the upper catchment, partly offsetting the high sediment input from the lower parts of the catchment. Some storage of flood waters in smaller dams, possibly offset by increased runoff from overgrazed and gullied hillslopes, largely in Lesotho. • Widespread overgrazing and soil erosion in the catchment (largely Lesotho and communal land) elevating fine sediment loads. Dams and weirs along tributaries and mainstem traps suspended and coarser bed sediment, partly offsetting the increases in sediment load. • Trampling and alien trees along banks and floodplain. Bank and bench erosion along both banks, resulting in a featureless marginal zone with steep banks. High sediment load results in plain bed with low habitat diversity and high silt content.
Hydrology (HAI)	D (55.7%)	F	• Direct abstractions from Orange River upstream of site for mainly irrigation purposes. • Dams in Lesotho impacting on all the flow components.
Physical-chemical (Diatoms)	C	NF	• Present Physical-chemical state of the system was estimated from the diatom results, due to the lack of Physical-chemical data for the PAI. • Diatom results indicated that the site experiences heavy organic pollution. • Elevated nutrient concentrations are expected to be prevalent at the site as a result 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.
ECOSTATUS	D (57.7%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td>Fish</td><td>This reach of the Orange River is characterised by laminar flow over an alluvial bed, with limited cover elements present. Fish species expected under reference conditions are all considered to be eurytopic and moderately tolerant to water quality impairment, with varying velocity-depth and cover preferences.

During the July 2022 survey, only two (2) of the seven (7) expected fish species were collected, with only a single specimen of each specie collected. It is however acknowledged that seasonal limitations were likely to impact results obtained, as was difficulty of sampling. Nevertheless, the species collected are likely to be permanent residence of the reach, albeit with a marginally lower frequency of occurrence. Although the reach was expected to act as a migratory conduit for species moving upstream during seasonal summer flows, the lack of cover features as well as the increased sediment input from upstream catchment erosional processes (due to decreased basal cover) has resulted in a decrease in the frequency of occurrence of most of the expected fish species. In addition, the presence of various dams within the catchment including Van Der Kloof Dam and Gariep Dam within the system has created barriers for the movement of fish species from the lower reaches of the system while also creating artificially elevated source populations for several fish that thrive in lentic environments, including alien fish species. Furthermore, development of various impoundments within the headwaters of Lesotho has resulted in flow modifications and possible decreased migratory cues.

<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>100.00</td><td>100.00</td></tr>
<tr><td>COVER</td><td>97.34</td><td>98.52</td></tr>
<tr><td>FLOW MODIFICATION</td><td>62.11</td><td>73.02</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>60.41</td><td>66.15</td></tr>
<tr><td>MIGRATION</td><td></td><td>62.21</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>44.43</td></tr>
<tr><td>FRAI</td><td colspan="2">PRESENT</td></tr>
<tr><td>FRAI (%)</td><td colspan="2">54.0</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">D</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates</td><td>The site's aquatic macroinvertebrate habitat exhibited limited diversity, with sand and mud being the predominant substrates. Marginal vegetation</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	was mostly absent, except for a few dead tree branches extending into the water. Unfortunately, due to inclement weather including heavy rain and lightning, sampling could not be conducted during the May 2023 survey. Therefore, the interpretation provided is solely based on a single survey conducted in July 2022. The 10 taxa recorded in July 2022, primarily indicated a preference for standing water and a muddy substrate, with low to very low requirements for unmodified physical-chemical conditions. Consequently, the assemblage represents moderate to largely modified conditions (C/D, 60.55%). The most impacted metrics at the site were water quality and habitat modification, scoring 51.3% and 57.1%, respectively, followed by flow modification at 66.0%. Erosion poses a significant challenge within the upper and surrounding catchment, particularly on the Eastern Cape side of the river. Extensive informal and rural settlements, along with excessive overgrazing and sand mining, have negatively affected the riparian and terrestrial vegetation, leading to increased runoff rates and volumes. This has resulted in habitat loss through sedimentation, which is further exacerbated by local sand mining. Several taxa were expected but absent from the assemblage, including Atyidae, Hydracarina, Aeshnidae, Corduliidae, Elmidae, and Hydraenidae. These taxa have varying preferences for velocity and habitat conditions, but all share a moderate requirement for modified physical-chemical conditions. This observation reinforces the notion that water quality is the primary driver affecting this community.

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	66.0	0.254	16.7619	3	80
HABITAT	H	57.1	0.317	18.1406	1	100
WATER QUALITY	WQ	51.3	0.302	15.4863	2	95
CONNECTIVITY & SEASONALITY	CS	80.0	0.127	10.1587	4	40
						315
INVERTEBRATE EC				60.5475		
INVERTEBRATE EC CATEGORY				C/D		

Riparian vegetation	The riparian zone has become infested with alien trees, notably *Populus canescens*, as well as *Acacia dealbata*, *Salix babylonica*. *Phragmites australis* which should be present was not observed along the margins, and indigenous woody species (i.e., *Salix mucronata*) represented a low

PES and causes

Component	Causes Present/Absent
	proportion of cover and abundance, with recruitment also impacted as a result of competition from alien trees. Non-woody vegetation that once occupied spaces between woody vegetation has been largely removed through shading, and banks have become degraded with bank collapse noted at various points along the lower banks. Riparian vegetation does not appear to have been significantly impacted by changes in water quality and quantity. Under natural conditions woody vegetation within the lower and upper zones would have played a primary role in maintaining instream habitat integrity, particularly in terms of stabilizing banks and buffering impacts to the river. It was noted that the marginal zone would have naturally contained large areas of exposed sand banks and alluvium.

LEVEL 4 ASSESSMENT	EWR03_I: Upper Orange					30 May 2023
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	29.6	0.4	2.8	2.0	1.2	Weighted according to extent
Lower zone	37.2	9.2	2.7	1.0	24.7	Weighted according to extent
Upper zone	64.4	47.7	2.6	3.0	74.1	Weighted according to extent
LEVEL 4 VEGRAI (%)						57.3
VEGRAI Ecological Category						**D**
AVERAGE CONFIDENCE						2.7

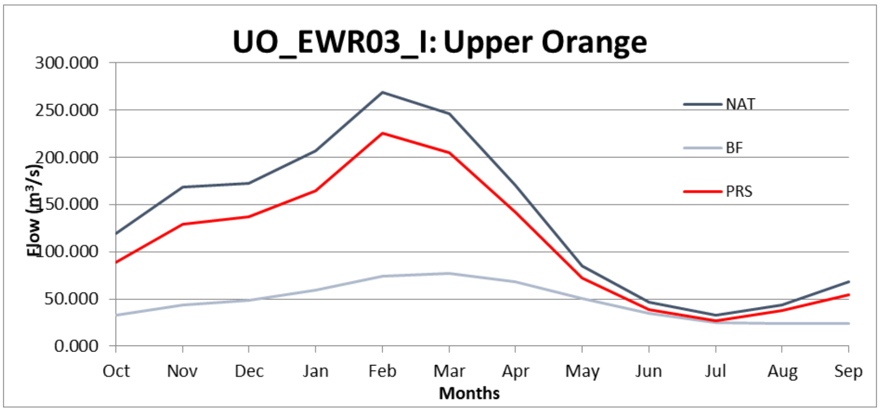
				Sub-zone		
	Marginal zone	**Lower zone**	**Upper zone**	**0.0**	**0.0**	**0.0**
VEGRAI % (Zone)	29.6	37.2	64.4	not assessed	not assessed	not assessed
EC (Zone)	**E**	**E**	**C**			
Confidence (Zone)	2.8	2.7	2.6			

Component	Causes Present/Absent
Hydrology	All the flow components have been impacted by the upstream dams (Lesotho) and abstractions for irrigation.

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFI-DENCE**
LOW FLOWS	3	80	3.0	3
ZERO FLOW DURATION	1	100	0.0	3
SEASONALITY	2	90	1.0	3
MODERATE EVENTS	3	80	4.0	2
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	4	70	4.0	2
HYDROLOGY SCORE	**55.7**			

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>

HYDROLOGY ECOLOGICAL CATEGORY	**D**



</td></tr>
<tr><td>Geomorphology</td><td>The overall geomorphology, as described by the geomorphic zone, of the Upper Orange has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. Localised sandmining drives resuspension of fine sediment and forms low points along the bed profile that drives bed sediment redistribution and instability. Bedload has also been reduced by the Katse and Mohale dams and weirs in the catchment.
The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Alien vegetation shades out smaller growth forms, reducing ground cover and species diversity. The aliens can drive bank erosion through forming dense superficial root structures that are undercut and subsequently falls over and destabilises the banks. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently low habitat diversity and low geomorphic stability within the channel and along the channel margins.</td></tr>
</table>

PES and causes

Component	Causes Present/Absent
	GEOMORPHOLOGY DRIVERS (see table below)

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.61	0.40	0.64	25.51	2.75
Sediment balance	3.00	70.00	2.46	0.28	0.69	20.00	2.82
Bed & bank stability	2.00	80.00	1.87	0.32	0.60	11.11	3.04
TOTALS		250.00		1.00	1.93		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					61.36		
HABITAT DRIVER CATEGORY					C	19.36	2.86
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					2.27	15.41	2.60
HABITAT CHANGE STATUS					54.59459		
HABITAT CHANGE CATEGORY					D		

Ecological trends for the EWR site (include components that were assessed)

Component	Trend (stable, decline, improvement)	Reason	Confidence (0-5)*
Fish	Stable/Decline	• Proposed Polihali Dam in Lesotho and possible dam upstream of EWR site to further change the flow regime • Further catchment degradation and sediment input expected	3
Macroinvertebrates	Stable	• Habitat availability remains naturally poor along this reach, thus no improvement to biotopes to improve the integrity or diversity of the macroinvertebrate community • 89% of the reference ASPT	3
Riparian vegetation	Stable	• It is unlikely that the vegetation will degrade more than its current highly degraded state unless added pressures developed adjacent to the river as well as from upstream through significant flow alterations.	3
Hydrology	Decline	• Proposed Polihali Dam in Lesotho and possible dam upstream of EWR site to further change the flow regime	2

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Geomorphology	Decline	• Ongoing catchment degradation and trees stabilising banks	3
Physical-chemical	Stable/Decline	• Sedimentation loading • Upstream sand mining compromising the water column	3
ECOSTATUS	Decline		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	D	• Continued sediment loads and deposition from upstream catchment wide activity. • Limited habitat availability for biota. • Limited moderate events mobilising the sediments to move downstream and reset substrate. • Changes to all the flow components due to large upstream dams.

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
High, High	Moderate, Moderate

Physical-chemical state of the system
Clarity was relatively low at this site, likely as a result of the intense sandmining upstream. The pH was also elevated although still within guideline limits (5.5 to 9 pH units).

PES	REC		AEC	
D	D	• Manage and maintain the EcoStatus	C/D	• This reach is not driven by water quality, but more so from sediment loads stemming from upstream activities; • Reduced flows; • Catchment and land management (sand mining, upstream practices within Lesotho); and • Lesotho to deliberate on implementing environmental flows.

OVERALL ASSESSMENT

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
AEC	C/D

Figure 7-9: Overall assessment for UO_EWR03_I (Upper Orange)

The overall EcoStatus for this EWR site was categorised as a D, with the system being largely modified (Figure 7-9). The degradation of the catchment is due to elevated suspended sediment loads, sedimentation of the channel and a reduction of habitat diversity as coarser habitats are covered by fine sediment and reduced flows. At the site, disturbance along the margins degrades the habitat associated with inset benches and banks. This is ultimately having a knock-on effect on the biota (fish and macroinvertebrates) of the system, owing to altered system dynamics in the form of catchment-scale impacts.
The development of several large impoundments within the upper reaches of the catchment (Lesotho) has resulted in altered hydrology as well as the lack of diverse substrate within the reach. The presence of impoundments and weirs below the reach that act as a migratory barrier, particularly for fish species moving upstream from the Orange River system during seasonal migrations.

The presence of Gariep Dam also offers an artificially elevated source population for several fish species moving upstream, including alien fish species. Alien trees present a major problem for riparian vegetation along the Orange River resulting in loss of function provided by native species, in particular protection and stabilisation of banks from floods and consequently erosion.

It is suggested that AEC of a C/D (close to moderately modified) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-9).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Catchment and land management (sand mining, upstream practices within Lesotho);
- Lesotho to deliberate on implementing environmental flows; and
- Transboundary RQOs to be implemented per transboundary resource unit as per the ORASECOM RQO study currently being conducted (Report No.: ORASECOM RQO 004/2023_Draft) (ORASECOM, 2023b).

7.4 UO_EWR04_I: LOWER CALEDON

Sample Date	11 July 2022 31 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR04_I	**Prioritised RU**	R_RU05
River	Lower Caledon	**Altitude (m.a.s.l.)**	1277
Latitude	-30.28011493	**Longitude**	26.65306029
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D24G-04958
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	F (0.001; Lowland)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-10) AND SITE PHOTOGRAPHS (Figure 7-11)

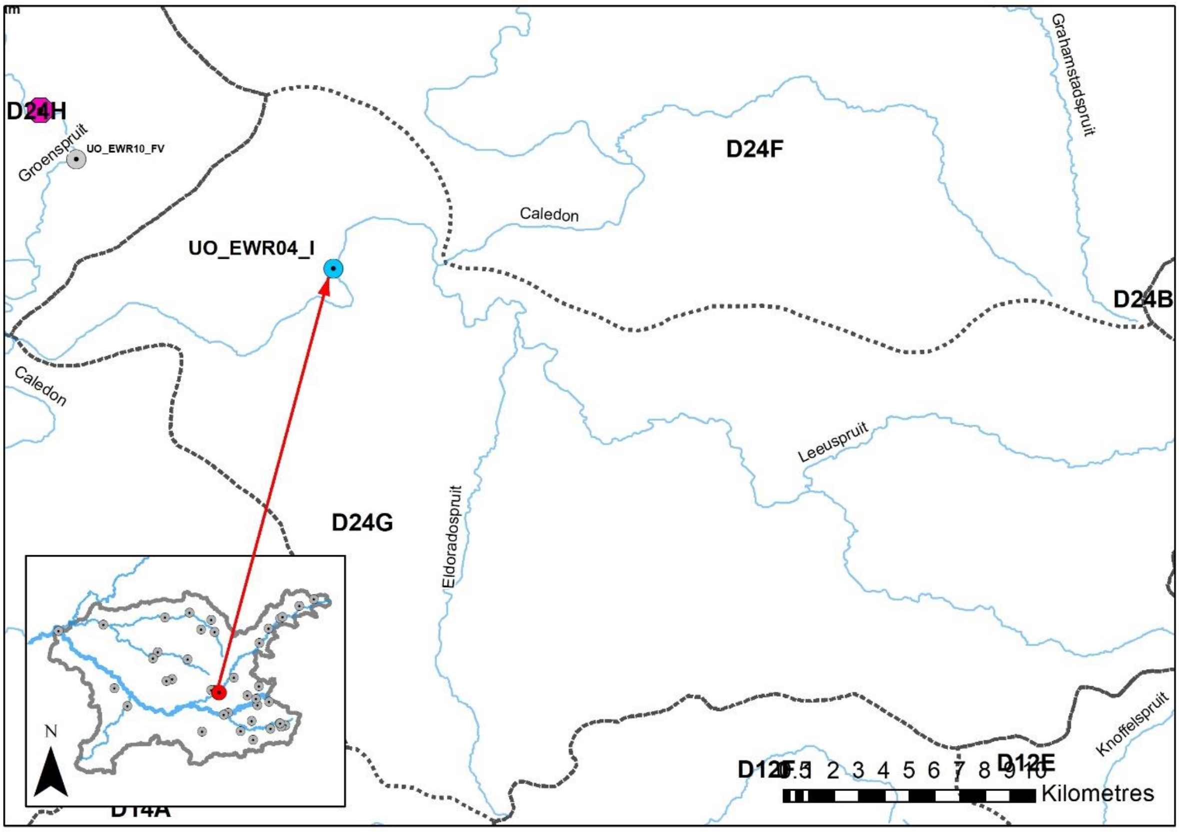


Figure 7-10: Location of site UO_EWR04_I (Lower Caledon) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)

Figure 7-11: Site photographs of the Lower Caledon EWR site

Upstream	Downstream

Site Description:

Just downstream of the N6 road bridge between Rouxville and Smithfield. The water transfer from the Caledon River to the Knellpoort Dam and the Welbedacht Dam are ~100km upstream. The surrounding land use is extensive sheep farming with localised irrigation of lucerne from the Caledon River. High silt loads in this river are causing significant problems for local farmers with “fines” (silt, clay and sand) clogging the soil pores and preventing water penetration.

The site is located along an unconfined low gradient reach. The channel is relatively straight, incised into the surrounding landscape with narrow flood features. The banks are steep and lined with alien invasive trees and annuals. Salix and Populus trees dot the riverbanks from the waterline to ~10 m from the water. The river at this site is ~50-70m wide and defined by a couple of strong basaltic intrusions diagonally across the river defining a narrow (~5m wide) resistant bedrock shelf and providing the key geomorphic structure to this reach of the river. Coarse material (boulder and cobble sized) has been introduced for the bridge construction. This has created a series of concrete shelves under the bridge and boulder and cobble shoots, runs and riffles directly downstream of the bridge. At the reach scale the system is dominated by the finer alluvial sands and silts from active upstream erosional processes. These sediments are regularly and extensively deposited onto the riverbanks and under lower flows defines a fine sediment dominated bed and braided main channel.

Biotopes that were available for macroinvertebrates for both surveys were SIC and GSM. Limited SOOC and no marginal vegetation was present owing to undercut banks and vegetation die back and erosion. Flow-depth velocity classes available for the fish included FD, SD, SS and FS.

The marginal riparian zones are bare with emergent *Salix mucronata* trees (including some that are dead). This pattern extends into the lower portion of the lower zone. Beneath the bridge there is a broad area of exposed rocks and sand with very little vegetation cover. There is an abrupt increase in vegetation cover higher up the non-marginal zone which exists as a mosaic of woody and non-woody vegetation. A number of IAPs were recorded (i.e., 16 species), namely *Cyperus eragrostis*, *Bidens pilosa*, *Gleditsia triacanthos*, *Persicaria lapathifolia*, *Populus nigra*, *Salix babylonica* and *Tagetes minuta.* Only 11 indigenous plant species were recorded.

Site impacts:

- Agriculture
- Abstraction and irrigation
- Cattle grazing and trampling
- Local water pump just upstream of the bridge
- Artificial habitats (as a result of construction material for the bridge which remain)
- Bank erosion
- Riparian alien invasives

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.7	8.4
EC (µS/cm)	259.0	217.4
TDS (g/l)	0.2	0.2
DO (mg/l)	10.1	9.2
DO% (%)	87.9	83.5
Clarity (cm)	27	11.5
Temperature (°C)	9.2	10.8
Salinity (ppt)	0.18	0.14
Discharge (m^3/s)	14.190	38.451

Diatoms:

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
July 2022				
23	7.9	D (Poor)	67.2	2.25
Dominant Species		*Eolimna subminµScula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of strong pollution and an indicator of industrial organic pollution		
May 2023				
16	6.4	D (Poor)	91.4	1.5
Dominant Species		1. *Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		

	2. *Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot*
Preference	1. Tolerant of strong pollution, indicator of industrial organic pollution 2. Some of the most pollution tolerant diatoms - indicate organic pollution (sewage) or are associated with organic detritus.

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3	• Stable site with fixed boulders	• Downstream of bridge with possible influences on flow pattern
Fish	3	• FS, FS, SD, SS velocity-depth classes present • Substrate cover elements present (although artificial) • JBS2 and JBS3 (Site OSAEH 26_08) • ORASECOM EFR C5	• High velocity flows • Difficulty sampling effectively
Macroinvertebrates	4	• SIC, SOOC • Varying flow velocities • JBS2 and JBS3 (Site OSAEH 26_08) • ORASECOM EFR C5	• Limited GSM biotope • Limited to no marginal vegetation or instream aquatic vegetation • High velocity flows • High turbidity • Bank erosion
Riparian vegetation	3	• Good access to site, and both banks at the site. • Riparian vegetation is representative for the reach.	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	2.8	• Historical images, literature on sediment dynamics	• Site located at bridge with introduced material. Recent large floods with widespread erosion along banks

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with a single flow observation

Fish						• FROC (Kleynhans et al., 2008) • PESEIS (2014) • JBS2 (Site OSAEH 26_08) • July 2022 and May 2023 surveys
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • July 2022 and May 2023 surveys • ORASECOM EFR C5
Hydrology						• Monthly modelled hydrology for the period 1920-2004 • D2H033 downstream Welbedacht Dam can be used for an indication of freshetes/ floods
Geomorphology						• Historical aerial images and literature on changes to land cover and sediment dynamics
Riparian vegetation						• Historical and recent aerial images. • Site OSAEH 26_8, approximately 50km downstream, assessed during JBS2 (2015) and JBS3 (2021). • May 2023 survey.
Diatoms						• JBS2 and JBS3 (Site OSAEH 26_08) • July 2022 and May 2023 diatom samples
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 and May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Enteromius paludinosus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Leptophlebiidae, Trichorythidae, Coenagrionidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Corydalidae, Hydropsychidae >2spp, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Simuliidae, Syrphidae, Tabanidae, Ancylidae, Lymnaeidae, Unionidae.
Riparian vegetation	The site is primarily defined by Upper Gariep Alluvial Vegetation, which is within the Dry Highveld Grassland Bioregion (of the Grassland Biome). The surrounding terrestrial vegetation comprises Xhariep Karroid Grassland. The river margins would have supported reedbeds and flooded grasslands

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
	on exposed alluvium, transitioning up the banks into the grassland dominated terrestrial environment.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Geomorphology	Low gradient alluvial fine bed channel with straight to wandering channel, possibly braided at very low flows. Alternating sand bars and possibly small gravel bars, mid-channel bars, with a deeper low flow channel, pools and vegetated and bare (recently deposited) inset benches that provide habitat along the margins. The banks will be of moderate gradient and will have a narrow active floodplain, set between the higher-lying terraces. The lower banks will be largely treeless.
Physical-chemical	Reference data for the site could not be obtained. Diatom results were used to infer the reference Physical-chemical state of the site. Diatom results indicated that the site is heavily contaminated with organic pollution, resulting from elevated nutrient concentrations at the site, JBS 2 (2015) diatom results also suggested elevated chloride concentrations. Lower nutrient concentrations are expected to be prevalent at the site under reference conditions. The recent diatom samples from May 2023 were dominated by species being the most pollution tolerant diatoms – indicative of organic pollution (sewage) and associated with organic detritus.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	D (46.3%)	F/NF	• Hydrological and water quality modification due to presence of Welbedacht Dam catchment activities (high erosion rates due to loss of basal cover leading to high sediment loads, increased catchment development) • Presence of migratory barriers downstream (Gariep Dam, Van Der Kloof Dam) and upstream (Welbedacht Dam) • Access limitations owing to high velocity conditions
Macroinvertebrates (MIRAI)	D (46.0%)	F/NF	• Bank erosion thus hampering marginal vegetation biotope • Some siltation on the SIC and SOOC biotope (high sediment loads transported downstream) • Access limitations owing to high velocity conditions
Riparian vegetation (VEGRAI)	D (50.9%)	F/NF	• Notable loss of vegetation cover along lower banks and margins due to recent floods/high flows following a period of limited floods prior to 2021, which has been exacerbated by encroachment of aliens and terrestrial species

			• High number of alien spp. – woody (mostly *Salix babylonica*) and non-woody • Removal of vegetation during construction of the bridge and erosion from stormwater runoff from the road
Geomorphology (GAI)	C (62)	23% flow related	• Low density of smaller farm dams and weirs along the tributaries that trap coarser bedload Welbedacht Dam reduces longitudinal transport of suspended and bed material, partly offsetting the high sediment input from the catchment. Some storage of flood waters in smaller dams, possibly offset by increased runoff from overgrazed and gullied hillslopes, largely from Lesotho • Widespread overgrazing and soil erosion in the upper catchment (largely from Lesotho and communal land) elevating fine sediment loads. Dams and weirs along tributaries and mainstem traps suspended and coarser bed sediment • Trampling and alien trees along banks and floodplain. Bank and bench erosion along both banks, resulting in a featureless bed with steep banks
Hydrology (HAI)	C (75.9%)	F	• Localised abstraction for irrigation • Releases from Welbedacht Dam • Transfer of water from Caledon River upstream of Welbedacht Dam to off-channel Dam (Knellpoort) for water use in Bloemfontein area • Impacts mainly on low and moderate/ baseflows.
Physical-chemical/Diatoms	D	NF	• Due to the lack of data to perform the PAI, the present physical-chemical state at the site was estimated using diatom results • Diatom data indicated heavy organic pollution at the site, resulting from elevated nutrient concentrations • Elevated suspended solids, resulting in low clarity. Also mentioned as an emerging issue in the JBS3 survey (site OSAEH 26_08) • Diatom results from May 2023 indicated further high sodium chloride salinity and especially irrigation return flow (*Pseudostaurosiropsis geocollegarum*)
ECOSTATUS	D (48.5%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone. Refer to Appendix C for the fish and aquatic macroinvertebrate inventories.

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td>Fish</td><td>This reach of the Caledon River is generally characterised by alluvial material, with much of the substrate currently present at the site being imported for the purpose of bridge construction. Fish species expected under reference conditions are all considered to be eurytopic and moderately tolerant to water quality impairment, with varying velocity-depth and cover preferences.

During the July 2022 and May 2023 survey, only two (2) of the eight (8) expected fish species were collected, with only two specimens of Labeo capensis collected. Although the reach was expected to act as a migratory conduit for species moving upstream during seasonal summer flows, the increased sediment input from upstream catchment erosional processes (due to decreased basal cover) as well as flow modification from Welbedacht Dam has resulted in a decrease in the frequency of occurrence of most of the expected fish species. In addition, the presence of various dams within the catchment including Gariep Dam (Orange River) and Welbedacht Dam (Caledon River) within the system has created barriers for the movement of fish species within the system while also creating artificially elevated source populations for several fish that thrive in lentic environments, including alien fish species.

<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>98.67</td><td>96.30</td></tr>
<tr><td>COVER</td><td>100.00</td><td>100.00</td></tr>
<tr><td>FLOW MODIFICATION</td><td>63.06</td><td>76.49</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>57.24</td><td>70.30</td></tr>
<tr><td>MIGRATION</td><td></td><td>70.98</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>29.58</td></tr>
<tr><td>FRAI</td><td colspan="2">PRESENT</td></tr>
<tr><td>FRAI (%)</td><td colspan="2">46.3</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">D</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates</td><td>The habitat in this reach of the Caledon River is primarily comprised GSM and artificial SIC and SOOC owing to the historical construction of the bridge. In the absence of the bridge, this section of the river would have consisted mainly of GSM and marginal vegetation, without a stone biotope. During both surveys, extensive sediment deposition along the banks, which is the main impact in this river, continues to result in the absence of marginal vegetation. Consequently, macroinvertebrates with a preference for this habitat were absent from the community.</td></tr>
</table>

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>However, the introduction of artificial substrate through the construction of the bridge has provided opportunities for flow and habitat-dependent taxa, particularly those associated with the stones biotope, to colonise the system, which would not have occurred during the reference conditions, thus having a positive impact from a habitat perspective. This is evident from the presence of Trichorythidae in an abundance.

Overall, the macroinvertebrate assemblage recorded in July 2022 and May 2023, primarily prefer very fast-flowing water conditions, cobbles (from the artificial substrate), GSM, and mostly low to very low physical-chemical conditions. Those taxa expected to occur, although were absent from the assemblage, and which have high froc's, included Caenidae, Coenagrionidae, Libellulidae, Gerridae, Naucoridae, Veliidae, Dytiscidae, Hydrophilidae, Ceratopogonidae, and Unionidae. Additionally, Atyidae, Leptophlebiidae, Aeshnidae, Corduliidae, and Elmidae were also absent, further supporting the notion that water quality is the primary driver affecting this community, as these taxa have a moderate requirement for unmodified physical-chemical conditions.

<table>
<tr><th colspan="2">INVERTEBRATE EC METRIC GROUP</th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>LOW MODIFICATION</td><td>FM</td><td>57.5</td><td>0.327</td><td>18.8316</td><td>2</td><td>90</td></tr>
<tr><td>ABITAT</td><td>H</td><td>48.1</td><td>0.291</td><td>14</td><td>3</td><td>80</td></tr>
<tr><td>VATER QUALITY</td><td>WQ</td><td>32.2</td><td>0.364</td><td>11.7203</td><td>1</td><td>100</td></tr>
<tr><td>ONNECTIVITY & SEASONALITY</td><td>CS</td><td>80.0</td><td>0.018</td><td>1.45455</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>275</td></tr>
<tr><td>NVERTEBRATE EC</td><td></td><td></td><td></td><td>46.0064</td><td></td><td></td></tr>
<tr><td>NVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>D</td><td></td><td></td></tr>
</table>
Consequently, the overall assemblage represents largely modified conditions (Ecological Category D, 46.0%) and is primarily driven by water quality (32.2%), followed by habitat modification (48.1%)—largely due to the lack of marginal vegetation caused by highly erodible soils and sediment deposition—and flow modification (57.5%).</td></tr>
<tr><td>Riparian vegetation</td><td>The marginal zone is largely confined to a narrow band, much reduced owing to the high baseflows that were experienced during the survey. High flows and floods in 2021 to present have scoured vegetation along the margins and lower banks – mostly likely there was a shift in woody and non-woody vegetation composition due to years of lower flows and limited flooding for many years leading up to 2021. The only vegetation remaining in the marginal zone is scattered Salix mucronata and Salix balyonica trees, with very few sedges (e.g., Juncus effusus). Vegetation removal can also be</td></tr>
</table>

PES and causes

Component	Causes Present/Absent

attributed to shading from *Salix babylonica* trees which are scattered throughout riparian zone. In addition, imported rock material for the construction of the bridge has altered substrate for vegetation to establish on.

Similarly, the lower zone is dominated by *Salix mucronata* followed by *Salix babylonica*, with increased cover provided by non-woody species, notably *Phragmites australis* and *Cynodon dactylon*. Several alien herbs and low growing shrubs have established within the zone, particularly *Tagetes minuta*. The upper zone has experienced encroachment of terrestrial woody species such as *Lycium hirsutum* together with an infestation of various aliens, including *Populus nigra, Tagetes minuta* and *Conyza sumatrensis*.

The lower zone played the dominant role in supporting riparian functions, mainly stabilizing of banks during high flows, while assisting in buffering upslope impacts (runoff and water quality) on the river channel together with vegetation in the upper zone. Under a more natural situation, the active channel would have been more structurally varied with gravel beds and sand bars forming in response to water and sediment flows allowing for woody and non-woody vegetation to periodically establish.

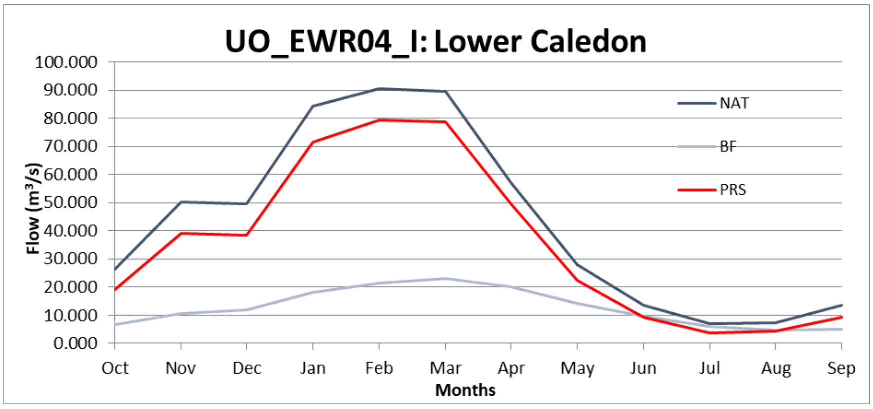
LEVEL 4 ASSESSMENT	EWR04_I: Lower Caledon					31 May 2023
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**Notes:**
Marginal zone	38.5	1.8	2.5	2.0	4.8	Weighted according to extent
Lower zone	56.0	13.3	2.5	1.0	23.8	Weighted according to extent
Upper zone	50.0	35.7	2.8	3.0	71.4	Weighted according to extent
LEVEL 4 VEGRAI (%)						50.9
VEGRAI Ecological Category						**D**
AVERAGE CONFIDENCE						2.6
				Sub-zone		
	Marginal zone	**Lower zone**	**Upper zone**	**0.0**	**0.0**	**0.0**
VEGRAI % (Zone)	38.5	56.0	50.0	not assessed	not assessed	not assessed
EC (Zone)	**D/E**	**D**	**D**			
Confidence (Zone)	2.5	2.5	2.8			

Hydrology

The main impact is on the low flows, especially during winter months when the baseflows are very low.

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFI-DENCE**
LOW FLOWS	2	85	3.0	3
ZERO FLOW DURATION	1	100	0.0	4
SEASONALITY	2	90	1.0	3
MODERATE EVENTS	3	75	2.0	3

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><td>EVENT HYDROLOGY (HIGH FLOWS-FLOODS)</td><td>4</td><td>60</td><td>0.0</td><td>3</td></tr>
<tr><td>HYDROLOGY SCORE</td><td>75.9</td></tr>
<tr><td>HYDROLOGY ECOLOGICAL CATEGORY</td><td>C</td></tr>
</table>



</td></tr>
<tr><td>Geomorphology</td><td>The broad geomorphology, as described by the geomorphic zone, of the Lower Caledon has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. Coarser bedload has also been reduced by weirs in the catchment.
The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Alien vegetation shades out smaller growth forms, reducing ground cover and species diversity. The alien trees drive bank erosion through forming dense superficial root structures that are often undercut and subsequently falls over and destabilises the banks. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently low habitat diversity and low geomorphic stability within the channel and along the channel margins.</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	(see table below)

GEOMORPHOLOGY DRIVERS							
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHTED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.58	0.40	0.63	32.46	2.54
Sediment balance	3.00	70.00	2.34	0.28	0.66	21.52	3.00
Bed & bank stability	2.00	80.00	1.85	0.32	0.59	13.52	2.87
TOTALS		250.00		1.00	1.88		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					62.41		
HABITAT DRIVER CATEGORY					C	23.34	2.77
					WEIGHTED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					1.88	19.59	2.50
HABITAT CHANGE STATUS					62.43243		
HABITAT CHANGE CATEGORY					C		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• No recent upstream water resource developments	3
Macroinvertebrates	Stable	• No recent upstream water resource developments	2
Riparian vegetation	Stable	• The vegetation community that had established prior to recent floods has been reset and expected to recover	2
Hydrology	Stable	• No recent upstream water resource developments	
Geomorphology	Stable	• Buffering of increased sediment and flood runoff by upstream dam	2
Physical-chemical			
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation					
COMPONENT	**PES 2014**	**JBS2 2015**	**JBS3 2021**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C/D	D*	D	• Excessive fine sedimentation loads from Welbedacht Dam – driven by the upper catchment practices. • Exposed sand banks – lack of stability and opportunity for alien invasive encroachment. • Cattle trampling and over grazing (unmanaged). • Perennial system, the system has continuous flows, limited to no zero flows.

**Not assessed fully and site ~50 km downstream of the EWR site*

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
High, High	Moderate, Moderate

Physical-chemical state of the system
Water clarity was low at this site, likely results of the cattle trampling, unstable banks and erosion resulting in high suspended solids in the river. The pH was also elevated, although still within guidelines.

PES	REC		AEC	
D	C/D	• Upstream water use and transfers to be better managed, especially during low flow months; • 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.	C/D	• No change from REC.

OVERALL ASSESSMENT

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
AEC	C/D

Figure 7-12: Overall EcoStatus assessment for UO_EWR04_I (Lower Caledon)

The overall EcoStatus for this EWR site was categorised as a D, with the system being largely modified (Figure 7-12). The degradation of the catchment is elevated suspended sediment loads, leading to sedimentation of the channel and a reduction of habitat diversity as coarser habitats are covered or clogged by fine sediment. At the site, disturbance along the margins is high, with concomitant degradation of the habitat associated with inset benches and banks. The integrity of the biota is compromised owing to altered system dynamics in the form of catchment-scale impacts. Hydrological and water quality modification due to presence of Welbedacht Dam and catchment activities (i.e., high erosion rates due to loss of basal cover leading to high sediment loads, intensive cultivation, increased catchment development) and the presence of migratory barriers for fish downstream (Gariep Dam, Van Der Kloof Dam) and upstream (Welbedacht Dam).

Riparian vegetation has been directly impacted following construction of the bridge, including localised stormwater runoff and erosion, and has experienced a moderate infestation of alien invasive plants, together with encroachment of woody shrubs. Recent flooding has removed most non-woody vegetation, and even some trees/shrubs, which were established along he margins and lower banks.

It is suggested that both the REC and AEC of a C/D (close to moderately modified) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-12).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Ensure overall land management of upstream activities from both South Africa and Lesotho with regards to cattle overgrazing, trampling and overstocking;
- Land use activities within upstream 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
- Transboundary RQOs to be implemented per transboundary resource unit as per the ORASECOM RQO study currently being conducted (Report No.: ORASECOM RQO 004/2023_Draft) (ORASECOM, 2023b).

7.5 UO_EWR05_I: SEEKOEI

Sample Date	12 July 2022 31 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR05_I	**Prioritised RU**	R_RU06
River	Seekoei	**Altitude (m.a.s.l.)**	1221
Latitude	-30.53390069	**Longitude**	24.96253678
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D32J-05237
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (0.002; Lower Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-13) AND SITE PHOTOGRAPHS (Figure 7-14)

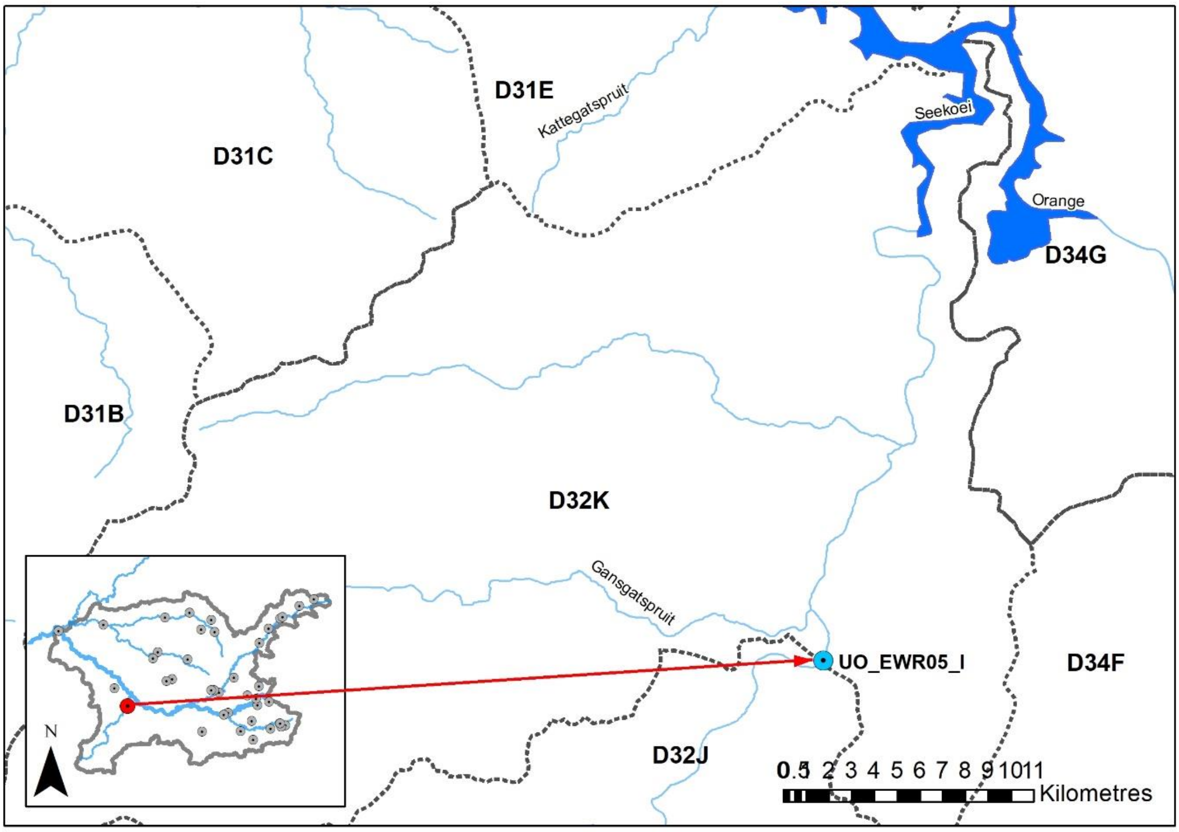


Figure 7-13: Location of site UO_EWR05_I (Seekoei) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)


Figure 7-14: Site photographs of the Seekoei EWR site

Upstream	Downstream

Site Description:

The reach is relatively unconfined with the river incised into the valley floor. Flood features are narrow and the river pattern is straight to sinuous with bedrock, boulder, cobble and gravel and finer habitats available at the site. The site is located off a large cross over bridge off a district road R369, approximately 40km northwest from Colesberg and approximately 60km downstream of the Karoo Gariep Nature Reserve. The site continues to have high baseflows following the floods. Various upstream dams and weirs along the river reach, with a gauging weir located just upstream of the site, resulting in inundation upstream, as well as sediment accretion resulting in various instream islands of *Phragmites sp*., as well as along both banks. Downstream of the weir, the site is dominated primarily by metamorphic sandstone with igneous intrusions forming the bedrock layer along this reach, along with small pockets GSM. The bedrock was blanketed by algae and silt. Furthermore, both instream and marginal vegetation was present for sampling macroinvertebrates. Flow-depth velocity classes available for the fish included FD, SD, SS and FS.

The riparian zone is spread across a flattened valley bottom with the macro-channel extending up to 200m. The weir upstream of the EWR site has inundated sections of marginal habitat and portions of the lower zone, and resulted in an increase in reeds (*Phragmites australis*). Downstream of the weir are several areas of flat, bedrock, and the marginal zone dominated by reeds and sedges. The lower zone of the right bank is relatively steep with low thicket comprising *Searsia pyroides*, *Lycium hirsuta*, *Heteromorpha arborescens* and *Vachellia karroo*, which flattens out into a broader upper zone with scattered tall shrubs interspersed by grasses, herbs and low shrubs. The left bank has a similar vegetation pattern, but is more sparse with more exposed alluvium.

Site impacts:

- Dams and weirs
- Irrigation
- Game and livestock farming
- Localised cultivation on terraces
- Bridge

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.8	8.5
EC (µS/cm)	695	580
TDS (g/l)	0.6	0.5
DO (mg/l)	11.1	10.0
DO% (%)	99.2	91.2
Clarity (cm)	30	25
Temperature (°C)	9.8	11
Salinity (ppt)	0.49	0.39
Discharge (m^3/s)	1.155	1.671

Diatoms:

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
July 2022				
44	12.4	C (Moderate)	11.2	0.25
Dominant Species		1. *Cocconeis pediculus Ehrenberg*		
		2. *Nitzschia dissipata (Kützing) Grunow*		
Preference		1. Epiphytic species in waters of moderate to high electrolyte content, including brackish conditions.		
		2. A cosmopolitan species found in waters of moderate to high electrolyte content, not present in waters of low electrolyte content. Highly mobile - siltation		
May 2023				
40	10.3	C (Moderate)	14.6	0.75
Dominant Species		1. *Cocconeis pediculus Ehrenberg*		
		2. *Nitzschia frustulum (Kützing) Grunow*		
		3. *Pseudostaurosiropsis geocollegarum (Witkowski & Lange-Bertalot) Morales*		
		4. *Staurosirella pinnata (Ehrenberg) Williams & Round*		
Preference		1. A cosmopolitan epiphytic species occurring in waters of a moderate to high electrolyte content, including brackish conditions		

	2. High conductivity, heavy agriculture, very tolerant of pollution
	3. Indicators of high sodium chloride salinity and especially irrigation return flow
	4. Often occurs attached to sand grains, Found in clean waters (mild pollution and only slight organic pollution), with moderate to high electrolyte content. pH>7

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2.5	• Stable bedrock bed • Gauging weir in close proximity	• Fairly complex channel with instream shrubs and reed clumps
Fish	3	• Variety of velocity-depth classes present • Variety of cover structures present	• Bedrock-driven reach • Substrate as a cover feature was limited • High density of weirs within the larger reach
Macroinvertebrates	3	• Marginal and instream aquatic vegetation present • Varying flow velocities	• Limited biotopes – dominated by bedrock • Just downstream of a weir (inundation upstream and flow modification downstream) • High turbid waters • High silt content • Bed modification owing to the bridge at the site
Riparian vegetation	3	• Good access to site, and across the site. • Riparian vegetation is representative for the reach, especially downstream of the weir.	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	2.3	• Easy access, moderate water clarity	• At bridge and gauging weir. Steep bedrock site, so not reflecting all the catchment impacts.

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with single low flow observation

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Fish						• FROC (Kleynhans et al., 2008) • PESEIS (2014) • Collection records • July 2022 and May 2023 surveys
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • July 2022 and May 2023 surveys
Hydrology						• Monthly modelled hydrology for the period 1920-2004. • Daily data from weir (D3H015) just upstream of the EWR site can be used for all flow components.
Geomorphology						• Historical air photos and limited literature on land cover change and sediment dynamics
Riparian vegetation						• Historical and recent aerial images. • Site OSAEH 26_12, approximately 25km downstream, assessed during JBS2 (2015) and JBS3 (2021). • May 2023 survey
Diatoms						• July 2022 and May 2023 diatom samples
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022. • NCMP data (1981 – 2018, n = 465) • July 2022 and May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Labeobarbus aeneus, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Leptophlebiidae, Trichorythidae, Coenagrionidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae 2spp, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Ancylidae, Bulinae, Lymnaeidae, Unionidae.

<table>
<tr><th colspan="4">Reference Conditions</th></tr>
<tr><th>COMPONENT</th><th colspan="3">DESCRIPTION OF REFERENCE CONDITIONS</th></tr>
<tr><td>Riparian vegetation</td><td colspan="3">The site is nested within the Nama Karoo Biome and forms part of the Upper Karoo Bioregion with two associated terrestrial vegetation types, namely Eastern Upper Karoo and Besemkaree Koppies Shrubland. As a result, the riparian zone should support largely sparse vegetation with grasses and low shrubs typical of the surrounding vegetation types with a higher presence of taller shrubs and trees.</td></tr>
<tr><td>Hydrology</td><td colspan="3">Natural flows at the EWR site available for the period 1920 to 2004.</td></tr>
<tr><td>Geomorphology</td><td colspan="3">The reference condition for the reach is likely be a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed with localised bedrock forming the bed. The reach type would mainly be pool-riffle or pool-rapid with sand bars forming in pools. A narrow floodplain can be present where the valley floor is wider.</td></tr>
<tr><td rowspan="8">Physical-chemical</td><td colspan="3">Reference Physical-chemical conditions for the site were determined using DWS data (site D3H015Q01, 1981 to 1989, n =245)</td></tr>
<tr><td rowspan="6">Physical Variables</td><td>pH:</td><td>The reference data reflected a 5th percentile of 7.1 pH units and a 95th percentile of 9 pH units which fell outside the DWA (2008) benchmark for Natural (0) rating. The Natural (0) for the site was therefore re-adjusted, such that the Natural (00 rating for the site was (≥ 7.1 and ≤ 9 pH units)</td></tr>
<tr><td>EC:</td><td>Reference site data indicated elevated conductivities at this site, with the 95th percentile = 144.85 mS/m. These elevated conductivities are largely driven by the catchment wide erosion/weathered geological material. This especially given the lack of anthropogenic impacts in this area.</td></tr>
<tr><td>Temperature:</td><td>No historical temperature records are available for the site. DWA (2008) benchmark tables were used for a low confidence, qualitative assessment of temperature reference condition</td></tr>
<tr><td>Clarity:</td><td>There are no clarity/turbidity records available for reference condition assessment. Reference condition was taken as that qualitatively described in the DWA (2008) benchmark tables.</td></tr>
<tr><td>Oxygen:</td><td>No dissolved oxygen records are available for this site. DWA guideline benchmark tables (2008) have been utilised to characterise the site’s reference condition</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Nutrients</td><td>TIN</td><td>The reference data indicated that the 50th percentile for TIN was 0.09 mg/l, which fell within the DWA (2008) Natural (0) rating benchmark of 0.25 mg/l. The DWA (2008) benchmark for TIN was used.</td></tr>
</table>

Reference Conditions			
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**		
		PO_4	The reference data indicated that the 50th percentile for PO_4 was 0.03 mg/l, which fell outside of the DWA (2008) Natural (0) rating benchmark of 0.005 mg/l. The Natural (0) rating for the site was re-benchmarked such that ≤ 0.03 mg/l.
	Toxins	Fluoride	In terms of the toxics listed within the DWA (2008) rating tables, only fluoride was monitored. The 95^{th} percentile for fluoride was calculated as 0.62 mg/l which fell within the DWA (2008) benchmark table.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	C (77.4%)	F/NF	• Longitudinal fragmentation due to high number of weirs • Flow modification • Non-native fish species
Macroinvertebrates (MIRAI)	C (67.2%)	F/NF	• Biotopes were dominated by bedrock (not an ideal biotope for macroinvertebrates) • Just downstream of a weir, resulting in some flow modifications, while upstream of weir there was inundation and too deep to access • High siltation loads covering the bedrock and SOOC biotopes
Riparian vegetation (VEGRAI)	B/C (77.7%)	NF	• Localised impacts from the weir and bridge have resulted in direct removal and some changes to the riparian vegetation. • Nutrient return flows from cultivation stimulate establishment of reeds in the channel and along the lower banks.
Geomorphology (GAI)	C (78)	15% F related	• Low density of smaller farm dams along tributaries and weirs along the mainstem that trap coarser bedload. Gullies and Badlands increase water and sediment routing. • Widespread grazing and soil erosion elevate fine sediment loads. Dams and weirs along tributaries and mainstem trap coarser bed sediment. • Grazing along banks, but low erosion evident as bank gradient is low, very rocky and well vegetated.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Hydrology (HAI)	B/C (80.2%)	F	Seasonal to ephemeral system with small dams for irrigation purposes, although limited irrigation in the catchment.
Physical-chemical (Diatoms)	C	NF	• Diatom results were used to infer the present Physical-chemical state of the system. • Diatoms indicated elevated electrolyte concentrations. • High conductivities have been recorded at this site as far back as early 1980s, as a result of high erosion and amounts of weathered geological material making its way into the river.
ECOSTATUS	C (74.6%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

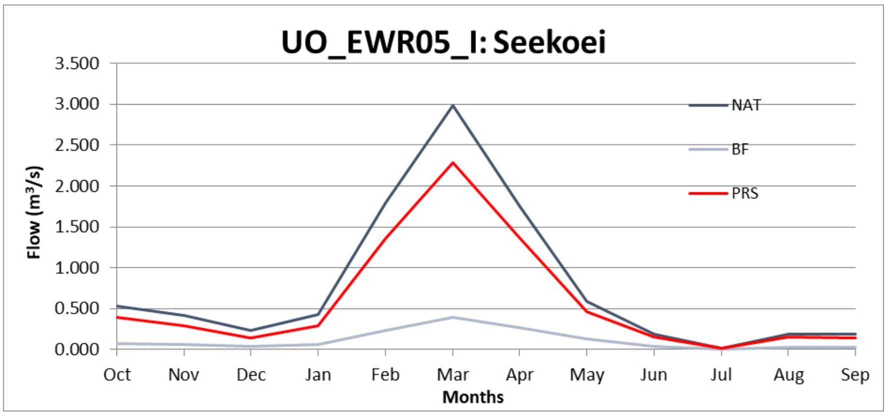
PES and causes	
Component	**Causes Present/Absent**
Fish	The reach of the Seekoei River is marked by multiple weirs along the length of the system which inundates much of the reach, with the lotic section assessed being dominated by bedrock. Fish species expected under reference conditions are all considered to be eurytopic and moderately tolerant to water quality impairment, with varying velocity-depth and cover preferences (although a common preference for slow-deep class was noted). All the fish species expected under reference conditions were present during the assessment, with a seasonal trend noted (higher diversity noted during May 2023). However, the fragmentation of the system from a longitudinal perspective is impacting the species' ability to breed successfully with the limited extents of lotic elements, with the presence of non-native fish also an impacting factor.

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	100.00	100.00
COVER	97.08	98.34
FLOW MODIFICATION	67.38	78.56
PHYSICAL-CHEMICAL	38.32	56.28
MIGRATION		63.19

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>34.47</td></tr>
<tr><td>FRAI</td><td colspan="2">PRESENT</td></tr>
<tr><td>FRAI (%)</td><td colspan="2">77.4</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">C</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates</td><td>
The dominant biotopes in this section of the Seekoei River consisted of bedrock, with abundant marginal and aquatic vegetation. Some GSM were present, but SIC was absent, and SOOC limited. During the July 2022 and May 2023 surveys, a total of 21 and 20 taxa were recorded respectively, resulting in a community of 30 taxa. The collected aquatic macroinvertebrate community was determined to represent moderately modified conditions (Ecological Category C, 67.2%). Consequently, there has been a significant change or loss of natural habitat, biota, and basic ecosystem functions.
The community mainly consisted of taxa with a preference for low to very low physical-chemical conditions, standing water, and the vegetation biotope. Absent taxa, which were expected to have high frequency of occurrences, included Aeshnidae, Leptophlebiidae, Trichorythidae, Libellulidae, and Elmidae. These taxa prefer the SIC biotope, which was absent at this site. Atyidae, Corduliidae, and Dixidae were also absent, all of which have a preference for moderately unmodified physical-chemical conditions. Other absent taxa included Gomphidae, Hydrometridae, and Unionidae. Therefore, the macroinvertebrate community responded to poor water quality, thus being the primary driver in this reach. Physidae was recorded during the July 2022 survey, although not in May 2023. Physidae do not form part of the reference conditions due to their status as alien invasive species. Hence, monitoring should be conducted to ensure their population remains at low abundances.
<table>
<tr><th>INVERTEBRATE EC METRIC GROUP</th><th></th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>FLOW MODIFICATION</td><td>FM</td><td>73.8</td><td>0.340</td><td>25.0541</td><td>2</td><td>90</td></tr>
<tr><td>HABITAT</td><td>H</td><td>68.8</td><td>0.264</td><td>18.1604</td><td>3</td><td>70</td></tr>
<tr><td>WATER QUALITY</td><td>WQ</td><td>59.2</td><td>0.377</td><td>22.331</td><td>1</td><td>100</td></tr>
<tr><td>CONNECTIVITY & SEASONALITY</td><td>CS</td><td>90.0</td><td>0.019</td><td>1.69811</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>265</td></tr>
<tr><td>INVERTEBRATE EC</td><td></td><td></td><td></td><td>67.2436</td><td></td><td></td></tr>
<tr><td>INVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>C</td><td></td><td></td></tr>
</table>
Overall, in the last hydrological year, water quality primarily drove the community (59.2%). During both surveys, a significant amount of filamentous algae was observed at the site, indicating nutrient enrichment
</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	and compromising water quality. Habitat modification was the subsequent driver of the system (68.6%) due to the dominance of bedrock as the biotope for macroinvertebrates, followed by flow modification (73.8%). The ASPT for the communities identified in July 2022 and May 2023 was 4.6 and 4.5, respectively, indicating that the community was mostly composed of tolerant taxa (Dickens and Graham, 2002).
Riparian vegetation	The marginal zone extends up to 10m due to the broad and flat valley bottom and is largely dominated by *Phragmites australis*, with a reasonable diversity of sedges, grasses and herbs interspersed. The left bank has a large flat bedrock shelf with little vegetation cover. Some removal in marginal vegetation has occurred because of the weir and bridge, with direct impacts restricted to the site, although there are several weirs distributed along Seekoei River system. The lower zone is broad and flat on the left bank, and more confined on the steeper right bank. The lower portion is dominated by reeds, which sharply transitions into sparsely vegetated shrubland (left bank) and denser thicket (right bank) dominated by *Vachellia karroo*, *Searsia pyroides* and *Heteromorpha arborescens* and a reasonable diversity of herbs, shrubs and climbers (e.g., *Clematis brachiata* and *Asparagus suaveolens*). The upper zone forms a continuation of the lower zone according to the respective banks. The marginal zone played the dominant role in supporting riparian functions, particularly in terms of bank stabilization and regulating sediment deposition, while buffering the lower banks during floods.

LEVEL 4 ASSESSMENT	EWR05_I: Seekoei River					31 May 202
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**Notes:**
Marginal zone	78.3	9.8	3.0	1.0	12.5	Weighted according to extent
Lower zone	75.8	37.9	3.1	2.0	50.0	Weighted according to extent
Upper zone	80.0	30.0	4.5	3.0	37.5	Weighted according to extent
0.0	not assessed			4.0		
0.0	not assessed			5.0		
0.0	not assessed			6.0		
	3.0				100.0	
LEVEL 4 VEGRAI (%)						77.7
VEGRAI Ecological Category						**B/C**
AVERAGE CONFIDENCE						3.5

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td>Hydrology</td><td>Some reduced freshets due to weirs and small dams upstream.
<table>
<tr><th colspan="5">HYDROLOGY DRIVER ASSESSMENT INDEX</th></tr>
<tr><th>HYDROLOGY METRICS</th><th>Rank</th><th>%wt</th><th>RATING</th><th>CONFI-DENCE</th></tr>
<tr><td>LOW FLOWS</td><td>3</td><td>80</td><td>2.0</td><td>4</td></tr>
<tr><td>ZERO FLOW DURATION</td><td>2</td><td>95</td><td>1.0</td><td>4</td></tr>
<tr><td>SEASONALITY</td><td>1</td><td>100</td><td>0.0</td><td>4</td></tr>
<tr><td>MODERATE EVENTS</td><td>3</td><td>75</td><td>2.0</td><td>4</td></tr>
<tr><td>EVENT HYDROLOGY (HIGH FLOWS-FLOODS)</td><td>4</td><td>60</td><td>0.0</td><td>4</td></tr>
<tr><td>HYDROLOGY SCORE</td><td>80.2</td><td></td><td></td><td></td></tr>
<tr><td>HYDROLOGY ECOLOGICAL CATEGORY</td><td>B/C</td><td></td><td></td><td></td></tr>
</table>


</td></tr>
<tr><td>Geomorphology</td><td>The broad geomorphology, as described by the geomorphic zone, of the Seekoei River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. Coarse bedload has also been reduced by weirs in the catchment, reducing this habitat at the site.
The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	and annual reworking. This results in a site with currently low habitat diversity (mostly bedrock).

GEOMORPHOLOGY DRIVERS							
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.25	0.43	0.54	22.50	2.13
Sediment balance	2.00	70.00	1.09	0.30	0.33	8.70	2.50
Bed & bank stability	3.00	60.00	0.76	0.26	0.20	5.88	2.29
TOTALS		230.00		1.00	1.07		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					78.52		
HABITAT DRIVER CATEGORY					C	13.96	2.28
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					1.30	18.03	2.30
HABITAT CHANGE STATUS					73.93939		
HABITAT CHANGE CATEGORY					C		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• No recent water resource developments or increase in impacting feature expected	3
Macroinvertebrates	Stable	• No recent water resource developments or increase in impacting feature expected	3
Riparian vegetation	Stable	• There has not been any significant change in riparian vegetation since the construction of the weir and bridge.	3
Hydrology	Stable	• No recent water resource developments	3
Geomorphology	Stable	• Ongoing pressures with no immediate change in drivers or site impact	3
Physical-chemical	Stable	• High conductivities are characteristic of this system. No recent developments that could alter the physical-chemical nature of the system.	3
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C	• Fairly small ephemeral system • Water quality impairments (irrigation, return flows), observed high filamentous algae • The system has a lot of weirs resulting in flow, bed modification and sediment trapping.

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023***
Moderate, Moderate	Moderate, Moderate

Physical-chemical state of the system
The pH is elevated, although still within guidelines. Clarity is low as a result of high suspended solids from upstream, likely as a result of erosion of topsoil. High conductivities were also recorded, which are characteristic of the system, as seen in the NCMP long term data.

PES	REC		AEC	
C	C	• Water quality improvements through controlled irrigation and return flows.	B/C	• Removal of redundant weirs; • This may mobilise sediment/gravel bars further downstream (additional potential habitat for fish spawning opportunity and macroinvertebrates).

OVERALL ASSESSMENT

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
AEC	B/C

Figure 7-15: Overall EcoStatus assessment for UO_EWR05_I (Seekoei)

The overall EcoStatus for this EWR site was categorised as a C, thus the system is in a moderately modified condition, with loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundances (Figure 7-15). The degradation of the catchment is elevating suspended sediment loads, but the multitude of weirs is trapping most of the sediment. At the site, disturbance along the margins is fairly low, but still shows degradation of the habitat associated with inset benches and banks. All the expected fish species were noted to be present within the assessed reach, as were non-native fish species. However, the fragmentation of the system as a result of various weirs is likely to be impacting the species present, with decreased recruitment from limited access to suitable spawning areas within the reaches between the weirs.

The macroinvertebrate community, although not diverse, owing to the dominant biotope being bedrock, which is not a preferred habitat, mostly responded to water quality modifications. The riparian vegetation is in a relatively good condition with impacts mainly attributed to the weir and bridge through vegetation removal and the site has a fairly low infestation of alien plants. The overall condition of the riparian zone was moderately modified (Ecological Category C).

Overall, it is suggested that the REC be maintained as the PES (category C), but a B/C is recommended for the AEC (Figure 7-15). This can be achieved should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Remove redundant weirs with the aim to mobilise gravel and sediment downstream;
- Land use activities (irrigation, abstraction, return flows) within upstream 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
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways).

7.6 UO_EWR06_I: UPPER RIET

Sample Date	13 July 2022 1 June 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR06_I	**Prioritised RU**	R_RU08
River	Upper Riet	**Altitude (m.a.s.l.)**	1278
Latitude	-29.53478727	**Longitude**	25.52449567
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	C51F-04071
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, High, Moderate
Geomorphological zone	E (0.001; Lower Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-16) AND SITE PHOTOGRAPHS (Figure 7-17)

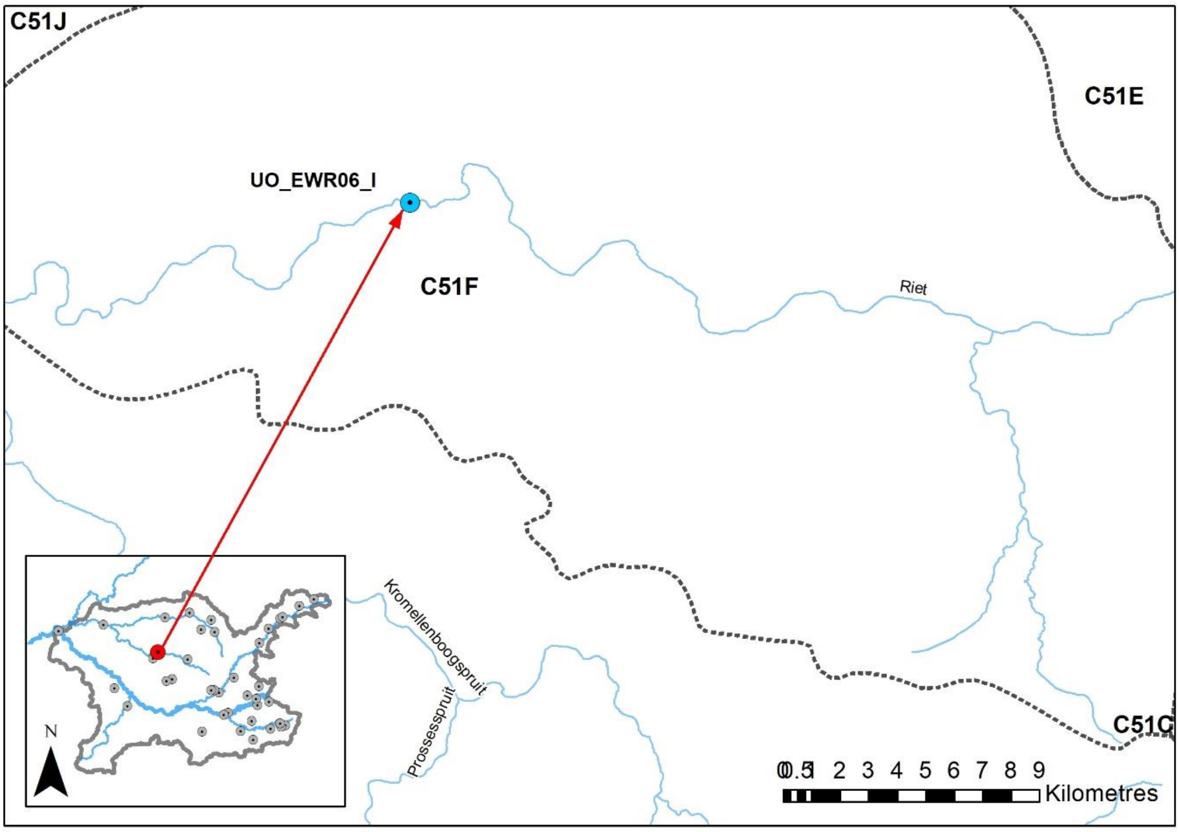


Figure 7-16: Location of site UO_EWR06_I (Upper Riet) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)

Figure 7-17: Site photographs of the Upper Riet EWR site

Upstream	Downstream

Site Description:

The reach is largely unconfined, with the macro channel incised into the gently sloping hillslopes. The river has a straight to sinuous macro channel pattern, with a braided low flow channel pattern. Bedrock, boulder, gravel and silt sediment types at the site. This site is located in the upper reaches of the Riet River, upstream of the Kalkfontein Dam Nature Reserve and ~20km upstream of the confluence of the Kromellenboog. Upstream of this site is the DWS REMP site and previous JBS3 site C5RIET-IFR03 and 26_10 respectively. The Riet River is a main tributary of the Vaal River and flows in a western direction. The site is located just downstream of a low water cross-over bridge, where log jams have occurred upstream of the bridge, impeding the hydraulics of the river, as well as inundation of the system upstream.

The channel is approximately 40m wide and braided downstream of the bridge owing to in-stream vegetated and gravel islands. These formed braids have resulted in small streams running through the instream islands with rocky habitat for macroinvertebrates and fish. The substrate at the site is dominated by gravel and cobbles, as well as a section of bedrock along the left side of the channel. The increased flows have allowed aquatic grass to establish in the deep runs. Marginal vegetation was abundant and comprised reeds, grasses and sedges. Bank erosion from cattle trampling was evident, more so along the right bank, along with undercut banks.

The riparian zone is characterised by a fairly steep left bank with denser vegetation and a wider, flatter, more open right bank with areas of exposed bedrock and alluvium. The marginal zone is narrow and dominated by dense clumps of *Schoenoplectus* interspersed by the occasional woody shrub/tree (e.g., *Salix mucronata*), which leads into a grassy strip of tall/robust *Miscanthus capensis* defining the lower edge of the non-marginal, with a broader band of *Cynodon dactylon* and other grasses above extending across the upper zone into the terrestrial areas. The upper, left bank has numerous patches of low, dense thicket comprising *Lycium* and *Asparagus spp.* with several large, alien trees (*Eucalyptus* and *Populus spp.*) scattered along the middle to upper bank. There are a number of islands and clusters of emergent *Schoenoplectus* with *Gomphostigma virgatum*. Impacts to the riparian zone are low to moderate and tend to be localised around the road crossing.

Site impacts:

- Rural development
- Cattle/game farming
- Cultivation
- Irrigation

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.8	8.34
EC (µS/cm)	486	557

TDS (g/l)	0.449	0.495
DO (mg/l)	9.9	8.98
DO% (%)	97.4	81.3
Clarity (cm)	22	13
Temperature (°C)	9.5	11.0
Salinity (ppt)	0.34	0.37
Discharge (m^3/s)	4.217	12.405

Diatoms:

No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
July 2022				
31	19.3	C (Moderate)	16.6	1
Dominant Species		1. *Cyclostephanos invisitatus (Hohn & Hellerman) Theriot, Stoermer & Hakans*		
		2. *Fragilaria biceps (Kützing) Lange-Bertalot*		
Preference		1. Species is of wide-spread occurrence and is common in the summer. Often found in plankton nutrient-rich waters		
		2. Cosmopolitan taxon. Often found in mesotrophic to eutrophic waters.		
May 2023				
20	6.2	D (Poor)	94.0	0.5
Dominant Species		*Nitzschia frustulum (Kützing) Grunow*		
Preference		High conductivity, heavy agriculture, very tolerant of pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Straight and relatively stable site	• Some midchannel bars and mobile bed sediment
Fish	3	• Variety of velocity depth classes • Variety of habitat cover features	• Deep water limited effective sampling • Substrate biotope lacking • Higher flows made sampling difficult in some sections
Macroinvertebrates	3	• Variety of aquatic biotopes available	• Highly turbid waters

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
		• Varying flow velocities	• Very fast flow over the SIC biotope limited effective sampling
Riparian vegetation	3	• Good access to site, and across the site. • Riparian vegetation is representative for the reach.	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months).
Geomorphology	2.5	• Good access	• High flow, turbid water

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics						• New site with one observation at moderate flow level
Fish						• FROC (Kleynhans et al., 2008) • PESEIS (2014) • Limited collection records • July 2022 and May 2023 surveys
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • July 2022 and May 2023 surveys
Hydrology						• Only monthly modelled data for the period 1920-2004
Geomorphology						• Historical air photos and very limited literature on land use changes and sediment dynamics
Riparian vegetation						• Historical and recent aerial images. • Site OSAEH 26_10, approximately 25km upstream, assessed during JBS2 (2015) and JBS3 (2021). • May 2023 survey
Diatoms						• July 2022 and May 2023 diatom samples
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • NCMP data (2011 to 2018, n = 29). • July 2022 and May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Enteromius paludinosus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis, Labeo umbratus, Tilapia sparrmanii* and *Pseudocrenilabrus philander*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Oligoneuridae, Trichorythidae, Coenagrionidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae.
Riparian vegetation	The site is nested within the Grassland Biome and forms part of the Dry Highveld Grassland Bioregion. The terrestrial vegetation surrounding the site is characterised by Xhariep Karroid Grassland with the riparian component defined as Highveld Alluvial Vegetation. As a result, the riparian zone should support a grassland and herbland mosaic that is seasonally flooded with influences from the associated terrestrial grasslands.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Geomorphology	The reference condition for the reach is likely to be a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed with localised bedrock forming the bed. The reach type would mainly be pool-riffle or pool-rapid with sand bars forming in pools. A narrow floodplain can be present where the valley floor is wider.
Physical-chemical	Historical Physical-chemical data at the site began in 2011, which did not reflect the reference conditions at the site. The reference Physical-chemical condition of the site was, therefore, inferred from the diatom data. The diatom data indicated that the site is free from organic pollution, however the system is prone to eutrophic conditions and high phosphorus concentrations. Lower nutrient conditions are expected to be prevalent under reference conditions.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	C (68.1%)	F/NF	• Weirs acting as upstream migration barriers • Flow modifications • Sediment input into the system due to catchment activities • Presence of non-native fish species
Macroinvertebrates (MIRAI)	C (62.6%)	NF	• Water quality (irrigation from adjacent and upstream agriculture, highly turbid and sediment inputs)

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Riparian vegetation (VEGRAI)	C (62.3%)	NF	• Nutrient inputs from upstream increasing vigour of sedges. • Pressure grazing and reduced fire intensity resulting in increased woody cover • Encroachment of both alien and terrestrial species.
Geomorphology (GAI)	C (73)	30% F related	• Low density of smaller farm dams along tributaries and weirs and dams along the mainstem that trap coarser bedload. Gullies and badlands increase water and sediment routing. • 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.
Hydrology (HAI)	C (67.9%)	F	• Mainly irrigation and Tierpoort Dam on a tributary of the Riet River resulting in reduced low flows, freshets and floods.
Physical-chemical (Diatoms)	D		• Due to the lack of historical physical-chemical data, the present physical-chemical state of the site was inferred from the diatom data. • The diatom results indicated heavily polluted waters (organic pollution) with elevated conductivities.
ECOSTATUS	C (63.7%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	Five (5) of the nine (9) indigenous species expected at the site under reference conditions were sampled during the July 2022 and May 2023 field surveys, with the fish assemblage determined to be in a moderately modified state. The presence of Kalkfontein Dam as well as several weirs within the larger system are expected to act as upstream migration barriers for fish moving up from lower reaches. In addition, the presence of Tierpoort Dam on a tributary of the Riet River has resulted in flow modifications which is likely to be impacting the fish assemblage during low-flow periods. Although expected only at low frequencies of occurrence, there was a notable absence of limnophilic fish species from the fish assemblage during field surveys despite the presence of suitable habitat, the reason for which cannot be determined.

PES and causes

Component	Causes Present/Absent

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	98.13	98.95
COVER	100.00	100.00
FLOW MODIFICATION	62.00	75.77
PHYSICAL-CHEMICAL	53.41	65.09
MIGRATION		61.52
IMPACT OF INTRODUCED		38.08
FRAI	PRESENT	
FRAI (%)	68.1	
EC: FRAI	C	

Component	Causes Present/Absent
Macroinvertebrates	The Upper Riet EWR site exhibited a diverse range of biotopes suitable for macroinvertebrates. However, it is important to note that the high flows over the SIC biotope posed challenges to accessibility and accordingly taken into consideration during interpretation. During the surveys conducted in July 2022 and May 2023, a total of 14 and 19 macroinvertebrate taxa were recorded respectively, resulting in a cumulative total of 25 taxa for the last hydrological year (July 2022 - May 2023). The assemblage of the collected aquatic macroinvertebrate community was found to be indicative of moderately modified conditions (Ecological Category C, 62.6%). The primary driver of these conditions was water quality (47.1%), followed by flow (68.8%) and habitat modification (73.0%). The recorded aquatic macroinvertebrate community at the Upper Riet River site predominantly exhibited preferences for low to very low water quality, stones and vegetation biotopes, and standing water. Only two sensitive taxa, Leptophlebiidae and Pyralidae, were recorded, both of which prefer moderate to high water quality, cobbles, and fast to very fast flowing water. Several taxa expected, but which were absent from the community, and which had high frequency of occurrences, included Hydracarina, Baetidae >2spp, Trichorythidae, Aeshnidae, Hydropsychidae >2spp, and Elmidae. These families all have a preference for moderate to high water quality conditions, further supporting water quality as a driving factor in the system. It is worth noting that the abundance of Simuliidae recorded in July 2022 (D abundance) had decreased and no Simuliidae were recorded during

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
the May 2023 survey. This decline may be attributed to the system being reset following the floods in February 2023, which caused habitat scouring.

<table>
<tr><th>INVERTEBRATE EC METRIC GROUP</th><th></th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>FLOW MODIFICATION</td><td>FM</td><td>68.8</td><td>0.304</td><td>20.8886</td><td>3</td><td>85</td></tr>
<tr><td>HABITAT</td><td>H</td><td>73.0</td><td>0.321</td><td>23.4698</td><td>2</td><td>90</td></tr>
<tr><td>WATER QUALITY</td><td>WQ</td><td>47.1</td><td>0.357</td><td>16.8333</td><td>1</td><td>100</td></tr>
<tr><td>CONNECTIVITY & SEASONALITY</td><td>CS</td><td>80.0</td><td>0.018</td><td>1.42857</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>280</td></tr>
<tr><td>INVERTEBRATE EC</td><td></td><td></td><td></td><td>62.6203</td><td></td><td></td></tr>
<tr><td>INVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>C</td><td></td><td></td></tr>
</table>

Overall, the ASPT for the communities identified in July 2022 and May 2023 was 4.6 and 5.4, respectively, indicative of the community being mostly tolerant taxa (Dickens and Graham, 2002).
</td></tr>
<tr><td>Riparian vegetation</td><td>
The marginal zone is well defined with a dense band of *Schoenoplectus brachyceras* (sedge) and *Miscanthus junceus* (grass), which provide good bank protection during floods and high flows. Growing amongst these robust graminoids are small aquatic herbs, including the creeping alien *Phyla nodiflora*. There is a smaller number of *Gomphostigma virgatum* (River Stars) interspersed along the marginal zone, and on a submerged island in the channel downstream of the road crossing. A few small to medium *Salix mucronata* trees, as well as the alien shrub *Persicaria lapathifolia* are scattered along the marginal zone of the right bank. The lower zone is also dominated by non-woody vegetation comprising a higher diversity of grasses (notably *Cynodon dactylon*) and a small number of forbs/herbs, including several alien plants (e.g., *Persicaria lapathifolia, Conyza bonariensis, Melilotus albus, Solanum pseudocapsicum, Xanthium strumarium*). The upper zone on right bank is flat and wide and supports mostly grass vegetation with large areas of exposed bedrock, while the steep, left bank has become dominated by thickets of *Lycium hirsutum* and *Asparagus suaveolens* with emergent alien trees (*Eucalyptus grandis* and *Populus canescens*).

The marginal zone played the dominant role in supporting riparian functions and stabilizing banks during high flows, with the lower zone providing a secondary role with buffering upslope impacts (runoff, erosion and water quality).

The riparian vegetation at the site has been impacted locally by the road crossing, with more widespread grazing impacts, mainly along the left bank.
</td></tr>
</table>

PES and causes

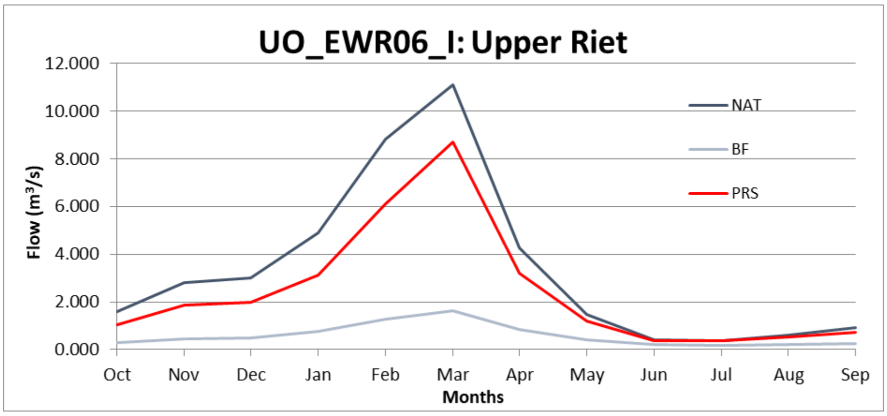
Component	Causes Present/Absent
	There is a fairly minor infestation by a moderate diversity of alien plants (~13 species) throughout the site.

LEVEL 4 ASSESSMENT	EWR06_I: Upper Riet River					01 June 202
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	80.0	2.6	3.0	1.0	3.2	Weighted according to extent
Lower zone	67.7	10.9	3.2	2.0	16.1	Weighted according to extent
Upper zone	60.6	48.8	3.2	3.0	80.6	Weighted according to extent
	3.0				100.0	
LEVEL 4 VEGRAI (%)						62.3
VEGRAI Ecological Category						C
AVERAGE CONFIDENCE						3.1

Component	Causes Present/Absent
Hydrology	Reduced freshets and floods due to dam and system changed from a seasonal to perennial river due to releases from dam for irrigation.

HYDROLOGY DRIVER ASSESSMENT INDEX

HYDROLOGY METRICS	Rank	%wt	RATING	CONFI-DENCE
LOW FLOWS	3	80	2.0	2.0
ZERO FLOW DURATION	1	100	0.0	3.0
SEASONALITY	2	95	1.0	2.0
MODERATE EVENTS	3	85	3.0	3.0
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	4	75	2.5	3.0
HYDROLOGY SCORE	**67.9**			
HYDROLOGY ECOLOGICAL CATEGORY	**C**			



PES and causes	
Component	**Causes Present/Absent**
Geomorphology	The broad geomorphology, as described by the geomorphic zone, of the Upper Riet River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. Coarse bedload has also been reduced by weirs in the catchment, reducing this habitat at the site. The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Grazing and trampling at the site further degrade the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently moderate habitat diversity.

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHTED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.25	0.43	0.54	41.25	2.75
Sediment balance	2.00	70.00	1.98	0.30	0.60	18.70	2.50
Bed & bank stability	3.00	60.00	0.71	0.26	0.18	29.41	2.29
TOTALS		230.00		1.00	1.33		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					73.41		
HABITAT DRIVER CATEGORY					C	31.30	2.55
					WEIGHTED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					1.30	29.09	2.61
HABITAT CHANGE STATUS					73.93939		
HABITAT CHANGE CATEGORY					C		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• No recent water resource developments or increase in impacting feature expected	3

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Macroinvertebrates	Stable	• No recent water resource developments, although turbidity levels continue to rise due to sediment supply.	3
Riparian vegetation	Stable	• There has not been any significant change in riparian vegetation since the construction of the bridge other than gradual encroachment of terrestrial and alien vegetation.	3
Hydrology	Stable	• No recent water resource developments	3
Geomorphology	Stable	• Ongoing pressures with no immediate change in drivers or site impact	3
Physical-chemical	Decline	• The diatoms have illustrated in a decline in water quality from being moderately modified to poorly modified (recent diatom samples taken in May 2023); and • The diatoms were indicative of the site being heavily contaminated with organic pollution.	3
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	• System remains stable

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
High, Moderate	High, Moderate

Physical-chemical state of the system
The pH is elevated but still within guidelines. Water clarity is low, as a result of heavy grazing causing unstable topsoil to be eroded into the river.

PES	REC		AEC	
C	C	• Water quality improvements through controlled irrigation and return flows.	B/C	• Aim to increase and improve the riparian vegetation • Aim to assist fish movement and spawning • Wate quality improvement through better management of return flows from irrigation and upstream town management and effluent releases.

OVERALL ASSESSMENT

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
AEC	B/C

Figure 7-18: Overall assessment for UO_EWR06_I (Upper Riet)

The overall EcoStatus for this EWR site was categorised as a C, thus the system is in a moderately modified condition, with loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundances (Figure 7-18). The degradation of the catchment is elevating suspended sediment loads leading to higher turbidity and silt deposits over coarser habitats. At the site, disturbance along the margins is fairly low, but still shows degradation of the habitat associated with inset benches and banks. The fish assemblage was noted to be in a moderately modified state, with Kalkfontein Dam and several weirs noted to be impacting the assemblage due to movement limitations. Additional elements impacting the fish species present included flow modifications as well as the presence of non-native species.

The macroinvertebrate community was found to be indicative of moderately modified conditions (Ecological Category C) as well, mostly responding to poor water quality. The marginal zone was found to be in a moderately good condition, while the lower zone and upper zone were more degraded – overall condition of the riparian zone was moderately modified (Ecological Category C).

Overall, it is suggested that the REC be maintained as the PES (category C), but a B/C is recommended for the AEC (Figure 7-18). This can be achieved should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Removal of the log jam occurring at the bridge impeding the hydraulics of the river, as well as inundation of the system upstream;

- Water quality improvement through better management of return flows from irrigation and upstream town management and effluent releases; and
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways).

7.7 UO_EWR07_I: UPPER MODDER (SANNASPOS)

Sample Date	14 July 2022 2 June 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR07_I	**Prioritised RU**	R_RU9a
River	Modder	**Altitude (m.a.s.l.)**	1333
Latitude	-29.160017°	**Longitude**	26.572492°
Level 1 EcoRegion	Highveld	**Quaternary catchment- SQ Reach**	C52B-03819
Level 2 EcoRegion	11.03	**DWS, 2014 PES, EI, ES**	D, Moderate, High
Geomorphological zone	E (0.001; Lower Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-19) AND SITE PHOTOGRAPHS (Figure 7-20)

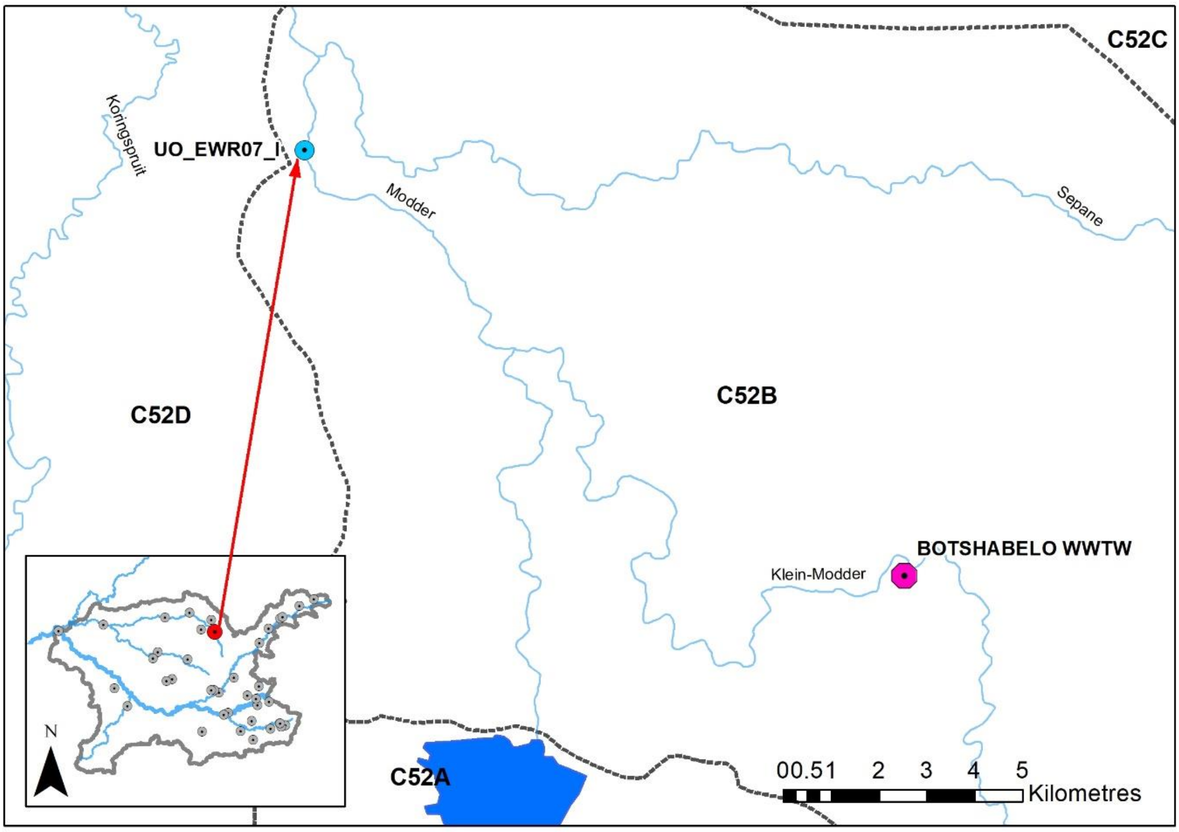


Figure 7-19: Location of site UO_EWR07_I (Upper Modder) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)

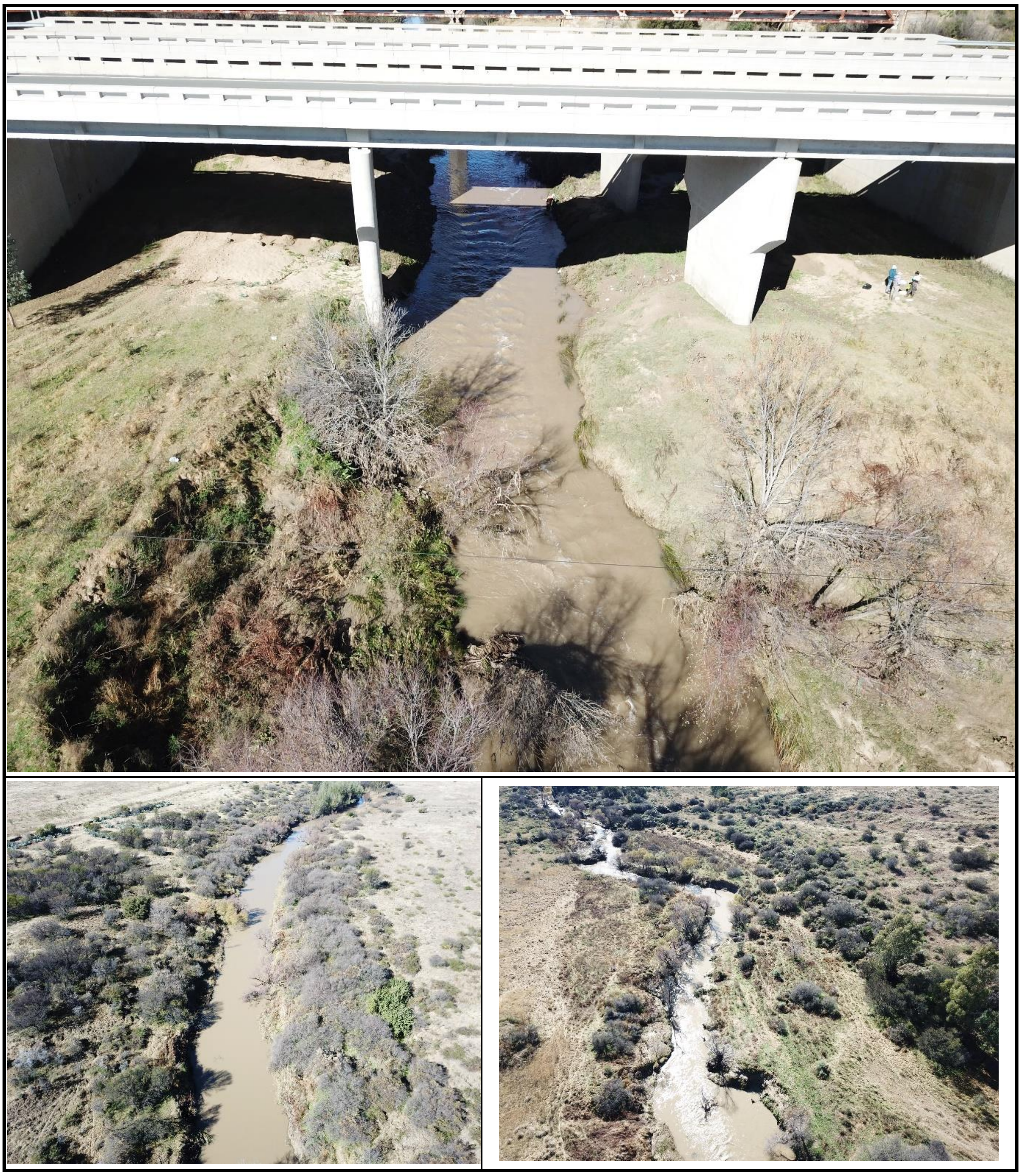


Figure 7-20: Site photographs of the Upper Modder EWR site

Upstream	Downstream

Site Description:

The reach is largely unconfined, with gently sloping hillslopes and an incised channel with narrow flood features. The site is bedrock controlled with silty banks and introduced coarser bed material. Gravel and sand bars are present downstream of the site. The site along the upper reaches of the Modder River is located ~30km east of Bloemfontein off the N8, with its confluence downstream with the Riet River near the town of Ritchie. The site is situated approximately 13 km downstream of Rustfontein Dam. It is impeded by two (2) railway crossings and a large bridge. Furthermore, a gauging weir is located just upstream of the site. The river width varies from 3 m to 15 m in places with inundation taking place just upstream of the weir. Owing to these influences and impediments, much of the instream substrate, downstream of the weir comprises riffles with artifical loose SIC, and some SOOC. However, bedrock is the dominant substrate from the bridge and further downstream. There is relatively good GSM, but marginal vegetation, being grasses and sedges, was limited owing to undercut banks and vegetaion die back during winter (representative of the season). Sedimentation is present downstream of the weir forming a back eddie along the sandbank with algae on the rocks at the river's edge. Overaal, considerable channel and bed modification is present at this site. Both banks are heavily eroded owing to recent flooding, flow modifications and cattle trampling.

The riparian zone has been affected by altered flows as a result of Rustfontein Dam located upstream and releases from the Botshabelo WWTW, with localised impacts caused by the bridge structures associated with the N8 and the railway line, as well as the gauging wier. The right bank, upstream of the weir has a dense stand of alien Popular trees (*Populus canescens*). There has been an increase in woody vegetation, inclusive of IAPs and encroachment of terrestrial species such as *Vachellia karroo* and *Searsia lancea.* Erosion along the banks is exacerbated by runoff from the N8, as well as concentration of flows under the bridge. Various signs of impacts from cattle were also noted at the site.

Current land uses in the catchment include agricultural activities (primarily irrigated crops), urbanisation and industrial activities. The Modder River supplies water to several urban areas including Bloemfontein, Botshabelo (upstream) and Thabu Nchu although this is supplemented to a large degree by water from the Caledon River via the Caledon - Modder River Government Water Scheme (CMRGWS).

At the time of the May 2023 survey, the system was recovering/resetting from a recent flood event, which took place two days prior, measuring at approxmately $60m^3/s$. This ultimately had an impact on the macroinvertebrate community and of which some of the biotopes could not be accessed namely the SIC during this survey.

Site impacts:

- Upstream dams
- Weirs
- WWTW discharges
- Agriculture
- Abstrations and irrigation
- Livestock trampling, grazing
- Industrial

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.4	7.96
EC (µS/cm)	459	155.7
TDS (g/l)	0.419	0.1404
DO (mg/l)	8.7	9.65
DO% (%)	76.6	86.2
Clarity (cm)	52	6.5
Temperature (°C)	9.9	10.4
Salinity (ppt)	0.32	0.10
Discharge (m^3/s)	0.673	9.180

Diatoms:

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
July 2022				

34	5.6	D (Poor)	73.1	8.75 (extreme deformities and cause for concern)
Dominant Species	*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*			
Preference	Tolerant of strong pollution, indicator of industrial organic pollution			
May 2023				
30	6.3	D (Poor)	30.0	0
Dominant Species	*1.Nitzschia frustulum (Kützing) Grunow*			
	2.Gomphonema parvulum (Kützing) Kützing			
	3.Navicula veneta Kützing			
	4.Nitzschia palea (Kützing) W.Smith			
Preference	1.High conductivity, heavy agriculture, very tolerant of pollution			
	2.Very high load of fine sediment, diatom cells present, mostly broken			
	3.Cosmopolitan, common in heavily eutrophicated, electrolyte-rich to brackish water. Very pollution tolerant, often the dominant species in industrially impacted waters.			
	4.A cosmopolitan and very commonly occurring species found in eutrophic and very heavily polluted to extremely polluted waters with moderate to high electrolyte content			

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Simple straight channel form	• Trampling along banks can alter cross section shape
Fish	4	• Upstream weir concentrates fish moving upstream, allowing for easier sampling	• Confined bedrock-dominated channel
Macroinvertebrates	4	• Varying flow velocities	• Upstream weir resulting in inundation upstream and too deep to access, and flow modifications downstream • The site is bedrock controlled with silty banks and introduced coarser artifical bed material. • Increased turbidity • Limited marginal vegettion owing to extensive bank erosion from cattle grazing, trampling

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Simple straight channel form	• Trampling along banks can alter cross section shape
Riparian vegetation	4	• Good access to site, and across the site. • Been assessed during ORASECOM surveys in 2015 and 2021 (JBS2 and JBS3).	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months). • Site is largely altered by the weir, roads, rail and bridges with an incised river channel.
Geomorphology	2.6	• Easy site access	• Highly impacted site with bridges and weirs

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics						• New site with single low flow observation
Fish						• FROC (Kleynhans et al., 2008) • PESEIS (2014) • Collection records • JBS2 and JBS3 (Site OSAEH 11_18) • July 2022 and May 2023 surveys
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • DWS REMP site further upstream (C5MODD-SANNA) • PES, 2014 • JBS2 and JBS3 (Site OSAEH 11_18) • July 2022 and May 2023 surveys
Hydrology						• Monthly modelled hydrology for period 1920-2004 • Daily data from gauging weir C5H003
Geomorphology						• Historical air photos and limited literature on land use change and sediment dynamics
Riparian vegetation						• Historical and recent aerial images. • JBS2 and JBS3 (Site OSAEH 11_18) • May 2023 survey
Diatoms						• JBS2 and JBS3 (Site OSAEH 11_18) • July 2022 and May 2023 diatom samples

Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 and May 2023 diatom results • REMP data (1987 to 2018, n=788)

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Trichorythidae, Coenagrionidae, Lestidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae.
Riparian vegetation	The site is nested within the Grassland Biome and forms part of the Dry Highveld Grassland Bioregion. The terrestrial vegetation surrounding the site is characterised by Central Free State Grassland with the riparian component defined as Highveld Alluvial Vegetation. As a result the riparian zone should support a largely grassland and herbland mosaic that is seasonally flooded with influences from the associated terrestrial grasslands.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Geomorphology	The reference condition for the reach is likely to be a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed with localised bedrock forming the bed. The reach type would mainly be pool-riffle or pool-rapid with sand bars forming in pools. A narrow floodplain can be present where the valley floor is wider.
Physical-chemical	Historical data (from 1987) for the site indicated substantial fluctuation of Physical-chemical properties over time. The earliest available data, therefore, did not represent the reference conditions at the site, especially with the Botshabelo Township upstream established in 1979. Diatoms data were used to infer the reference Physical-chemical condition at the site. Diatom data indicated strong organic and inorganic pollution. Under reference conditions, lower nutrient concentrations are expected to be present at the site, especially with the absence of the impacts from Botshabelo and Thaba Nchu WWTWs upstream.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	C (68.6%)	F/NF	• Significant water quality impairment due to raw sewage input from Botshabelo (Klein Modder) • Flow modification • Habitat modification • Migration barrier (upstream weir) • Non-native (alien) fish
Macroinvertebrates (MIRAI)	D (50.0%)	F/NF	• Loss of habitat – marginal vegetation owing to cattle trampling and overgrazing, bank erosion • Site is mainly dominated by bedrock (not an ideal biotope for macroinvertebrates) • High sediment loads over SIC, SOOC • Decrease water quality (highly turbid , run-off from Botshabelo - situated on the Klein-Modder River which confluences with the Modder upstream of the site) • Channel and flow modifications (weir, various bridges at the site, upstream Rustfontein dam)
Riparian vegetation (VEGRAI)	D (46.4%)	F/NF	• Notable loss of vegetation cover due to trampling and erosion, together with an increase in woody vegetation. • River channel is largely incised through the site. • Number of aliens at the site with dense stand of *Populus alba*. • Removal of vegetation from construction of the roads, rail, bridges and weir.
Geomorphology (GAI)	D (49)	38% flow related	• A moderate density of smaller farm dams along tributaries and weirs and a large dam along the mainstem that trap coarser bedload. Gullies and areas of sheet erosion increase water and sediment routing. • 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.
Hydrology (HAI)	C/D (58.3%)	F	• Rustfontein Dam upstream impacting on all the flow components. • Discharges from Botshabelo WWTW resulting in increased flows, especially during winter months.
Physical-chemical (Diatoms)	D	NF	• The present Physical-chemical state at the site was inferred from the diatom data. • Diatom data indicated strong organic and inorganic pollution, arising from urban runoff and poorly

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
			treated wastewater from the Botshabelo township upstream.
ECOSTATUS	D (51.7%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	The reach assessed was noted to be subjected to instream habitat modification due to channel confinement and erosion to bedrock, with substrate alterations. In addition, a large weir was present immediately upstream of the reach assessed, with the reach assessed thus presenting the upstream-most extent of fish movement from Mocke's Dam. Of the six (6) fish species expected to be present under reference conditions, three (3) were confirmed during both the July 2022 and the May 2023 assessments (comprising smaller specimens), with an additional two having frequent collection records. Even though, significant sewage input from Botshabelo via the Klein Modder was confirmed during July 2022, the fish assemblage remained within a moderately modified state due to the assemblage's tolerance to poor water quality, with lower frequency of occurrence of several species noted. Furthermore, although water quality impacts were expected to largely deter upstream migration within the reach, the reach is likely to present the only feasible corridor for fish moving upstream from Mocke's Dam. Such severe water quality impacts related to raw sewage input have further implications in providing a likely causal mechanism for fish kill events within the reach as a result of depleted oxygen levels due to organic decomposition and concentration of fish against the weir.

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	98.12	96.02
COVER	100.00	100.00
FLOW MODIFICATION	62.70	73.23
PHYSICAL-CHEMICAL	52.77	64.74
MIGRATION		67.38
IMPACT OF INTRODUCED		38.09
FRAI		PRESENT
FRAI (%)		68.6
EC: FRAI		C

PES and causes	
Component	**Causes** **Present/Absent**
Macroinvertebrates	The available biotopes for aquatic macroinvertebrates in this stretch mainly consist of bedrock, artificial SIC and SOOC, GSM, and some marginal vegetation. During the July 2022 survey, flows were sufficient, allowing for accessible sampling of biotopes. However, the May 2023 survey was hindered by flooding caused by recent rainfall events, resulting in limited access, and only some GSM and marginal vegetation could be sampled. A total of 10 taxa were recorded during both surveys for this study. However, over the last hydrological year, a total of 14 taxa were documented at this site. Consequently, the aquatic macroinvertebrate community collected in this study is considered to represent largely modified conditions (Ecological Category D, 50.03%). Despite being largely modified, the presence of artificial habitats provides for additional substrate for macroinvertebrates to colonise. Nonetheless, there has been a substantial change or loss of biota and fundamental ecosystem functions, primarily attributable to the water quality state in this system. The assemblage supports this observation, mostly having low to very low requirement for unmodified physical-chemical conditions, irrespective of habitat or flow conditions. The only taxa with moderate sensitivity to flow, habitat, and water quality recorded in the last hydrological year were the Baetidae >2spp. Sensitive taxa that were absent from the assemblage during the last hydrological year, with high froc's observed, included Hydropsychidae >2 spp (during the survey, only 1 species was recorded) and Trichorythidae. Other absent taxa influenced by habitat conditions included Trichorythidae, Aeshnidae, and Elmidae (associated with cobbles) and Atyidae (associated with vegetation). These taxa typically prefer moderate water quality, which explains their absence. Furthermore, Atyidae, Caenidae, Gomphidae, Gerridae, Notonectidae, Veliidae, Dytiscidae, and Culicidae were absent in the current assemblage compared to the reference state. These taxa generally favour standing water. However, as this site is located just downstream of a gauging weir, flow conditions are frequently regulated. Nonetheless, during the May 2023 survey, noticeably higher flows eliminated standing water habitats.

PES and causes

Component	Causes Present/Absent

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	47.3	*0.291*	13.7605	3	80
HABITAT	H	59.1	*0.327*	19.3295	2	90
WATER QUALITY	WQ	43.6	*0.364*	15.8474	1	100
CONNECTIVITY & SEASONALITY	CS	60.0	*0.018*	1.09091	4	5
						275
INVERTEBRATE EC				50.0283		
INVERTEBRATE EC CATEGORY				D		

Overall, in the last hydrological year, the community composition was primarily influenced by water quality (43.6%), flow modification (47.3%), and habitat (59.1%). The ASPT for the communities found in July 2022 and May 2023 was 4.0 and 3.6, respectively, indicating that the community was predominantly composed of very tolerant taxa (Dickens and Graham, 2002).

Riparian vegetation

The marginal zone has been largely impacted by the construction of the weir, resulting in back flooding of the original marginal zone. Downstream the channel has also become incised resulting in a narrowly confined marginal zone which is further impacted by erosion and bank collapse. A dense stand of Popular trees (*Populus alba*) on the right bank, upstream of the weir has resulted in the loss of some non-woody vegetation, and there remain a few scattered *Salix mucronatae* trees within and overhanging the margins. A low diversity of sedge and grasses were observed within the marginal zone (i.e., *Bulbostylis cf hispidula*, *Echinochloa sp.*, *Hemarthria altissima*, *Paspalum distichum*). The lower zone is also dominated by non-woody vegetation (notably *Cynodon dactylon* and *Pennisetum clandestinum*), and the banks have become severely degraded following a large flood in April 2022. The structure of the upper banks has been altered by the abutments that have been constructed for the roads and railway lines, and have created a sheltered environment for woody terrestrial and alien shrubs and trees to establish (e.g., *Diospyros lycioides subsp. Lycioides, Vachellia karroo, Cestrum laevigatum, Nicotiana glaucea, Pyracantha angustifolia, Schinus molle*).

The marginal zone played the dominant role in supporting riparian functions and stabilizing banks during high flows, with the lower zone providing a secondary role with buffering upslope impacts (runoff, erosion and water quality).

The riparian vegetation at the site has been heavily impacted by bridge structures for the road and railway, with increased erosion and channel

PES and causes

Component	Causes Present/Absent
	incision below the abutments. There is a moderate infestation of alien plants (24 species recorded), making up 47% of the plant diversity recorded at the site. Grazing impacts and trampling of vegetation by livestock is concentrated at the site, particularly along the right bank.

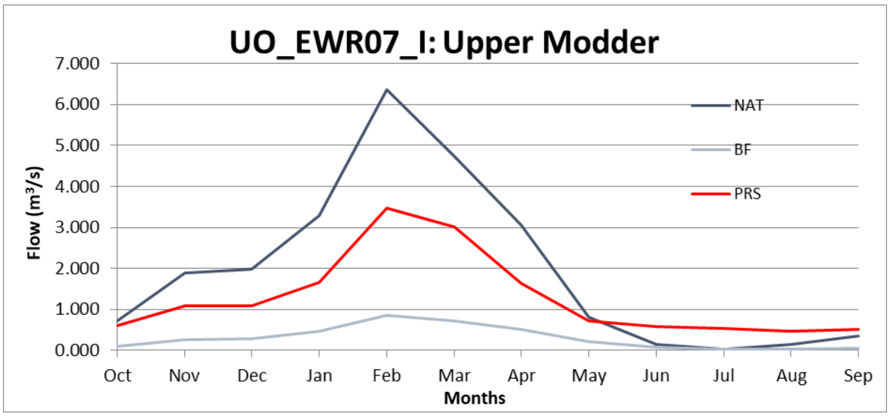
LEVEL 4 ASSESSMENT	EWR07_I: Upper Modder					02 June 2023
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	38.4	1.8	2.7	1.0	4.8	Weighted according to extent
Lower zone	34.8	8.3	2.7	2.0	23.8	Weighted according to extent
Upper zone	50.8	36.3	2.5	3.0	71.4	Weighted according to extent
LEVEL 4 VEGRAI (%)						46.4
VEGRAI Ecological Category						D
AVERAGE CONFIDENCE						2.6

	Sub-zone					
	Marginal zone	Lower zone	Upper zone	0.0	0.0	0.0
VEGRAI % (Zone)	38.4	34.8	50.8	not assessed	not assessed	not assessed
EC (Zone)	D/E	E	D			
Confidence (Zone)	2.7	2.7	2.5			

Component	Causes Present/Absent
Hydrology	All the flow components have been impacted, with lower freshets and floods due to the infrequent spilling and no releases from Rustfontein Dam and increased low flows due to the constant releases from the WWTW.

HYDROLOGY DRIVER ASSESSMENT INDEX

HYDROLOGY METRICS	Rank	%wt	RATING	CONFI-DENCE
LOW FLOWS	3	80	3.0	2
ZERO FLOW DURATION	1	100	0.0	3
SEASONALITY	2	95	3.0	3
MODERATE EVENTS	4	70	2.0	3
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	5	60	3.0	2
HYDROLOGY SCORE	**58.3**			
HYDROLOGY ECOLOGICAL CATEGORY	**C/D**			

PES and causes	
Component	**Causes Present/Absent**
	
Geomorphology	The broad geomorphology, as described by the geomorphic zone, of the Upper Modder River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in the increased flashiness of flows and increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. The coarser bedload has also been reduced by weirs and dams in the catchment. The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Alien vegetation shades out smaller growth forms, reducing ground cover and species diversity. The alien trees drive bank erosion by forming dense superficial root structures that are often undercut and subsequently fall over and destabilise the banks. Grazing and trampling at the site further degrades the banks and inset features, making them vulnerable to scour and annual reworking. This results in a largely modified site with currently low habitat diversity and low geomorphic stability within the channel and along the channel margins.

PES and causes	
Component	**Causes Present/Absent**

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHTED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	2.31	0.40	0.92	58.55	2.67
Sediment balance	3.00	70.00	2.49	0.28	0.70	30.00	3.15
Bed & bank stability	2.00	80.00	2.85	0.32	0.91	19.44	2.17
TOTALS		250.00		1.00	2.53		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					49.31		
HABITAT DRIVER CATEGORY					D	38.04	2.64
					WEIGHTED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					2.50	63.78	2.54
HABITAT CHANGE STATUS					50		
HABITAT CHANGE CATEGORY					D		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Decline	• Long-term decline of water quality through failing/dysfunctional sewage infrastructure	4
Macroinvertebrates	Decline	• Ongoing pressures at a catchment level • Long-term decline of water quality through failing/dysfunctional sewage infrastructure	4
Riparian vegetation	Decline	• The riparian vegetation has experienced a recent decline following floods in 2022, which is exacerbated by poor conditions at the site as well as the degraded landscape surrounding the site.	4
Hydrology	Stable	• No recent water resource developments	3
Geomorphology	Decline	• Ongoing pressures at catchment level and at the site	3.5
Physical-chemical	Decline	• Long-term decline of water quality through failing/dysfunctional sewage infrastructure	3
ECOSTATUS	Decline		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation					
COMPONENT	**PES 2014**	**JBS2 2015**	**JBS3 2021**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C	C/D	D	• Seriously compromised water quality owing to the following: • Return flows from WWTW, including raw sewage inputs into upstream tributaries • Irrigation and return flows • Rustfontein Dam upstream impacting on all the flow components.

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
Moderate, Moderate	Low, Moderate

Physical-chemical state of the system
The pH is elevated but still within guidelines. Dissolved oxygen, TDS and Conductivity do not necessarily reflect the impacts coming in from the Klein-Modder upstream. DO (%) is among the lower recorded in the catchment (less than 80%). The impacts from the Klein-Modder are likely minimised by dilution from the larger Modder River and the Rustfontein Dam upstream during the wet months. Diatoms do, however, reflect the impacts on the Physical-chemical state downstream of Botshabelo township and the WWTW.

PES	REC		AEC	
D	C	• 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).	C	• No change from REC.

OVERALL ASSESSMENT

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
AEC	C

Figure 7-21: Overall EcoStatus assessment for UO_EWR07_I (Upper Modder)

The overall EcoStatus for this EWR site was categorised as a D, with the system being largely modified (Figure 7-21). The degradation of the catchment is elevating suspended sediment loads leading to higher turbidity and silt deposits over coarser habitats. At the site, disturbance along the margins is widespread leading to degradation of the habitat associated with inset benches and banks. The water quality is highly compromised, with the diatoms reflecting the impacts on the physical-chemical state downstream of Botshabelo and the unmaintained and dysfunctional WWTW. This is ultimately and primarily having a major impact on the biota within the system, particular with both fish and macroinvertebrates responding to very poor water quality (i.e., raw sewage input from Botshabelo and smaller upstream tributaries), could further suggest that fish kill events are likely to take place.

This reach does present the only feasible movement corridor for fish moving upstream from Mocke's Dam. The marginal and lower zones were found to be in a poor to severely modified state largely due to bank erosion, livestock grazing/trampling, stormwater runoff impacts, and altered habitat structure from the weir and bridges – overall condition of the riparian zone is poor (Ecological Category D).

It is suggested that both the REC and AEC of a C (moderately modified) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-21).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Land use activities within upstream 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);
- DWS need to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance; and
- Upstream municipal infrastructure must be reviewed and maintained and upgraded.

7.8 UO_EWR08_I: LOWER KRAAI

Sample Date	7 July 2022 30 May 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR08_I	**Prioritised RU**	R_RU03
River	Kraai	**Altitude (m.a.s.l.)**	1298
Latitude	-30.69007°	**Longitude**	26.74157°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D13M-05442
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (0.001; Lower foothills)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, re-measurements of slope and water levels, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-22) AND SITE PHOTOGRAPHS (Figure 7-23)

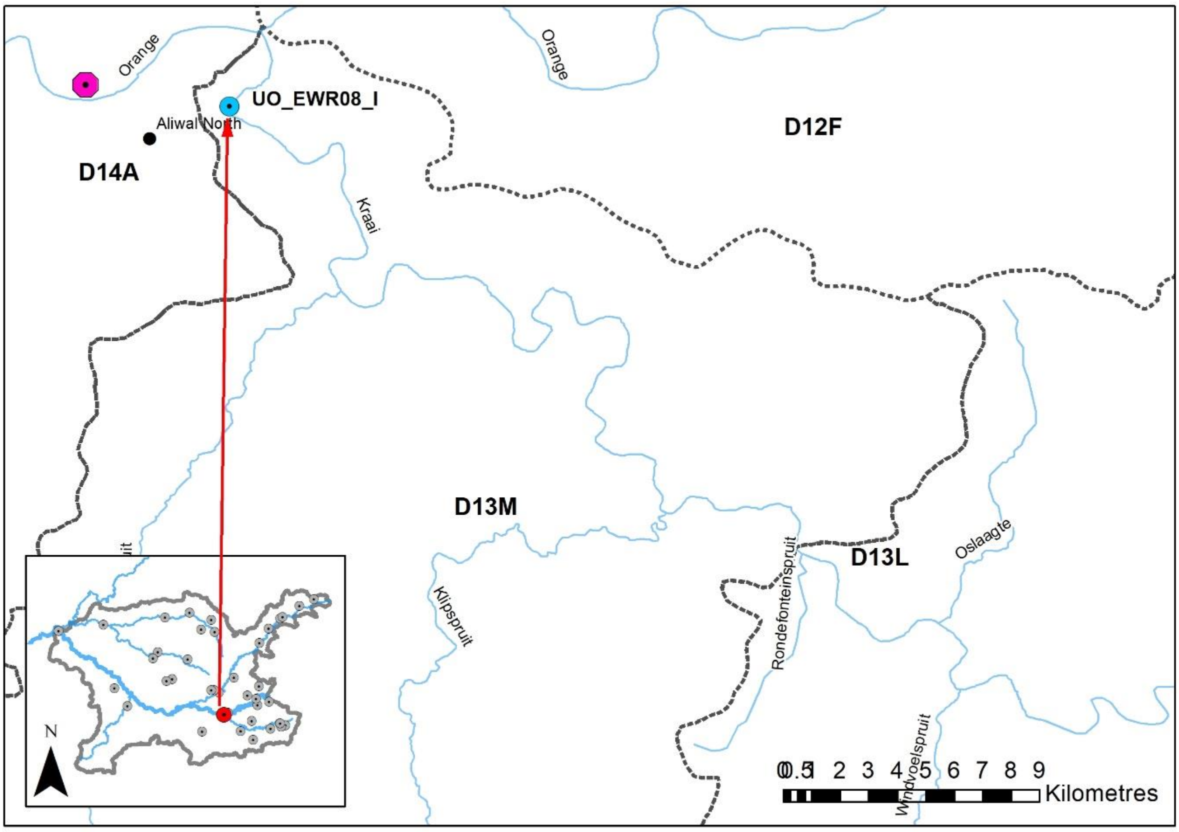


Figure 7-22: Location of site UO_EWR08_I (Lower Kraai) in relation to the study area

Site Photographs: Survey 1 (July 2022)

Site Photographs: Survey 2 (May 2023)


Figure 7-23: Site photographs of the Lower Kraai EWR site

Upstream	Downstream

Site Description:

This site is ORASECOM JBS3 site (26_11) and the DWS REMP site D1KRAA-ALIWA.The reach has a partly confined valley setting, straight to wandering channel form and pool-riffle sequences. The channel is incised with narrow flood features. The site is immediately downstream of a causeway/ bridge which is frequently used by farmers. There is a sluice gate on the right end of the bridge – which can be closed in times of drought or should the Orange River dry up. This functions in pooling the river upstream of the bridge for Basic Human Needs support.

This river is a free flowing river, ~30 m wide and has a range of biotopes. There is a solid igneous bedrock base with riffles and runs below the causeway. Much filamentous algae coverage over the SIC biotopes. Most of the river in the area has deeper, slow flowing pools. The river comprises various sections of riffles and pools downstream of the bridge, providing a range of habitats. All biotopes for the macroinvertebrates are present, SIC, SOOC, GSM, although vegetation is limiting owing to undercut banks and vegetation die back/erosion. For fish, there are FD, SD, SS and FS habitats. During both the July and May 2022 survey, the baseflows were higher than expected for the time of year as a result of the high rainfall during the latter part of summer.

Left bank is dominated by non-woody vegetation, with several, large Popular trees (*Populus canescens*) growing along the lower banks upstream of the weir. The site is spilt by the weir/ causeway, which results in marginal zone being inundated. Downstream of the weir is a broad, flat bench of mostly bare/exposed alluvium with patches of raised alluvial mounds covered with *Cynodon dactylon* and a narrow strip of dense *Cyperus marginatus* growing along the marginal zone. The outer edge of the riparian is marked by a steep bank leading up into the terrestrial zone. The right bank has dense wooded vegetation comprising a mix of indigenous (e.g., *Celtis africana*, *Diospyros lyciodides, Lycium sp.*, *Salix mucronata* and *Searsia pyroides*) and IAPs (e.g., *Populus canescens* and *Salix babylonica*) which are sheltered from high velocities during flood events. There is a steep bank between the lower and upper zones. The riparian vegetation is mainly affected by vegetation removal due to roads, 4x4 tracks, footpaths, cultivation (right banks), as well as shading by IAPs. There is also serious erosion leading from the terrestrial areas into the riparian areas, especially on the left bank, as well as bank collapse and scour erosion.

The main land use in the area is agriculture with several centre pivot irrigation fields close to the river immediately upstream. *Salix sp.* line the banks both upstream and downstream. The flood debris line is ~3 m above the water level indicating large volumes passing through during flood events.

Site impacts:

- Agriculture
- Cattle activity
- Irrigation
- Causeway/ weir

SUMMARY RESULTS

WATER QUALITY AND FLOW

***In situ* water quality:**

Parameter	Survey 1 (July 2022)	Survey 2 (May 2023)
pH	8.6	8.3
EC (µS/cm)	218	139.4
TDS (g/l)	0.2	0.1
DO (mg/l)	10.1	8.9
DO% (%)	87.7	82.1
Clarity (cm)	68	12
Temperature (°C)	9.1	11.7
Salinity (ppt)	0.15	0.09
Discharge (m^3/s)	17.300	19.030

Diatoms:

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
July 2022				
34	13.8	C (Moderate)	7.8	0
Dominant Species		*Gomphonema pumilum*		
Preference		Strongly polluted water and high electrolytes as well as some siltation.		
May 2023				
31	9.8	C (Moderate)	62.2	1.75
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of strong pollution, indicator of industrial organic pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Straight channel with fairly stable bed	• High-flow water surface levels might vary due to the weir possibly pushing water onto the wide bedrock shelf along the left bank
Fish	4	• Various velocity-depth classes present • Various cover featured present • Presence of low wate bridge assists in concentrating fish	• Marginal vegetation as a cover feature limiting • Reach upstream of low water bridge inundated for some distance • Reach below the low water bridge likely to be significantly inundated by push-back from the Orange River when Orange River flows are high
Riparian vegetation	4	• Good access to site, and across the site. • Been assessed during ORASECOM surveys in 2015 and 2021 (JBS2 and JBS3).	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months). • Upstream portion of the site is altered by the weir and back flooding.
Macroinvertebrates	5	• A variety of aquatic biotopes • Varying flow velocities	• Limited marginal vegetation - owing to undercut banks and bank erosion along the banks • No instream aquatic vegetation • Low water bridge at site resulting in inundation upstream – too deep to access and some bed modification downstream near the sluice gate • Algae smothering SIC biotope (nutrients)
Geomorphology	2.8	• Easy access, clear water • Good range of morphological features and sediment types	• Impacted site at low water bridge, possibly driving local bank erosion

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			X			• New site with one flow observation during moderate flow levels
Fish				X		• FROC (Kleynhans et al., 2008) • PESEIS (2014) • JBS2 and JBS3 (Site OSAEH 26_11)** • ORASECOM EFR K7 • July 2022 survey
Macroinvertebrates					X	• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • DWS REMP site further upstream (D2KRAA-ALIWA) • PES, 2014 • JBS2 and JBS3 (Site OSAEH 26_11)** • ORASECOM EFR K7 • July 2022 survey
Hydrology			X			Monthly modelled hydrology for period 1920-2004. Gauging weir D1H011 to provides indication of freshets/ floods (~20km upstream of EWR site).
Riparian vegetation				X		• Historical and recent aerial images • JBS2 and JBS3 (Site OSAEH 26_11)** • May 2023 survey
Geomorphology			X			• Historical air photos and literature on land use change and sediment dynamics in the upper catchment
Diatoms					X	• Data from JBS2 and JBS3 • July 2022 and May 2023 diatom samples
Physical-chemical			X			• Green Drop Reports 2011, 2013, 2021 and 2022. • July 2022 and May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*
*** ORASECOM, 2023a*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae ,Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae,

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
	Chlorocyphidae, Coenagrionidae, Lestidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Hydropsychidae 1sp, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Lymnaeidae, Planorbinae.
Riparian vegetation	The site is primarily defined by Upper Gariep Alluvial Vegetation forming a mosaic of well-defined riparian thickets (in positions that are more sheltered from floods) and flooded grasslands/herblands. Riparian thickets would typically be dominated by trees and shrubs (i.e., *Vachellia karroo*, *Celtis africana*, *Diospyros lycioides*, *Lycium hirsutum*, *Salix mucronata* subsp. *mucronata*, *Searsia pyroides*). The river margins would have supported grasses, reeds and sedges growing on exposed alluvium. The surrounding terrestrial vegetation transitions from Dry Highveld Grassland (of the Grassland Biome) into Upper Karoo (of Nama-Karoo Biome) and comprises a mosaic of Aliwal North Dry Grassland and Besemkaree Koppies Shrubland.
Geomorphology	The reference condition for the reach is likely to be a lower gradient mixed bed alluvial channel with sand, gravel and cobble dominating the bed with localised bedrock lining the bed. The reach type would mainly be pool-riffle or pool-rapid with sand and gravel bars forming in pools. Inset benches and flood benches should form in relation to freshets and floods. A narrow floodplain can be present where the valley floor is wider.
Hydrology	Natural flows at the EWR site available for the period 1920 to 2004.
Physical-chemical	Historical Physical-chemical data for the site could not be obtained. The diatom results were used to infer the reference Physical-chemical state of the site. The diatom results indicated strongly polluted with evidence of elevated electrolyte concentrations. Lower electrolyte concentrations are expected to be prevalent in the system, under reference conditions.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish (FRAI)	C (73.7%)	F/NF	• Water quality modifications • Flow modifications • Migration barrier • Non-native fish species
Macroinvertebrates (MIRAI)	C (65.4%)	F/NF	• Habitat modification (algae smothering SIC, upstream inundation from weir) • Water quality (high nutrient loading from agricultural return flows – resulting in the high levels of algae)

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
			• Flow modification (owing to the agricultural return flows and in other cases extensive irrigation for adjacent pivots resulting in reduced baseflows)
Riparian vegetation (VEGRAI)	D/E (40.6%)	NF/F	• Site is heavily impacted by alien trees, especially along the right bank, resulting in shading out of understorey. • Non-woody vegetation has been severely scoured due to recent floods, especially along marginal and lower zones. The flood bench on the left bank is accessed for sand mining.
Geomorphology (GAI)	C (75)	17% F related	• Low density of smaller farm dams along tributaries and weirs along the mainstem that trap coarser bedload. Gullies and small areas with low vegetation cover increase water and sediment routing. • Widespread grazing and some soil erosion elevate fine sediment loads. Low water bridges and weirs along tributaries and mainstem trap coarser bed sediment. • Localised erosion along left bank due to the weir. Grazing along banks and bars. New inset benches forming along right bank.
Hydrology (HAI)	B (87.9%)	F	• Extensive irrigation in some of the tributaries and along main stem resulting in reduced baseflows.
Physical-chemical (Diatoms)	C	NF	• The present Physical-chemical state of the system was inferred from the diatom results. • Diatom results indicated that the current Physical-chemical state of the site is characterised by elevated electrolyte concentrations and pollutants.
ECOSTATUS	C (64.3%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	To a large degree, all fish expected to be present within the reach were still present or expected to be present, albeit at a marginally reduced frequency of occurrence, with flow modifications, water quality modification, instream barriers and cover elements acting as drivers to the moderately modified ecological state obtained. The further presence of non-native fish

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>species within the reach (and within upper reaches) is expected to provide a further driver to the ecological state, albeit to a lesser degree. Although fish are able to traverse the weir during high flows (via the left-hand bank over the causeway and at night), the excess energy expenditure below the weir is expected to create an energy deficient for successful migration to the upstream catchment. The reach nevertheless is a preferred migration route for fish moving upstream within the Orange River during high flows due to the lack of sediment input and comparatively clear water relative to the mainstem Orange River.

<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>100.00</td><td>97.34</td></tr>
<tr><td>COVER</td><td>99.40</td><td>100.00</td></tr>
<tr><td>FLOW MODIFICATION</td><td>65.41</td><td>78.15</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>58.32</td><td>71.23</td></tr>
<tr><td>MIGRATION</td><td></td><td>62.77</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>38.86</td></tr>
<tr><th>FRAI</th><th colspan="2">PRESENT</th></tr>
<tr><td>FRAI (%)</td><td colspan="2">74.1</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">C</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates</td><td>The lower Kraai River offers a variety of biotopes and flow velocities that support diverse aquatic macroinvertebrate communities. However, the presence of undercut banks limits the growth of marginal vegetation in this area. In the July 2022 survey, a total of 14 taxa were recorded. Unfortunately, subsequent high flows and flooding prevented DWS from conducting their Routine REMP sampling at this site since last year. Nevertheless, there is substantial macroinvertebrate data available, allowing for confident interpretation.

Overall, the aquatic macroinvertebrate community indicates moderately modified conditions (Ecological Category C, 65.37%). This categorisation trend aligns with the findings of the JBS3 study conducted in 2021 (ORASECOM, 2023). Most of the recorded taxa exhibited a preference for moderately fast flowing water, as well as standing water, cobbles, and a combination of varying water quality conditions.

Sensitive taxa to flow and water quality, recorded in July 2022, included Hydracarina, Perlidae, Baetidae >2spp, Leptophlebiidae, Trichorythidae, Aeshnidae, Elmidae, and Dixidae. However, several other expected taxa sensitive to flow and water quality were absent from the community. These</td></tr>
</table>

PES and causes

Component	Causes Present/Absent
	taxa, with high froc's, included Atyidae, Oligoneuridae, Chlorocyphidae, Lestidae, Corduliidae, Hydropsychidae >2spp, and Hydraenidae. The absence of these taxa may be attributed to elevated return flows from irrigation and increased flow velocities resulting from channel restriction caused by a low-water bridge crossing, which reduces preferential habitat for these taxa. Additionally, increased nutrient levels have led to algal growth and smothering of the stones biotope. This further limits the availability of this biotope.

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	73.5	0.327	24.0545	2	90
HABITAT	H	62.4	0.364	22.6989	1	100
WATER QUALITY	WQ	59.0	0.291	17.1636	3	80
CONNECTIVITY & SEASONALITY	CS	80.0	0.018	1.45455	4	5
						275
INVERTEBRATE EC				65.3716		
INVERTEBRATE EC CATEGORY				C		

Component	Causes Present/Absent
	Consequently, the community dynamics are primarily influenced by water quality (59.0%), followed by habitat (62.4%) and flow modification (73.5%). The ASPT for the communities in July 2022 was 6.2, indicating a predominance of tolerant taxa (Dickens and Graham, 2002). However, it is important to note the presence of many sensitive taxa recorded at this site, as mentioned earlier.
Riparian vegetation	Under the natural/reference state the right bank would have been dominated by woody vegetation with inset benches of alluvium deposited around the inner bend of the channel. The non-marginal zone along the right has since become infested by alien trees (i.e., *Salix babylonica, Populus canescens* and *Robinia pseudoacacia*). Consequently, indigenous non-woody vegetation has been shaded out leaving the banks exposed and destabilized. The upper zone has a well-defined band of riparian thicket, including some elements of the natural state, but has also been encroached by terrestrial species (e.g., *Diospyros lycioides* subsp. *lycioides* and *Lycium horridum*) and alien plants. The left bank has retained its mostly non-woody vegetation character, except for, large Popular trees upstream of the weir. Downstream of the weir, large patches of flooded grassland have been removed from the broad, flat flood bench – likely caused by increased scour erosion over the edge of the weir during floods. This area is also actively used for sand

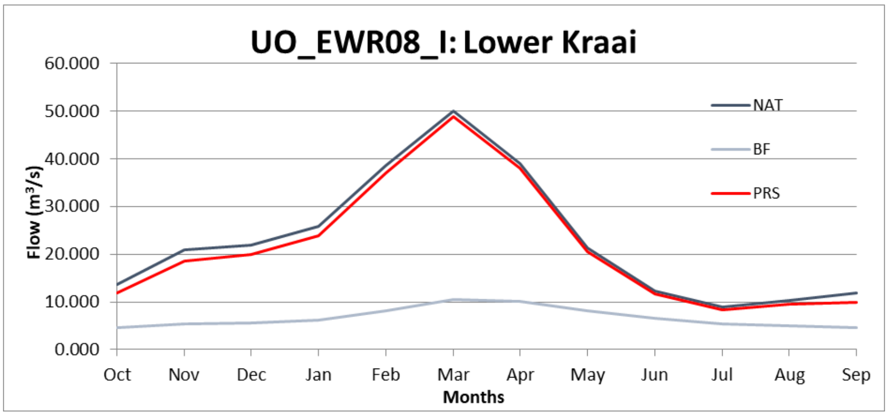
PES and causes

Component	Causes Present/Absent
	mining, resulting in further disturbance to the riparian vegetation along the lower and upper zones. The weir has altered the structure of the riparian zone through inundation of the marginal zone and parts of the lower zone. The recent floods experienced over the last two years have resulted in most of the marginal vegetation being scoured out, leaving the banks bare and exposed. Other impacts affecting the riparian vegetation at the site include recreational fishing/camping, livestock pressures (grazing and trampling), as well as 4x4 driving. Under natural conditions, non-woody vegetation within the marginal zone would have played a primary role in maintaining instream habitat integrity, particularly through bank stabilization and buffering impacts to the lower banks during floods. This would have been especially important along the outer bend of the channel (left bank).

LEVEL 4 ASSESSMENT	EWR08_I: Lower Kraai					30 May 2023
RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	Notes:
Marginal zone	36.8	1.8	2.8	2.0	5.0	Weighted according to extent
Lower zone	46.0	6.9	2.7	1.0	15.0	Weighted according to extent
Upper zone	39.8	31.8	2.8	3.0	80.0	Weighted according to extent
LEVEL 4 VEGRAI (%)						40.6
VEGRAI Ecological Category						D/E
AVERAGE CONFIDENCE						2.8
				Sub-zone		
	Marginal zone	Lower zone	Upper zone	0.0	0.0	0.0
VEGRAI % (Zone)	36.8	46.0	39.8	not assessed	not assessed	not assessed
EC (Zone)	E	D	D/E			
Confidence (Zone)	2.8	2.7	2.8			

Component	Causes Present/Absent
Hydrology	The floods and freshets are near natural as no dams in the upper reaches. Baseflows are lower due to abstractions for irrigation, especially during dry periods.

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFI-DENCE**
LOW FLOWS	3	90	2.0	3
ZERO FLOW DURATION	1	100	0.0	3
SEASONALITY	2	95	0.0	3
MODERATE EVENTS	3	80	1.0	2
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	4	65	0.0	2

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><td>HYDROLOGY SCORE</td><td>87.9</td></tr>
<tr><td>HYDROLOGY ECOLOGICAL CATEGORY</td><td>B</td></tr>
</table>


</td></tr>
<tr><td>Geomorphology</td><td>The broad geomorphology, as described by the geomorphic zone, of the Lower Kraai River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates. Coarse bedload has also been reduced by weirs in the catchment, reducing this habitat type at the site.
The increased flashiness of the system drives the erosion of marginal habitats such as inset benches. Grazing and trampling at the site further degrade the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently moderate habitat diversity.</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	(spreadsheet below)

GEOMORPHOLOGY DRIVERS							
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.00	0.43	0.43	25.00	2.75
Sediment balance	2.00	70.00	1.30	0.30	0.40	19.13	3.00
Bed & bank stability	3.00	60.00	1.50	0.26	0.39	0.00	2.79
TOTALS		230.00		1.00	1.22		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					75.54		
HABITAT DRIVER CATEGORY					C	16.69	2.84
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					1.20	31.82	3.00
HABITAT CHANGE STATUS					76.06061		
HABITAT CHANGE CATEGORY					C		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers at catchment scale considered stable • Should large impoundments be proposed for the reach, trend is likely to decline	4
Macroinvertebrates	Stable	• catchment processes appear to be relatively established and buffered • Pressure remains from agricultural return flows • JBS2 (2015), JBS3 and DWS REMP results reflect the aquatic macroinvertebrate community being representative of moderately modified conditions (category C) or close to (category C/D).	4
Riparian vegetation	Decline	The site has declined slightly since 2021 when riparian vegetation was assessed as a category D by ORASECOM during JBS3. This has been due to the exacerbated pressure of floods on the riparian zone which has poor attenuation and stabilising capacity.	4

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Hydrology	Stable	No recent water resource developments	3
Geomorphology	Stable	• Drivers at a catchment scale and site scale seem stable	3
Water quality	Stable	• No recent water resource developments	3
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation					
COMPONENT	**PES 2014**	**JBS2 2015**	**JBS3 2021**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	C/D	C	• Water quality impairments (high algae smothering over aquatic biotopes, owing to extensive irrigation, nutrient enrichment and siltation

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
High, High	High, High

Physical-chemical state of the system
The pH is elevated but still within guidelines. All the other parameters were also within guidelines. Although slightly elevated, pH, TDS and conductivity are comparable to those recorded in the JBS3 survey

PES	REC		AEC	
C	B/C	• 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.	B	• Removal of alien vegetation along the riparian zone and continual management; and • Catchment management (buffer zones for irrigation, overgrazing, trampling).

OVERALL ASSESSMENT

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
AEC	B

Figure 7-24: Overall EcoStatus assessment for UO_EWR08_I (Lower Kraai)

The overall EcoStatus for this EWR site was categorised as a C, thus the system is in a moderately modified condition, with loss and change of natural habitat and biota having occurred in terms of frequencies of occurrence and abundances (Figure 7-24). The degradation of the catchment is elevating suspended sediment loads leading to higher turbidity during higher flows and silt deposits over coarser habitats. At the site, disturbance along the margins is moderate leading to some degradation of the habitat associated with inset benches and banks. To a large degree, all fish expected to be present within the reach were still present, albeit at a marginally reduced frequency of occurrence, with flow modifications, water quality modification, instream barriers and cover elements acting as drivers to the moderately modified ecological state obtained.

The aquatic macroinvertebrate community is still stable and indicative of moderately modified conditions (category C). Although several sensitive macroinvertebrates were recorded with a preference for both good water quality and fast to very fast flow conditions, the majority of the community responded to water quality modifications. The marginal vegetation was found to be in a severely modified state due to extensive scour erosion and removal of marginal vegetation, which extended up into the lower zone. The habitat structure associated with the marginal and lower zones upstream of the weir have been altered from the weir, and the right bank is compromised by alien plants. The overall condition of the riparian zone is poor to seriously modified (Ecological Category D/E).

It is suggested that a REC and AEC of a B/C (close to largely natural) and a B (largely natural with few modifications) respectively can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-24).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Land use activities within the upstream catchment and adjacent to the site (irrigation, abstraction, return flows) should be managed to prevent degradation of the ecological health of the system and deterioration of the water quality (buffer zones to be implemented);
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways); and
- Alien invasive vegetation along the riparian zone to be managed appropriately.

7.9 UO_EWR09_I: LOWER RIET

Sample Date	-	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR09_I	**Prioritised RU**	R_RU10
River	Lower Riet	**Altitude (m.a.s.l.)**	1080
Latitude	-29.026963	**Longitude**	24.512919
Level 1 EcoRegion	Southern Kalahari	**Quaternary catchment-SQ Reach**	C51L-03878
Level 2 EcoRegion	29.02	**DWS, 2014 PES, EI, ES**	D, Very High, High
Geomorphological zone	E (0.002; Lower foothills)		

Components sampled: Hydraulic data from Vaal comprehensive study (Vaal_EWR19) and biological data from JBS2, JBS3 ORASECOM site OSAEH 29_5 (ORASECOM, 2023a) and DWS REMP site C5RIET-DEKRA

MAP ILLUSTRATION (Figure 7-26)

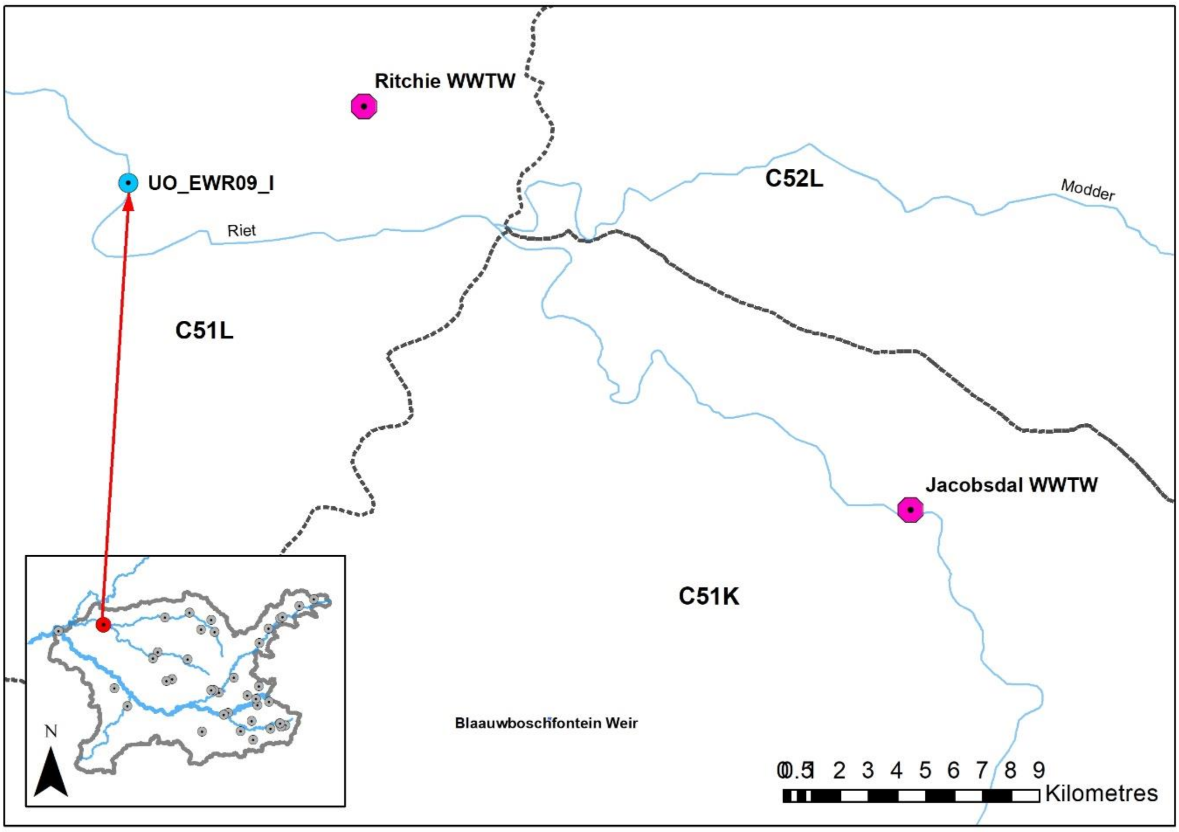


Figure 7-25: Location of site UO_EWR09_I (Lower Riet) in relation to the study area

Site Description:

The site is downstream of the Modder River confluence and the small farming town of Modderrivier. There are two dams upstream, the Krugersdrif Dam on the Modder River (~140 km upstream), north of Bloemfontein, and the Kalkfontein Dam (~80 km upstream) on the Riet River SSE of Koffiefontein. The site is in the Mokala National Park with intensive irrigation of crops upstream on the banks of both the Modder and the Riet Rivers.

The site lies along a confined reach of the Riet system and is largely controlled by bedrock. The channel is straight to wandering with localised anastomosing sections. Sand bars are present along the pools, and inset benches and flood features are narrow with no flood plain. The bedrock forms steeper riffles and rapids interspersed by long pools. Boulders, cobble and gravel are present along the riffles and rapids, with fine sediment or bedrock dominating the pools.

The river is approximately 40 to 50 meters wide with turbid waters. The stream bed is dominated by bedrock, with some GSM. The riverbanks are dominated by phragmites, potentially due to the lack of regular scouring from flood events, Salix is also present on the banks.

Site impacts:

- Upstream settlements
- Agriculture
- Cattle activity
- Irrigation
- Large dams and numerous abstraction weirs

SUMMARY RESULTS

WATER QUALITY

In situ water quality *(data obtained from JBS3, October 2021, site OSAEH 29_5) (ORASECOM, 2023a):*

- pH: 8.8
- EC: 321 µS/cm
- TDS: 0.112 g/l
- DO: 10.1 mg/l
- Clarity: 12cm
- Temperature: 20.5°C

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Straight simple channel form	• Based on previous study with no new observed data
Fish	2	• Based on previous study with no new observed data	• Based on previous study with no new observed data
Riparian vegetation	2	• Based on previous study with no new observed data	• Based on previous study with no new observed data
Macroinvertebrates	2	• Based on previous study with no new observed data	• Based on previous study with no new observed data • The stream bed is dominated by bedrock with limited GSM. The banks lined with phragmites (ORASECOM, 2023a)
Geomorphology	2.5	• In a protected area with limited local disturbances	• The bedrock nature of the site does not reflect the

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Straight simple channel form	• Based on previous study with no new observed data
			changes to the drivers clearly

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics						• Based on previous assessment with no new observed data • Stable cross-section and still relevant
Fish						• JBS3 ORASECOM site OSAEH 29_5 • Vaal comprehensive study (Vaal_EWR19)
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • DWS REMP site (C5RIET-DEKRA) – last dataset was in 2020 • SANParks monitoring site • PES, 2014 • JBS3 ORASECOM site OSAEH 29_5 • Vaal comprehensive study (Vaal_EWR19)
Hydrology						• Monthly modelled hydrology for period 1920-2004. • Daily data available from gauging weir C5H014.
Geomorphology						• Google Earth images and historical aerial images
Riparian vegetation						• JBS3 ORASECOM site OSAEH 29_5 • Vaal comprehensive study (Vaal_EWR19)
Diatoms						• JBS3 ORASECOM site OSAEH 29_5
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022. • 2021 Diatom results. (JBS3 results) • NCMP data (1970 to 2017, n= 724)

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Enteromius paludinosus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis* and *Labeo umbratus*
Macroinvertebrates	Reference conditions used from DWS REMP (C5RIET-DEKRA): Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Lestidae, Platycnemididae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Polycentropodidae, Psychomyiidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Thiaridae, Corbiculidae, Sphaeridae and Unionidae
Geomorphology	The reference condition for the reach is likely to be a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed with localised bedrock forming the channel boundary. The reach type would mainly be pool-riffle or pool-rapid with sand bars forming in pools. Pools are likely to be longer than riffle and rapid sections. A narrow floodplain can be present where the valley floor is wider.
Hydrology	Natural flows available for the period 1920-2004.
Physical-chemical	Historical Physical-chemical data obtained for the site indicated high salt concentrations, which has been linked to irrigation return flows from the Riet River Irrigation Scheme and has been raised as an issue in the system. The reference condition was therefore determined from the diatom data. The diatom data indicated elevated electrolyte concentrations and turbidity. Lower electrolyte concentrations are expected to have been prevalent at the site under reference conditions.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish*	C	NF	• Decreased substrate quality and sedimentation • Increased turbidity • Decreased species diversity and abundance • Reduced baseflows
Macroinvertebrates*	C	NF	• Water quality (nutrient enrichment from upstream agriculture and town)
Riparian vegetation (VEGRAI)*	B	NF	• Vegetation removal • Water quantity (abstraction for irrigation and small impoundments upstream of the site)

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Geomorphology	C (67%)	32 % flow related	• 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.
Hydrology	C (64.2%)	F	• Both freshets and flood components severely impacted by upstream dams.
Physical-chemical (Diatoms)*	C	NF	• Present Physical-chemical condition was estimated as of the RQS data ending in 2018, which did not reflect the current conditions at the site. • The diatom results indicated 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.
ECOSTATUS*	C		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories
**Results used and interpreted from JBS3 (ORASECOM, 2023a)*

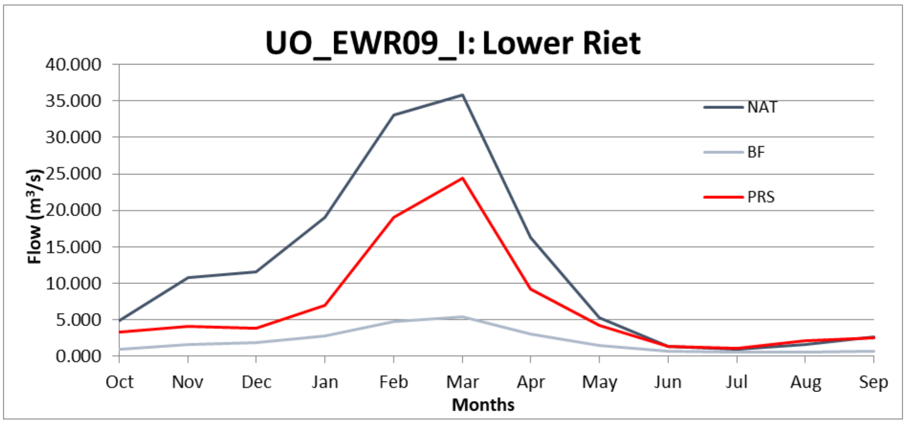
PES and causes	
Component	**Causes Present/Absent**
Fish	The lower Riet River survey was not conducted for this study, as information from the JBS3 conducted in 2021 (ORASECOM, 2023a) were utilised instead. Based on the JBS3 results, a marginal reduction in the frequency of occurrence was observed for most fish species anticipated to be present. Only *Clarias gariepinus* (Sharptooth Catfish), *Labeo capensis* (Orange River Mudfish), *Pseudocrenilabrus philander* (Southern Mouthbrooder), and *Tilapia sparrmanii* (Banded Tilapia) were recorded at the expected frequencies. A significant increase in invasive aquatic macrophytes within the channel and heightened algal growth on rocks were documented during the survey period. Furthermore, it was expected that water abstraction from upstream dams (Krugersdrift and Kalkfontein) would continue to decrease baseflows, resulting in reduced spring flushes and moderate flood events. This reduction would then diminish migratory cues for indigenous species in the

PES and causes	
Component	**Causes** **Present/Absent**
	catchment, leading to decreased recruitment. Consequently, the fish community at this site was classified as moderately modified (Ecological Category C) (ORASECOM, 2023a).
Macroinvertebrates	The lower Riet River survey was not conducted for this study, as information from the Vaal comprehensive study (Vaal_EWR19), JBS3 conducted in 2021 (ORASECOM, 2023a), and the DWS REMP site (C5RIET-DEKRA) were utilised instead. Based on the results obtained from REMP, JBS1 (2010), and JBS3 (2021), the aquatic macroinvertebrate community consistently exhibited moderate modification (Ecological Category C). However, JBS2 (2015) indicated conditions that were close to being largely natural (Ecological Category B/C). In the most recent JBS3 assessment conducted by ORASECOM (2023a), it was observed thatwater quality, habitat, and flow modification, were similarly impacted at the site. The higher flows during JBS3 compared to JBS2 resulted in reduced sampling effort, leading to minor differences in category assignments during those surveys (ORASECOM, 2023a). Overall, the taxa most affected in the JBS3 assessment were those that preferred very fast flowing water and standing water, while those with very low preferences for unmodified water quality were less affected. Water quality in this area is compromised due to upstream agriculture and settlements. Eutrophication was evident, with algal growth on the bedrock and boulder habitats, and filamentous algae in the water column (ORASECOM, 2023a).
Riparian vegetation	The lower Riet River survey was not conducted for this study, as information from the JBS3 conducted in 2021 (ORASECOM, 2023a) were used instead. According to ORASECOM (2023a), vegetation along the marginal zone was limited and confined to areas between large boulders and bedrock at the time of the survey. Observations revealed vegetation removal, the presence of limited alien vegetation, and further indicated slight changes in the water quantity available within the system (abstraction/irrigation). Overall, the woody vegetation was more limited due to grazing on the right-hand bank, while the non-woody vegetation played a dominant role in maintaining the integrity of the river's instream habitat. The marginal zone played a secondary role in terms of bank stabilisation and functioned as a buffer between the terrestrial systems and the river's instream habitat. There were no signs of vegetation removal in the non-marginal zone or the presence of alien vegetation at the site. It was largely dominated by grasses, with scattered occurrences of opportunistic woody vegetation species.

PES and causes	
Component	**Causes Present/Absent**
	Non-woody vegetation played the dominant role in supporting the integrity of the instream habitat, even though its overall cover, abundance, and species diversity slightly decreased compared to the reference state. In contrast, the coverage of woody vegetation slightly increased (ORASECOM, 2023a). The non-marginal zone played the dominant role in bank stabilisation and functioned as a buffer between the terrestrial systems and the river's instream habitat due to its size and heterogeneous vegetation cover.
Hydrology	See table and figure below
Geomorphology	The broad geomorphology, as described by the geomorphic zone, of the Lower Riet River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover, agriculture and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased

HYDROLOGY DRIVER ASSESSMENT INDEX

HYDROLOGY METRICS	Rank	%wt	RATING	CONFI-DENCE
LOW FLOWS	3	80	1.0	3
ZERO FLOW DURATION	1	100	0.0	2
SEASONALITY	2	90	2.0	3
MODERATE EVENTS	4	60	4.0	3
EVENT HYDROLOGY (HIGH FLOWS-FLOODS)	3	75	3.0	3
HYDROLOGY SCORE	**64.2**			
HYDROLOGY ECOLOGICAL CATEGORY	**C**			



PES and causes	
Component	**Causes Present/Absent**
	the erosion of soil and delivery of sediment and water. This results in increased flashiness of flows and increased suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates. The coarse bedload has also been reduced by weirs and dams in the catchment, reducing this habitat type at the site. The increased flashiness and reduced bedload of the system drive the erosion of marginal habitats such as inset benches. This results in a site with currently moderate habitat diversity.

GEOMORPHOLOGY DRIVERS							
COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1,00	100,00	1,96	0,43	0,85	44,56	2,78
Sediment balance	2,00	70,00	1,30	0,30	0,40	12,17	2,85
Bed & bank stability	3,00	60,00	1,50	0,26	0,39	32,94	2,50
TOTALS		230,00		1,00	1,64		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					67,22		
HABITAT DRIVER CATEGORY					C	31,67	2,73
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					1,80	36,06	2,50
HABITAT CHANGE STATUS					63,9394		
HABITAT CHANGE CATEGORY					C		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish*	Unclear	Due to the high flows at the time of the JBS3 assessment, it was difficult to determine trends with previous results. It was however likely that the trend will reflect a stable trajectory.	2
Macroinvertebrates*	Unclear		2
Habitat integrity: Instream	-	-	-
Habitat integrity: Riparian	-	-	-
Hydrology	Stable	No recent water resource developments	3
Geomorphology	Stable	Drivers were altered several decades ago, so the system has formed a new equilibrium. Disturbance along the reach is minimal due to the protected area with low game densities.	3
ECOSTATUS*	Stable		

** 0 – no confidence to 5 – high confidence*
**Results used and interpreted from JBS3 (ORASECOM, 2023a)*

Overall change and reason for deviation					
COMPONENT	**PES 2014**	**Vaal_ EWR19***	**JBS2 2015**	**JBS3 2021**	**REASON FOR DEVIATION**
ECOSTATUS	D	D	B/C	C	• Continued water quality concerns owing to upstream agriculture and towns/settlements • Upstream weirs and abstraction (irrigation) • Large dams upstream of the site • Increased erosion rates in the catchment.

**DWA, 2010*

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Intermediate, 2022**
Very high, High	Very High, High

*

Physical-chemical state of the system
Site observations indicated turbid water which suggests high suspended solids and low clarity in the system. Elevated pH was also recorded in the JBS3 survey. However, it must be noted that *in situ* water quality is a snapshot in time and thus interpreted as such.

PES	REC		AEC	
C	B/C	• The site is located within Mokale National Park Reserve and thus requiring attention to the conservation / environmental needs. It is further a recreational fishing area (Largemouth Yellowfish).	B/C	• No change from REC.

OVERALL ASSESSMENT

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
AEC	B/C

Figure 7-26: Overall EcoStatus assessment for UO_EWR09_I (Lower Riet)

The overall EcoStatus for this EWR site was categorised as a C, thus the system being in a moderately modified condition (Figure 7-26). There is degradation in the catchment due to grazing, changes in hillslope-channel connectivity and cropping elevating fine sediment loadings and siltation of coarser habitats. The dams and weirs along the Modder and Riet Rivers trap bedload sediment, reducing coarser habitat extent for the reach. Disturbance along the banks and channel margins are localised due to the protected area. From a biological perspective, the fish and macroinvertebrate communities represent moderately modified conditions (category C), while the riparian vegetation component continues to be largely natural with few modifications, most from a water quality perspective and vegetation removal from cattle trampling.

It is suggested that a REC and AEC of a B/C (close to largely natural most of the time) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-26).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- DWS to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance;
- Upstream municipal infrastructure to be reviewed and maintained/upgraded; and
- Land use activities within upstream 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).

7.10 UO_EWR10_I: LOWER ORANGE

Sample Date	3 June 2023	**Reserve Level Assessment**	Intermediate
Site Name	UO_EWR10_I	**Prioritised RU**	R_RU07
River	Lower Orange	**Altitude (m.a.s.l.)**	1000
Latitude	-29.14485	**Longitude**	23.691403
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D33K-03723
Level 2 EcoRegion	26.01	**DWS, 2014 PES, EI, ES**	C, High, Moderate
Geomorphological zone	F (0.001; Lowlands)		

Components sampled: Fish, aquatic macroinvertebrates, riparian vegetation, *in situ* water quality, diatoms, cross-section, discharge, geomorphology

MAP ILLUSTRATION (Figure 7-27) AND SITE PHOTOGRAPHS (Figure 7-28)

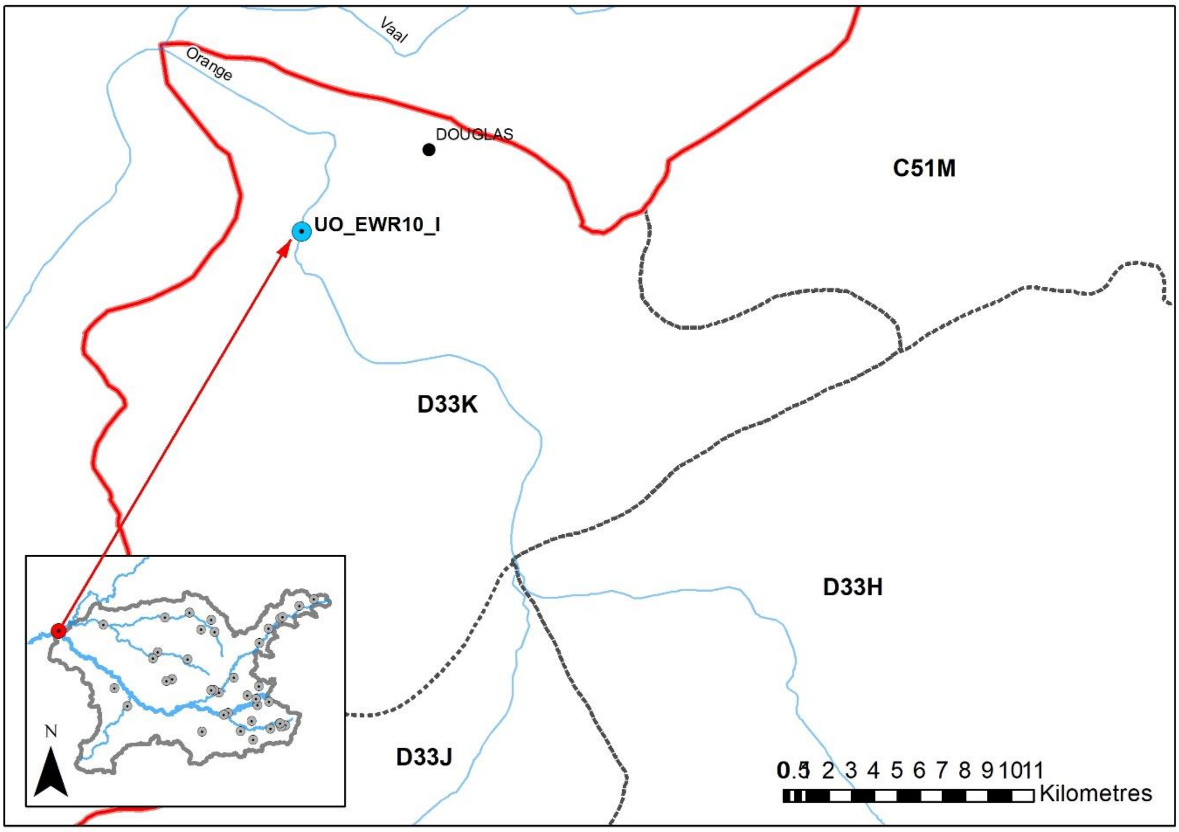


Figure 7-27: Location of site UO_EWR10_I (Lower Orange) in relation to the study area

Site Photographs: Survey 2 (May 2023)

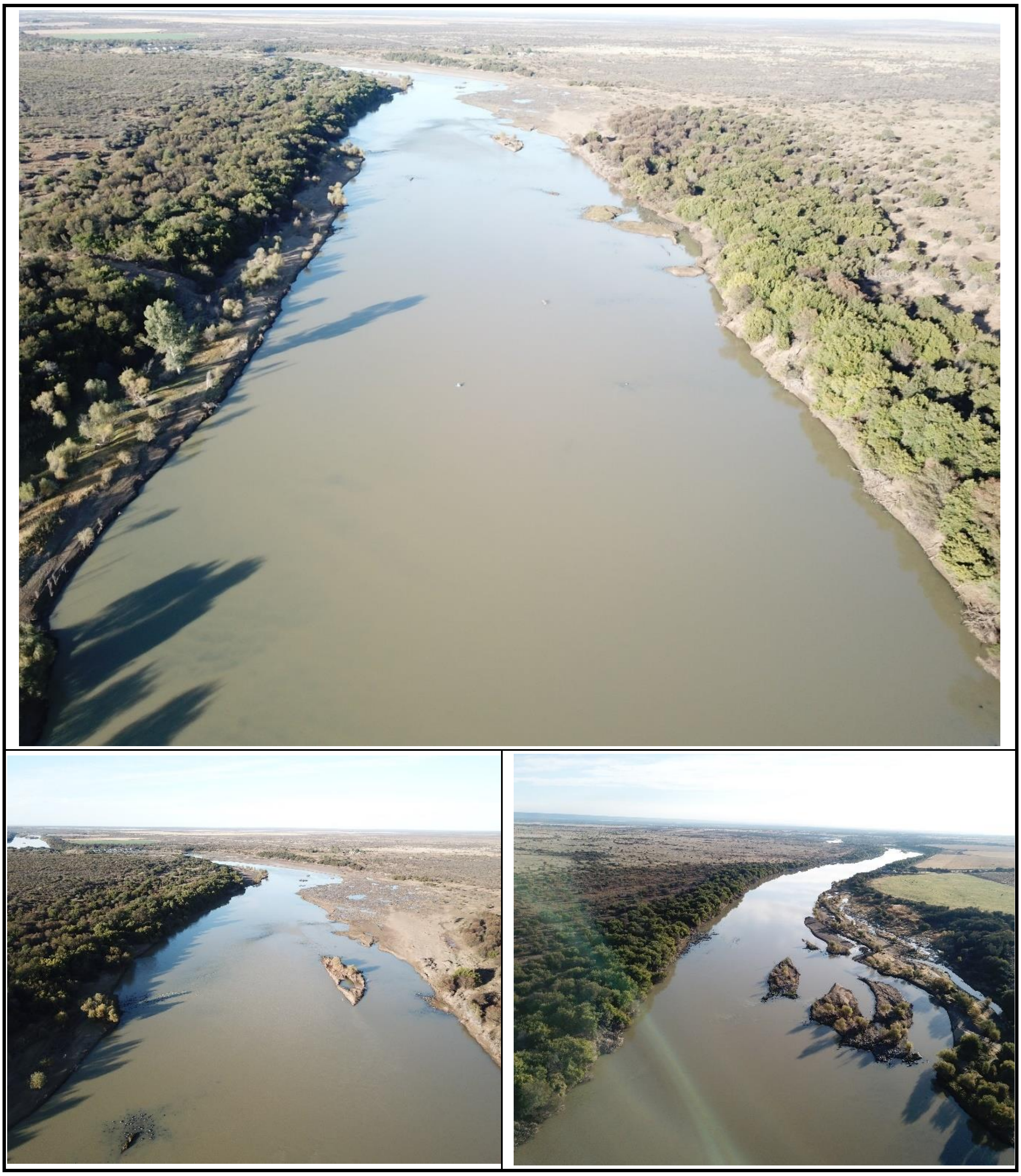


Figure 7-28: Site photographs of the Lower Orange EWR site

Upstream	Downstream

Site Description:

This EWR site is located approximately 13km south-west of Douglas, 12km upstream of the confluence with the Vaal River and 2.5km downstream of Marksdrift weir. It is defined by an incised macro-channel of approximately 160m wide. The channel has a straight to sinuous planform with pool-riffle and poolrapid reach types. The riffles have cobble and gravel sediment, with bedrock and boulders forming the rapids. The pools are longer than the riffles and have sand bars and lateral bars in places. Islands form on bedrock with sedimentary coverings. The banks are steep due to the incised nature of the river and composed of fine silt and sand.

The primary land-use is irrigated agriculture/cultivation, principally centre pivots and peacan nut orchards. Water is pumped from the Orange River at Marksdrift and transferred to Douglas Weir on the Vaal River, which is 23.5km upstream of the confluence. This water transfer scheme is used mainly for irrigation and to improve the water quality in the lower Vaal River. Vanderkloof Dam is located approximately 175km upstream, with Gariep Dam positioned further upstream (approximately 55km upstream of Vanderkloof Dam).

Up until 2020, the site was characterised by several small to medium islands covered by dense reeds and sedges, with a braided network of pools and runs. These channel features have since become covered by sediments that have been deposited at the site during recent floods. The active channel is now more confined to the mainstem, with the exception of two side channels along the left bank, that provides some riffle habitat comprising boulder and some cobble substrate. Fine sediments, gravel and sand were confined. The aquatic macroinvertebrate biotopes included SIC, SOOC and GSM. Owing to various recent flood events in this system, all marginal vegetation has been removed, although evidence of pockets of reeds beginning to establish. The different flow-depth-velocity classes present for fish included FS, SD (dominance), SS and some FD.

The riparian zone associated with the EWR site is characterized by short, steep banks that flattens out into the surrounding savanna (left bank) and agricultural lands (right bank). The marginal zone is made up of bare sand/alluvium with some exposed bedrock and occasional overhanging trees on the left bank. The lower portion of the lower zone is also sandy with scattered dead trees and shrubs, becoming more vegetated further up the banks with patches of *Cynodon dactylon* and riparian thickets of *Vachellia karroo*, *Diospyros lycioides, Lycium hirsutum* and *Ziziphus mucronata*. The lower zone of the right bank is wider than the left bank and has a raised sand bar with a band of bare sand, leading into a grassy strip of *Cynodon dactylon*, then low thicket (mostly dead *Lycium* shrubs, with some *Salix mucronata* and *Ziziphus mucronata*). Beyond the sand bar the bank drops into a depression, which becomes a side channel activated during high flows. From here the bank rises steeply into the densely wooded upper zone, with mature Buffalo Thorn (*Ziziphus mucronata*) and Sweet Thorn (*Vachellia karroo*) trees. The riparian vegetation is primarily impacted by altered flows caused from Vanderkloof and Gariep Dams upstream, which affect the natural disturbance regime resulting in changes to riparian vegetation structure and composition.

Site impacts:

- Agriculture
- Cattle activity
- Extensive irrigation
- Changed flow regime due to releases from upstream dams for water use in the lower Orange River and estuarine requirements

SUMMARY RESULTS

WATER QUALITY ANF FLOW

In situ water quality:

- pH: 8.17
- EC: 217.5 µS/cm
- TDS: 0.1825 g/l
- DO: 9.64 mg/l
- DO%: 91.9%
- Clarity: 24 cm
- Temperature: 13.2°C
- Salinity: 0.14
- Discharge: 63.71 m^3/s

Diatoms

No. species	SPI**	Categorisation (quality)	%PTV***	%Deformed cells****
29	7.8	D (Poor)	*80.3*	0
Dominant Species		*Nitzschia liebetruthii Rabenhorst*		
Preference		Cosmopolitan species found in very electrolyte-rich to brackish water.		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Straight and simple channel form	• Mobile bed, so possible changes to cross sectional area. • Observed flows for relatively low discharges. • One observation
Fish	3	• Variety of velocity-depth classes	• Instream and marginal vegetation limited/absent

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Straight and simple channel form	• Mobile bed, so possible changes to cross sectional area. • Observed flows for relatively low discharges. • One observation
		• Presence of substrate and water column as cover features • Braided channel allows for sampling of wadable sections	• Much of reach is non-wadable, presenting sampling limitations • Often rapid rises in water levels due to upstream hydropower releases
Riparian Vegetation	4	• Been assessed during ORASECOM surveys in 2015 and 2021 (JBS2 and JBS3).	• Season not optimum for assessing non-woody vegetation (i.e., limited floral or above-ground presence during winter months). • Limited access to both banks.
Macroinvertebrates	2	• GSM • Small pocket of boulders	• Wide homogenous channel. • Limited aquatic biotopes – dominated by muddy substrate. • Small pocket of boulders, although highly embedded • No marginal vegetation – bare banks. • High sediment deposition
Geomorphology	2.58	• Variety of habitats present at the site • Low anthropogenic disturbance at the site	• Murky water makes it difficult to see the quality of the bed material

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• Straight simple channel form • New site and rating curve based on one observation
Fish				■		• FROC (Kleynhans et al., 2008)

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
				■		• PESEIS (2014) • Collection records • JBS3 ORASECOM site OSAEH 26_3 • May 2023 survey
Macroinvertebrates					■	• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • PES, 2014 • JBS3 ORASECOM site OSAEH 26_3 • May 2023 survey
Hydrology				■		• Monthly modelled data for the period 1920-2004. • Daly data from gauging weir D3H008 at Marksdrift.
Riparian vegetation					■	• Historical and recent aerial images • JBS2 and JBS3 (Site OSAEH 26_3) • May 2023 survey
Geomorphology			■			• Google Earth imagery and historical aerial images
Diatoms					■	• JBS3 ORASECOM site OSAEH 26_3 • May 2023 diatom sample
Physical-chemical					■	• Green Drop Reports 2011, 2013, 2021 and 2022. • JBS3 ORASECOM site OSAEH 26_3 • NCMP data (1966 to 2018, n = 1397) • May 2023 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Enteromius oraniensis, Enteromius paludinosus, Enteromius trimaculatus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Clarias gariepinus, Labeo capensis, Labeo umbratus, Pseudocrenilabrus philander* and *Tilapia sparrmanii*
Macroinvertebrates	Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae,

<table>
<tr><th colspan="4">Reference Conditions</th></tr>
<tr><th>COMPONENT</th><th colspan="3">DESCRIPTION OF REFERENCE CONDITIONS</th></tr>
<tr><td></td><td colspan="3">Culicidae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Ancylidae, Lymnaeidae, Thiaridae, Corbiculidae and Sphaeridae</td></tr>
<tr><td>Riparian vegetation</td><td colspan="3">The site is primarily defined by Upper Gariep Alluvial Vegetation comprising well-define riparian thickets along the edge of the broad and flat active channel of the Orange River with alluvial terraces supporting flooded grasslands, reedbeds and herblands. Riparian thickets would be dominated trees and shrubs: Verchellia karroo, Celtis africana, Diospyros lycioides, Lycium hirsutum, Salix mucronata subsp. mucronata, Searsia pyroides. The surrounding terrestrial landscape comprises Northern Upper Karoo Vegetation, which forms part of the Upper Karoo Bioregion (of the Nama-Karoo Biome).</td></tr>
<tr><td>Geomorphology</td><td colspan="3">The reference condition for the reach is likely to be a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed with localised bedrock forming the bed. The reach type would mainly be pool-riffle or pool-rapid with sand bars forming in pools. A narrow floodplain can be present where the valley floor is wider.</td></tr>
<tr><td>Hydrology</td><td colspan="3">Natural flows available for the period 1920-2004.</td></tr>
<tr><td rowspan="8">Physical-chemical</td><td colspan="3">Reference condition for the site was determined using the DWS RQS data for site D3H008Q01 (1967 to 1980, n =163)</td></tr>
<tr><td rowspan="5">Physical Variable</td><td>pH</td><td>The reference data indicated that the 5th percentile was 6.7 pH units and the 95th percentile was 8.0 pH units. These values both fell within the Natural (0) rating according to DWA (2008). The DWA (2008) Natural (0) rating for pH was therefore used.</td></tr>
<tr><td>EC</td><td>The reference data indicated that the 95th percentile for the site was 27.34 mS/m, which fell within the 30 mS/m Natural (0) benchmark according to DWA (2008).</td></tr>
<tr><td>Temperature:</td><td>No historical temperature records are available for the site. DWA (2008) benchmark tables were used for a low confidence, qualitative assessment of temperature reference condition</td></tr>
<tr><td>Clarity:</td><td>There are no clarity/turbidity records available for reference condition assessment. Reference condition was taken as that qualitatively described in the DWA (2008) benchmark tables.</td></tr>
<tr><td>Oxygen:</td><td>No dissolved oxygen records are available for this site. DWA guideline benchmark tables (2008) have been utilised to characterise the site's reference condition</td></tr>
<tr><td rowspan="2">Nutrients</td><td>TIN</td><td>Reference data indicated a 50th percentile of 0.16 mg/l, which fell within the DWA (2008) Natura (0) rating of 0.25 mg/l.</td></tr>
<tr><td>PO_4</td><td>The reference data indicated a 50th percentile 0.014 mg/, which fell outside of the DWA (2008)</td></tr>
</table>

Reference Conditions			
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**		
			Natural (0) rating of 0.005 mg/l. The Natural PO_4 rating of the site was, therefore, re-benchmarked such that it was ≤ 0.014.
	Toxins	Fluoride	In terms of the toxics listed within the DWA (2008) rating tables, only fluoride was monitored. The 95th percentile for fluoride was calculated as 0.29 mg/l which fell within the DWA (2008) benchmark table.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	B/C (80.1%)	F/NF	• Flow modification from upstream hydropower discharges • Non-native fish species • Water quality impairment • Migratory barriers (Marksdrift Weir)
Macroinvertebrates	D (50.4%)	F/NF	• Flow modification from upstream hydropower discharges • Habitat modification – the marginal vegetation has completely been removed due to all the floods and hydro-peaks (scouring and sediment deposition) • Water quality impairment (extensive irrigation and return flows)
Riparian vegetation (VEGRAI)	C (77.7%)	NF	Site is heavily impacted by alien trees, notable *Populus canescens*, resulting in widespread removal of non-woody cover and bank destabilisation, especially along marginal and lower zones.
Geomorphology	C/D (60%)	60% flow related	• Catchment degradation elevates suspended sediment concentrations and sedimentation on coarse habitat types. • Weirs and dams trap bedload and reduce coarse habitat extent
Hydrology (HAI)	C/D (58.2%)	F	• All flow components impacted with reduced floods, increased/ constant baseflows during summer months and reduced baseflows during winter months.
Physical-chemical (diatoms)	D	NF	• Present physical-chemical condition at the site was inferred from the diatom results, as a result of the RQS data only ending in 2018, and, therefore, not representative of current physical-chemical state of the site.

			• The diatom results indicated very electrolyte-rich to brackish water, as a result of the irrigation return flows in the system. • The return flows appears to be the major physical-chemical driving factor. Historical data also shows that salinities in the system started increasing in the mid 1990s, corresponding with the increase in irrigated agriculture/cultivation in the area.
ECOSTATUS	C (71.5%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	All fish species expected to be present were present, with several species occurring at a lower frequency of occurrence relative to reference state. A notable reduction in the frequency of occurrence of *Enteromius oraniensis* likely due to loss of slow-shallow velocity-depth class and instream vegetation cover elements. Significant flow modifications as a result of the presence of two large upstream impoundments (Gariep Dam and Vanderkloof Dam) as well as daily hydropower discharges has resulted in the loss of seasonal flows and migratory cues.
Macroinvertebrates	All biotopes were accessible for sampling, except for marginal vegetation, which was completely absent. This absence can be attributed to the continuous floods that have occurred in the system, resulting in significant sediment deposition and the formation of sandbars. The riffles in the system were dominated by bedrock and boulders, with some cobbles and gravel present in the interstitial zones. However, during the survey, there was a noticeable impact on the macroinvertebrate community, characterised by low diversity and

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	96.50	98.04
COVER	100.00	100.00
FLOW MODIFICATION	57.51	70.31
PHYSICAL-CHEMICAL	58.87	71.07
MIGRATION		61.45
IMPACT OF INTRODUCED		38.04
FRAI	PRESENT	
FRAI (%)	80.1	
EC: FRAI	C/B	

abundance of expected families. This impact was likely due to the recent flooding caused by the hydro-peak measured at gauging station D3H012 several days prior to our survey at this EWR site.

Overall, the collected aquatic macroinvertebrate assemblage was determined to be representative of seriously modified conditions (Ecological Category D, 50.3%). This represents a significant change from previous surveys conducted by DWS REMP and the JBS3 survey in 2021 (prior to the major La Nina floods), where the macroinvertebrate community consistently exhibited moderately modified conditions (Ecological Category C). The continuous flooding since the latter part of 2021 has noticeably had a major impact on the macroinvertebrate community, with insufficient time for recolonisation before the next hydro-peak or flood flushes the system again.

During the May 2023 survey, a total of 7 taxa were recorded, all of which exhibited a preference for low to moderate water quality, cobbles, and varying hydraulic conditions. Flow modification (47.9%) primarily influenced the community composition. This is supported by the low abundance of flow-dependent taxa, such as Baetidae (only 1 species recorded), Leptophlebiidae, and Elmidae (only 1 individual recorded), indicating the influence of water level fluctuations. These fluctuations are not solely attributed to hydro-peaks caused by hydropower operations, but also to upstream abstraction activities and agricultural practices near Douglas. Habitat (49.0%) was the second driver of the macroinvertebrate community. Families with a high preference for vegetation, such as Coenagrionidae, Belostomatidae, Dytiscidae, and Lymnaeidae, were not recorded due to the complete absence of marginal vegetation resulting from sediment deposits and bank scouring caused by the floods. Further, the absence of Oligochaeta and Gomphidae, and the recording of just 1 individual of Corbiculidae in the sand-dominated substrate, further potentially is indicative of unfavourable conditions in terms of sediment dynamics. Water quality (53.7%) was the third driver.

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	47.9	*0.357*	17.1218	1	100
HABITAT	H	49.0	*0.304*	14.8848	3	85
WATER QUALITY	WQ	53.7	*0.321*	17.2674	2	90
CONNECTIVITY & SEASONALITY	CS	60.0	*0.018*	1.07143	3	5
						280
INVERTEBRATE EC				50.3455		
INVERTEBRATE EC CATEGORY				D		

Riparian vegetation

In the natural/reference state the riparian zone would have had extensive flood benches supporting flooded grasslands and reedbeds with some sedges and aquatic plants scattered along the marginal zone. Areas of exposed alluvium would vary according to floods from the previous high flow season. The upper banks would have supported well defined riparian thickets with the upper edge transitioning into the surrounding grasslands with encroachment maintained by fires.

Lack of floods prior to 2021 resulted in non-woody vegetation (notably *Phragmites australis*) becoming well established. Since then several medium-sized floods, ranging from 1000 to 2500 cumecs, have allowed the active channel and lower banks to be reset and create more open areas of alluvium and bedrock to provide opportunities for riparian plants to recruit and establish. This has, however, also resulted in large areas of vegetation being completely removed due to the terrestrialization and encroachment that occurred prior to the floods.
At present, the marginal zones are almost entirely bare, with little to no non-woody vegetation cover. Only a minor number of small to medium *Salix mucronata* trees remain, mostly along the right bank and on the islands, with a large number of dead trees forming a mass of debris. The lower zone is steep and narrow on the left bank, with limited cover, but is much more extensive on the right bank, regulated by ongoing sediment deposition. The vegetation cover remaining on the lower zone comprises mainly of *Salix mucronata* and *Cynodon dactylon*, with some regrowth of *Phragmites australis* taking place. The left bank is mostly woody in character blending into the upper zone higher up the banks. The riparian thickets on both banks include several indigenous trees/shrubs (e.g. *Acacia?* karroo, *Diospyros lycioides* subsp. *lycioides*, *Grewia flava*, *Searsia lancea*, *Lycium hirsutum* and *Ziziphus mucronata*), with the right bank becoming more wooded.

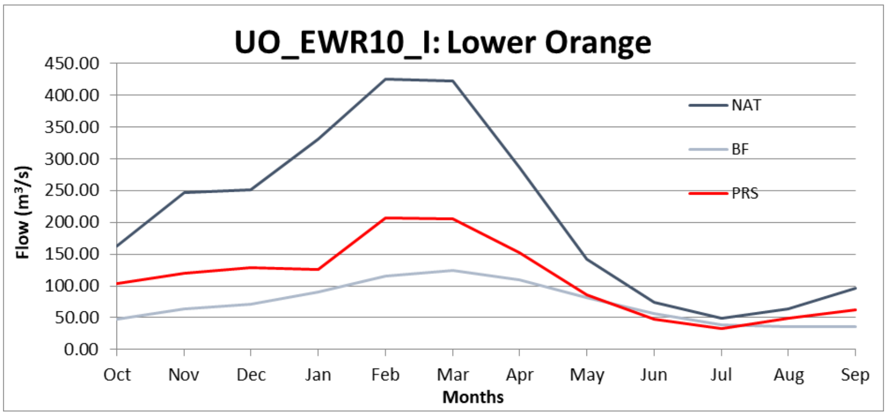
The riparian vegetation, particularly along the marginal and lower zones, is mainly impacted by hydrological alterations as a result of flow regulations from Vanderkloof and Gariep Dams. A small infestation of a moderate number of alien weeds was noted, particularly within the lower zone (e.g., *Argemone ochroleuca*, *Conyza bonariensis*, *Gomphrena celosioides*, Phyla nodiflora and *Xanthium strumarium*).

LEVEL 4 ASSESSMENT	**EWR10_I: Orange River @ Douglas**					**03 June 202**
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**Notes:**
Marginal zone	46.2	1.3	2.3	1.0	2.8	Weighted according to extent
Lower zone	68.2	9.5	3.1	2.0	13.9	Weighted according to extent
Upper zone	68.3	56.9	3.3	3.0	83.3	Weighted according to extent
0.0	not assessed			4.0		
0.0	not assessed			5.0		
0.0	not assessed			6.0		
LEVEL 4 VEGRAI (%)						67.7
VEGRAI Ecological Category						**C**
AVERAGE CONFIDENCE						2.9

				Sub-zone		
	Marginal zone	**Lower zone**	**Upper zone**	**0.0**	**0.0**	**0.0**
VEGRAI % (Zone)	46.2	68.2	68.3	not assessed	not assessed	not assessed
EC (Zone)	**D**	**C**	**C**			
Confidence (Zone)	2.3	3.1	3.3			

<table>
<tr>
<td>Hydrology</td>
<td>
Reduced floods due to large upstream dams, increased/ constant baseflows during summer months and reduced baseflows during winter months. The effect of hydro-peaking due to hydropower releases at Vanderkloof is still visible, however much less than closer to the dam.

<table>
<tr><th colspan="5">HYDROLOGY DRIVER ASSESSMENT INDEX</th></tr>
<tr><th>HYDROLOGY METRICS</th><th>Rank</th><th>%wt</th><th>RATING</th><th>CONFI-DENCE</th></tr>
<tr><td>LOW FLOWS</td><td>3</td><td>85</td><td>2.5</td><td>3</td></tr>
<tr><td>ZERO FLOW DURATION</td><td>1</td><td>100</td><td>0.0</td><td>2</td></tr>
<tr><td>SEASONALITY</td><td>2</td><td>95</td><td>1.0</td><td>3</td></tr>
<tr><td>MODERATE EVENTS</td><td>4</td><td>75</td><td>4.0</td><td>3</td></tr>
<tr><td>EVENT HYDROLOGY (HIGH FLOWS-FLOODS)</td><td>5</td><td>70</td><td>4.0</td><td>3</td></tr>
<tr><td>HYDROLOGY SCORE</td><td>58.2</td><td></td><td></td><td></td></tr>
<tr><td>HYDROLOGY ECOLOGICAL CATEGORY</td><td>C/D</td><td></td><td></td><td></td></tr>
</table>



</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>
The broad geomorphology, as described by the geomorphic zone, of the Lower Orange River has not changed due to anthropogenic influence. There have however been changes to the drivers in terms of catchment connectivity, sediment supply and pressures at the site, changing the condition of the geomorphology and habitat. Low basal cover and increased hillslope-channel connectivity (gullies, rills and roads, etc.) have increased the erosion of soil and the delivery of sediment and water. This results in increased fine bedload and suspended sediment loadings. The increased concentrations lead to fine sediment deposition on coarser substrates, degrading the already limited coarser habitats. The coarser bedload has also been reduced by weirs and dams in the catchment.
Grazing and trampling at the site further degrade the banks and inset features, making them vulnerable to scour and annual reworking. This results in a site with currently low habitat diversity and low geomorphic stability within the channel and along the channel margins.
</td>
</tr>
</table>

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTIN G (%)	RATING	WEIGHT	WEIGHE D SCORE	FLOW RELATE D	CONFIDENCE
System Connectivity	1.00	100.00	2.77	0.43	1.21	53.51	2.68
Sediment balance	2.00	70.00	1.43	0.30	0.44	9.57	2.72
Bed & bank stability	3.00	60.00	1.32	0.26	0.35	25.00	2.26
TOTALS		230.00		1.00	1.99		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					60.26		
HABITAT DRIVER CATEGORY					C	32.70	2.5
					WEIGHE D SCORE	FLOW RELATE D	CONFIDENCE
Morphological change					2.11	60.00	2.80
HABITAT CHANGE STATUS					57.87879		
HABITAT CHANGE CATEGORY					D		

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• No new water resource impacts envisaged. • No amendments to hydropower discharges expected	3
Macroinvertebrates	Stable	• No new water resource impacts envisaged. • The system continues to be highly modified. • Prolonged flooding since end of 2021 have had an impact on the macroinvertebrate community	3
Riparian vegetation	Decline	• The riparian vegetation has become more degraded since it was last assessed in October 2021 during JBS3, but is expected to improve into the next summer season. • Alien weeds expected to re-establish quicker that indigenous riparian species.	3
Hydrology	Stable	• No recent new water resource developments	
Geomorphology	Stable	• The reach has adapted to the changes in flow and sediment so have reached a new equilibrium state, with limited anthropogenic disturbances at the site.	3

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Physical-chemical	Stable	• The reach continues to adapt to the temperature changes and sediments along this reach • Continued run-off from adjacent agricultural activities	3
ECOSTATUS	Stable		

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation					
COMPONENT	**PES 2014**	**JBS2 2015**	**JBS3 2021**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	C	C	• Site downstream of Gariep and Vanderkloof Dams • Flow modification continue owing to hydropower/ hydropeaks –although not to the level as further upstream (sacrificial zone) • Very high irrigation and return flows compromising water quality

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Re-assessed, 2023**
High, Moderate	Moderate, Moderate

Physical-chemical state of the system
High salinities are prevalent in the system as a result of agricultural irrigation return flows.

PES	**REC**		**AEC**	
C	C	• 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.	B/C	• A conceptual FMP is currently being compiled for the sacrificial zone between the 2 dams and just downstream of Vanderkloof Dam; • This component will be included within the EWR Quantification Report (Report number: RDM/WMA13/00/CON/COMP/1323) for further detail on immediate, short term, medium term and long

PES	REC		AEC	
				term recommendations and action plans for this river and its associated impacts; • The conceptual FMP is to be taken further into the classification of the Upper Orange study (subsequent study); • Once these recommendations can be further investigated and implemented, this AEC may be achievable; • Land management (alien invasive vegetation clearing, buffer zones for irrigation); and • Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways)

OVERALL ASSESSMENT

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
AEC	B/C

Figure 7-29: Overall EcoStatus assessment for UO_EWR10_I (Lower Orange)

The overall EcoStatus for this EWR site was categorised as a C, thus the system is in a moderately modified condition, with loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundances (Figure 7-29). Catchment degradation has increased the suspended sediment loads, resulting in sedimentation of coarser habitats. Localised weirs and dams trap bedload further upstream, reducing the extent of coarse sediment habitats.

Trampling and vegetation changes at the reach scale are relatively minor, with recent scouring and deposition evident from the last floods. To a significant extent, all the fish species expected under reference conditions were confirmed, with several species occurring at a lower frequency of occurrence than expected. The presence of two large impoundments upstream of the reach as well as hydropower discharges are however expected to be the primary drivers of the deviation from reference.

From a macroinvertebrate perspective, the community is clearly stressed owing to the continuous flood events since the end of 2021 and hydro-peaks. They do not seem to get an opportunity to recolonise, as what was observed during the May 2023 survey resulting in a community representative of largely modified conditions; Ecological Category D. The marginal vegetation zone has degraded, mostly from flooding and scouring of banks, while the lower and upper zones remain in a more moderate state. Overall, riparian vegetation at the site is moderately modified; Ecological Category C, with flow alterations unlikely to change significantly to assist to manage vegetation condition.

It is suggested that a REC and AEC of a C (moderately modified) and a B/C (close to largely natural most of the time) respectively can be achieved, should the proposed mitigation measures/recommendations be assessed and applied (Figure 7-29).

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways); and
- Review and take forward the conceptual FMP as described within the EWR Quantification Report (Report number: RDM/WMA13/00/CON/COMP/1323).

Please refer to Table 12-1, Figure 12-2 and Figure 12-3 for a summary of the EcoStatus and proposed REC for all Intermediate EWR sites for this study.

8. ECO-CATEGORISATION: RAPID 3 SITES FOR THE UPPER ORANGE CATCHMENT

8.1 UO_EWR01_R: LITTLE CALEDON

Sample Date	4 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR01_R	**Prioritised RU**	R_RU13
River	Little Caledon	**Altitude (m.a.s.l.)**	1692
Latitude	-28.557796°	**Longitude**	28.405709°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D21D - 03094
Level 2 EcoRegion	15.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (Lower Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, diatoms, cross-section, discharge

MAP ILLUSTRATION (Figure 8-1) AND SITE PHOTOGRAPHS (Figure 8-2)

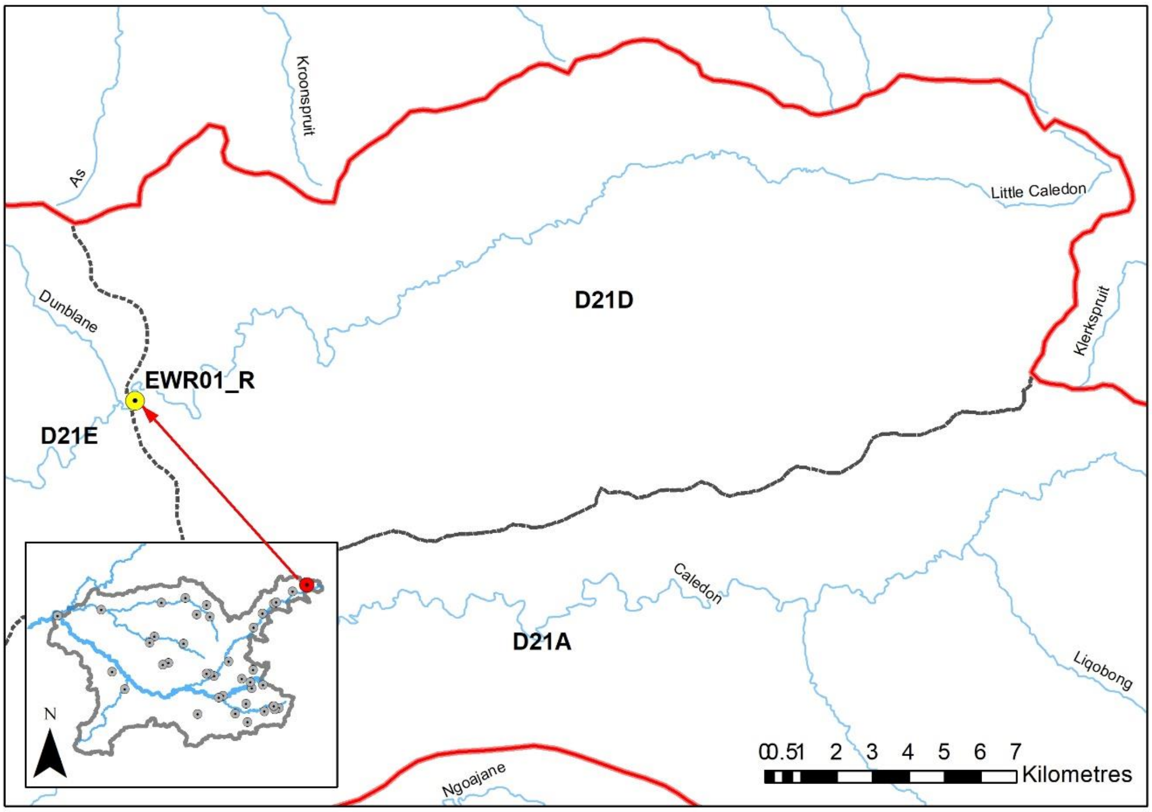


Figure 8-1: Location of site UO_EWR01_R (Little Caledon) in relation to the study area

Figure 8-2: Site photographs of the Little Caledon EWR site

Upstream	Downstream

Site Description:

The site is located downstream from the town of Clarens along an incised floodplain reach. Localised channel modification and bank modification are evident. Farm road/bridge crossing, along and immediately upstream a causeway/bridge which is frequently used by farmers and cattle crossing the river. Both banks show localised erosion. No large upstream dams. The river is ~5m wide and has a range of biotopes for both macroinvertebrates (marginal vegetation, Stones-In-Current and Stones-Out-of-Current (SIIC, SOC) and Gravel, Sand, Mud (GSM). For fish, Slow Deep (SD), Slow Shallow (SS) and Fast Shallow (FS). The marginal vegetation is limited owing to steep undercut banks and vegetation die-back. There is much in-stream vegetation debris creating additional habitat for biota. The riparian vegetation zone is modified primarily owing to agriculture/croplands encroachment, although thickets of *Phragmites australis* and *Salix sp*. also occur within the zone. Just downstream of the bridge there is a section of riffles and runs downstream of the causeway. There are upstream deep pools with a meandering channel. The flows were higher than expected for the dry season owing to enhanced baseflows due to a very wet and late rainfall season.

The main land use in the area is agriculture, croplands and cattle trampling and grazing. Alien Salix trees line the banks both upstream and downstream, facilitating erosion along both banks.

Site impacts:

- Seasonal abstraction
- Agriculture
- Cattle trampling and grazing
- Upstream town of Clarens (possible water quality impacts from WWTW)
- Upstream Clarens golf course, potential source of pesticides, fertilisers
- Stream crossings and bridges

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- Ph: 8.6
- EC: 246 µS/cm
- TDS: 0.247g/l

- DO: 12.7 mg/l
- DO%: 103.6%
- Clarity: 87cm
- Temperature: 6.6°C
- Salinity: 0.18
- Discharge: 0.425m^3/s

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
16	10.5	C (Moderate)	66.8	2.5
Dominant Species		*Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot*		
Preference		Very pollution tolerant – organic pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3.5	• Stable bed with straight and simple channel form	• Large woody debris upstream might alter flow dynamics
Fish	3	• Available literature • Wadable reach • Habitat availability: FS, SD (predominant), SS, SD (present) • Substrate within FS, SD (undercut banks)	• Season limitations • Limited collection records
Macroinvertebrates	4	• SIC, SOOC, GSM	• Season limitations • Limited vegetation (die-back) • Undercut banks • Higher than usual baseflows (not representative of the season) • Some bed modification owing to the bridge at the site and upstream causeway High silt content

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site and single moderate flow level observation

Fish						• Limited collection records • FROC (Kleynhans et al., 2008) • Russell & Skelton, 2014 • PES, 2014 • July 2022 survey
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • DWS REMP site further upstream (D2CAL-EWR01) • SANParks biomonitoring (Golden Gate) • PES, 2014 • July 2022 survey
Hydrology						• Only monthly modelled hydrology for the period 1920-2004
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 diatom results
Diatoms						• July 2022 diatom sample

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis* ; *Labeobarbus aeneus*
Macroinvertebrates	Porifera; Turbellaria; Oligochaeta; Hirudinea; Potamonautidae; Atyidae; Hydracarina; Perlidae, Baetidae >2spp; Caenidae; Leptophlebiidae; Heptageniidae, Trichorythidae; Chlorolestidae; Coenagrionidae; Aeshnidae; Gomphidae; Belostomatidae; Corixidae; Gerridae; Hydrometridae; Notonectidae; Pleidae; Veliidae; Ecnomidae; Hydropsychidae 2spp; Philopotamidae; Psychomyiidae; Hydroptilidae; Leptoceridae; Pisuliidae, Dytiscidae; Elmidae; Gyrinidae; Hydraenidae; Hydrophilidae; Psephenidae, Athericidae; Ceratopogonidae; Chironomidae; Culicidae; Dixidae; Empididae, Muscidae; Simuliidae; Tabanidae; Tipulidae; Ancylidae; Physidae, Planorbinae, Corbiculidae and Sphaeridae.
Physical-chemical	Historical physical-chemical data for the site could not be obtained. Diatom data were used to infer the reference physical-chemical condition at the site. The diatom data indicated that the site is heavily contaminated with organic pollution. This likely arise from the Clarens WWTW upstream. The town of Clarens was established in 1912 and the impacts on the physical-chemical state of the system probably deteriorated since then. Lower nutrient concentrations and overall organic pollution are expected to have been prevalent at the site prior to the impacts of WWTW.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (50.4%)	NF	• Alien fish species (*Oncorhynchus mykiss*) – not recorded, but collection records with likely predation impact on native fish and macroinvertebrates • Decrease in marginal vegetation which acts a spawning substrate as well as provides cover for fry • Downstream dams preventing seasonal migration of *Labeobarbus aeneus*
Macroinvertebrates	D (57.75%)	NF / F	• Combination of both flow and non-flow (SIC, pools driving the community • Higher than usual baseflows (F) • Limited vegetation biotope (NF)
Habitat Integrity: Instream*	B (85%)	NF / F	• Water abstraction and irrigation • Channel modification (bridges) • Physical-chemical • Algae growth • Erosion
Habitat Integrity: Riparian*	B (85%)	NF	• Vegetation removal (trampling, wood harvesting) • Alien vegetation • Bank erosion
ECOSTATUS	C (65.04%)		

*** Refer to Appendix E of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2 for the IHI results*

PES and causes	
Component	**Causes Present/Absent**
Fish	*Enteromius oraniensis*, a eurytopic species which are expected to be the only permanent resident fish species within the reach throughout the year, is expected to occur at a reduced FROC as a result of the stocking of alien *Oncorhynchus mykiss* within the catchment which would prey on the smaller barb species. In addition, incision of the channel and bank erosion has resulted in a decrease in the extent of inundated marginal vegetation which act as a substrate for adhesive eggs and cover for the fry. Furthermore, previous collection of *Labeobarbus aeneus* (Smallmouth Yellowfish), another eurytopic species, within the reach has only taken place in Summer, suggesting seasonal migration and thus presence within the reach. However, there have been little to no records of the species occurring within the reach following the construction of downstream impoundments, suggesting that their FROC within the reach is likely to be limited (although their presence cannot be excluded entirely).

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	99.67	97.03
COVER	100.00	100.00
FLOW MODIFICATION	57.50	75.24
PHYSICAL-CHEMICAL	29.46	53.34
MIGRATION		55.66
IMPACT OF INTRODUCED		36.18
FRAI	**PRESENT**	
FRAI (%)	50.4	
EC: FRAI	D	

Macroinvertebrates

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	60.7	0.333	20.2214	2	95
HABITAT	H	59.3	0.351	20.8221	1	100
WATER QUALITY	WQ	52.9	0.316	16.7013	3	90
CONNECTIVITY & SEASONALITY	CS	80.0	0.000	0	0	0
						285
INVERTEBRATE EC				57.7448		
INVERTEBRATE EC CATEGORY				D		

A diversity and abundance of biotopes were available to sample, except for both instream vegetation (absent) and limited marginal vegetation owing to undercut banks and vegetation die-off (representative of the season). However, the aquatic macroinvertebrate assemblage collected was determined to be representative of largely modified conditions (Ecological Category D, 57.74%). For the hydrological year (2021-2022), a total of 25 taxa were recorded out of a reference community of 55 taxa (45% of the reference community was present). Despite some sensitive taxa being recorded viz Baetidae >2spp, Leptophlebiidae and Trichorythidae, the community was primarily driven by water quality. This was supported by the majority of the community (13 out of 22 reference taxa recorded) tolerant to low water quality. Habitat was the second driver with the assemblages having a preference for the stone biotope.

Taxa expected with a high FROC (3-5) but which were absent from the reach included Belostomatidae, Corixidae, Veliidae, Dytiscidae, Athericidae and Tabanidae. These taxa further have preferences towards low water quality and standing water. Hydropsychidae 2 spp (with a preference for fast-flowing water, high water quality and the stone biotope) and Dixidae (sensitive to moderate water quality and standing water) were also absent. Overall, the ASPT for the last hydrological year (2021- 2022) was 5.5 (84% of the reference ASPT value), indicative of tolerant taxa (Dickens and Graham, 2002).

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments since PES, 2014, Google Earth)	3
Macroinvertebrates	Stable	• Driver impact unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • No additional bed modification/erosion • Habitat availability remains?? • Average ASPT: ~5.0 - 5.5 (84% of the reference	4
Habitat integrity: Instream	Stable	• Driver impact unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, google earth) • No additional bed modification	3
Habitat integrity: Riparian	Stable	• Continuous agriculture along the reach with a buffer zone • Continuity mostly intact	3
ECOSTATUS	Stable	• Sustaining as a category C	3

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR CHANGE**
ECOSTATUS	C	C	N/A

Revised Ecological Importance and Ecological Sensitivity	
EI/ES, 2014	**Rapid 3, 2022**
High, High	High, High

Physical-chemical state of the system
The physical-chemical state of this system is largely driven by the impacts of upstream activities in the town of Clarens. The Clarens WWTW discharges into the system. It is currently classified as high risk, with effluent compliance of 44%. The physical and chemical compliances of the WWTW are excellent at 91% and 97%, respectively. Microbiological compliance however is at 9%, suggesting discharge of microbiologically contaminated water posing an increased risk to downstream communities. The *in-situ* water quality parameters do not necessarily reflect the impact of the WWTW, since most of the parameters vary greatly depending on the time of day and

conditions. The diatoms do however suggest organic pollution in the system, very likely as a result of the Clarens WWTW.

PES	REC	
C	B/C	• As per the recommendations in Chapter 11, if the water quality within this system improves, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-3: Overall EcoStatus assessment for UO_EWR01_R (Little Caledon)

The overall EcoStatus was categorised as a C category. This was mostly owing to the fish component being in a category D (alien species, decrease in spawning substrate and cover features and downstream dams preventing seasonal migration of *Labeobarbus aeneus*) from the Caledon River. The macroinvertebrates were recorded in a category D (limited habitat availability, particularly limited instream and marginal vegetation owing to vegetation die-back and undercut banks – although seasonally driven) (Figure 8-3). The fish community responded to some degree to flow conditions and physical-chemical conditions. The main driver affecting the macroinvertebrate assemblages was water quality and decreased habitat availability, followed by flow modification.

It is suggested that the REC of a B/C (close to largely natural most of the time) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations.
- Land use activities within the upstream 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).
- Where instream movement barriers are proposed, ensure such developments consider facilitation of fish movement, viz fishways).
- Improvement in the functioning of the Clarence WWTW.

8.2 UO_EWR02_R: BRANDWATER (GROOT)

Sample Date	4 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR02_R	**Prioritised RU**	R_RU14
River	Brandwater (Groot)	**Altitude (m.a.s.l.)**	1583
Latitude	-28.680340°	**Longitude**	28.139926°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D21G-03101
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (Lower Foothills)		
Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, diatoms, cross-section, discharge			
MAP ILLUSTRATION (Figure 8-4) AND SITE PHOTOGRAPHS (Figure 8-5)			

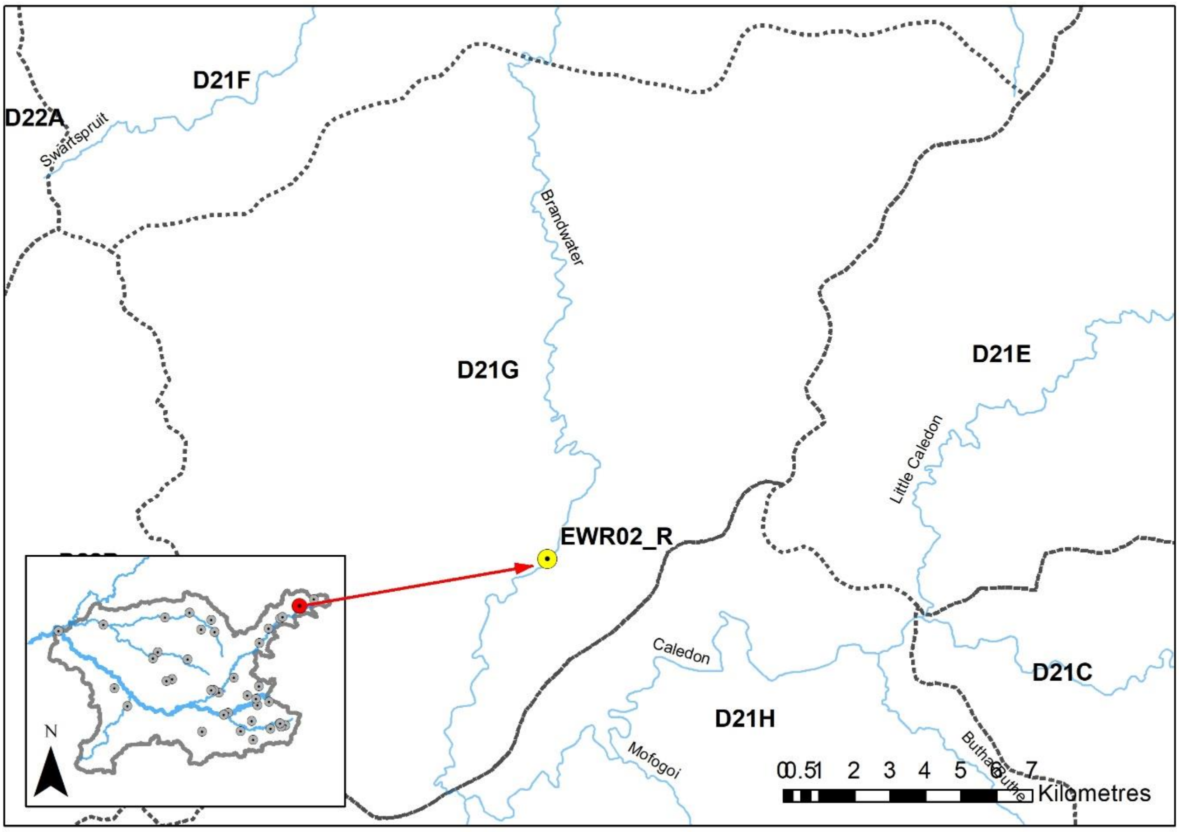


Figure 8-4: Location of site UO_EWR02_R (Brandwater) in relation to the study area


Figure 8-5: Site photographs of the Brandwater EWR site

Upstream	Downstream

Site Description:

The site is located approximately 10km from the town of Fouriesburg, off a road bridge on the R26. The reach has a partly confined valley setting and the channel is incised. The river is ~5m wide with bed and channel modification owing to the bridge construction, and cattle trampling and grazing. Localized erosion and lateral head cut erosion, mostly upstream of the bridge. Biotopes available for macroinvertebrates included SIC, limited SOOC and GSM. Marginal vegetation was absent owing to undercut banks, grazing and vegetation die back. For fish there was SD, SS and FS. Just upstream of the bridge is a section of riffles and runs, with deep pools upstream. High algae content smothering SIC biotopes. The riparian zone is mostly unvegetated and just grass and shrubs, with the alien *Salix sp* located along mostly the left bank. Overall, floodplains, partly confined valley settings and back swamp wetlands further downstream of the site. The flows were higher than expected for the dry season owing to enhanced baseflows due to a very wet and late rainfall season.

Site impacts:

- Water abstraction
- Irrigation
- Cattle trampling and grazing
- Various upstream small dams
- Algae

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 8.4
- EC: 307 µS/cm
- TDS: 0.299g/l
- DO: 14.2 mg/l
- DO%: 118.6%
- Clarity: 37cm
- Temperature: 7.6°C
- Salinity: 0.22
- Discharge: 0.648m^3/s

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
23	9	C (Moderate)	23.2	5.75
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
		Fragilaria capucina var. vaucheriae (Kützing) Lange-Bertalot		
		Nitzschia sp.		
Preference		1. Tolerant of heavy pollution, indicative of industrial organic pollution		
		2. Wide ecological range, not clearly defined		
		3. Generally, siltation and moderate pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Stable bed and simple channel shape	• Bridge immediately downstream could change flow dynamics during high flows. Cattle crossing might alter channel shape
Fish	1	• Habitat availability: SD (predominant), FS (sparse) • Substrate within FS and undercut banks and water column within SD	• Season limitations • No collection records • Limited diversity of velocity-depth classes and cover features
Macroinvertebrates	5	• SIC, SOOC, GSM are present, but limited	• Limited vegetation (die-off) • No instream vegetation • Undercut banks • High algae content smothering SIC biotopes • Higher than usual baseflows (not representative of the season) • Some bed modification owing to the bridge at the site

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with a single flow observation
Fish		■				• PES, 2014

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
						• No collection records • Rapid Reserve studies which include fish do exist but were unable to be obtained from either DWS or the authors. • July 2022 survey
Macroinvertebrates						• River Eco-status Monitoring Programme (REMP) river database (macroinvertebrate data) • DWS REMP site further downstream (D2GROOT-FARM1) • PES, 2014 • Rapid Reserve studies which include macroinvertebrate data unable to be obtained from either DWS or the authors. • July 2022 survey
Hydrology						• Only monthly modelled hydrology is available for 1920-2004
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 diatom results
Diatoms						• July 2022 diatom sample

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Labeo capensis, Labeobarbus aeneus*
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Leptophlebiidae, Oligoneuridae, Trichorythidae, Coenagrionidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Gerridae, Naucoridae, Pleidae, Veliidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Muscidae, Simuliidae, Tipulidae, Ancylidae, Physidae and Planorbinae
Physical-chemical`	Historical Physical-chemical data for the site could not be obtained. The reference Physical-chemical condition at the site was inferred from the diatom results. The diatom results indicated strong organic pollution at the site arising from the Mashaeng WWTW which has been discharging untreated wastewater into the system as far back as 2009. No organic pollution is expected under reference condition and in the absence of the upstream WWTW impacts.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (52.8%)	NF	• Agricultural return flows resulting in nutrient enrichment • Loss of habitat cover features as a result of erosion and sedimentation
Macroinvertebrates	D (57.12%)	NF	• Erosion and sedimentation have eliminated cobbles and vegetation habitats • Limited to no vegetation owing to undercut banks and vegetation die-off • Surrounding cultivation and irrigation contribute to poor water quality • High algae growth smothering stone biotope • Macroinvertebrates with a preference for standing water
Habitat Integrity: Instream	C (75%)	NF/F	• Irrigation • Dams in upper catchment and tributaries • Algae, possibly WWTW effluent, irrigation • Silt loads
Habitat Integrity: Riparian	B/C (80%)	NF	• Road crossings/bridges • Cattle grazing and trampling
ECOSTATUS	C (64.28%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	Habitat diversity and cover features within the reach were noted to be limited, with slow-deep conditions dominant. *Enteromius oraniensis* (, a eurytopic species which are expected to be the only permanent resident fish species within the reach throughout the year, is likely to be present at reduced FROC as a result of water quality impacts within the catchment. Such water quality impacts are also expected to result in reduced FROC for *Labeo capensis* (Orange River Mudfish) and *Labeobarbus aeneus* (Smallmouth Yellowfish) due to reduced seasonal movement into the area (which under natural conditions are likely to be limited) and loss of cover features because of sedimentation and erosion of instream features.

PES and causes

Component	Causes Present/Absent

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	99.85	97.13
COVER	100.00	100.00
FLOW MODIFICATION	58.40	75.73
PHYSICAL-CHEMICAL	27.40	57.65
MIGRATION		55.55
IMPACT OF INTRODUCED		30.55
FRAI	PRESENT	
FRAI (%)	52.8	
EC: FRAI	D	

Macroinvertebrates

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	60.2	*0.370*	22.2784	1	100
HABITAT	H	66.0	*0.296*	19.5658	3	80
WATER QUALITY	WQ	45.8	*0.333*	15.2764	2	90
CONNECTIVITY & SEASONALITY	CS	60.0	*0.000*	0	0	0
						270
INVERTEBRATE EC				57.1206		
INVERTEBRATE EC CATEGORY				D		

Habitat availability at this site was poor during the July 2022 survey. For the hydrological year 2021-2022, 20 taxa were recorded out of an expected 37 (54% of the reference community). The aquatic macroinvertebrate assemblage was determined to be representative of a largely modified condition (Ecological Category D, 57.12%). Despite some sensitive taxa being recorded, viz Baetidae >2spp, Leptophlebiidae and Trichorythidae, the community primarily responded to the water quality conditions. This was supported by the majority of the community responding to and having a preference for low to very low water quality (10 out of 17 and 5 out of 10 reference taxa recorded respectively). Flow modification was the second driver of the system with the assemblages further having a preference for standing water. Taxa expected with a high FROC (3-5) but which were absent from the reach included Potamonautidae, Hydracarina, Aeshnidae, Libellulidae, Pleidae, Hydropsychidae >2spp (sensitive to water quality), Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae and Muscidae. This was to be expected as the majority of these taxa prefer moderate to fast-flowing water, which was limited and the stones biotope, also limited coupled with being smothered by algae and silt. Overall, the ASPT for the last hydrological year was 3.5 (58% of the

PES and causes	
Component	**Causes Present/Absent**
	reference ASPT value), indicative of tolerant taxa (Dickens and Graham, 2002).

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers of change are likely unchanged as no new land uses are identified	2
Macroinvertebrates	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • Erosion increasing which may have future impacts on the community • Average ASPT: ~4.5 – 4.9 (58% of the reference)	5
Habitat integrity: Instream	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • No additional bed modification	3
Habitat integrity: Riparian	Stable	• Continuous agriculture along the reach but with a buffer zone • Continuity mostly intact	3
ECOSTATUS	Stable	Continues as a category C	5

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	N/A

Revised Ecological Importance and Ecological Sensitivity		
EIES, 2014	**Rapid 3, 2022**	**Criteria changes**
High, High	High, Moderate	Ecological sensitivity changed : • Fish no-flow sensitivity (high to moderate) • Invert physical-chemical sensitivity (very high to low) • Inverts velocity sensitivity (very high to moderate)

		• Stream size sensitivity to modified flow/water level changes (high to moderate)

Physical-chemical state of the system
The physical-chemical state of the system is likely to be deteriorating as a result of the Mashaeng WWTW. The volumes of water treated in this WWTW has been reduced by 52% between 2013 and 2021, suggesting that untreated wastewater does not reach the WWTW. This is also evident in the satellite imagery which suggests that untreated wastewater has been making its way into the river system as far back as 2009. This is also supported by the dominance of pollutant tolerant diatom species. The pH was elevated, but still within guidelines. Clarity was low resulting from erosion causing high suspended solids within the river.

PES	REC	
C	B/C	• As per the recommendations as in Chapter 11, if the water quality within this system improves, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-6: Overall EcoStatus assessment for UO_EWR02_R (Brandwater)

The overall EcoStatus was categorised as a C category, mostly owing to fish (D), macroinvertebrates (D) and instream habitat integrity (C) (Figure 8-6). The main driver affecting the macroinvertebrate assemblages were water quality conditions, which was also the driver of the instream habitat integrity, as well as high silt loads. Within the fish assemblage, water quality was similarly noted to increase in contribution to the ecological state obtained relative to the perceived natural state of the system. However, cover as well as velocity-depth metrics were still determined to be the primary contributors to the ecological state obtained.

It is suggested that the REC of a B/C (close to largely natural most of the time) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations
- Land use activities within the upstream 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).
- Upgrading and maintenance of the dysfunctional WWTW.

8.3 UO_EWR03_R: MOPELI

Sample Date	5 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR03_R	**Prioritised RU**	R_RU16
River	Mopeli	**Altitude (m.a.s.l.)**	1503
Latitude	-29.101205°	**Longitude**	27.570751°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D22G-03732
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		
Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, diatoms, cross-section, discharge			
MAP ILLUSTRATION (Figure 8-7) AND SITE PHOTOGRAPHS (Figure 8-8**)**			

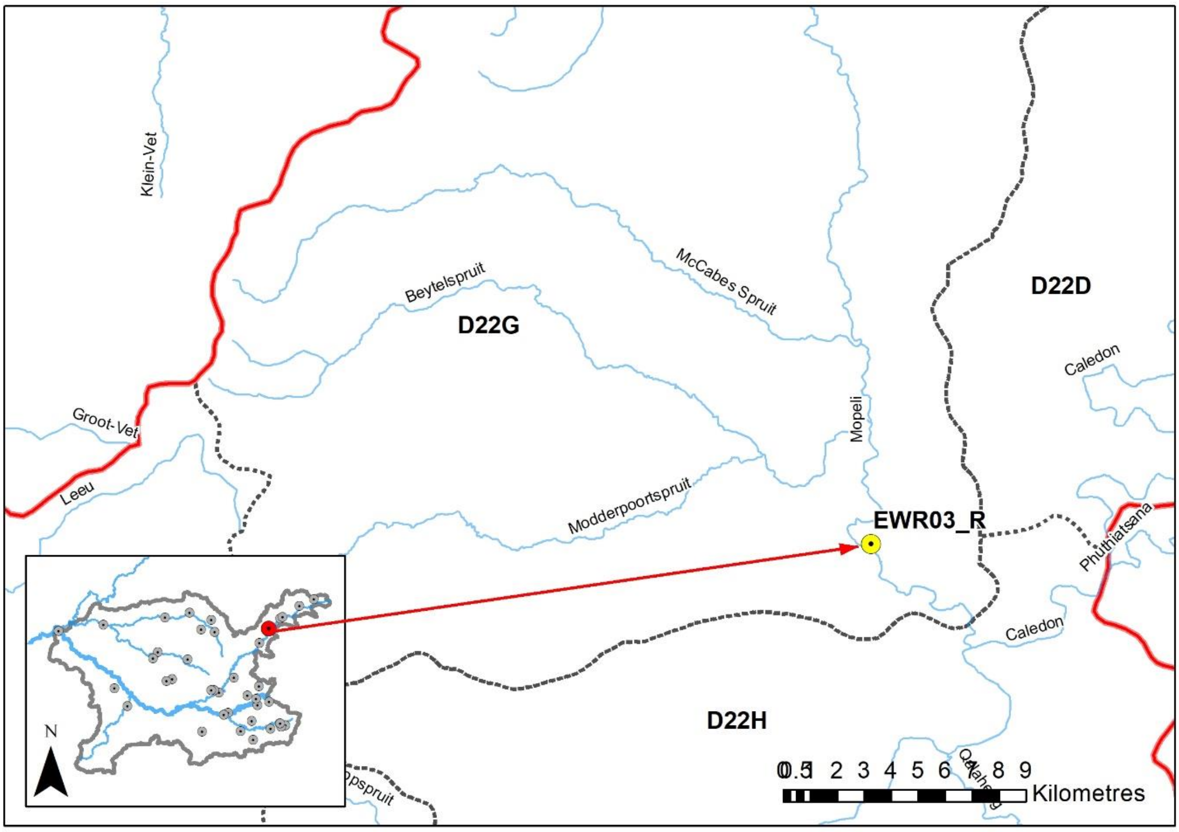


Figure 8-7: Location of site UO_EWR03_R (Mopeli) in relation to the study area

Figure 8-8: Site photographs of the Mopeli EWR site

Upstream	Downstream

Site Description:

The site is located off the R26 and S872 roads along a confined valley setting. Upstream of the site is a derelict weir, a cross-over bridge, along with a broken-up causeway bridge, where much of the bridge rubble and log jams are impeding the hydraulics of the river and associated left bank. The site on the Mopeli is considerably modified – both the channel, banks and high flow modification. The highly eroded banks, particularly the right bank is being scoured as a result of the blockage at the bridge altering the local hydraulics. Following recent flood events, much vegetation debris has accumulated upstream by the cross-over bridge, resulting in blocking and slowing the high flows, reducing flow velocities directly downstream of the bridge and leading to excessive sediment deposition. This has formed a large lee bar that is diverting the river to the right, eroding the right bank and eroding the side/approach of the bridge. Furthermore, consolidated mud islands have formed further downstream due to the erosion of former consolidated floodplain deposits along the channel.

Biotopes available for macroinvertebrates are dominated by bedrock, with mud, but limited gravel and sand. Marginal vegetation was absent owing to undercut banks and vegetation die-offs. For fish, there was SD, SS and FS. The system is eutrophic, with significant algae masses smothering the bedrock habitat and turbid water. The riparian zone on the left bank is degraded with much of the sediment loading taking place, while the right bank is slightly more vegetated with trees, although some have fallen due to erosion. The flows were higher than expected for the dry season owing to enhanced baseflows due to a very wet and late rainfall season.

Site impacts:

- Cattle trampling and grazing
- Upstream dams
- Abstraction for irrigation
- Sediment deposition downstream of the bridge driving bank erosion
- Bridge crossings and weir

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 9.1
- EC: 230 µS/cm

- TDS: 0.212g/l
- DO: 13.1 mg/l
- DO%: 114.7%
- Clarity: 35cm
- Temperature: 9.5°C
- Salinity: 0.2
- Discharge: 0.808m^3/s

DIATOMS					
No. species	**SPI**	**Categorisation (quality)**	**%PTV**		**%Deformed cells**
23	10.7	C (Moderate)	56.9		1.5
Dominant Species		1. *Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*			
		2. *Nitzschia dissipata (Kützing) Grunow*			
Preference		1. Tolerant of heavy pollution, an indicator of industrial organic pollution			
		2. A cosmopolitan species found in waters of moderate to high electrolyte content, not present in waters of low electrolyte content. Highly mobile; associated with siltation			

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	4	• Stable and simple channel form	• Higher flows could be less accurate once water flows in a back channel
Fish	1	• Perennial flow, with higher-than-normal baseflows • Wadable reach • Habitat availability: FS & SD (predominant), SS (sparse)	• Seasonal limitations • No previous collection records or literature • Limited cover features present within velocity-depth classes
Macroinvertebrates	2	• Perennial flow, with higher-than-normal baseflows • GSM present	• Aquatic biotope dominated by bedrock • Limited vegetation (die-back) • Undercut banks • High algae content smothering bedrock biotopes • High silt content • Bed modification owing to the bridge at the site • Much vegetation debris has accumulated upstream by the cross-over bridge, resulting in blocking and

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
			slowing the high flows, reducing flow velocities directly downstream of the bridge and leading to excessive sediment deposition.

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with a single observation during high baseflow
Fish		■				• PES, 2014 • No collection records • Rapid Reserve studies which include fish do exist but were unable to be obtained from either DWS or the authors. • July 2022 survey
Macroinvertebrates		■				• PES, 2014 • Rapid Reserve studies which include macroinvertebrate data unable to be obtained from either DWS or the authors. • July 2022 survey
Hydrology		■				Only modelled monthly hydrology for the period 1920-2004
Physical-chemical		■				• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 diatom results
Diatoms		■				• July 2022 diatom sample

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Clarias gariepinus, Labeo capensis, Labeo umbratus, Labeobarbus aeneus*
Macroinvertebrates	Turbellaria, Potamonautidae, Atyidae, Perlidae, Baetidae >2spp, Caenidae, Leptophlebiidae, Polymitarcyidae, Trichorythidae, Chlorolestidae, Coenagrionidae, Lestidae, Aeshnidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae >2spp, Psychomyiidae,

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
	Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Simuliidae, Tabanidae, Tipulidae and Ancylidae
Physical-chemical	Historical Physical-chemical data for the site could not be obtained. The reference Physical-chemical state of the site was, therefore, inferred from diatom results. The diatom results indicated heavy organic pollution at the site. Lower nutrient concentrations are expected to be prevalent under reference conditions and in the absence of the catchment wide impacts.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (43.0%)	NF/F	• Agricultural return flow is likely to be contributing nutrients and increasing sediment input • Several weirs within the reach are expected to limit fish movement into the area from the mainstem Caledon River • Variable seasonal flows • Lack of cover features
Macroinvertebrates	D (55.35%)	NF/F	• Habitat naturally limiting (bedrock driven) • Erosion and sedimentation have eliminated vegetation habitats • Limited to no vegetation owing to undercut banks and vegetation die-off • Surrounding cultivation and irrigation contribute to poor water quality • High algae mass smothering bedrock biotope
Habitat Integrity: Instream	C (71%)	NF/F	• Irrigation • Dams in the upper catchment • Physical-chemical modification owing to eutrophication (high algae growth) • Channel modification owing to upstream log jam by bridge impeding on hydraulics and scouring of the river downstream • High silt loads
Habitat Integrity: Riparian	C (72%)	NF	• Alien vegetation (Honey locust, *Salix* sp.) • Bank erosion owing to scouring of banks, log jam • Road crossings/bridges/broken upstream weir • Cattle grazing and trampling
ECOSTATUS	D (60.78%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	Results obtained suggest significantly reduced FROC for all species likely to be present within the reach. Although all species of fish expected to occur within the reach are considered eurytopic, the loss of connectivity with the mainstem Caledon River (i.e., fragmentation of the system) as a result of various impeding structures located through-out the reach as well as the seasonal nature of flows was expected to impact recruitment of fish within the catchment, as is the increase in nutrient input into the system. In addition, erosion/scouring of the channel and siltation of slower-flowing sections (including behind weirs) has resulted in limited cover features being present for fish to utilise.

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	96.85	95.34
COVER	100.00	100.00
FLOW MODIFICATION	66.75	75.33
PHYSICAL-CHEMICAL	38.78	56.53
MIGRATION		74.62
IMPACT OF INTRODUCED		28.70
FRAI	PRESENT	
FRAI (%)	43.0	
EC: FRAI	D	

Macroinvertebrates	

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	64.8	0.327	21.1491	2	80
HABITAT	H	68.0	0.245	16.6454	3	60
WATER QUALITY	WQ	40.0	0.408	16.3265	1	100
CONNECTIVITY & SEASONALITY	CS	60.0	0.020	1.22449	4	5
						245
INVERTEBRATE EC				55.3456		
INVERTEBRATE EC CATEGORY				D		

Overall, a low diversity of aquatic macroinvertebrate taxa occurs at this site. In July 2022, a total of 5 taxa were recorded out of an expected 43 reference taxa (12% of the reference community). The aquatic macroinvertebrate assemblage collected was determined to be representative of being largely modified conditions (Ecological Category D, 55.35%). Only 1 sensitive taxon (Baetidae>2sp) was recorded out of an expected 8 sensitive taxa for this reach. However, cognisance must be taken that bedrock was the dominant

PES and causes	
Component	**Causes Present/Absent**
	biotope, of which is not a suitable biotope for macroinvertebrates. Nonetheless, the primary driver of the community was water quality, an observation supported by the majority of the taxa recorded having a tolerance for low to very low water quality and standing to slow-flowing water. Overall, the ASPT of this community was 6.1 (88% of the reference ASPT), however, this must be interpreted with caution as the number of taxa was low and included one sensitive taxon (at low abundances) which numerically increases the ASPT value. Overall, the ASPT was indicative of tolerant taxa (Dickens and Graham, 2002).

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	stable	• Drivers unchanged due to impacts remaining unchanged (no new developments (Google Earth)	2
Macroinvertebrates	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments (Google Earth) • However, erosion and sandbars are increasing • Hydraulics are changing owing to an upstream major log jam by the bridge • Impacts to flow resulting in impacts to flow-dependent taxa • Habitat availability a declining trend, also owing to the scouring of the left bank • Average ASPT: 88% of the reference	2
Habitat integrity: Instream	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • No additional bed modification (bedrock dominated)	2
Habitat integrity: Riparian	Decline	• Increased scouring • Increased bank erosion • Increased alien vegetation encroachment	2
ECOSTATUS	Stable		2

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	D	N/A

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Rapid 3, 2022**
Moderate, Moderate	Moderate, Moderate

Physical-chemical state of the system
Elevated pH is among the higher readings recorded in the catchment. Clarity was low because of erosion, resulting in high suspended solids loads within the river. Although the parameters were within guidelines, the diatom results showed that the physical-chemical state of the system was altered and deteriorated from the natural.

PES	REC	
D	C/D	As per the recommendations as in Chapter 11, if the water quality within this system improves, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-9: Overall EcoStatus assessment for UO_EWR03_R (Mopeli)

The overall EcoStatus was categorised as a C/D category, mostly owing to fish (D) and macroinvertebrates (D) (Figure 8-9). Poor habitat availability (as the site was dominated by bedrock) and flow conditions were the primary metrics driving the low diversity of aquatic macroinvertebrate taxa at this site resulting in a D category. From the perspective of the fish assemblage, fragmentation of the reach due to various weirs limiting connectivity to the Caledon River as well as variable seasonal flows was noted as the primary driver of the ecological category obtained, as was physical-chemical modification.

It is suggested to maintain the PES of a C/D as the REC (close to moderately modified most of the time) that can be achieved, should the proposed mitigation measures/recommendations be assessed and applied).

RECOMMENDATIONS

- Remove derelict bridge and weir as well as logs against the road bridge.
- Refer to Chapter 11 for general recommendations.
- Land use activities within the upstream catchment should be managed to prevent degradation of the ecological health of the system and deterioration of the water quality (riparian buffer zones should be implemented).
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways).

8.4 UO_EWR04_R: UPPER KRAAI

Sample Date	9 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR04_R	**Prioritised RU**	R_RU11a
River	Upper Kraai	**Altitude (m.a.s.l.)**	1714
Latitude	-30.85179°	**Longitude**	27.77689°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D13E -05629
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	E (Lower Foothills)		
Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, cross-section, discharge			
MAP ILLUSTRATION (Figure 8-10) AND SITE PHOTOGRAPHS (Figure 8-11)			

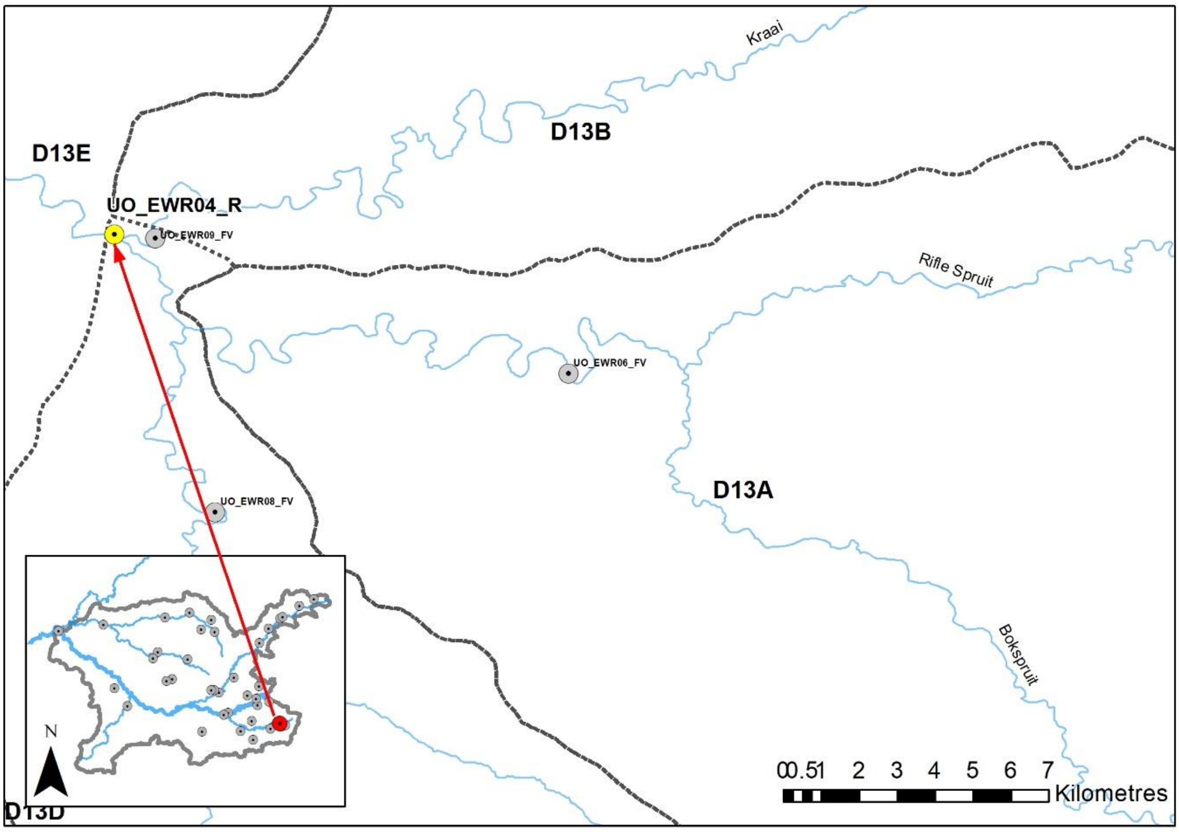


Figure 8-10: Location of site UO_EWR04_R (Upper Kraai) in relation to the study area

	
Figure 8-11: Site photographs of the Upper Kraai EWR site	
Upstream	**Downstream**
Site Description:	
The upper Kraai site is located along a partly confined valley. The channel is approximately 40m wide and follows a pool-riffle longitudinal pattern. It is located just downstream of the Bell/Kraai River, approximately 200m downstream of the confluence with the Sterkspruit. Localised bed and channel modification is observed downstream of the large bridge crossing and upstream weir, along with some cattle trampling along the riparian zone. Localized erosion and lateral head cut erosion, mostly up and downstream of the bridge. Some scouring along both banks with several lee bars in-stream and along the left bank downstream. The riparian zone is partly intact, representative of the season. The left bank is generally covered with grasses, shrubs (blackjacks) and *Salix sp*. The right bank is along a cliff face and shrubs. The river comprises various sections of riffles up and downstream of the bridge, composed of boulder and cobble material along the riffles and gravel and sand along the pools. All biotopes for the macroinvertebrates are present, SIC, SOOC, GSM, although vegetation is limiting owing to undercut banks and vegetation die-off. Localised algal patches covering the SIC biotope and detritus along the substrate. Fish habitats include SD, FD, SS and FS. The land use is predominantly farmlands, with small croplands and cattle grazing. The flows were higher than expected for the dry season owing to enhanced baseflows due to a very wet and late rainfall season.	
Site impacts:	
• Abstraction for irrigation • Cattle grazing • Floodplain/terrace cultivation	
SUMMARY RESULTS	
WATER QUALITY AND FLOW	
In situ water quality: • pH: 8.3 • EC: 145 µS/cm • TDS: 0.152 g/l • DO: 11.8 mg/l • DO%: 92.7%	

- Clarity: >1m
- Temperature: 5.2°C
- Salinity: 0.11
- Discharge: 2.325m^3/s

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
19	16.2	B (Good)	2.7	2.25
Dominant Species		*Achnanthidium sp.*		
Preference		Moderate to good quality waters		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	2	• Stable bed with fixed boulders	• Located in a bend with a pool along the right margin
Fish	3	• Collection records available • Wadable reach • Velocity-depth classes available: SD, FS (dominant), SS (abundant), FD (moderate)	• Seasonal limitations
Macroinvertebrates	2	• Good diversity of aquatic biotopes: SIC, SOOC, marginal vegetation and GSM	• Limited vegetation (die-back) • Undercut banks • Localised algae covering the SIC biotope Considerable abundance of Simuliidae (indicative of constant flows in the upper parts of the Kraai River)

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics						• New site with a single high baseflow observation
Fish						• Various collection records • FROC (Kleynhans et al., 2008) • PES, 2014 • July 2022 survey
Macroinvertebrates						• PES, 2014 • July 2022 survey

Hydrology						• Only monthly modelled hydrology for the period 1920-2004
Diatoms						• July 2022 diatom sample
Physical-chemical						• Green Drop Reports 2011, 2013, 2021 and 2022. • July 2022 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Austroglanis sclateri, Clarias gariepinus, Enteromius oraniensis, Labeobarbus aeneus*
Macroinvertebrates	Turbellaria, Oligochaeta, Amphipoda, Potamonautidae, Hydracarina, Notonemouridae, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Trichorythidae, Chlorolestidae, Coenagrionidae, Platycnemidae, Aeshnidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Dipseudopsidae, Ecnomidae, Hydropsychidae 1sp, Hydropsychidae >2spp, Philopotamidae, Psychomyiidae, Hydroptilidae, Leptoceridae, Sericostomatidae, Dytiscidae, Elmidae, Gyrinidae, Helodidae, Hydraenidae, Hydrophilidae, Athericidae, Blepharoceridae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Planorbinae, Corbiculidae and Sphaeridae
Physical-chemical	Historical Physical-chemical data for the site could not be obtained. The reference Physical-chemical condition for the site was inferred from the diatoms data. The diatoms data indicated good quality water at the site, owing to minimal if any upstream impacts. Although not at natural conditions, it is expected that the physical-chemical condition at the site has not changed by much from the reference.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (52.8)	NF	• Alien fish species (*Oncorhynchus mykiss*) • Weirs downstream impacting the migration of *Labeobarbus aeneus* into upper reaches to some degree • Agricultural return flow resulting in some sediment and nutrient input
Macroinvertebrates	C (71.56%)	NF/F	• Cattle trampling and grazing • Some irrigation • High than usual baseflows and constant flows (high rainfall events in the catchment) thus being

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
			responded to by a high abundance of Simuliidae smothering the stones biotope
Habitat Integrity: Instream	A/B (90%)	-	None
Habitat Integrity: Riparian	A/B (90%)	-	None
ECOSTATUS	C (77.04%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td>Fish</td><td>
The development of various weirs within the lower reaches of the Kraai River is expected to impede/delay upstream migration of particularly Labeobarbus aeneus from the Orange River into the upper reaches for spawning during the summer period. Some Labeobarbus aeneus, particularly juveniles, are however expected to be present within the reach throughout the year at lower FROCs. In addition, competition with and predation by Oncorhynchus mykiss which are present within the reach is expected to further limit the occurrence of fish species within the reach, particularly Enteromius oraniensis which will be susceptible to such predation.
<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>96.96</td><td>97.96</td></tr>
<tr><td>COVER</td><td>100.00</td><td>100.00</td></tr>
<tr><td>FLOW MODIFICATION</td><td>63.94</td><td>82.33</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>32.12</td><td>47.83</td></tr>
<tr><td>MIGRATION</td><td></td><td>88.59</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>75.47</td></tr>
<tr><th>FRAI</th><th colspan="2">PRESENT</th></tr>
<tr><td>FRAI (%)</td><td colspan="2">52.8</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">D</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td>Macroinvertebrates</td><td>
<table>
<tr><th>INVERTEBRATE EC METRIC GROUP</th><th></th><th>METRIC GROUP CALCULATED SCORE</th><th>CALCULATED WEIGHT</th><th>WEIGHTED SCORE OF GROUP</th><th>RANK OF METRIC</th><th>%WEIGHT FOR METRIC GROUP</th></tr>
<tr><td>FLOW MODIFICATION</td><td>FM</td><td>75.6</td><td>0.333</td><td>25.1923</td><td>2</td><td>95</td></tr>
<tr><td>HABITAT</td><td>H</td><td>71.8</td><td>0.316</td><td>22.6794</td><td>3</td><td>90</td></tr>
<tr><td>WATER QUALITY</td><td>WQ</td><td>67.5</td><td>0.351</td><td>23.6953</td><td>1</td><td>100</td></tr>
<tr><td>CONNECTIVITY & SEASONALITY</td><td>CS</td><td>80.0</td><td>0.000</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>285</td></tr>
<tr><td>INVERTEBRATE EC</td><td></td><td></td><td></td><td>71.567</td><td></td><td></td></tr>
<tr><td>INVERTEBRATE EC CATEGORY</td><td></td><td></td><td></td><td>C</td><td></td><td></td></tr>
</table>
A diversity and abundance of biotopes were available to sample at this site, with varying flow conditions. The aquatic macroinvertebrate assemblage collected was determined to be representative of moderately modified conditions (Ecological Category C, 69.56%). During the current survey (as no other monitoring events have taken place along this river reach), a total of 17 taxa were recorded out of a reference community of 59 taxa (29% of the reference community was present). Despite this site being in the upper reaches of the Kraai River, where there are limited spatial impacts, a number of the sensitive taxa assemblage was absent. Only 4 (Perlidae, Baetidae >2spp, Leptophlebiidae and Trichorythidae) out of 18 expected sensitive taxa were recorded, which have a preference for moderate to high water quality, the stones biotope coupled with high flow velocities. Taxa expected with a high FROC (3-5) but which were absent from the reach included Hydracarina, Heptageniidae, Aeshnidae, Libellulidae, Corixidae, Gerridae, Veliidae, Hydropsychidae >2spp, Dytiscidae, Elmidae, Gyrinidae, Hydrophilidae, Tabanidae and Tipulidae. These taxa have a preference for varying water quality and the stones biotope. In addition, at the time of the survey, a considerably high abundance (D abundance) of simulids was recorded at the site. These simulids were smothering the stone biotope (Figure a below). Simuliidae is indicative of modified water quality owing to their high tolerance levels, as well as constant flows. However, as there are no dams within the Upper Kraai reach supporting the constant flows, the constant flows may well have been owing to the high rainfall events experienced in the catchment during this season. Thus, the Simuliidae community may be responding to these higher-than-normal baseflows, which are not representative of the season (July 2022). This may be recorded as an isolated event, as further down at the Lower Kraai site (UO_EWR08_I), their abundances were limited. Therefore overall, the low number of sensitive taxa, along with the rest of the recorded assemblage, was primarily driven by water quality (the majority of the macroinvertebrates had a preference for low to very low water quality), followed by habitat and flow modifications. The ASPT for the community
</td></tr>
</table>

PES and causes	
Component	**Causes Present/Absent**
	was 5.5 (85% of the reference ASPT), indicative of tolerant taxa (Dickens and Graham, 2002).  Figure a: Simuliidae (Blackfly larvae)

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments (Google Earth) and alien fish species are self-sustaining	3
Macroinvertebrates	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • No additional bed modification / erosion (localised) • Habitat availability remains good • River reach not monitored previously • 85% of the reference ASPT	2
Habitat integrity: Instream	Stable	• Instream habitat integrity intact, with limited impacts	2
Habitat integrity: Riparian	Stable	• Riparian integrity intact, with limited impacts (alien vegetation)	2
ECOSTATUS	Stable		2

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	N/A

Revised Ecological Importance and Ecological Sensitivity		
EIES, 2014	**Rapid 3, 2022**	**Criteria changes**
Moderate, High	High, High	Ecological importance changed: • Instream habitat integrity category (high to very high) • Riparian wetland zone habitat integrity class (high to very high) • Habitat diversity class (very low to low)

Physical-chemical state of the system
Although pH was slightly elevated, other in situ parameters indicated good water quality, with high visibility (clarity) and other parameters within guidelines.

PES	REC	
C	B	• The PES of a C is to some extent due to the D category for the fish (alien predator fishes in the river that is not flow related. Thus, owing to no upstream dams, WWTW and only localised impacts, mainly irrigation abstractions, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-12: Overall EcoStatusassessment for UO_EWR04_R (Upper Kraai)

The overall EcoStatus was categorised as a C category, mostly owing to fish (D, non-flow related) and macroinvertebrates (C) (Figure 8-12). Although a diversity of biotopes was present for macroinvertebrates, there was a considerably high presence of Simuliidae restraining the SIC biotope. Overall, the macroinvertebrate community was driven primarily by water quality and habitat.

In addition, the fish assemblage within the reach is impacted by the presence of barriers within the lower reaches of the Kraai River which would impede upstream migration from the Orange River, as well as the presence of predatory alien *Oncorhynchus mykiss* within the reach which are considered an important economic driver within the area.

It is suggested that the REC of a B (largely natural with few modifications) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations;
- Land use activities within the upstream 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
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways).

8.5 UO_EWR05_R: WONDERBOOMSPRUIT

Sample Date	11 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR05_R	**Prioritised RU**	R_RU12
River	Wonderboomspruit	**Altitude (m.a.s.l.)**	1383
Latitude	-31.005262°	**Longitude**	26.341938°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	D14E-05804
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		
Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, cross-section, diatoms, discharge			
MAP ILLUSTRATION (Figure 8-13) AND SITE PHOTOGRAPHS (Figure 8-14)			

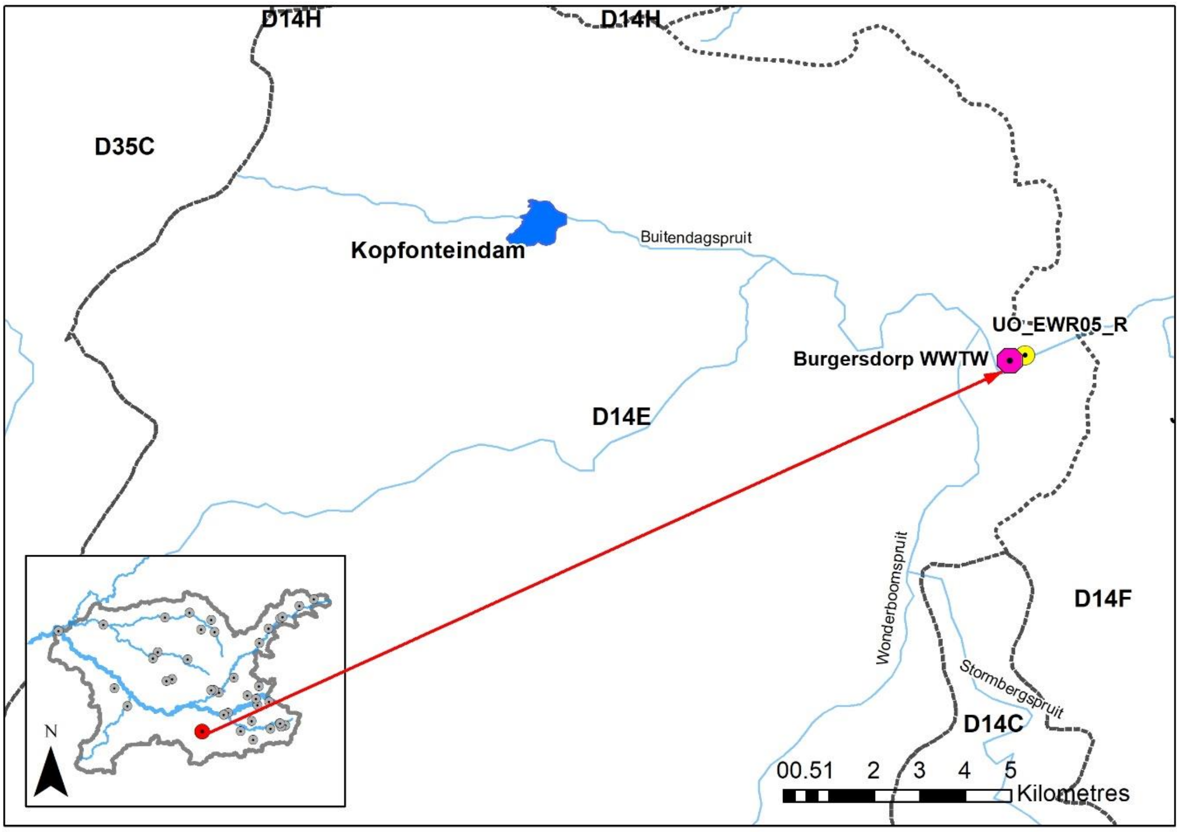


Figure 8-13: Location of site UO_EWR05_R (Wonderboomspruit) in relation to the study area


Figure 8-14: Site photographs of the Wonderboomspruit EWR site

Upstream	Downstream

Site Description:

The site is located downstream from the town of Burgersfort off the R391 road. There is a large cross-over bridge upstream from the site, and a gauging weir approximately 500m downstream from the site on the Wonderboomspruit, resulting in some inundation of the river downstream of the EWR site. The river is located within a valley setting which is confined, with cobbles, rocks and small boulders forming riffles and pools. The river is ~5m wide and flows relatively straight towards the gauging weir where it meanders further downstream. Some erosion on both banks, due to cattle trampling and grazing. Biotopes available for macroinvertebrates included SIC, SOOC, both marginal and in-stream aquatic vegetation and limited GSM. Fish habitats included FS, FD and SD. The stones biotopes were heavily smothered with algae and sludge, as the system has a significant input of nutrients with a strong sewage odour as well as black organic mud deposited in slow-flowing sections. Very abundant macroplastic material are present in-stream, as well as littered throughout the riparian zone and beyond. The riparian zone is mostly sedges on both banks, along with alien invasive vegetation namely *Eucalyptus sp., Salix sp.* and *Populus* sp.on both banks.

Land use is predominantly urban (Burgersfort) with rural development and open lands along the reach. Low-intensity agriculture with some croplands and cattle grazing areas occur.

Site impacts:

- The town of Burgersfort (possible water quality impacts)
- Upstream wastewater treatment works
- Small dams in upper catchment
- Cattle trampling and grazing
- Macroplastics along the riparian zone

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 8.5
- EC: 414 µS/cm
- TDS: 0.382 g/l
- DO: 13.2 mg/l
- DO%: 116.0%
- Clarity: 61cm

- Temperature: 9.6°C
- Salinity: 0.29
- Discharge: 1.129 m^3/s

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
21	4.6	E (Serious)	71	0
Dominant Species		*Nitzschia frustulum (Kützing) Grunow*		
Preference		High conductivity, extensive agriculture, very tolerant of pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3	• Stable fixed boulder site	• Higher flows will spread across flood features with varying roughness/vegetation
Fish	2	• Perennial flow, with higher-than-normal baseflows • Wadable reach • Velocity-depth classes well represented: SD and SS (abundant), FS (moderate), FD (sparse) • Various cover features present: substrate dominant with good cover of marginal/emergent vegetation	• Seasonal limitations • Limited collection records
Macroinvertebrates	3	Good diversity of aquatic biotopes: SIC, SOOC, marginal and in-stream vegetation and GSM	• High algal covering of the SIC biotope • The considerable abundance of Hirudinea (Leeches; indicative of very poor water quality) • Evidence of poor water quality (i.e., sewage) • Instream macroplastics

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			■			• New site with a single high baseflow observation
Fish		■				• PES, 2014 • Limited collection records • July 2022 survey
Macroinvertebrates		■				• PES, 2014 • July 2022 survey
Hydrology				■		Monthly modelled hydrology for the period 1920-2004 Daily data from gauging weir D1H001 downstream of the site
Diatoms				■		• Information from Upper Orange recon survey (October 2021) • July 2022 diatom sample
Physical-chemical					■	• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions			
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**		
Fish	*Clarias gariepinus, Enteromius oraniensis, Labeo capensis, Labeo umbratus, Labeobarbus aeneus*		
Macroinvertebrates	Turbellaria, Oligochaeta, Hirudinea, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Leptophlebiidae, Trichorythidae, Coenagrionidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Corydalidae, Hydropsychidae >2spp, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Simuliidae, Syrphidae, Tabanidae and Unionidae		
Physical-chemical	The reference Physical-chemical condition was determined using the RQS data (site D1H001Q01, 1967 to 1980, n = 101)		
	Physical Variable	pH	The reference data indicated a 5th percentile of 7.1 pH units and a 95th percentile of 8.2 pH units. The Natural (0) rating for the site was therefore re-benchmarked, such that the Natural (0) rating for pH for the site was ≥ 7.1 and ≤ 8.2pH units
		EC	The reference data indicated that the 95th percentile was 84.51 mS/m, which was higher than 30 mS/m as stated in DWA (2008) benchmarks table. This suggests that these EC reading do not reflect the reference conditions.

Reference Conditions			
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**		
		Temperature:	No historical temperature records are available for the site. DWA (2008) benchmark tables were used for a low confidence, qualitative assessment of temperature reference condition.
		Clarity:	There are no clarity/turbidity records available for reference condition assessment. Reference condition was taken as that qualitatively described in the DWA (2008) benchmark tables.
		Oxygen:	No dissolved oxygen records are available for this site. DWA guideline benchmark tables (2008) have been utilised to characterise the site's reference condition.
	Nutrients	TIN	The reference data indicated a 50th percentile of 0.04 mg/l, which was within the Natural (0) rating of 0.25 mg/l in terms of the DWA (2008) benchmarks table. The DWA (2008) limit was used as the Natural (0) rating.
		PO_4	The reference data indicated that the 50th percentile was 0.018 mg/l, which fell above the Natural (0) rating according to DWA (2008). The Natural (0) rating for the site was, therefore benchmarked such that it was ≤0.018 mg/l
	Toxins	Fluoride	In terms of the toxics listed within the DWA (2008) rating tables, only fluoride was monitored. The 95th percentile for fluoride was calculated as 0.45 mg/l which fell within the DWA (2008) benchmark table.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (48.7)	NF	• Physical-chemical modification (downstream of Burgersdorp & WWTW, with evidence of sewage pollution) • Downstream weir impacting upstream migration of fish • Likely high fishing pressure
Macroinvertebrates	D (56.86%)	NF	• Physical-chemical modification (downstream of Burgersdorp & WWTW, with evidence of sewage pollution)
Habitat Integrity: Instream	C (70%)	NF/F	• Physical-chemical modification owing to upstream WWTW, evidence of sewage and high algae content • Channel and bed modification owing to cattle trampling, bridges, weirs

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Riparian	C/D (61%)	NF	• Vegetation removal owing to cattle trampling and grazing, wood harvesting and developments within the buffer zone • Physical-chemical modification owing to infrastructure of upstream WWTW within the riparian zone and macroplastics
ECOSTATUS	D (57.05%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	Despite the presence of suitable velocity-depth classes and cover features, the ecological state of the fish assemblage was noted to be largely modified (Ecological Category D). Primary drivers in this regard were the impacts on the movement of species from downstream reaches through the establishment of various weirs along the reach, as well as impacts on water quality because of sewage input and solid waste from the town of Burgersfort as well as failing municipal infrastructure. Although all species expected to occur under natural conditions are regarded as eurytopic, prevailing impacts are expected to reduce the FROC of most species, with *Labeobarbus aeneus* (Smallmouth Yellowfish) expected to be absent from the reach.

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	98.65	99.21
COVER	100.00	100.00
FLOW MODIFICATION	66.58	80.41
PHYSICAL-CHEMICAL	37.21	60.23
MIGRATION		70.93
IMPACT OF INTRODUCED		32.51
FRAI	PRESENT	
FRAI (%)	48.7	
EC: FRAI	D	

PES and causes

Component	Causes Present/Absent
Macroinvertebrates	(see table and text below)

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	63.0	0.290	18.282	3	90
HABITAT	H	59.6	0.323	19.2252	2	100
WATER QUALITY	WQ	30.0	0.258	7.74194	1	80
CONNECTIVITY & SEASONALITY	CS	90.0	0.129	11.6129	4	40
						310
INVERTEBRATE EC				56.8621		
INVERTEBRATE EC CATEGORY				D		

Although a diversity and abundance of biotopes were available to sample, the aquatic macroinvertebrate assemblage collected was determined to be representative of being largely modified conditions (Ecological Category D, 56.86%). For the hydrological year (2021-2022), a total of 20 taxa were recorded out of a reference community of 39 taxa (51% of the reference community was present). The aquatic macroinvertebrate community primarily responded to water quality. This was supported by majority of the community preferring low to very low water quality (16 taxa recorded out of 27 expected taxa). The exceptions were Baetidae >2spp and Leptophlebiidae, which prefer moderate to high water quality and flow. However, these two taxa were recorded in low abundances. Taxa absent from the site with a high FROC mostly prefer moderate water quality, with Dixidae and Hydropsychidae >2spp being sensitive taxa (10 and 12 respectively out of 15) out of the absent community. The ASPT for the last hydrological year was 5.0 (77% of the reference ASPT), indicative of tolerant taxa (Dickens and Graham, 2002). Overall, this tolerant macroinvertebrate community was expected owing to the stones biotopes being heavily smothered with algae and sludge, as the system had a significant input of nutrients with a clear sewage odour (very poor water quality), as well as black organic sludge deposited in slow flowing sections. Very high macroplastics in-stream, as well as littered throughout the riparian zone and beyond.

Ecological trends for the EWR site (include components that were assessed)

Component	Trend (stable, decline, improvement)	Reason	Confidence (0-5)*
Fish	Decline	• Failing municipal infrastructure • Increased growth of Burgersdorp • No recruitment from downstream reach	3
Macroinvertebrates	Decline	• Water quality deterioration owing to failing municipal infrastructure	2

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
		• Habitat availability declining owing to increased silt loads • Average ASPT: 77% of the reference	
Habitat integrity: Instream	Stable	• Poorly maintained WWTW continue	2
Habitat integrity: Riparian	Decline	• Increased littering	2
ECOSTATUS	Decline		2

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	D	• Compromised water quality: unmaintained and infrastructure failure on WWTW upstream • Algae smothering macroinvertebrate habitats

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Rapid 3, 2022**
Moderate, Moderate	Moderate, Moderate

Physical-chemical state of the system
This river system runs through the town of Burgersdorp. The Burgersdorp WWTW discharges into the system. The WWTW is classified as a critical risk with effluent compliance of 6%, suggesting poorly treated raw sewage/wastewater being discharged into the system. The *in situ* water quality parameters were within guidelines. These, however, show only a snapshot of the water quality at a single point in time and largely vary according to time of day or conditions. The dominance of pollution-tolerant macroinvertebrates and diatoms indicates a poor physical-chemical state of the river. The abundance of algae indicates high nutrient load from the untreated sewage discharged at Burgersdorp WWTW.

PES	REC	
D	C/D	• As per the recommendations as in Chapter 11, if the water quality within this system improves, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-15: Overall EcoStatus assessment for UO_EWR05_R (Wonderboomspruit)

The overall EcoStatus was categorised as a D category, mostly owing to fish (D), macroinvertebrates (D) and riparian habitat integrity (C/D) (Figure 8-15). These components were mostly driven by impaired physical-chemical modification, owing to the upstream town of Burgersdorp and the associated unmaintained and failing municipal infrastructure namely the WWTW, whereby there was evidence of instream and riparian sewage pollution. The presence of weirs within the reach is further limiting upstream migration and recruitment of key fish species from lower reaches.

It is suggested that the REC of a C/D (close to moderately modified most of the time) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations.
- DWS need to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance.
- Upstream municipal infrastructure must be reviewed, maintained, and upgraded.
- Land use activities within the upstream catchment should be managed to prevent degradation of the ecological health of the system and further deterioration of the water quality (buffer zones to be implemented).
- Where instream movement barriers are proposed, ensure such developments consider facilitating movement of biota (e.g., fishways)

8.6 UO_EWR06_R: MIDDLE MODDER (SOETDORING)

Sample Date	14 July 2022	**Reserve Level Assessment**	Rapid 3
Site Name	UO_EWR06_R	**Prioritised RU**	R_RU09b
River	Modder	**Altitude (m.a.s.l.)**	1263
Latitude	-28.807191°	**Longitude**	26.109695°
Level 1 EcoRegion	Highveld	**Quaternary catchment-SQ Reach**	C52H-03155
Level 2 EcoRegion	11.08	**DWS, 2014 PES, EI, ES**	D, High, High
Geomorphological zone	E (Lower Foothills)		
Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, diatoms, cross-section, discharge			
MAP ILLUSTRATION (Figure 8-16) AND SITE PHOTOGRAPHS (Figure 8-17)			

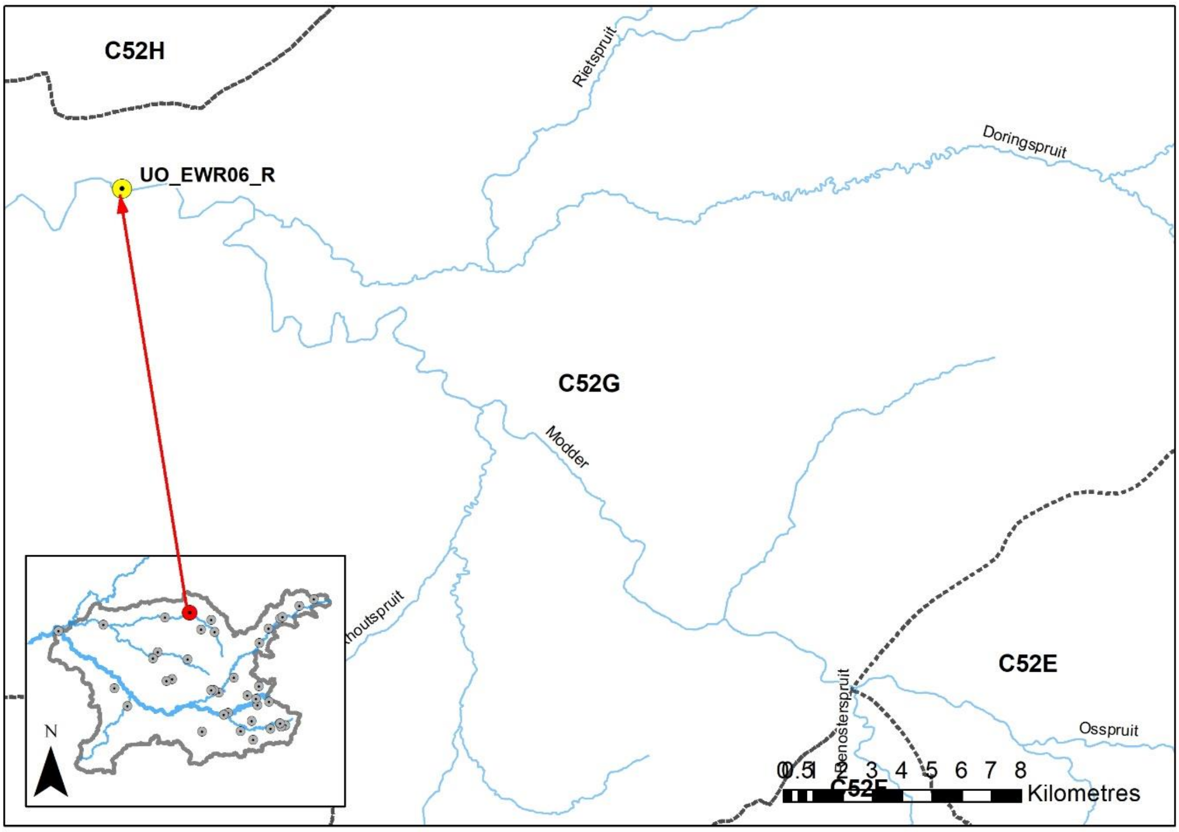


Figure 8-16: Location of site UO_EWR06_R (Middle Modder) in relation to the study area

Figure 8-17: Site photographs of the Middle Modder EWR site

Upstream	Downstream

Site Description:

The site is located off the R700 road, ~30km north of Bloemfontein, approximately 4km downstream of the confluence with the Doringspruit and within the boundary of the Soetdoring Nature Reserve. Downstream of the site is the Krugersdrif Dam which has resulted in large-scale inundation of the system downstream of the EWR site. The reach has an unconfined valley setting, with the macro channel incised into the surrounding landscape. Flood features are narrow along the channel margins and the bed is locally controlled by bedrock. The macro channel is straight to moderately sinuous with a pool riffle sequence where habitats are not drowned out by dams or weirs. Boulder, cobble and gravel are deposited in between the bedrock sections, with sandy and silty inset benches forming along the margins. The site is located along a sinuous deep run which is dominated by bedrock and large rocks, covered in algae and silt. Marginal vegetation is well established and dominated by *Phragmites sp*., blackjacks and other shrubs. The upper marginal zone is dominated by large trees, encroaching into the riparian area. Artificial habitat diversity is present under the road bridge in the form of riffles as well as instream vegetation. Aquatic macroinvertebrate biotopes include SIC, SOOC, marginal vegetation and limited GSM. Fish habitats comprised FS, FD, SS and SD.

Landuse influence on the system results predominantly from agriculture and return flows from WWTWs.

Site impacts:

- Agriculture
- Irrigation
- Return flows from WWTWs
- Numerous weirs upstream

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 8.8
- EC: 426 µS/cm
- TDS: 0.392 g/l
- DO: 10.4 mg/l

• DO%: 91.2% • Clarity: 27cm • Temperature: 9.6°C • Salinity: 0.29 • Discharge: 2.257m^3/s				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
31	6.8	D (Poor)	59.9	1.5
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of heavy pollution; an indicator of industrial organic pollution		

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Hydraulics	3	• Stable fixed boulder bed	• Reed density can vary significantly depending on season or previous floods
Fish	2	• Perennial flow, with higher-than-normal baseflows • Velocity-depth classes well represented: SD and SS (abundant), FS (moderate), FD (sparse) • Various cover features present: substrate (moderate), water column (abundant), marginal vegetation (sparse)	• Seasonal limitations • Short wadable lotic reach (backwater effect from the downstream dam from downstream of the bridge; upstream weir limiting extent of reach)
Macroinvertebrates	3	• Perennial flow, with higher-than-normal baseflows • Boulders/SIC, SOOC, bedrock	• Limited GSM owing to accessibility constraints and large boulders dominating the biotopes • Limited marginal vegetation owing to undercut banks and vegetation die-off. *Phragmites spp.* along the margins was only available to sample (woody). • High algae and silt covering the stones biotope

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Hydraulics			X			• New site with one high baseflow observation
Fish			X			• FROC (Kleynhans et al., 2008) • PESEIS, 2014 • Some collection records • July 2022 survey
Macroinvertebrates					X	• DWS REMP site further upstream along the Modder River (C5MODD-SANNA) • PES, 2014 • July 2022 survey
Hydrology			X			• Modelled monthly hydrology for the period 1920-2004 • Daily data from gauging weir, but with limited value as some tributaries are present between the gauge and EWR site
Diatoms				X		• Information from JBS3 • July 2022 diatom sample
Physical-chemical				X		• Green Drop Reports 2011, 2013, 2021 and 2022 • July 2022 diatom results

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Clarias gariepinus, Enteromius oraniensis, Enteromius paludinosus, Labeo capensis, Labeo umbratus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Pseudocrenilabrus philander, Tilapia sparrmanii*
Macroinvertebrates	Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Trichorythidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Protoneuridae, Aeshnidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Simuliidae, Ancylidae, Bulinae, Lymnaeidae, Physidae, Planorbinae and Sphaeridae
Physical-chemical	Historical Physical-chemical data for the site could not be obtained. Therefore, the reference Physical-chemical condition at the site was estimated from the diatom data. The diatom data indicated high levels of pollution at the site arising from the WWTWs discharging upstream. Low

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
	nutrient concentrations are expected to be prevalent in the system under natural conditions.

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	D (57.0)	F / NF	• Krugersdrift Dam pushback immediately below site • Extensive irrigation • Fragmentation of longitudinal connectivity • Alien introduced species (*Cyprinus carpio, Gambusia affinis, Micropterus salmoides* (likely)) • Physical-chemical modification (Nutrient input, impacts from Bloemfontein)
Macroinvertebrates	D (55.89%)	NF	• Decreased water quality due to extensive agriculture and irrigation • Physical-chemical modification (Nutrient input, impacts from Bloemfontein) • Loss of habitat particularly marginal vegetation owing to erosion and impacts on the riparian zone • In-stream biotope dominated by bedrock with cobbles and gravel in between but smothered with algae and high silt deposition • Increased turbidity due to catchment runoff and loss of vegetation in the surrounding areas and in upper catchment has led to increased deposits of sediments
Habitat Integrity: Instream	D (54%)	F/NF	• Water abstraction and extensive irrigation in the upstream catchment • Flow modification owing to return flows from numerous WWTW, Rustfontein Dam in the upper catchment • Bed modification due to armouring along riffle, siltation along inundated zones, weirs, dams and bridges • Inundation owing to several weirs and dams
Habitat Integrity: Riparian	D (58%)	NF	• Vegetation removal from cattle grazing and trampling and various centre pivots adjacent to the river reach • Channel modification owing to weirs, bridges, pump stations • Alien vegetation namely *Salix sp. Eucalyptus sp.,* Black Wattle, *Pyracantha spp.* and cultivation
ECOSTATUS	D (57.14%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes

Component	**Causes Present/Absent**
Fish	Despite the presence of diverse habitat at the site, the fish assemblage was noted to be impacted by habitat fragmentation as a result of Krugersdrift Dam (downstream) as well as the presence of weirs (upstream). Consequently, only a short reach of the river was noted to support lotic conditions where spawning may take place, thus resulting in a reduced FROC for species with reach-scale migration requirements as well as those species with a moderate intolerance to no-flow conditions. However, the diversity of substrate within the reach was limited to larger features such as boulders which would limit the success of substrate spawners such as *Labeo capensis* and *Labeobarbus* spp.. Physical-chemical modification is further expected to impact the presence of some species such as *Labeobarbus kimberleyensis*, while predatory alien fish species are also considered a contributing factor.

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	93.01	93.15
COVER	100.00	100.00
FLOW MODIFICATION	58.45	70.67
PHYSICAL-CHEMICAL	54.17	65.36
MIGRATION		63.53
IMPACT OF INTRODUCED		40.43
FRAI	PRESENT	
FRAI (%)	57.0	
EC: FRAI	D	

Component	**Causes Present/Absent**
Macroinvertebrates	

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	57.1	0.154	8.79121	3	40
HABITAT	H	60.3	0.385	23.2051	1	100
WATER QUALITY	WQ	42.4	0.346	14.6635	2	90
CONNECTIVITY & SEASONALITY	CS	80.0	0.115	9.23077	4	30
						260
INVERTEBRATE EC				55.8906		
INVERTEBRATE EC CATEGORY				D		

Habitat availability was limited for aquatic macroinvertebrates, as it was dominated by boulders and bedrock, of which cobble and gravel were deposited in between these sections. These biotopes were smothered by high algal growth and silt deposition. Furthermore, marginal vegetation was

PES and causes	
Component	**Causes Present/Absent**
	limited to *Phragmites* sp. For the last hydrological year (2021-2022), 11 taxa were recorded out of an expected 50 (22% of the reference community). The aquatic macroinvertebrate assemblage collected was determined to be representative of largely modified conditions (Ecological Category D, 43.85%). Ultimately, the community was primarily driven by water quality, followed by flow modification and then habitat. This was supported by the majority of the community having a tolerance for low to very low water quality; likely a consequence of the return flows from numerous and unmaintained WWTW. A total of 37 taxa were expected, but not recorded (FROC of between 3 – 5). The preference of these taxa was standing water and cobbles, both of which were limited at the site owing to the former not being present and the stones biotope being compromised and smothered by high algal growth and silt deposition. Overall, the average score per taxa for the last hydrological year was 5.1 (78% of the reference ASPT), indicative of tolerant taxa (Dickens and Graham, 2002).

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers are unchanged due to impacts remaining unchanged (Google Earth). • Some expansion of Bloemfontein is however expected.	3
Macroinvertebrates	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments and since PES, 2014, Google Earth) • No additional bed modification • Limited habitat availability remains restrictive • 78% of the reference ASPT	2
Habitat integrity: Instream	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments) • No additional bed modification	2
Habitat integrity: Riparian	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments)	2
ECOSTATUS			

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	D	N/A

Revised Ecological Importance and Ecological Sensitivity		
EIES, 2014	**Rapid 3, 2022**	**Criteria changes**
High, High	Moderate, Moderate	Ecological importance: • Riparian wetland zone habitat integrity class (very high to moderate) • Instream habitat integrity class (moderate to low) Ecological sensitivity: • Fish physical-chemical sensitivity (high to moderate) • Fish no-flow sensitivity (high to low) • Invert physical-chemical sensitivity (very high to moderate) • Inverts velocity sensitivity (very high to low) • Stream size sensitivity to modified flow/water level changes (low to moderate)

Physical-chemical state of the system
Physical-chemical state of the system is altered by the impacts from Bloemfontein and surrounding areas upstream, especially effluent discharges from the various WWTWs. The diatoms and macroinvertebrates show that the physical-chemical state of the system is in a poor condition. pH was elevated. Clarity was also low, indicating high suspended solids input upstream result from stream modification and erosion upstream.

PES	REC	
D	C/D	• As per the recommendations as in Chapter 11, if the water quality within this system improves, this REC will be achievable.

OVERALL ASSESSMENT

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

Figure 8-18: Overall EcoStatus assessment for UO_EWR06_R (Middle Modder)

The overall EcoStatus was categorised as a D, owing to the condition of all components, viz. fish (D), macroinvertebrates (D), instream (D) and riparian habitat integrity (D) (Figure 8-18). These components were mostly driven by physical-chemical modification, owing to the upstream urban areas, and associated unmaintained and failing municipal infrastructure namely WWTWs. From the fish perspective, fragmentation of longitudinal connectivity was also noted to be a significant driver of the ecological state of the fish assemblage, limiting movement.

Water quality continues to be compromised by unmaintained and failing municipal infrastructure upstream, as well as extensive agriculture and irrigation, with high nutrient return flows.

It is suggested that the REC of a C/D (close to moderately modified most of the time) can be achieved, should the proposed mitigation measures/recommendations be assessed and applied.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations
- DWS to review the Water Use License and monitoring programmes of the upstream WWTW to ensure compliance
- Upstream municipal infrastructure to be reviewed and maintained/upgraded
- Land use activities within the upstream catchment should be managed to prevent degradation of the ecological health of the system and deterioration of the water quality; buffer zones needs to be implemented.

Please refer to Table 12-1, Figure 12-4 and Figure 12-5 for a summary of the EcoStatus and proposed REC for all Rapid 3 EWR sites for this study.

9. *ECO-CATEGORISATION: FIELD VERIFICATION ASSESSMENTS FOR THE UPPER ORANGE CATCHMENT*

It is important to note that the PES for these field verification sites were derived as per professional opinion and further based on the diatoms and IHI results, taking into consideration the results of the 2014 desktop PES/EI/ES.

9.1 UO_EWR01_FV: MEULSPRUIT

Sample Date	5 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR01_FV	**Prioritised RU**	R_RU30
River	Meulspruit	**Altitude (m.a.s.l.)**	1536
Latitude	-28.885731°	**Longitude**	27.834944°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D22B D22B-03442
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: Diatoms, IHI, *in situ* water quality, discharge

Figure 9-1: Site photographs of the Meulspruit field verification site

Upstream	Downstream

Site Description:

The site is located just outside Ficksburg off the R26 road, just downstream of the Meulspruit Dam wall. The Meulspruit Dam has no release capacity and does not release into the Meulspruit. Thus, there are periods when this tributary is dry. The site on the Meulspruit is located upstream of the confluence with the Caledon River, with high baseflows owing to recent flooding events.

The site is located along a confined reach with possible bedrock influence. The river is ~6m wide with bed and channel modification owing to railway bridges constructed upstream, coupled with the construction of the Meulspruit Dam wall. The channel is highly scoured as a result of longitudinal sediment starvation downstream of the dam. Localised unnatural deposits of rocks at the site owing to a stream crossing. There is further cement barrels instream, along with fallen tree debris within the channel. High bank erosion and lateral head cut erosion at the stream crossing. Biotopes available for macroinvertebrates included SIC, SOOC with riffles and GSM. Marginal vegetation was absent owing to undercut banks and vegetation die-off. For fish, there was SD, SS, FS and some deep pools upstream. High algae content and turbid water. The riparian zone is limited to grasses, shrubs, *Salix sp and Populus sp. (alien invasive)* located along mostly the left bank.

Site impacts:

- Alien invasives
- Meulspruit Dam
- Irrigation upstream of the dam
- Cut and fill associated with the road crossing, including introduced rock aggregate

Preliminary Results

In situ water quality:

- pH: 8.9
- EC: 278 µS/cm
- TDS: 0.270g/l
- DO: 11.9 mg/l
- DO%: 99.6%
- Clarity: 34cm
- Temperature: 7.7°C
- Salinity: 0.2

- Discharge: 0.741m^3/s

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
22	9.3	C (Moderate)	40.3	0

Dominant Species	1. *Achnanthidium eutrophilum (Lange-Bertalot) Lange-Bertalot*
	2. *Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*
Preference	1. Found in well-oxygenated eutrophic fresh water. Tolerant only to slight or moderate pollution
	2. Tolerant of strong pollution, an indicator of industrial organic pollution

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (71%)	F/NF	• Flow modification (artificial debris, bridges, cattle crossings, upstream dam, irrigation)

			• Bed modification • Physical-chemical modification (diatoms indicative of moderately modified water quality, turbidity) Introduced aquatic fauna (*Cyprinus carpio*)
Habitat Integrity: Riparian	C/D (61%)	F/NF	• Bank erosion (cattle trampling, grazing) • Alien riparian vegetation • Channel modification (upstream dam, weirs)
ECOSTATUS*	D		

**The EcoStatus (current PES for this study) for all field verification sites is based on 1. Water quality (primarily from the diatom results), the IHI, site observations and professional opinions.*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	
ECOSTATUS	D	D	

Recommended Ecological Category	
D	• Small system, dependant on spills from Meulspruit Dam and some seepage from the catchment for flows • Current water quality impacts will continue which include: • Impacts due to upstream irrigation • Nutrient enrichment • Cattle trampling and grazing

9.2 UO_EWR02_FV: WITSPRUIT

Sample Date	6 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR02_FV	**Prioritised RU**	R_RU31
River	Witspruit	**Altitude (m.a.s.l.)**	1389
Latitude	-30.008260°	**Longitude**	26.928315°
Level 1 EcoRegion	Highveld	**Quaternary catchment- SQ Reach**	D24C D24C-04692
Level 2 EcoRegion	11.03	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms, discharge

Figure 9-2: Site photographs of the Witspruit field verification site

Upstream	Downstream

Site Description:

The site is located downstream from Van Stadensrus along an incised valley with limited floodplain development. The site is inundated through successive weirs with alluvial deposition. There is a weir located upstream with in-stream consolidated sediment islands. The flow is limited by a low water causeway and a downstream weir, resulting in deep slow flowing habitats.

The biotopes present for the macroinvertebrates include both marginal and in-stream vegetation along with GSM. Slow deep habitats were present for fish. Algae are present within the water column and cause high turbidity. The riparian zone is intact, with some wetland features, although high-density patches of *Populus sp (*alien*)* occur along both banks.

Site impacts:

- Alien invasive vegetation (riparian)
- Low water cross-over bridge
- Upstream town of Van Stadensrus (possible water quality impacts)
- Upstream dam near Van Stadensrus (possible flow modifications)
- Upstream and downstream small weirs

Preliminary Results

In situ water quality:

- pH: 9.6
- EC: 201 µS/cm
- TDS: 0.185 g/l
- DO: 10.36 mg/l
- DO%: 91.2%
- Clarity: 18cm
- Temperature: 9.6°C
- Salinity: 0.14
- Discharge: 0.1 m^3/s

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
31	6.7	D (Poor)	48.8	1.5

Dominant Species	1. *Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot* 2. *Nitzschia sp.*
Preference	1. Very pollution tolerant - organic pollution 2. Generally, siltation and moderate pollution

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (74%)	F/NF	• Water abstraction (irrigation) • Channel modification
Habitat Integrity: Riparian	B (86%)	F/NF	• Channel modification (weirs, low water bridge) • Inundation (weirs)
ECOSTATUS	C/D		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C/D	• Water quality impairments: diatoms indicated poor water quality • Under reference conditions – there are several sensitive macroinvertebrates (i.e., Heptageniidae, Tricorythidae) and fish species (*Labeobarbus aeneus*)

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
			expected, but likely not present at the time of the field verification owing to limited flow conditions

Recommended Ecological Category	
C	• Although EI and ES moderate, it is a small system sensitive to flow and quality changes. A REC of C is achievable if the water quality is improved through management of the upstream town WWTW • Under reference conditions – there are several sensitive macroinvertebrates (i.e., Heptageniidae, Tricorythidae) and *Labeobarbus aeneus* expected, but likely not present at the time of the field verification owing to limited flow conditions • Upstream dams (flow modification) • Upstream WWTW – aim to be reassessed/maintained to achieve improvement in water quality • Regulation of abstraction for irrigation

9.3 UO_EWR03_FV: GRYSKOPSPRUIT

<table>
<tr><td>Sample Date</td><td>6 July 2022</td><td>Reserve Level Assessment</td><td>Field verification</td></tr>
<tr><td>Site Name</td><td>UO_EWR03_FV</td><td>Prioritised RU</td><td>R_RU22</td></tr>
<tr><td>River</td><td>Gryskopspruit</td><td>Altitude (m.a.s.l.)</td><td>1526</td></tr>
<tr><td>Latitude</td><td>-30.339629°</td><td>Longitude</td><td>27.176878°</td></tr>
<tr><td>Level 1 EcoRegion</td><td>Eastern Escarpment Mountains</td><td>Quaternary catchment-SQ Reach</td><td>D12D
D12D-04976</td></tr>
<tr><td>Level 2 EcoRegion</td><td>15.01</td><td rowspan="2">DWS, 2014 PES, EI, ES</td><td rowspan="2">D, Moderate, Moderate</td></tr>
<tr><td>Geomorphological zone</td><td>E (Lower Foothills)</td></tr>
<tr><td colspan="4">Components sampled: IHI, in situ water quality, diatoms</td></tr>
<tr><td colspan="4">
Figure 9-3: Site photographs of the Gryskopspruit field verification site</td></tr>
<tr><td colspan="4">Downstream</td></tr>
<tr><td colspan="4">Site Description:</td></tr>
<tr><td colspan="4">The site is located just upstream of Montagu Dam (Zastron), along an unconfined floodplain reach. The site is further characteristic of a channelled valley bottom wetland, possibly due to the backwater effects taking place from the dam located further downstream. Upstream is dense wetland vegetation, however once the water flows through the low lying cross-over culverted bridge – the water dissipates downstream through the floodplain.

Salix sp. are located within the channel downstream of the low-lying bridge.</td></tr>
<tr><td colspan="4">Site impacts:</td></tr>
<tr><td colspan="4">• Some irrigation
• The town of Zastron (possible water quality impacts)</td></tr>
<tr><td colspan="4">Preliminary Results</td></tr>
</table>

In situ water quality: • pH: 8.5 • EC: 337 µS/cm • TDS: 0.306 g/l • DO: 11.9 mg/l • DO%: 105.8% • Clarity: 48cm • Temperature: 10.1°C • Salinity: 0.23				
Discharge: Not taken				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
28	2.5	E (Serious)	12	1.75
Dominant Species		*Nitzschia sp.*		
Preference		Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (75%)	F/NF	• Water quality impairments (diatom results indicative of seriously modified conditions) • Flow modification
Habitat Integrity: Riparian	B/C (79%)	F/NF	• Channel modification (reed encroachment within the channel upstream of the low-lying bridge) • Bank erosion • Upstream dam breach • Berms • Various canals feeding farm dams
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C	• Small system along an unconfined floodplain whereby water quality could be improved with catchment management processes

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
			• Current categorisation for habitat integrity for instream and riparian

Recommended Ecological Category	
C	• Small system, sensitive to flow and water quality changes. However, no improvement in REC as it is functioning primarily as a wetland system • Upstream dam • WWTW reassessment and maintenance (improvements to water quality) • Catchment management (control sedimentation, cattle grazing/trampling - erosion)

9.4 UO_EWR04_FV: KARRINGMELKSPRUIT

Sample Date	7 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR04_FV	**Prioritised RU**	R_RU26
River	Karringmelkspruit	**Altitude (m.a.s.l.)**	1635
Latitude	-30.811765°	**Longitude**	27.264973°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13K D13K-05454
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	B, Very High, High
Geomorphological zone	D (Upper Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms


Figure 9-4: Site photographs of the Karringmelkspruit field verification site

Upstream	Downstream

Site Description:

The Karringmelkspruit is a tributary of the Kraai River. The site was located along a confined valley dominated by boulder and cobble bed material. This almost pristine meandering river through a gorge comprises all macroinvertebrate biotopes namely SIC, SOOC, GSM, although the marginal vegetation is limited owing to undercut banks and vegetation die-off. There are large fallen down boulders from the adjacent gorge in-stream, some with sediment abrasions from previous floods. The fish habitats comprise FS, SS and SD. Limited impacts, clear water and no algae visible. Some bank erosion on both banks due to the recent floods. The riparian zone is partly intact, representative of the season, particularly the left bank while the right bank has some areas of bare soil. Some encroachment of alien invasive vegetation along the riparian zone, including blackjacks.

Site impacts:

- Limited abstraction for irrigation
- Cattle grazing

Preliminary Results

In situ water quality:

- pH: 8.5
- EC: 106 µS/cm
- TDS: 0.125 g/l
- DO: 9.2 mg/l
- DO%: 81.3%
- Clarity: >1m
- Temperature: 9.7°C
- Salinity: 0.1

Discharge: Not measured but estimated to be approximately 0.4 m^3/s

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
20	15.2	B (Good)	2.9	1.75
Dominant Species		1. *Achnanthidium sp.*		
		2. *Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
		3. *Reimeria sinuata (Gregory) Kociolek & Stoermer*		
Preference		1. Moderate to good quality waters		
		2. Nutrient and salinity increases (eutrophication)		
		3. A cosmopolitan aerophilic species found in montane biotopes, mosses, springs and streams. Tolerant of high levels of Eutrophication.		

IHI

COMPONENT	PES category & score	Flow/ Non-flow	EXPLANATION
Habitat Integrity: Instream	A (95%)	NF	• Introduced aquatic fauna (*Oncorhynchus mykiss*) present (although not a habitat modifier – but a predator on both fish/macroinvertebrates)
Habitat Integrity: Riparian	A (92%)		• N/A
ECOSTATUS	B		

Overall change and reason for deviation

COMPONENT	PES 2014	EcoStatus, 2023	REASON FOR DEVIATION
ECOSTATUS	B	B	N/A

Recommended Ecological Category	
B	• Retain water quality and flow regimes owing to the presence of water quality and flow-sensitive macroinvertebrates • Part of Strategic Water Source Area (SWSA) • Ensure limited to no upstream catchment development • Important migratory corridor for *Labeobarbus aeneus*

9.5 UO_EWR05_FV: BOKSPRUIT

Sample Date	9 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR05_FV	**Prioritised RU**	R_RU23
River	Bokspruit	**Altitude (m.a.s.l.)**	1760
Latitude	-30.884690°	**Longitude**	27.884557°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13A D13A-05679
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	E (Lower Foothills)		

Components sampled: Fish, IHI, *in situ* water quality, diatoms, discharge

Figure 9-5: Site photographs of the Bokspruit field verification site

Upstream	Downstream

Site Description:

The Bokspruit, a tributary of the Sterkspruit (Kraai River system), is in good condition and approximately 10m wide. The reach has a partly confined valley setting with narrow flood features. However, owing to the bridge at the sampling site, coupled with some log and debris jams on the left side, are impeding the hydraulics of the river, scouring and resulting in localised erosion, particularly on the left bank, both up and downstream of the bridge. The scouring is contributing to the downstream lee bar on the left, although further downstream, another lee bar was observed on the right bank. Owing to the *Salix sp.* on the left bank, the banks are stabilised thus avoiding further localised bank erosion. Both bed and channel modification occur at this site, but are localised. The riparian zone is partly intact, representative of the season, and mostly covered with grasses, shrubs and trees, most of which are alien invasive namely Salix spp. and Pyracantha.

The river comprises various sections of riffles up and downstream of the bridge. All biotopes for the macroinvertebrates are present, SIC, SOOC, GSM, although vegetation is limiting owing to undercut banks and vegetation die-off. Localised algae covering the SIC biotope. For fish, there is SD, SS and FS habitats.

The land use is predominantly farmlands, with small croplands and cattle grazing.

Site impacts:
• Abstractions for irrigation • Cattle grazing
Preliminary Results
In situ water quality: • pH: 8.9 • EC: 109 µS/cm • TDS: 0.116 g/l • DO: 10.9 mg/l • DO%: 84.4% • Clarity: >1m • Temperature: 4.9°C • Salinity: 0.08
Discharge: 0.649 m^3/s

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
23	10.2	C (Moderate)	0.9	5.5 (extreme deformities and cause for concern)
Dominant Species		1. *Achnanthidium sp.*		
		2. *Diatoma vulgaris Bory*		
		3. *Nitzschia sp.*		
Preference		1. Moderate to good quality waters		
		2. Found in mesotrophic to eutrophic waters with average electrolyte content. The cells are joined at the corners forming zig-zag colonies.		
		3. Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (86%)	F/NF	• Some water abstraction • Introduced aquatic fauna (*Oncorhynchus mykiss*) present (although not a habitat modifier – but a predator on both fish/macroinvertebrates) • Channel modification (agricultural fields and berms)
Habitat Integrity: Riparian	B (88%)	F/NF	• Bank erosion • Channel modification • Alien vegetation (canopies of *Salix sp*. and others)

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
ECOSTATUS	B/C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B/C	• Retain flow regimes owing to the presence of water quality and flow-sensitive macroinvertebrates • Habitat integrity categorised for both instream and riparian as a B

Recommended Ecological Category	
B	• Water quality improvements (agricultural run-off) • Part of Strategic Water Source Area (SWSA) • Retain flow regimes owing to the presence of flow-sensitive macroinvertebrates • Ensure the control, authorised and management of any potential and further upstream catchment developments • Important migratory corridor for *Labeobarbus aeneus* • Water quality and flow-sensitive aquatic macroinvertebrates present under reference conditions namely Perlidae, Heptageniidae, Leptophlebiidae, Tricorythidae

9.6 UO_EWR06_FV: HOLSPRUIT

Sample Date	10 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR06_FV	**Prioritised RU**	R_RU27
River	Holspruit	**Altitude (m.a.s.l.)**	1413
Latitude	-30.995316°	**Longitude**	27.056639°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13J D13J-05741
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	B, High, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms

Figure 9-6: Site photographs of the Holspruit field verification site

Upstream	Downstream

Site Description:

The site is located near Floukraal along a confined valley. The Holspruit has localised modifications owing to a cross-over bridge which impedes the river channel, along with an upstream weir and derelict and broken-down culverted bridge coupled with construction debris. Furthermore, beneath the cross-over bridge in-stream are artificial cement slabs. Both banks up and downstream of the bridge are well vegetated although dominated by alien invasives namely *Populus sp.,* as well as pockets of *Salix sp.* and *Pyracantha*. Although these are aiding in bank stability. All these impediments have resulted in the multiple diversions of the river flowing downstream, with a lee bar on the left bank downstream of the bridge. Turbid waters with some algae and sediment loads over the stone’s biotopes.

Biotopes available for macroinvertebrates is dominated by various sections of riffles, SIC and SOOC. Marginal vegetation is present but limited owing to undercut banks and vegetation die-off (representative of the season). Fish habitats comprised SD, SS, FD and FS.

Site impacts:

- Cattle trampling and grazing
- Upstream small dams (off-channel)
- Abstraction for irrigation

• Bridge crossings • Extensive alien vegetation infestation				
Preliminary Results				
In situ water quality: • pH: 8.4 • EC: 332 µS/cm • TDS: 0.326 g/l • DO: 10.4 mg/l • DO%: 85.8% • Clarity: 39cm • Temperature: 7.3°C • Salinity: 0.24				
Discharge: Not measured				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
26	9.7	C (Moderate)	14.9	1
Dominant Species		*Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
Preference		Nutrient and salinity increases (eutrophication)		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (70%)	F/NF	• Flow modification; centre pivots, farm dams, upstream weir, small dams, various bridges, dryland agriculture and irrigation • Water abstraction • Physio-chemical; nutrient enrichment - agriculture • Introduced aquatic fauna (*Oncorhynchus mykiss*) present (although not a habitat modifier – but a predator – fish/macroinvertebrates)
Habitat Integrity: Riparian	C (72%)	F/NF	• Alien vegetation (extensive – *Populus sp.)* • Bank erosion (cattle grazing/trampling) • Inundation (weirs)
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	B	C	• Water quality impairments: diatoms indicated moderately modified water quality • Habitat integrity for both instream and riparian • Extensive alien vegetation along the riparian zone

Recommended Ecological Category	
C	• Aim to retain the current PES as the REC • Ensure the control, authorised and management of any potential and further upstream catchment developments • Eradicate and manage riparian alien vegetation (*Populus sp.*)

9.7 UO_EWR07_FV: STERKSPRUIT (TRIBUTARY OF THE KRAAI/BELL)

Sample Date	9 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR07_FV	**Prioritised RU**	R_RU11b
River	Sterkspruit	**Altitude (m.a.s.l.)**	1740
Latitude	-30.917621°	**Longitude**	27.800753°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13C D13C-05701
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	E (Lower Foothills)		
Components sampled: IHI, *in situ* water quality, diatoms, discharge			

Figure 9-7: Site photographs of the Sterkspruit, a tributary of the Bell/Kraai River field verification site

Downstream
Site Description:
The Sterkspruit, a tributary of the Bell/Kraai River is in a good condition at the site and approximately 10m wide. The bridge at the sampling site is causing scouring of both banks, resulting in localised erosion up and downstream of the bridge. Bank rehabilitation gabions have been constructed up and downstream of the bridge for stabilisation. However, the gabions on the banks above the bridge have destabilised and disassembled, and gabion material and debris are impeding the flow beneath the bridge and slightly downstream of the bridge, with gabion material observed in-stream. Most of the gabions on the banks below the bridge are still intact and

functioning to alleviate bank erosion and further scouring. Nonetheless, the scouring is contributing to the downstream lee bar on the left bank. Both bed and channel modification at this site is localised. The riparian zone is partly intact, representative of the season, mostly covered with grasses, shrubs and trees (limited *Salix sp*., further downstream) and the presence of *Populus* sp. upstream.

The river comprises various sections of riffles and pools up and downstream of the bridge. All biotopes for macroinvertebrates are present, SIC, SOOC, GSM, although vegetation is limited owing to undercut banks and vegetation die-off. Localised algae covering the SIC biotope. For fish, there is SD, SS and FS habitats.

The land use is predominantly farmlands, with small croplands along terraces and widespread cattle grazing.

Site impacts:

- Abstractions for irrigation
- Cattle grazing

Preliminary Results

In situ water quality:

- pH: 8.6
- EC: 147 µS/cm
- TDS: 0.159 g/l
- DO: 12.2 mg/l
- DO%: 93.0%
- Clarity: >1m
- Temperature: 4.1°C
- Salinity: 0.12

Discharge: 0.763 m^3/s

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
22	12	C (Moderate)	7.1	1.75
Dominant Species		1. *Achnanthidium sp.*		
		2. *Nitzschia sp.*		
Preference		1. Moderate to good quality waters		
		2. Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (82%)	F/NF	• Physio-chemical (high agriculture along this reach) • Water abstraction is high • Introduced aquatic fauna (*Oncorhynchus mykiss*) present (although not a habitat modifier – but a predator on both fish/macroinvertebrates)
Habitat Integrity: Riparian	B/C (82%)	F/NF	• Bank erosion (cattle tramping, grazing) • Alien vegetation (destabilising banks) • Channel modification (river training)
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	N/A

Recommended Ecological Category	
B/C	• Water Quality improvements (agricultural, irrigation) • Part of Strategic Water Source Area (SWSA) • Reference macroinvertebrates indicate preference for good water quality and flow • Manage riparian alien vegetation (*Populus sp.*) • Under reference conditions - water quality and flow sensitive aquatic macroinvertebrates present namely Perlidae, Heptageniidae, Leptophlebiidae, Tricorythidae)

9.8 UO_EWR07_FV: BELL

Sample Date	9 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR07_FV	**Prioritised RU**	R_RU11c
River	Bell (DWS – Kraai)	**Altitude (m.a.s.l.)**	1723
Latitude	-30.852601°	**Longitude**	27.786557°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13B D13B-05474
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms, discharge

Figure 9-8: Site photographs of the Bell field verification site

Upstream	Downstream

Site Description:

The Bell River (although still named the Kraai according to PES, 2014), and which lies approximately 3km upstream from UO_EWR04_R (Upper Kraai River) is in an almost pristine condition with localised impacts. A large upstream bridge has been constructed on solid boulders and bedrock foundation, although some head cut erosion taking place on the left bank of the bridge. There is scouring and bank erosion on both banks going downstream, the recent floods being a contributing factor coupled with on-going widespread cattle grazing and trampling. Gravel and cobble bars are common along the reach. The riparian zone is intact, mostly covered with grasses, shrubs (blackjacks) and trees (*Salix sp*.) along the reach.

The river comprises various sections of riffles and pools up and downstream of the bridge. All biotopes for the macroinvertebrates are present, SIC, SOOC, GSM, although vegetation is limiting owing to undercut banks and vegetation die-back. Localised algae covering the SIC biotope. For fish, there is FD, SS and FS habitats.

The land use is predominantly farmlands, with small croplands and widespread cattle grazing.

Site impacts:				
• Abstraction for irrigation • Cattle grazing • Alien predatory fish present				
Preliminary Results				
In situ water quality: • pH: 8.6 • EC: 149 µS/cm • TDS: 0.145 g/l • DO: 11.15 mg/l • DO%: 93.9% • Clarity: >1m • Temperature: 7.7°C • Salinity: 0.11				
Discharge: 0.736 m^3/s				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
10	17.3	A (High)	3.2	0.5
Dominant Species		1. *Achnanthidium sp.*		
		2. *Reimeria sinuata (Gregory) Kociolek & Stoermer*		
Preference		1. Moderate to good quality waters		
		2. A cosmopolitan aerophilic species found in montane biotopes, mosses, springs and streams. Tolerant of elevated levels of Eutrophication.		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B/C (81%)		• Water abstraction (agriculture) • Some bed modification (bridges) • Introduced aquatic fauna (*Oncorhynchus mykiss*) present (although not a habitat modifier – but a predator – fish/macroinvertebrates)
Habitat Integrity: Riparian	B (84%)		• Alien vegetation • Bank erosion (cattle tramping, grazing) • Alien vegetation (destabilising banks) • Channel modification (river training)
ECOSTATUS	B/C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B/C	• Water quality is good (diatoms) • Continued presence of *Oncorhynchus mykiss* • Water quality and flow sensitive macroinvertebrates (reference taxa, PES, 2014) • Habitat integrity for riparian categorised as largely natural

Recommended Ecological Category	
B	• Fish Freshwater Ecosystem Priority Area (FEPA) • Part of Strategic Water Source Area (SWSA) • Under reference conditions - water quality and flow sensitive aquatic macroinvertebrates present namely Perlidae, Heptageniidae, Leptophlebiidae, Tricorythidae) • Important for contributing to the flows in the Kraai River further downstream

9.9 UO_EWR09_FV: GROENSPRUIT

Sample Date	11 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR09_FV	**Prioritised RU**	R_RU32a
River	Groenspruit	**Altitude (m.a.s.l.)**	1333
Latitude	-30.24119°	**Longitude**	26.56130°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	D24H D24H-04835
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms

Figure 9-9: Site photographs of the Groenspruit field verification site

Upstream	Downstream

Site Description:

The site is located off the N6 road on the 1036/1981 bridge (main bridge), downstream of Smithfield. The Groenspruit is a tributary of the Skulpspruit, which is a tributary of the Caledon River within a partly confined floodplain setting. Several small farm dams upstream. A derelict bridge is located just upstream of the main bridge, causing a blockage of vegetation debris, a restriction of flow and thus the river pools at this area. Downstream of the main bridge the channel narrows to approximately 1.5m wide, with head-cut erosion occurring along both banks downstream.

The habitats available for macroinvertebrate include SIC, SOOC, GSM and no marginal vegetation owing to undercut banks and vegetation die back. Some algae are smothering the SIC biotope. Fish habitats include SS, SD and FS. The riparian zone is dominated by grasses and shrubs, but trees are limited.

The land use is predominantly open lands, low-intensity agriculture with some croplands and cattle grazing areas.

Site impacts:

- Agriculture
- Cattle grazing and trampling

<table>
<tr><td colspan="5">Bank erosion</td></tr>
<tr><td colspan="5">Preliminary Results</td></tr>
<tr><td colspan="5">In situ water quality:
pH: 8.2
EC: 445 µS/cm
TDS: 0.419 g/l
DO: 9.1 mg/l
DO%: 78.7%
Clarity: >1m
Temperature: 8.8°C
Salinity: 0.32</td></tr>
<tr><td colspan="5">Discharge: not measured</td></tr>
<tr><td colspan="5">DIATOMS</td></tr>
<tr><td>No. species</td><td>SPI</td><td>Categorisation (quality)</td><td>%PTV</td><td>%Deformed cells</td></tr>
<tr><td>30</td><td>7.3</td><td>D (Poor)</td><td>74.6</td><td>0.5</td></tr>
<tr><td colspan="2">Dominant Species</td><td colspan="3">Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin</td></tr>
<tr><td colspan="2">Preference</td><td colspan="3">Tolerant of strong pollution, an indicator of industrial organic pollution</td></tr>
</table>

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (73%)	F/NF	• Physio-chemical (upstream WWTW – although appears inactive, diatoms indicated poor water quality) • Bed modification (bridge, weirs) • Flow modification (bridge, weirs)
Habitat Integrity: Riparian	C (77%)	F/NF	• Alien vegetation • Bank erosion (breached weir upstream, cattle grazing, trampling and crossings) • Channel modification (bridges) • Physical-chemical (WWTW and stormwater drainage adjacent to the reach)
ECOSTATUS	C/D		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C/D	• Water quality impairments (diatoms indicated poor water quality) • WWTW (Smithfield)

Recommended Ecological Category	
C	• Upstream WWTW infrastructure to be upgraded and maintained with the aim to achieve improvement in water quality and overall REC

9.10 UO_EWR10_FV: SKULPSPRUIT

Sample Date	11 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR10_FV	**Prioritised RU**	R_RU32b
River	Skulpspruit	**Altitude (m.a.s.l.)**	1333
Latitude	-30.23444°	**Longitude**	26.51134°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D24H D24H-04686
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms

Figure 9-10: Site photographs of the Skulpspruit field verification site

Upstream	Downstream

Site Description:

The site is situated off the R701 at a single high-water bridge crossing. The Skulpspruit is a tributary of the lower Caledon River with small in-stream farm dams upstream, primarily low-intensity agricultural activities. The river is located within a partly confined floodplain setting. The channel is ~10 m wide and relatively homogenous up and downstream of the bridge. There is a small diversion where the channel has several sections of riffles with SIC and SOOC biotopes for macroinvertebrates. The increased flow has allowed aquatic grass to establish in the deep runs. Marginal vegetation was limiting owing to undercut banks and vegetation die-back/erosion. The habitats available for fish comprise SD, SS, FD and FS. The riparian vegetation is relatively intact with grasses, shrubs, as well as trees (both indigenous – *Searsia lancea* (Karee) and some alien *Salix sp* and Acacia (wattle)).

The land use is predominantly open lands, low-intensity agriculture with some croplands and cattle grazing areas.

Site impacts:

- Agriculture
- Cattle grazing and trampling
- Bank erosion

Preliminary Results				
In situ water quality: • pH: 8.5 • EC: 545 µS/cm • TDS: 0.517 g/l • DO: 10.8 mg/l • DO%: 92.0% • Clarity: >1m • Temperature: 8.5°C • Salinity: 0.39				
Discharge: Not measured				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
36	10.7	C (Moderate)	5.4	1.75
Dominant Species		*1. Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
		2. Nitzschia sp.		
Preference		1. Nutrient and salinity increases (eutrophication)		
		2. Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B/C (80%)	F/NF	• Water abstraction (irrigation, agricultural drylands) • Bed modification (inundation, upstream and downstream weirs, bridges) • Physical-chemical (dryland agriculture, diatoms indicative of moderate water quality)
Habitat Integrity: Riparian	B (82%)	F/NF	• Vegetation removal (cultivation, cattle grazing/trampling) • Alien vegetation (*Populus sp.*) • Bank erosion (gullies, cattle trampling, grazing, crossings)
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	• N/A

Recommended Ecological Category	
C	• Small seasonal system with limited options to improve flows (various weirs in the system) • Aim to improve water quality through catchment management practices

9.11 UO_EWR11_FV: FOURIESPRUIT

Sample Date	13 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR11_FV	**Prioritised RU**	R_RU18
River	Fouriespruit	**Altitude (m.a.s.l.)**	1357
Latitude	-29.671211°	**Longitude**	26.074393°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	C51A C51A-04269
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	D, High, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms

Figure 9-11: Site photographs of the Fouriespruit field verification site

Upstream	Downstream

Site Description:

This site is located off the R717 road, off the N6. It is a tributary of the Upper Riet River further upstream of site UO_EWR06_I. The reach valley setting is unconfined, with an incised macro channel. The site is bedrock controlled, with a braided/anastomosing low-flow channel. The site is located downstream of a dam. Direct impacts on this system include the low water bridge and several upstream weirs, resulting in inundation along the reach. These impediments are altering the flow and resulting in bed modification. The riparian zone is relatively rocky and well vegetated with limited alien invasive plant species. The turbid channel is ~10m wide and braided downstream of the bridge owing to in-stream vegetated and rocky/gravel islands. The substrate at the site is dominated by bedrock, GSM, and the braids downstream have resulted in small streams running through the instream island with rocky habitat for macroinvertebrates and fish, as well as sections of SOOC.

The primary land use is cattle farming, small agricultural activities.

Site impacts:

- Cattle farming

<table>
<tr><td colspan="5">Cultivation
Irrigation</td></tr>
<tr><td colspan="5">Preliminary Results</td></tr>
<tr><td colspan="5">In situ water quality:
pH: 8.6
EC: 481 µS/cm
TDS: 0.452 g/l
DO: 10.6 mg/l
DO%: 91.3%
Clarity: 48cm
Temperature: 8.9°C
Salinity:0.34</td></tr>
<tr><td colspan="5">Discharge: Not measured</td></tr>
<tr><td colspan="5">DIATOMS</td></tr>
<tr><td>No. species</td><td>SPI</td><td>Categorisation (quality)</td><td>%PTV</td><td>%Deformed cells</td></tr>
<tr><td>35</td><td>11.2</td><td>C (Moderate)</td><td>16.6</td><td>0.75</td></tr>
<tr><td colspan="2">Dominant Species</td><td colspan="3">Cyclostephanos invisitatus (Hohn & Hellerman) Theriot, Stoermer & Hakans</td></tr>
<tr><td colspan="2">Preference</td><td colspan="3">species is of wide-spread occurrence and is common in the summer plankton nutrient-rich waters</td></tr>
</table>

<table>
<tr><td colspan="4">IHI</td></tr>
<tr><td>COMPONENT</td><td>PES category & score</td><td>Flow/ Non-flow</td><td>EXPLANATION</td></tr>
<tr><td>Habitat Integrity: Instream</td><td>C (75%)</td><td>F/NF</td><td>Water abstraction (irrigation)
Inundation, flow and bed modification (various weirs along the reach)
Physical-chemical (diatoms indicative of moderately modified water quality – nutrients)</td></tr>
<tr><td>Habitat Integrity: Riparian</td><td>B/C (79%)</td><td>F/NF</td><td>Bank erosion (cattle trampling, grazing, crossings and gullies)
Channel modification (various weirs along the reach)
Inundation (weirs)</td></tr>
<tr><td>ECOSTATUS</td><td>C</td><td colspan="2"></td></tr>
</table>

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C	• Habitat integrity for both the instream and riparian is categorized as a C and B/C respectively • Water quality (diatoms indicated moderately modified wate quality conditions

Recommended Ecological Category	
C	• Small system with limited options to improve flows (various weirs in the system) • Aim to improve water quality through catchment management practices

9.12 UO_EWR12_FV: RENOSTER

Sample Date	2 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR12_FV	**Prioritised RU**	R_RU37
River	Renoster	**Altitude (m.a.s.l.)**	1334
Latitude	-29.11632	**Longitude**	26.328701
Level 1 EcoRegion	Highveld	**Quaternary catchment- SQ Reach**	C52F C52F-03763
Level 2 EcoRegion	11.08	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-12: Site photographs of the Renoster field verification site (The red dotted line indicates the foam, indicative of raw sewage)

Upstream	**Downstream**

Site Description:

This site is located off the N8 road. It is a tributary of the Modder River. The reach receives return flows from the semi-formal settlements upstream and a number of WWTWs in the Bloemfontein area.
During the site visit the flows were very high due to heavy rains the previous day. Some smaller dams are situated in smaller tributaries and some abstraction for irrigation occurs just upstream of the site.

Site impacts:

- Upstream dysfunctional WWTWs and high return flows
- Upstream urban/ semi-urban activities
- Upstream dams and irrigation

Preliminary Results

In situ water quality: Not taken (probable health hazard; sewage smell and foam on the water surface)

Discharge: Not taken				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
10	4.2	E (Serious)	93.1	1.5
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of strong pollution, indicator of industrial organic pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	D (57%)	F/NF	• Physical-chemical (diatoms indicative of serious modified water quality) • High nutrients levels and organic pollution • Bed modification • Flow modification (WWTW) • Water abstraction (limited irrigation) • Some dams in tributaries
Habitat Integrity: Riparian	D (55%)	NF	• Alien vegetation (extensive stands of *Eucalyptus, Salix sp. Populus sp.)* • Physical-chemical (WWTW)
ECOSTATUS	D/E		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	D/E	• Water quality impairment (diatoms indicated seriously modified water quality conditions) • Habitat integrity for instream is largely modified

Recommended Ecological Category	
D	• Aim to improve water quality via catchment management practices and improvements to the WWTWs. • This will assist the improvement of the downstream Modder River, downstream of the confluence.

9.13 UO_EWR13_FV: OS-SPRUIT

Sample Date	2 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR13_FV	**Prioritised RU**	R_RU21
River	Os-Spruit	**Altitude (m.a.s.l.)**	1344
Latitude	-28.93917	**Longitude**	26.511411
Level 1 EcoRegion	Highveld	**Quaternary catchment-SQ Reach**	C52E C52E-03480
Level 2 EcoRegion	11.1	**DWS, 2014 PES, EI, ES**	C, High, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-13: Site photographs of the Os-spruit field verification site

Upstream	**Downstream**

Site Description:

This site is located off the R717 road off the N1 near Bloemfontein. It is a tributary of the Modder with a low-level stream crossing over the site. The reach is densely populated with vegetation i.e.,, *Phragmites* sp. and water remains in pools during the dry season when there is little flow.

Site impacts:

- Water quality
- Irrigation
- Cattle farming

Preliminary Results

In situ water quality: Not taken

Discharge: Not taken

DIATOMS

No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
33	12.8	C (Moderate)	4.5	0.25
Dominant Species		*Epithemia sorex Kützing*		

Preference	Species of fresh and brackish water environments, generally present in polytrophic waters and characterized by a high pH

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (82%)	NF	• Physical-chemical (diatoms indicative of moderately modified water quality)
Habitat Integrity: Riparian	B/C (81%)	NF	• Bank erosion • Alien vegetation
ECOSTATUS	B/C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B/C	N/A

Recommended Ecological Category	
B/C	• Small system with limited options to improve the flows, presence of upstream dams, irrigation • Aim to improve water quality through catchment management practices

9.14 UO_EWR14_FV: HONDEBLAF

Sample Date	4 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR14_FV	**Prioritised RU**	R_RU33
River	Hondeblaf	**Altitude (m.a.s.l.)**	1197
Latitude	- 30.205138	**Longitude**	24.71803
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D31C - 04847
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Low, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-14: Site photographs of the FHondeblaf field verification site

Upstream	Downstream

Site Description:

This site is located off the R369 road off the R48 towards Petrusville. Small, possibly seasonal to ephemeral tributary of the Orange river flowing towards Vanderkloof Dam. There is evidence of some erosion on both banks, due to cattle trampling and grazing. At the time of the site visit, the reach was dry save for a few pools where diatom samples were taken. Substrates observed at the time of the visit were mainly gravel and sand. The riparian zone is mostly sedges and grass on both banks.

Site impacts:

- Cattle farming
- Limited irrigation

Preliminary Results

In situ water quality: Not taken

Discharge: Not taken

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells

27	15	B (Good)	10.2	0.75
Dominant Species		*1. Epithemia sorex Kützing*		
		2. Nitzschia dissipata (Kützing) Grunow		
Preference		1. Species of fresh and brackish water environments, generally present in polytrophic waters and characterized by a high pH		
		2. A cosmopolitan species found in waters of moderate to high electrolyte content, not present in waters of low electrolyte content. Highly mobile - siltation		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (85%)	F/NF	• Localised impacts (weirs, low water bridges)
Habitat Integrity: Riparian	B (87%)	F/NF	• N/A
ECOSTATUS	B		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B	N/A

Recommended Ecological Category	
B	• Flow appears to be the primary driver, as water quality appears to be in s good state.

9.15 UO_EWR15_FV: TRIBUTARY OF VAN ZYLSPRUIT

Sample Date	4 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR15_FV	**Prioritised RU**	R_RU40
River	Trib Van Zyl	**Altitude (m.a.s.l.)**	1409
Latitude	-30.031203°	**Longitude**	25.786463
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	C51G - 04734
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, High, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms


Figure 9-15: Site photographs of the Tributary of Van Zylspruit field verification site

Upstream	Downstream

Site Description:

This site is located off the R704 off the R717 in the town of Trompsburg. It is a tributary of the Van Zylspruit flowing out from Langseekoeigat Dam. Diatom samples were collected at the site. The banks were stable and well-vegetated with grasses. Water was polluted with plastics due to the proximity to settlements. Very low flows were observed at the time of the site visit with water flowing less than 0.5m deep.

Site impacts:

- The town of Tromsburg (possible water quality impacts)
- Housing settlements
- Cattle trampling and grazing
- Macroplastics along the riparian zone

Preliminary Results

In situ water quality: Not taken

Discharge: Not taken

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells

22	10.5	C (Moderate)	4.8	0
Dominant Species		*Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot*		
Preference		A common species in standing and flowing, circumneutral to alkaline waters with a moderate to high electrolyte content. Capable of tolerating critically polluted conditions.		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B/C (81%)	NF	• Large range of dumping instream (building material, car tyres and domestic macroplastics) • Water quality problems (upstream WWTW, the town of Trompsburg and diatoms indicative of moderately modified water quality)
Habitat Integrity: Riparian	C (71%)	NF	• Vegetation removal; continuous cattle grazing, trampling and firewood collection • Bank erosion; bridges, weirs, cattle trampling and crossing points
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	N/A

Recommended Ecological Category	
C	• Water quality impairment continues owing to dysfunction upstream WWTW. • The aim must be to improve water quality through better catchment management practices.

9.16 UO_EWR16_FV: SLYKSPRUIT

Sample Date	4 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR16_FV	**Prioritised RU**	-
River	Slykspruit	**Altitude (m.a.s.l.)**	1282
Latitude	-30.393003	**Longitude**	26.120925
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	D24L - 05100
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-16: Site photographs of the Slykspruit field verification site

Upstream	Downstream

Site Description:

This site is located off the R701 road towards Bethulie. It is a tributary of the Caledon River, located upstream of Gariep Dam. Water in the channel was slow-moving on the day of the verification as a result of back flooding from downstream. Diatom samples were taken from rocks found close to the channel banks. Both banks show evidence of erosion and marginal vegetation was absent possibly due to cattle grazing.

Below are photos of the Slykspruit taken further downstream at the bridge crossing on the R701.

Site impacts:

- Cultivation
- Irrigation
- Cattle grazing

Preliminary Results

In situ water quality: Not taken

Discharge: Not measured

DIATOMS

No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
28	14.9	B (Good)	2.3	0
Dominant Species		*Epithemia sorex Kützing*		
Preference		Species of fresh and brackish water environments, generally present in polytrophic waters and characterized by a high pH		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B/C (81%)	F/NF	• Bed modification (localised gravel mining, river crossings, weirs) • Some irrigation in lower reaches
Habitat Integrity: Riparian	B/C (82%)	F/NF	• Grazing, river crossings and gravel mining • Channel modification (localised changes due to gravel mining, weir construction and river crossings, channel straightening)
ECOSTATUS	B/C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B/C	N/A

Recommended Ecological Category	
B/C	• Small seasonal system with limited options to improve the flows, presence of irrigation practices.

9.17 UO_EWR17_FV: LANGKLOOFSPRUIT

Sample Date	6 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR17_FV	**Prioritised RU**	R_RU11d
River	Langkloofspruit	**Altitude (m.a.s.l.)**	1426
Latitude	-30.954126	**Longitude**	27.606129
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D13D-05766
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-17: Site photographs of the Langkloofspruit field verification site

Upstream	Downstream

Site Description:

The site is located northeast of the town Barkly East off the R396 road. It is a tributary of the Kraai River. There is a large cross-over bridge upstream from the site. The river is located within a valley setting which is confined, with cobbles, rocks and small boulders forming riffles and pools. The river is ~8m wide and flows relatively straight. Some erosion on both banks, due to cattle trampling and grazing. The river banks are vegetated with grasses, and sedges.

Site impacts:

- Rubbish dumping
- Sand mining

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells

24	14.1	B (Good)	9.5	2.75
Dominant Species		1. *Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
		2. *Reimeria sinuata (Gregory) Kociolek & Stoermer*		
Preference		1. Nutrient and salinity increases (eutrophication)		
		2. A cosmopolitan aerophilic species found in montane biotopes, mosses, springs and streams. Tolerant of high levels of Eutrophication.		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (87%)	NF	• Irrigation in the upper catchment • Rubbish dumping; car parts, hydrocarbons (? More info) and considerable nappy dumping
Habitat Integrity: Riparian	B/C (80%)	NF	• Channel modification; sand mining on flood benches, bridge approach and river access, berms around fields • Vegetation removal from continued cattle grazing and trampling
ECOSTATUS	B/C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B/C	• Instream habitat integrity in a B category • Diatoms indicative of Largely natural with few modifications

Recommended Ecological Category	
B	• Instream and riparian habitat integrity continues to be stable • Part of Strategic Water Source Area (SWSA) • Catchment management practices are needed; rubbish dumping, sand mining and cattle activity must be managed

9.18 UO_EWR18_FV: WASBANKSPRUIT

Sample Date	6 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR18_FV	**Prioritised RU**	R_RU25
River	Wasbankspruit	**Altitude (m.a.s.l.)**	1520
Latitude	-31.15554	**Longitude**	27.284442
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D13G - 05996
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	D, Moderate, High
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

Figure 9-18: Site photographs of the Wasbankspruit field verification site

Upstream	Downstream

Site Description:

The site is located northeast of Rossouw off the R396 road towards Barkly East. It is a tributary of the Kraai River. The reach has a partly confined valley setting and the channel is incised. Both banks show evidence of erosion and marginal vegetation was absent owing to undercut banks and grazing.

The land use is rural development and cattle farming.

Site impacts:

- Cattle farming
- Cultivation
- Limited Irrigation
- Rural development

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured				
DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
30	12.4	C (Moderate)	0.7	0.5
Dominant Species		1. *Achnanthidium sp.*		
		2. *Cocconeis placentula var. euglypta (Ehrenberg) Grunow*		
		3. *Nitzschia dissipata var. media (Hantzsch) Grunow*		
		4. *Nitzschia sp.*		
Preference		1. Moderate to good quality waters		
		2. Nutrient and salinity increases (eutrophication)		
		3. A cosmopolitan species found in waters of moderate to high electrolyte content, not present in waters of low electrolyte content.		
		4. Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (84%)	F/NF	• Irrigation • Flow modification (dams in tributaries) • Water quality; Irrigation return flows and diatoms indicative of moderately modified water quality
Habitat Integrity: Riparian	C (69%)		• Extensive bank erosion; cattle trampling, grazing, and scour related to bridge infrastructure • Vegetation removal; grazing and firewood collection
ECOSTATUS	C		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C	• Diatoms indicative of moderately modified water quality • Instream habitat integrity in a B category

Recommended Ecological Category	
B/C	• Catchment management practices are needed (bank erosion, bridge infrastructure, cattle activity) • Part of Strategic Water Source Area (SWSA)

9.19 UO_EWR19_FV: LOWER MODDER

Sample Date	2 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR19_FV	**Prioritised RU**	R_RU39
River	Modder	**Altitude (m.a.s.l.)**	1220
Latitude	-28.89166	**Longitude**	25.656
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	C52K-03183
Level 2 EcoRegion	26.02	**DWS, 2014 PES, EI, ES**	D, Very High, High
Geomorphological zone	F (Lowlands)		

Components sampled: IHI, diatoms

Figure 9-19: Site photographs of the Lower Modder field verification site

Upstream	Downstream

Site Description:

The site is located approximately 30km downstream of Krugersdrift Dam. The channel is 50m wide. Numerous weirs in this reach for the abstraction of water for mainly irrigation purposes. Substrates observed were boulders, cobbles and gravels. The downstream reaches were vegetated with grasses and sedges. The primary land use is cultivation.

Site impacts:

- Weirs
- Irrigation

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells

22	12	C (Moderate)	3.8	0
Dominant Species		*Stephanodiscus minutulus (Kützing) Cleve & Moller*		
Preference		Alkaline, eutrophic water		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	D (56%)	F/NF	• Water quality impairment; diatoms indicated water quality to be moderately modified • Extensive irrigation • Flow modification; Krugersdrift Dam upstream with releases for irrigation abstraction • Bed modification; numerous weirs, crossings, inundation and siltation • Flow modification; bridges, weirs, pump infrastructure
Habitat Integrity: Riparian	C (75%)	F/NF	• Bank erosion; trampling, weirs and bridges changing local hydraulics • Riparian zones inundated due to numerous weirs
ECOSTATUS	C/D		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	D	C/D	Riparian habitat integrity continues to be stable and water quality is moderately modified

Recommended Ecological Category	
C	• Limited options to improve flows due to various weirs in the system and Krugersdrift Dam upstream. • The aim must be to improve water quality through catchment management practices. • Water quality and flow-sensitive aquatic macroinvertebrates present under reference conditions namely Leptophlebiidae and Tricorythidae.

9.20 UO_EWR20_FV: UPPER KROMELLENBOOG

Sample Date	9 October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR20_FV	**Prioritised RU**	R_RU19a
River	Upper Kromellenboog	**Altitude (m.a.s.l.)**	1404
Latitude	-30.066282	**Longitude**	25.6811
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	C51G - 04735
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms


Figure 9-20: Site photographs of the Upper Kromellenboog field verification site

Upstream	Downstream

Site Description:

The site is located at a low water cross-over bridge located off the R717 road approximately 10km outside of Trompsburg. The Kromellenboog is a tributary of the Riet. The reach is located along a partly confined valley setting with a straight to sinuous macro channel plan format. At the time of the site visit, the river was flowing low with high water marks visible on the banks. The riverbanks are vegetated with grasses, sedges and *Phragmites* sp.

Site impacts:

- Irrigation
- Cultivation
- Game farming
- Small-scale cattle farming

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured

DIATOMS				
No. species	**SPI**	**Categorisation (quality)**	**%PTV**	**%Deformed cells**
34	9.1	C (Moderate)	9.7	1
Dominant Species		1. *Navicula zanoni Hustedt*		
		2. *Nitzschia sp.*		
Preference		1. A tropical to sub-tropical species, found commonly in alkaline waters in South Africa.		
		2. Generally, siltation and moderate pollution		

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B (85%)	F/NF	• Localised bed and channel modification (localised bridge and weirs)
Habitat Integrity: Riparian	B (87%)	F/NF	• Cattle trampling and grazing • Localised weirs
ECOSTATUS	B		

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	B	• Both instream and riparian habitat integrity in good state with limited water quality impacts

Recommended Ecological Category	
B	• Instream and riparian habitat integrity continues to be stable. • Small system with few impacts and can be improved through catchment management practices.

9.21 UO_EWR21_FV: LOWER KROMELLENBOOG

Sample Date	13 July 2022	**Reserve Level Assessment**	Field verification, with high confidence
Site Name	UO_EWR21_FV	**Prioritised RU**	R_RU19b
River	Lower Kromellenboog	**Altitude (m.a.s.l.)**	1258
Latitude	-29.65360°	**Longitude**	25.43507°
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment- SQ Reach**	C51H - 04284
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	B, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: Fish, aquatic macroinvertebrates, IHI, *in situ* water quality, discharge

Figure 9-21: Site photographs of the Lower Kromellenboog field verification site

Upstream	**Downstream**

Site Description:

The Kromellenboog is a main tributary of the Riet. The site is located along a gravel road amongst private game farms, approximately 20km north of the town of Jagersfontein. The confluence with the Prossesspruit, a tributary of the Kromellenboog is approximately 13km upstream. At the time of the survey, the baseflows were relatively high, thus not representative of its hydrology during the dry season.

The Kromellenboog is approximately 13m wide and the reach is located along a partly confined valley setting with a straight to sinuous macro channel plan form. The macro channel is incised into the surrounding landscape, with poorly developed flood features. The active channel is braided downstream of the bridge, owing to various in-stream vegetated islands. Bedrock, gravel, sand and silt are the main substrates. The site is located at a low water cross-over bridge, where log jams have occurred upstream of the bridge, impeding the hydraulics of the river and associated left bank. The left bank is dominated by slated bedrock, while the riparian zone along the right bank is intact with grasses, sedges and *Phragmites sp.* with limited bank erosion.

All biotopes are present for macroinvertebrates, which include SIC (which also comprised broken down slate bedrock), SOOC, GSM and both in-stream (including freshwater alien invasive macrophytes – i.e., *Azolla filiculoides* (red water fern)) and marginal vegetation. Some fine silt and algal growth predominantly over the SIC biotope. Fish habitats include SS, SD and FD.

The primary land use is game farming, small scale cattle farming and upstream mining.

Site impacts:

- Cultivation
- Irrigation
- Game farming
- Small-scale cattle farming
- Upstream (along the Prossesspruit) is mining, knock-on impacts on the Kromellenboog

SUMMARY RESULTS

WATER QUALITY

In situ water quality:

- pH: 8.7
- EC: 535 µS/cm
- TDS: 0.509 g/l
- DO: 9.3 mg/l
- DO%: 80.6%
- Clarity: 56cm
- Temperature: 8.8°C
- Salinity: 0.38

DIATOMS

No. species	SPI	Categorisation (quality)	%PTV	%Deformed cells
41	8	D (Poor)	27.2	1
Dominant Species		1. *Nitzschia frustulum (Kützing) Grunow*		
		2. *Nitzschia sp.*		
Preference		1. High conductivity, heavy agriculture, very tolerant of pollution		
		2. Generally, siltation and moderate pollution		

FLOW

- Gauging weir: None
- Discharge: 3.39m^3/s

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
Fish	1	• Perennial flow, with higher-than-normal baseflows • Wadable reach	• Seasonal limitations • No collection records • Cover features limited: emergent vegetation

Site Evaluation			
Component	**Confidence Score***	**Advantages**	**Disadvantages**
		• Velocity-depth classes well represented: FS (abundant), SS (moderate), SD (sparse), FD (rare)	(moderate) and substrate (sparse)
Macroinvertebrates	3	• Perennial flow, with higher-than-normal baseflows • Good diversity of aquatic biotopes: SIC, SOOC, bedrock, marginal and in-stream vegetation and GSM	• High silt coverage over the bedrock, SIC and SOOC biotopes

** Confidence scores: 0 = no confidence; 5 = high confidence*

Information Availability						
COMPONENT	**INFORMATION AVAILABILITY***					**DESCRIPTION OF INFORMATION**
	0	1	2	3	4	
Fish						• FROC (Kleynhans et al., 2008) • PES, 2014
Macroinvertebrates						• PES, 2014
Hydrology						Only monthly modelled hydrology for period 1920-2004
Diatoms						• Information from this current survey

** 0 (no information) to 4 (large amount of data available)*

Reference Conditions	
COMPONENT	**DESCRIPTION OF REFERENCE CONDITIONS**
Fish	*Enteromius oraniensis, Enteromius paludinosus, Clarias gariepinus, Labeo capensis, Labeo umbratus, Labeobarbus aeneus, Pseudocrenilabrus philander* and *Tilapia sparrmanii*
Macroinvertebrates	Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Baetidae >2spp, Caenidae, Leptophlebiidae, Coenagrionidae, Lestidae, Aeshnidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae >2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Gyrinidae, Hydraenidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Lymnaeidae and Physidae

PES per component for EWR site and EcoStatus			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Fish	B/C (78.1)	NF	• Limited impacts. Some possible physical-chemical impacts from upstream farming, and potential impact to species moving upstream
Macroinvertebrates	D (43.03%)	F/NF	• Erosion and sedimentation • Although high baseflows are not representative of the dry season, log jams upstream of the bridge are impeding the hydraulics of the river and associated left bank, thus affecting flows
Habitat Integrity: Instream	B (84%)	F	• Channel and bed modifications owing to weirs, bridges, crossings and siltation, as well as flow diversions at weirs
Habitat Integrity: Riparian	B (88%)	-	• None
ECOSTATUS	C (74.54%)		

Refer to Appendix A for the Habitat Integrity assessment scores for the riparian and instream zone
Refer to Appendix C for the fish and aquatic macroinvertebrate inventories

PES and causes	
Component	**Causes Present/Absent**
Fish	The reach of the Kromellenboog is located upstream of Kalkfontein Dam which is located on the Riet River below the confluence of the Kromellenboog. As such, connectivity to the lower reaches of the Riet and Modder rivers (and thus the Vaal River) has been lost, and movements of fish species within the associated catchment is therefore expected to be isolated to the catchment upstream of Kalkfontein Dam. In addition, diamond mining activities within the catchment near the town of Jagersfontein were not expected to be contributing substantially to water quality impacts present at the time of the assessment, while agricultural activities were expected to be contributing to some degree of sedimentation within the system. In general, the moderately modified state of the fish assemblage present or expected to be present was noted be driven largely by cover and velocity-depth metrics, while a higher contribution of flow modification and physical-chemical modification metrics were noted under present state relative to reference state. Furthermore, the migration metric was identified as having a notable contribution to the ecological state of the reach with limited impacts associated with introduced species.

<table>
<tr><th colspan="2">PES and causes</th></tr>
<tr><th>Component</th><th>Causes
Present/Absent</th></tr>
<tr><td></td><td>
<table>
<tr><th>METRIC GROUP</th><th>REFERENCE WEIGHTS (%)</th><th>PRESENT WEIGHTS (%)</th></tr>
<tr><td>VELOCITY-DEPTH</td><td>97.06</td><td>95.46</td></tr>
<tr><td>COVER</td><td>100.00</td><td>100.00</td></tr>
<tr><td>FLOW MODIFICATION</td><td>62.99</td><td>78.86</td></tr>
<tr><td>PHYSICAL-CHEMICAL</td><td>40.23</td><td>63.00</td></tr>
<tr><td>MIGRATION</td><td></td><td>60.03</td></tr>
<tr><td>IMPACT OF INTRODUCED</td><td></td><td>31.45</td></tr>
<tr><td>FRAI</td><td colspan="2">PRESENT</td></tr>
<tr><td>FRAI (%)</td><td colspan="2">78.1</td></tr>
<tr><td>EC: FRAI</td><td colspan="2">C/B</td></tr>
</table>
</td></tr>
<tr><td>Macroinvertebrates</td><td>This reach of the Kromellenboog was characterised by a diversity of biotopes and varying flow conditions, although slightly turbid with a fine silt layer over the stones biotope. The aquatic macroinvertebrate assemblage collected was determined to be representative of largely modified conditions (Ecological Category D, 43.03%). A total of 13 taxa were recorded out of a reference community of 40 taxa (33% of the reference community was present). This was primarily owing to the macroinvertebrate community mostly responding to water quality, followed by flow modifications and the habitat metric. This was supported by most of the taxa having a preference for low to very low water quality. Key taxa with a high FROC (3-5) expected but which were not observed, included Hirudinea, Hydracarina, Leptophlebiidae, Lestidae, Aeshnidae, Gomphidae, Libellulidae, Belostomatidae, Corixidae, Hydrometridae, Naucoridae, Notonectidae, Hydropsychidae>2spp, Hydroptilidae, Leptoceridae, Dytiscidae, Hydraenidae, Hydrophilidae, Culicidae, Dixidae, Empididae, Tabanidae, Tipulidae and Lymnaeidae. The majority of these macroinvertebrates have a preference for very fast flow and the stones biotope. Owing to the site having moderately fast-flowing conditions and the silt layer smothering both the SIC and SOOC biotopes, appeared to be the main factors which reduced the number of taxa at this site. The ASPT for the community was 5.0 (78% of the reference ASPT), indicative of tolerant taxa (Dickens and Graham, 2002).</td></tr>
</table>

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
Fish	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments (Google Earth)	3
Macroinvertebrates	Stable	• Drivers unchanged due to impacts remaining unchanged (no new	2

Ecological trends for the EWR site (include components that were assessed)			
Component	**Trend (stable, decline, improvement)**	**Reason**	**Confidence (0-5)***
		developments and since PES, 2014, Google Earth) • No additional bed modification/ erosion (localised) • 78% of the reference ASPT	
Habitat integrity: Instream	Stable	• Drivers unchanged due to impacts remaining unchanged (no new developments) • No additional bed modification/ erosion (localised)	2
Habitat integrity: Riparian	Stable	• Drivers unchanged	2
ECOSTATUS	Stable		2

** 0 – no confidence to 5 – high confidence*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	B	C	• Sediment and silt loads contributing to impacts on biota • Poor water quality, possibly due to mining activities and town of Jagersfontein upstream

Revised Ecological Importance and Ecological Sensitivity	
EIES, 2014	**Rapid 3, 2022***
Moderate, Moderate	High, Moderate

**Refer to Appendix B for the detailed table and rationale*

Recommended Ecological Category	
B/C	• Instream and riparian habitat integrity continues to be stable • Water quality must be improved by appropriate catchment management practices; aquatic macroinvertebrates with a preference for good water quality will establish within the reach, improving the overall ecological category of the macroinvertebrate assemblage • Ecological Importance was revised to High

OVERALL ASSESSMENT

The overall EcoStatus was categorised as a C category, mostly owing to the macroinvertebrate community (D). This was primarily due to the macroinvertebrate community responding to water quality, followed by flow modifications and habitat metrics.

The primary driver is an increase in sedimentation and siltation levels, having a knock-on effect on overall habitat availability for biota.

RECOMMENDATIONS

- Refer to Chapter 11 for general recommendations
- Mining activities within the upstream catchment must be managed to prevent degradation of the ecological health of the system and deterioration of the water quality.

9.22 UO_EWR22_FV: TELE

Sample Date	October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR22_FV	**Prioritised RU**	R_RU41
River	Tele	**Altitude (m.a.s.l.)**	1411
Latitude	-30.4494	**Longitude**	27.5777
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D18K -05157
Level 2 EcoRegion	15.02	**DWS, 2014 PES, EI, ES**	B, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		

Components sampled: IHI, diatoms

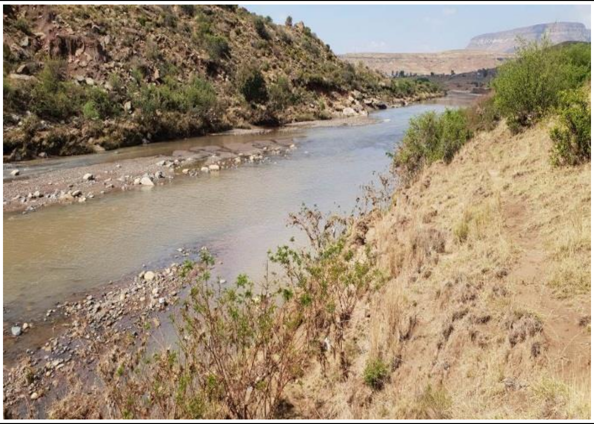



Figure 9-22: Site photographs of the Tele field verification site

Upstream	**Downstream**

Site Description:

This site is located off the R393 road just outside of the town Tele on the Southwestern border of Lesotho and South Africa. It is a tributary of the Orange River. The river reach is relatively straight, along a confined valley consisting of all aquatic biotopes, although at the time of the survey, the flow was high just after some heavy rains. Both banks showed evidence of erosion and marginal vegetation showing signs of cattle trampling, grazing and paths.

Site impacts:

- Cultivation
- Cattle grazing and trampling
- Bank erosion

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured

DIATOMS

No diatom cells present in the sample

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	B/C (79%)	F/NF	• Bed modification; siltation due to catchment degradation • Some irrigation in lower reaches
Habitat Integrity: Riparian	C (63%)	F/NF	• Bank erosion; cattle trampling, grazing and gully erosion
ECOSTATUS	C*		

**Based on IHI, owing to limited other information (water quality)*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C	Instream and riparian habitat integrity continues to be stable

Recommended Ecological Category	
C	• Instream and riparian habitat integrity continues to be stable • Transboundary river, with most of the catchment within Lesotho

9.23 UO_EWR23_FV: UPPER ORANGE RIVER

Sample Date	October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR23_FV	**Prioritised RU**	R_RU02b
River	Orange	**Altitude (m.a.s.l.)**	1366
Latitude	-30.398957	**Longitude**	27.343186
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D12A - 05144
Level 2 EcoRegion	15.02	**DWS, 2014 PES, EI, ES**	B, High, Moderate
Geomorphological zone	F (Lowlands)		

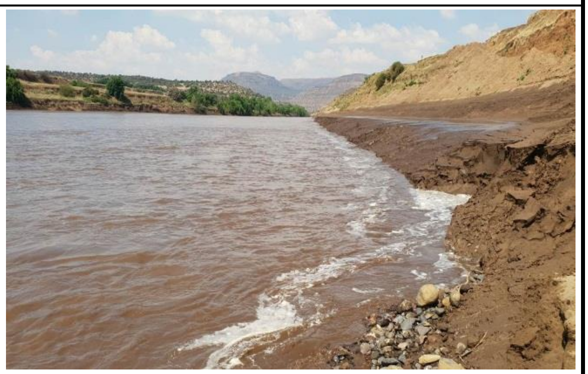
Components sampled: IHI, diatoms

Figure 9-23: Site photographs of the Upper Orange River field verification site

Upstream	Downstream

Site Description:

This site is located off the R726 road on the main stem of the Orange River, just downstream of the confluence with a small tributary named Hendrik Smitstroom, adjacent to the town of Walaza. The river reach is a wide channel, along a confined valley dominated by bedrock. Extensive marginal vegetation clearing on both banks and severe bank erosion owing to poor catchment management practices, including sand mining and road cutting for vehicle access to the river (see site photographs below). The water is also highly turbid.



Site impacts:

• Extensive sand mining • Cattle grazing and trampling • Extensive bank erosion • Dams in Lesotho changing flow regime • Riparian zone completely modified
Preliminary Results
In situ water quality: Not measured
Discharge: Not measured
DIATOMS
High load of fine sediment, very few diatom cells present

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (63%)	F/NF	• Flow modifications; upstream dams in Lesotho impact all flow components • Bed modification; high siltation due to catchment degradation • Channel modification; extensive sand mining
Habitat Integrity: Riparian	D (54%)	F/NF	• Bank erosion; cattle trampling, grazing, gully erosion and sand mining • Alien vegetation; *Salix* species – mostly along the right bank • Channel modification; sand mining and road cutting for mining access
ECOSTATUS	C/D*		

**Based on IHI, owing to limited other information (water quality)*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	B	C/D	• The PES cannot realistically be improved owing to habitat availability along this reach. There are limited aquatic biotopes primarily for aquatic macroinvertebrates, and also limited flow depth velocity classes required for the fish population, even limited marginal vegetation for cover.

Recommended Ecological Category	
C	• Major catchment management practices must be implemented to aid in reducing the extensive bank erosion primarily owing to sand mining • The aim must be to improve water quality (sediment loads)

9.24 UO_EWR24_FV: MAGHALENG RIVER

Sample Date	October 2021	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR24_FV	**Prioritised RU**	R_RU42
River	Maghaleng	**Altitude (m.a.s.l.)**	1416
Latitude	-30.164105	**Longitude**	27.399101
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment- SQ Reach**	D15H - 04889
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	C, Moderate, Moderate
Geomorphological zone	F (Lowlands)		

Components sampled: IHI, diatoms

Figure 9-24: Site photographs of the Maghaleng field verification site

Upstream	Downstream

Site Description:

The site is located on the lower reaches of the Maghaleng River and is dominated by a muddy substrate with extensive bank erosion, particularly along the right bank. Limited aquatic biotopes are present due to high siltation caused by extensive catchment degradation. Furthermore, these sediment loads are contributing to channel widening along the system.
Maghaleng River originates in Lesotho with overgrazing and trampling resulting in erosion and high sediment loads entering South Africa.

Site impacts:

- Cattle grazing and trampling
- Bank erosion

Preliminary Results

In situ water quality: Not measured

Discharge: Not measured

DIATOMS

High load of fine sediment, and very few diatom cells present

IHI			
COMPONENT	**PES category & score**	**Flow/ Non-flow**	**EXPLANATION**
Habitat Integrity: Instream	C (72%)	F/NF	• Bed modification; heavy sedimentation due to catchment degradation and resulting silt loads
Habitat Integrity: Riparian	D (53%)	F/NF	• Alien vegetation; *Salix* sp. and other invasive plant species • Bank erosion; cattle trampling, grazing, channel widening to accommodate sediment load
ECOSTATUS	C/D*		

**Based on IHI, owing to limited other information (water quality)*

Overall change and reason for deviation			
COMPONENT	**PES 2014**	**EcoStatus, 2023**	**REASON FOR DEVIATION**
ECOSTATUS	C	C/D	• N/A

Recommended Ecological Category	
C/D	• Major catchment management practices must be implemented to aid in reducing the extensive bank erosion and sedimentation both in Lesotho and South Africa • The aim must be to improve water quality; decrease sedimentation loads • Transboundary river between South Africa and Lesotho

Please refer to Table 12-1, Figure 12-6 and Figure 12-7 for a summary of the EcoStatus and proposed REC for all Field Verification EWR sites for this study.

9.25 UO_EWR25_FV: MIDDLE CALEDON

Sample Date	5 July 2022	**Reserve Level Assessment**	Field verification
Site Name	UO_EWR25_FV	**Prioritised RU**	R_RU04
River	Middle Caledon	**Altitude (m.a.s.l.)**	1474
Latitude	-29.368925°	**Longitude**	27.405189°
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D23A-04069
Level 2 EcoRegion	15.01	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (0.001; Lower Foothills)		

Components sampled: IHI, *in situ* water quality, diatoms. Intermediate study not conducted during the low flows owing to limited access across the channel due to high flows. JBS3 biological data collected in October 2021 will be used to determine PES and REC.

Figure 9-25: Site photographs of the Middle Caledon field verification site

Upstream	Downstream

Site Description:

This site is ORASECOM JBS3 site (15_6) and the DWS River Ecosystem Monitoring Programme (REMP) site D2CALE-LADY2. The confluence with the Phuthiatsana River is just 5 km upstream and the confluence with a bigger river, also called the Phuthiatsana is about 30 km upstream. Lesotho's capital city of Maseru lies ~7 km upstream. The surrounding area is a mix of settlements, grazing areas and small-scale croplands. The Lesotho side is heavily overgrazed and eroded contributing to the already high fine sediment load and evidence of sediment deposition (but not extensive along both banks).

The reach has a partly confined valley setting and a straight to sinuous macro-channel pattern. The active channel has a wandering planform, alternating between sand bars. The channel is deeply incised into the surrounding terraces, with a narrow active floodplain. The site is a wide and homogenous sand bed channel with limited habitat diversity. Localised fine to medium gravel bars form along the active channel. The inset benches were largely missing due to widespread bank erosion, with limited evidence of new benches forming. The banks are composed of fine sand and silt, steep and highly erodible. The banks have clusters of Salicaceae and Salix trees upstream and a heavy infestation of Poplus sp. on the riverbanks downstream of the site. The river is ~50m wide and with some inundanted sandbars along the channel. The water is turbid, and the riverbed has a high silt and clay content.

Biotopes available for macroinvertebrates is dominated by sand and silt, with small gravel deposits over the sandy substrate. Marginal vegetation was absent owing to recent erosion of inset benches and lower banks along both banks. There are no SIC or SOOC available. For fish there was SD and SS habitats.

Site impacts:

- Sand mining
- Small upstream dams along tributaries
- Settlements
- Cattle grazing areas
- Small-scale croplands on terraces
- Alien invasives (*Salix sp., Populus sp., Wattle sp*.)
- Vegetation removal
- Macroplastics (plastics/litter) along both banks

SUMMARY RESULTS

WATER QUALITY AND FLOW

In situ water quality:

- pH: 8.7
- EC: 260 µS/cm
- TDS: 0.230 g/l
- DO: 11.3 mg/l
- DO%: 102.9%
- Clarity: 46cm
- Temperature: 11.0°C
- Salinity: 0.17
- Discharge: not measured

DIATOMS*

No. species	SPI**	Categorisation (quality)	%PTV***	%Deformed cells****
26	10.3	C (Moderate)	72	0.75
Dominant Species		*Eolimna subminuscula (Manguin) Moser, Lange-Bertalot & Metzeltin*		
Preference		Tolerant of strong pollution and an indicator of industrial organic pollution		

**Refer to Appendix A of Report number RDM/WMA13/00/CON/COMP/1123 (a): Eco-categorisation Report-VOLUME 2*

***Specific Pollution sensitivity Index (>17: A-high water quality; 13-17: B-good water quality; 9-13: C-moderate water quality; 5-9: poor water quality; and <5: E seriously modified water quality) (adapted from Eloranta & Soininen, 2002)*

****The percentage of pollution tolerant valves (<20: site free from organic pollution; 21-40: some evidence of organic pollution; 41-60: Organic pollution likely to contribute significantly to eutrophication; and >61: Site is heavily contaminated with organic pollution (adapted from Kelly, 1998)*

*****Deformed cells: a red flag (>2%) showing potential harmful pollutants within the water column. These toxins have the potential to disturb the cell walls morphogenesis and the silica which is then laid down incorrectly in the cell wall causing changes in the cell outline or in the striae patterns of the species. Therefore, a lack to no deformed cells suggests heavy metals are not a consistent issue at the site.*

IHI

COMPONENT	PES category & score	Flow/ Non-flow	EXPLANATION
Habitat Integrity: Instream	C (71%)	F/NF	• Flow modification (artificial debris, bridges, cattle crossings, upstream dam, irrigation) • Bed modification • Physical-chemical modification (diatoms indicative of moderately modified water quality, turbidity)
Habitat Integrity: Riparian	C/D (61%)	F/NF	• Bank erosion (cattle trampling, grazing) • Alien riparian vegetation • Channel modification (upstream dam, weirs)
ECOSTATUS*	D		

Physical-chemical state of the system

The *in-situ* water quality was comparable to that recorded in the JBS3 and JBS2 surveys at this site. The pH, although higher, was comparable to the previous surveys at this site. Diatoms did however reflect an altered/poor physical-chemical state of the system as a result of impacts from Lesotho's capital city Maseru, its industrialised areas and Lesotho's largest WWTW the Ratjomose Sewage Treatment Plant just 7km upstream.

Overall change and reason for deviation

COMPONENT	PES 2014	EcoStatus, 2023	
ECOSTATUS	D	D	

Recommended Ecological Category

C/D	• Although EI and ES moderate, REC of C/D achievable with better catchment management and improved water quality. • Ensure overall land management of upstream activities from both South Africa and Lesotho with regards to cattle overgrazing, trampling and overstocking.

10. SITES NOT SURVEYED

The following sites listed below could not be surveyed, either owing to the site being dry, inaccessibility due to locked farm gates, health hazard (raw sewage) and/or time constraints during the surveys.

10.1 JOGGEMSPRUIT

Site Name	N/A	**Prioritised RU**	R_RU24
River	Joggemspruit	**Altitude (m.a.s.l.)**	1699
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D13E D13E-05541
Level 2 EcoRegion	15.06	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	E (Lower Foothills)		
The site was not sampled owing to access being prevented by a locked farm gate. *Use 2014 desktop PES/EI/ES*			

10.2 ELANDSKLOOF

Site Name	N/A	**Prioritised RU**	R_RU34
River	Elandskloof	**Altitude (m.a.s.l.)**	1419
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	D32A D32A-06085
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	D, Low, Moderate
Geomorphological zone	E (Lower Foothills)		
The site was not sampled owing to access being prevented by a locked farm gate. *Use 2014 desktop PES/EI/ES*			

10.3 KLEIN-SEEKOEI

Site Name	N/A	**Prioritised RU**	R_RU35
River	Klein-Seekoei	**Altitude (m.a.s.l.)**	1396
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	D32C D32C-06210
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	B, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		
The site was not sampled owing to access being prevented by a locked farm gate. *Use 2014 desktop PES/EI/ES*			

10.4 MIDDLE RIET

Site Name	N/A	**Prioritised RU**	R_RU36
River	Middle Riet	**Altitude (m.a.s.l.)**	1163
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	C51K C51K-03878
Level 2 EcoRegion	26.02	**DWS, 2014 PES, EI, ES**	D, Very High, Moderate
Geomorphological zone	F (Lowland)		
Not sampled due to time constraints *Use 2014 desktop PES/EI/ES*			

10.5 KLEIN MODDER

Site Name	N/A	**Prioritised RU**	R_RU20
River	Klein Modder	**Altitude (m.a.s.l.)**	1355
Level 1 EcoRegion	Highveld	**Quaternary catchment-SQ Reach**	C52B C52B-03854
Level 2 EcoRegion	11.03	**DWS, 2014 PES, EI, ES**	D, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		
The site was not sampled due to almost raw sewage being present in the river *Use 2014 desktop PES/EI/ES*			

10.6 RIETSPRUIT, TRIBUTARY OF MODDER RIVER

Site Name	N/A	**Prioritised RU**	R_RU38
River	Rietspruit	**Altitude (m.a.s.l.)**	1298
Level 1 EcoRegion	Highveld	**Quaternary catchment-SQ Reach**	C52G C52G-03335
Level 2 EcoRegion	11.08	**DWS, 2014 PES, EI, ES**	B, Moderate, Moderate
Geomorphological zone	E (Lower Foothills)		
Not sampled due to time constraints *Use 2014 desktop PES/EI/ES*			

10.7 UPPER CALEDON

Site Name	N/A	**Prioritised RU**	R_RU15
River	Upper Caledon	**Altitude (m.a.s.l.)**	1634
Longitude	-28.65080	**Latitude**	28.38750
Level 1 EcoRegion	Eastern Escarpment Mountains	**Quaternary catchment-SQ Reach**	D21A D21A-03207
Level 2 EcoRegion	15.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (Lower Foothills)		
Not sampled due to time constraints *Use 2010 intermediate EFR (EFR-C5) and 2014 desktop PES/EI/ES results*			

10.8 LEEUSPRUIT

Site Name	N/A	**Prioritised RU**	R_RU17
River	Leeuspruit	**Altitude (m.a.s.l.)**	1464
Longitude	-29.5201	**Latitude**	27.1294
Level 1 EcoRegion	Highveld	**Quaternary catchment-SQ Reach**	D23D D23E-04213
Level 2 EcoRegion	11.03	**DWS, 2014 PES, EI, ES**	C, High, High
Geomorphological zone	E (Lower Foothills)		
Not surveyed due to time constraints *Use REMP, 2021 JBS3 (Site 11_20) and 2014 desktop PES/EI/ES results*			

10.9 KLIPSPRUIT

Site Name	N/A	**Prioritised RU**	R_RU28
River	Klipspruit	**Altitude (m.a.s.l.)**	1558
Level 1 EcoRegion	Drought Corridor	**Quaternary catchment-SQ Reach**	D13M D13M-05591
Level 2 EcoRegion	18.04	**DWS, 2014 PES, EI, ES**	C, High, Very high
Geomorphological zone	D (Upper Foothills)		
Not surveyed due to time constraints *Use 2014 desktop PES/EI/ES results*			

10.10 ORANGE RIVER

Site Name	N/A	**Prioritised RU**	R_RU29
River	Orange	**Altitude (m.a.s.l.)**	1287
Longitude	-30.5714	**Latitude**	26.45166
Level 1 EcoRegion	Nama Karoo	**Quaternary catchment-SQ Reach**	D14J D14J-05259
Level 2 EcoRegion	26.03	**DWS, 2014 PES, EI, ES**	C, Moderate, High
Geomorphological zone	F (Lowlands)		
Not surveyed due to time constraints *Use 2021 JBS3 (site 26_14) and 2014 desktop PES/EI/ES results*			

11. RECOMMENDATIONS

11.1 FOCUSED ON WATER QUALITY

From the results of this study, it is evident that deteriorated water quality is the driving factor for most of 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 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. Consequently, the knock-on effect is high nutrient loads and eutrophication in the river systems ultimately resulting in a very poor water quality status throughout the catchment. As water quality is one of the ecological drivers for water quality sensitive aquatic biota and their diversity, these communities are impacted upon compared to reference conditions.

It is the mandate and responsibility of DWS to ensure enforcement and accountability within the municipalities that are responsible for these WWTWs (National Water Act, 1998). Investigations into this issue are essential for the Department to improve and regulate the water quality issues that this catchment area faces.

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.

This is essential for this part of the study, leading up to the setting of the Reserve.

11.2 GENERAL HOLISITIC RECOMMENDATIONS

- *In situ* water quality must be monitored bi-annually;
- Diatom samples must be taken minimum every 2 years;
- Macroinvertebrates (MIRAI) must continue to be undertaken bi-annually at these EWR sites. Should the sites overlap the REMP sites, these are to be undertaken quarterly. MIRAI models must be continually updated;
- Capacity building (training) regarding fish identification and PES determination (FRAI), for future fish monitoring, must be undertaken annually during wet/summer season (i.e., November to January);
- Fish (FRAI) at all Intermediate Reserve sites should be conducted annually, or bi-annual should there be events (i.e., fish-kill) or other biophysical data triggering an updated FRAI to be run;
- Capacity building (training) on riparian vegetation within the catchment, and PES determination (VEGRAI),
- Desktop vegetation assessment (woody to non-woody to open area comparisons using Google Earth) – annually;
- Belt transect assessments – record cover of life form (reed vs grass vs forbs vs trees vs no vegetation), including presence and absence of species and compare - annually;
- Riparian vegetation (VEGRAI) at all Intermediate EWR sites to be conducted every 5 years;

- IHI at all Rapid EWR sites must be conducted annually;
- Catchment management strategies must be developed to assist with the management of overgrazing, etc;
- Riverine buffers must be implemented for all new applications, and grazing management within these buffer zones strictly controlled; and
- Satellite imagery must be interrogated regularly (e.g., Google Earth and other sources) and a reach scale PES derived. This information together with physical-chemical and other information sources (OSINT, etc.) must be used to develop Thresholds of Probable concern to trigger follow-up investigations.

12. CONCLUSION

In general, the findings of this study demonstrate that the Upper Orange catchment area predominantly exhibits moderately to seriously altered conditions (falling under ecological categories C and D). The main factors influencing the catchment are compromised water quality, primarily caused by unmaintained and dysfunctional WWTW (particularly the Modder-Riet catchment area) and/or sediment deposits (particularly the Caledon and Orange River systems). 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 and AEC can and will be achieved.

Please refer to Table 12-1 and Table

Table 12-2 for a summary of the current PES of all EWR sites (Intermediate, Rapid 3 EWR sites and Field Verification sites), in comparison to the DWS, 2014. This is further illustrated in Figure 12-1 to Figure 12-7 with the trends in the PES shown as circles and proposed RECs in stars throughout the study area. The colour codes for the PES and REC as per Figure 12-1 below.

Figure 12-1: The PES and REC colour code guide

Table 12-1: Summary of the Present Ecological States of all Intermediate and Rapid 3 EWR sites

RU	EWR site code	River	Quat	Main driving impacts	PES (DWS, 2014)	EI-ESE	Ecostate (2023)	Revised EI-ES	REC	AEC
INTERMEDIATE EWR SITES										
R_RU04	UO_EWR01_I	Middle Caledon	D22D	• Sediment deposition • Poor land and catchment management	D	Moderate, Moderate	D/E	Moderate, Moderate	D	C
R_RU01	UO_EWR02_I	Sterkspruit	D12B	• Water quality (nutrients, poorly maintained and dysfunctional WWTW)	C	Moderate, High	D	Moderate, Moderate	C/D	C
R_RU02a	UO_EWR03_I	Upper Orange	D12F	• Sediment deposition • Sand mining	C	High, High	D	Moderate, Moderate	D	C/D
R_RU05	UO_EWR04_I	Lower Caledon	D24J	• Sediment deposition • Poor land and catchment management	C	High, High	D	Moderate, Moderate	C/D	C/D
R_RU06	UO_EWR05_I	Seekoei	D32J	• Water quality and quantity (abstraction, irrigation, return flows)	D	Moderate, Moderate	C	Moderate, Moderate	C	B/C
R_RU08	UO_EWR06_I	Upper Riet	C51F	• Water quality and quantity (abstraction, irrigation, return flows)	C	High, Moderate	C	High, Moderate	C	B/C
R_RU09a	UO_EWR07_I	Upper Modder (Sannaspos)	C52G	• Water quality (nutrients, poorly maintained and dysfunctional WWTW)	D	Moderate, High	D	Low, Moderate	C	C
R_RU03	UO_EWR08_I	Lower Kraai	D13M	• Water quality (abstraction, irrigation, return flows)	C	High, High	C	High, High	B/C	B
R_RU10	UO_EWR09_I	Lower Riet	C51L	• Water quality (abstraction, irrigation, return flows) • Water quality (upstream Modder River)	D	Very High, High	C	Very High, High	B/C	B/C
R_RU07	UO_EWR10_I	Lower Orange	D33K	• Flow modification (hydropower) • Sediment deposition	C	High, Moderate	C	Moderate, Moderate	C	B/C
RAPID 3 EWR SITES										
R_RU13	UO_EWR01_R	Little Caledon	D21D	• Water quality (nutrients, upstream town) • Water quantity (abstraction and irrigation)	C	High, High	C	High, High	B/C	-
R_RU14	UO_EWR02_R	Brandwater (Groot)	D21G	• Poor land and catchment management • Water quantity (abstraction)	C	High, High	C	High, Moderate	B/C	-
R_RU16	UO_EWR03_R	Mopeli	D22G	• Poor land and catchment management	D	Moderate, Moderate	D	Moderate, Moderate	C/D	-
R_RU11a	UO_EWR04_R	Upper Kraai	D13E	• Water quantity (abstraction)	C	Moderate, High	C	High, High	B	-
R_RU12	UO_EWR05_R	Wonderboomspruit	D14E	• Water quality (nutrients, poorly maintained and dysfunctional WWTW)	C	Moderate, Moderate	D	Moderate, Moderate	C/D	-
R_RU09b	UO_EWR06_R	Middle Modder (Soetdoring)	C52H	• Water quality and quantity (abstraction, irrigation, return flows)	D	Moderate, Moderate	D	High, Moderate	C/D	-

Table 12-2: Summary of the Present Ecological States of all field verification sites

RU	EWR site code	River	Quat	Pes, 2014 EI-ESE	EcoStatus (2023)	REC
R_RU30	UO_EWR01_FV	Meulspruit	D22B	Moderate, Moderate	D	D
R_RU31	UO_EWR02_FV	Witspruit	D24C	Moderate, Moderate	C/D	C
R_RU22	UO_EWR03_FV	Gryskopspruit	D12D	Moderate, Moderate	C	C
R_RU26	UO_EWR04_FV	Karringmelkspruit	D13K	Very High, High	B	B
R_RU23	UO_EWR05_FV	Bowsprit	D13A	Moderate, High	B/C	B
R_RU27	UO_EWR06_FV	Holspruit	D13J	High, Moderate	C	C

RU	EWR site code	River	Quat	Pes, 2014 EI-ESE	EcoStatus (2023)	REC
R_RU11b	UO_EWR07_FV	Sterkspruit (trib of Bell/Kraai)	D13C	Moderate, High	C	B/C
R_RU11c	UO_EWR08_FV	Bell	D13B	Moderate, High	B/C	B
R_RU32a	UO_EWR09_FV	Groenspruit	D24H	Moderate, Moderate	C/D	C
R_RU32b	UO_EWR10_FV	Skulpspruit	D24H	Moderate, Moderate	C	C
R_RU18	UO_EWR11_FV	Fouriespruit	C51A	High, Moderate	C	C
R_RU37	UO_EWR12_FV	Renoster	C52F	Moderate, Moderate	D/E	D
R_RU21	UO_EWR13_FV	Os-spruit	C52E	High, Moderate	B/C	B/C
R_RU33	UO_EWR14_FV	Hondeblaf	C31C	Low, Moderate	B	B
R_RU40	UO_EWR15_FV	Trib van Zyl	C51G	High, Moderate	C	C
-	UO_EWR16_FV	Slykspruit	D24L	Moderate, Moderate	B/C	B/C
R_RU11d	UO_EWR17_FV	Langkloofspruit	D13D	High, High	B/C	B
R_RU25	UO_EWR18_FV	Wasbankspruit	D13G	Moderate, High	C	B/C
R_RU39	UO_EWR19_FV	Lower Modder	C52K	Very High, High	C/D	C
R_RU19a	UO_EWR20_FV	Upper Kromellenboog	C51G	Moderate, Moderate	B	B
R_RU19b	UO_EWR21_FV	Lower Kromellenboog	C51H	Moderate, Moderate	C	B/C
R_RU41	UO_EWR22_FV	Tele	D18K	Moderate, Moderate	C	C
R_RU02b	UO_EWR23_FV	Orange	D12A	High, Moderate	C/D	C
R_RU42	UP_EWR24_FV	Maghaleng	D15H	Moderate, Moderate	C/D	C/D
R_RU04	UO_EWR25_FV	Middle Caledon	D23A	Moderate, Moderate	D	C/D

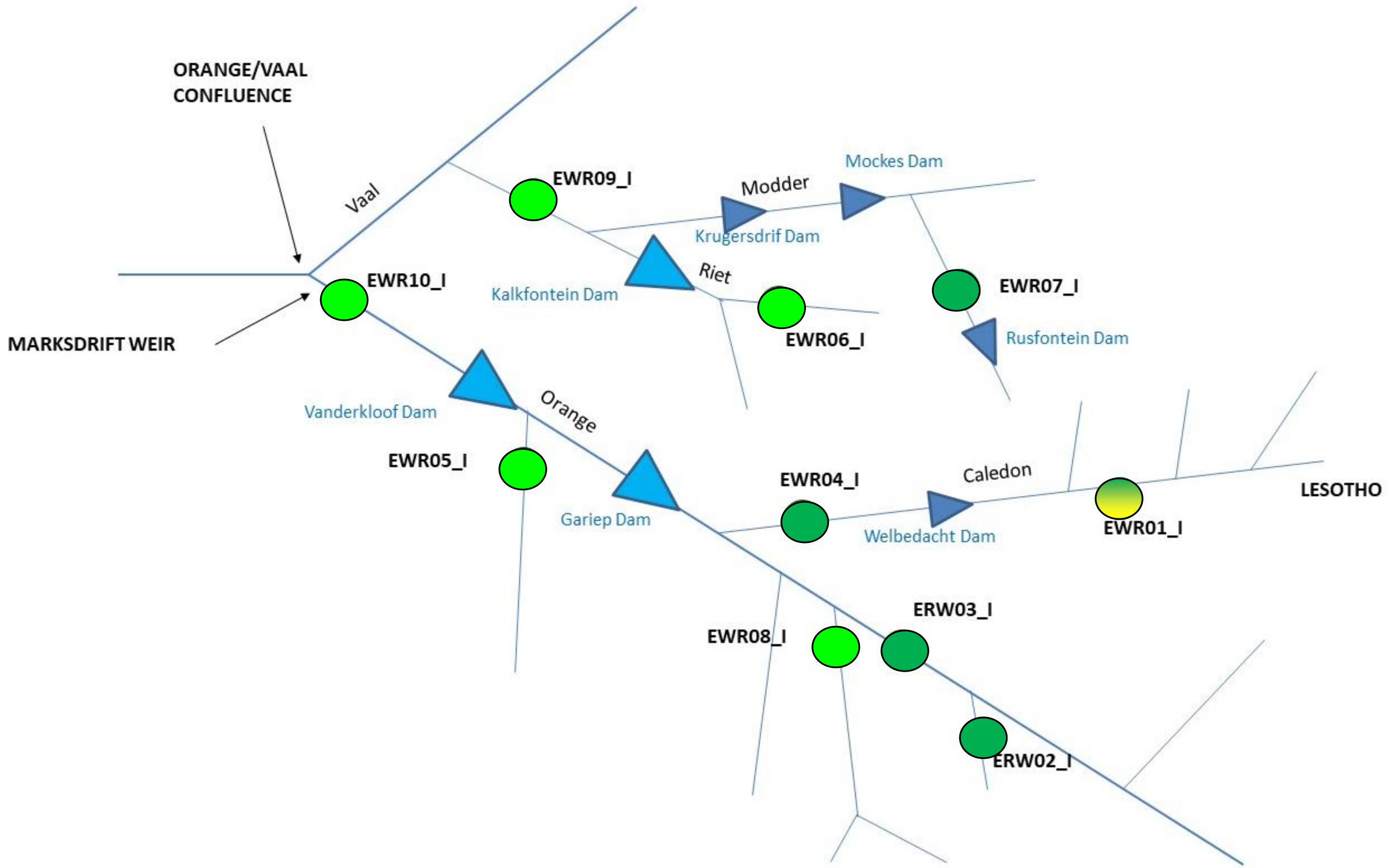


Figure 12-2: Summary of the PES trend for all Intermeidate EWR sites

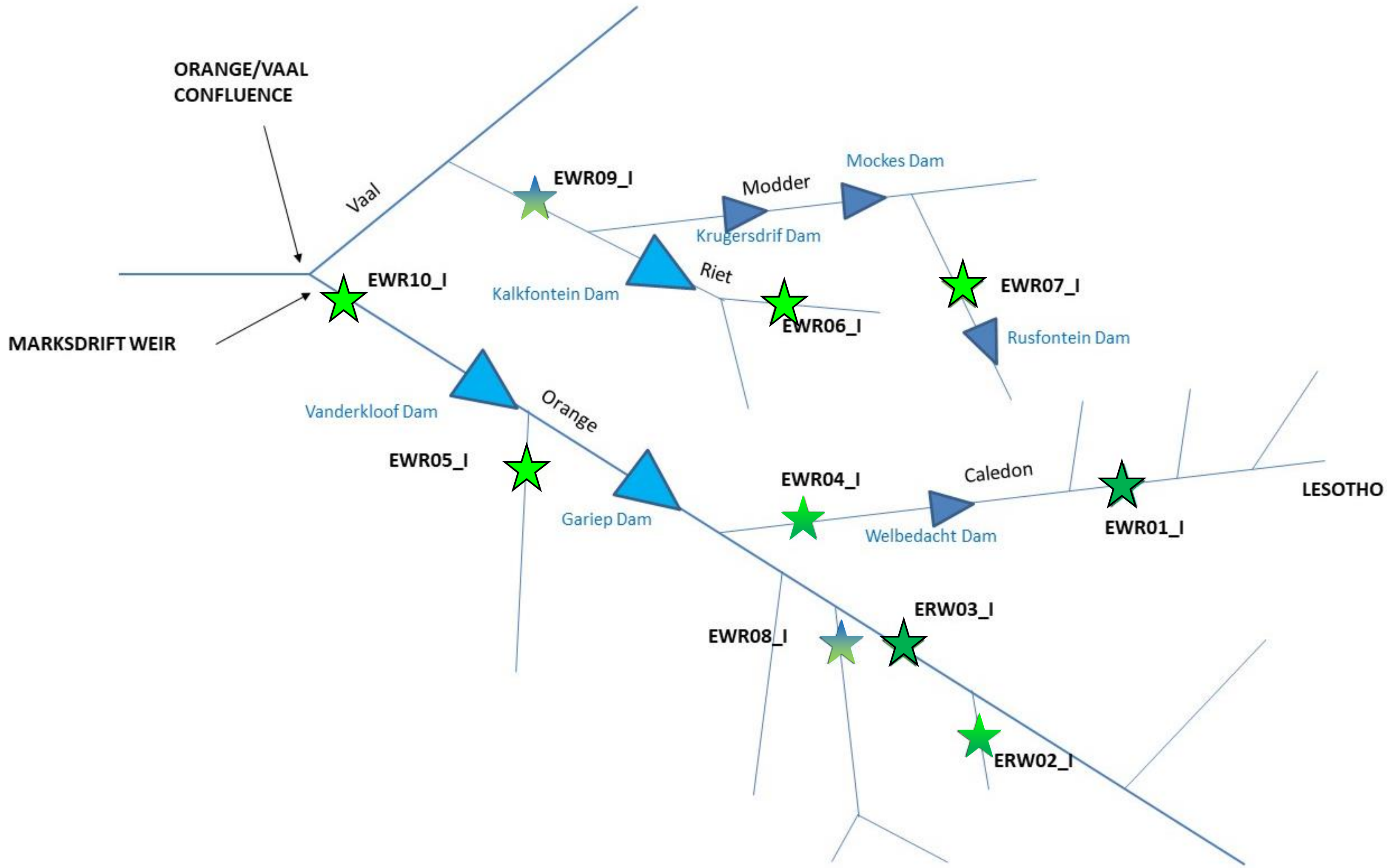


Figure 12-3: Summary of the proposed REC for all Intermediate EWR sites

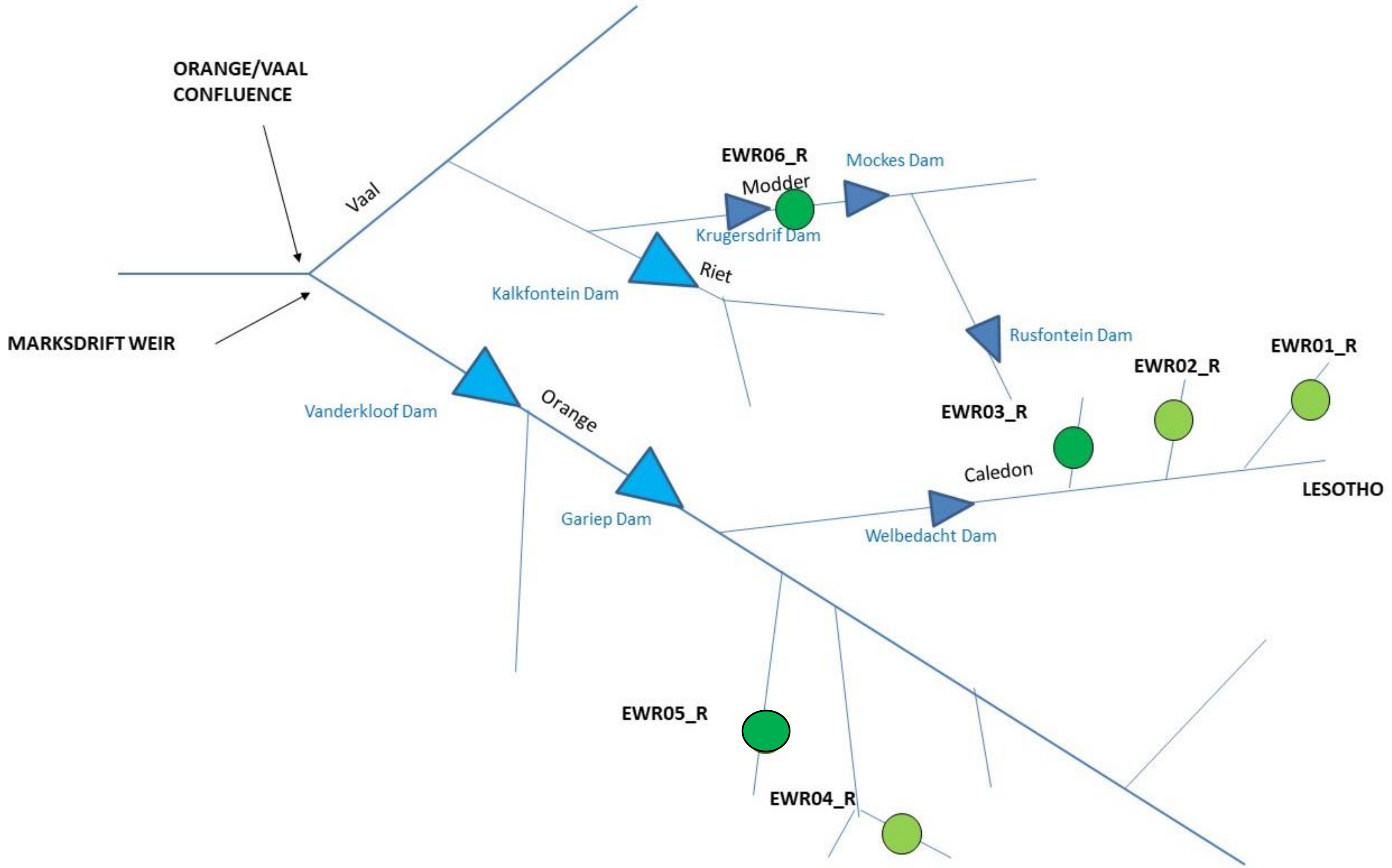


Figure 12-4: Summary of the PES trend for all Rapid 3 EWR sites

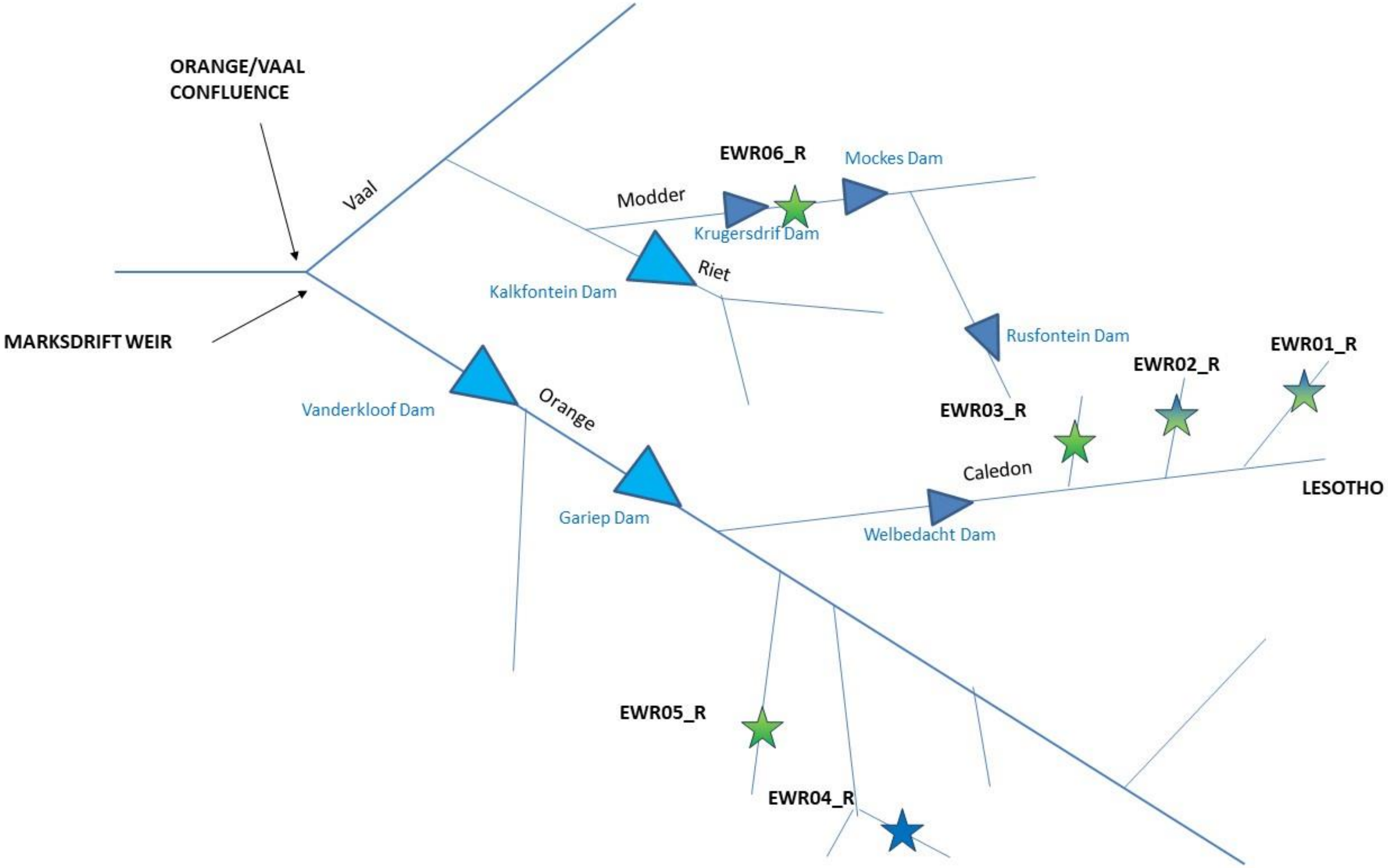


Figure 12-5: Summary of the proposed REC for all Rapid 3 EWR sites

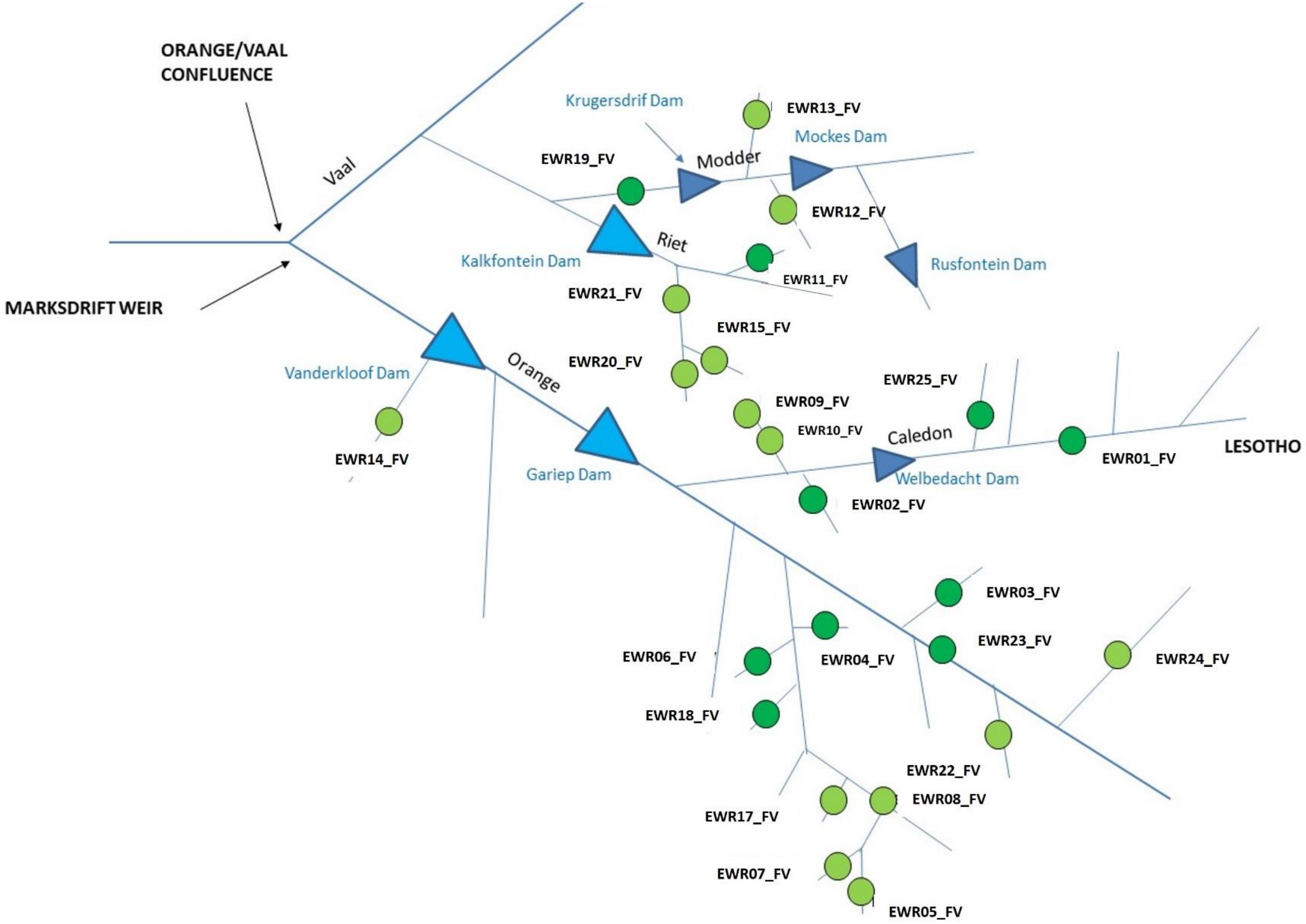


Figure 12-6: Summary of the PES trend for all field verification sites

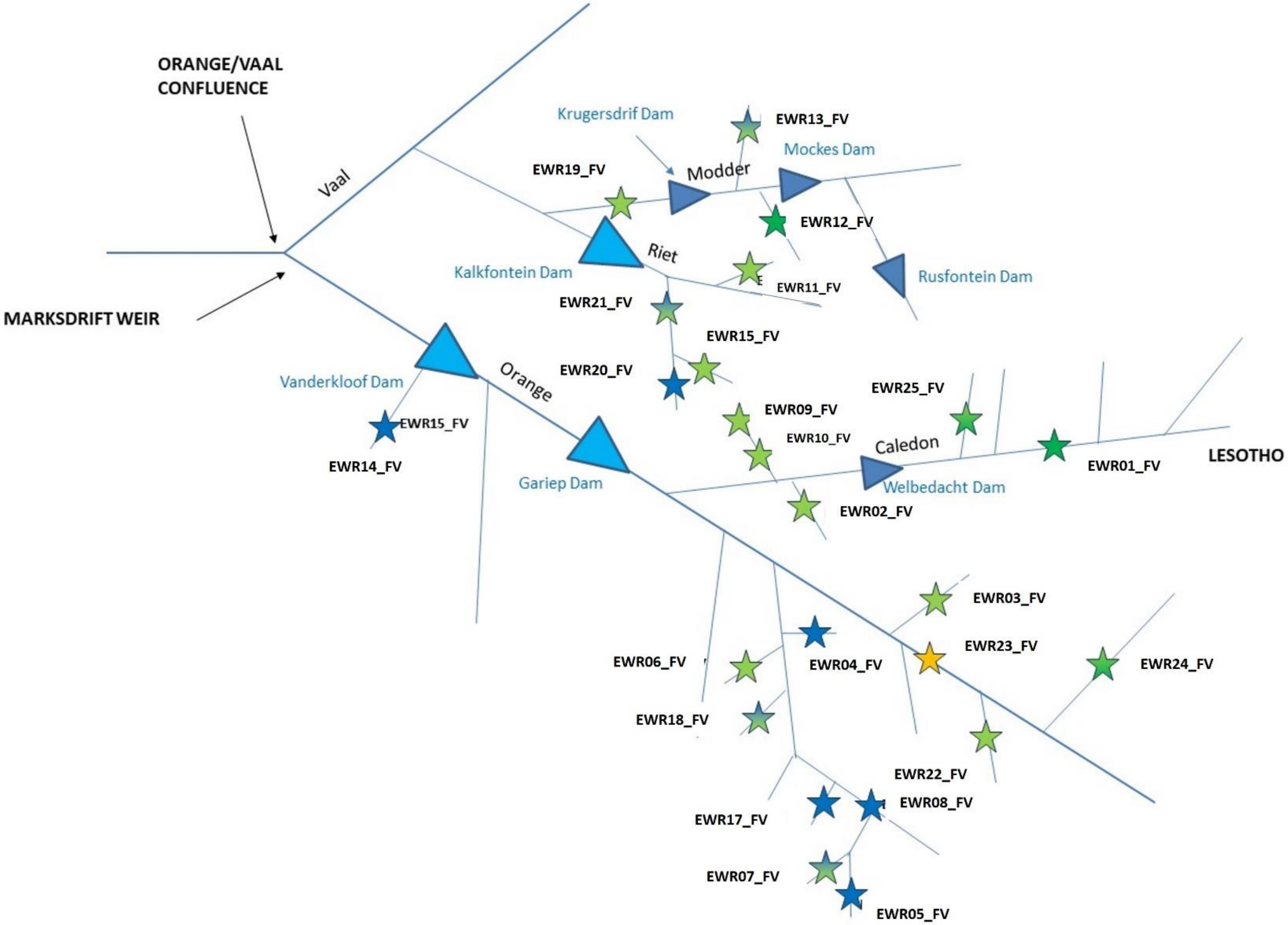


Figure 12-7: Summary of the proposed REC for all field verification sites

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14. APPENDICES

Please refer to Volume 2 for all Appendices