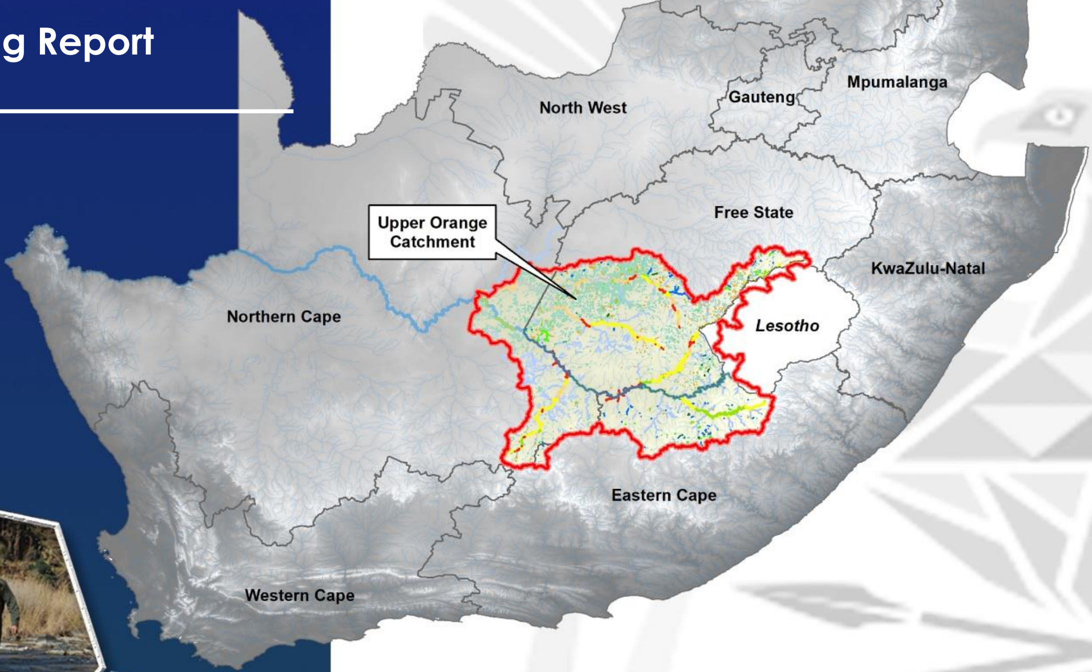
DEPARTMENT OF WATER AND SANITATION

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

WP11343

Capacity Building Report



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……………………………………………………………………………………………………….

Dr Mark Graham *Date*

Director, GroundTruth

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems Management

Approved for DWS by:

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Date: ……………………………………… *Date:* ……………………………………

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Director: Yakeen Atwaru

Date: …………………………………………………..

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LIST OF ACRONYMS

BHN	Basic Human Needs
CS	Citizen Science
CD: WEM	Chief Directorate: Water Ecosystems Management
DRM	Desktop Reserve Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIS	Ecological Importance and Sensitivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FIFHA	Flow, Habitat Assessment Model
FRAI	Fish response assessment index
GAI	Geomorphology Driver Assessment Index
HAI	Hydrological Driver Assessment Index
IEI	Integrated ecological index
IHI	Index of habitat integrity
IWUI	Integrated water use index
MIRAI	Macroinvertebrate response assessment index
PAI	Physical-chemical Driver Assessment Index
PES	Present Ecological State
PSP	Professional Service Provider
REC	Recommended Ecological Category
REMP	River Eco-Status Monitoring Programme
RU	Resource Unit
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area
WRCS	Water Resource Classification System

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1. INTRODUCTION

1.1 Background

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

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

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

The Reserve has priority over other water uses in terms of the NWA and should be determined before license applications are processed, particularly in stressed and over utilised catchments. Accordingly, the CD: WEM identified the need to determine the Reserve for the ecosystems (rivers, wetlands and groundwater) of the Upper Orange River catchment in the Orange Water Management Area (WMA 6). The aim is to provide adequate protection for (i) possible hydraulic fracturing (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 has been undertaken, not only the main stem Orange River

and major tributaries, but inclusive of the smaller tributaries within the catchment. Groundwater and wetland priority resources and their interactions 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 template 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 Objectives of the Capacity Building Programme

The study team is cognisant of the DWS's and specifically the CD: WEM imperative to build capacity and transfer skills in water resource management and protection. A capacity building programme was developed and is included as **Appendix A** as per the inception phase of this study. This programme is based on a model well received by DWS officials on previous projects implemented by this team which includes introductory training before each key workshop, and mentoring of DWS officials by specialists during field surveys, EWR and scenario workshops, etc. DWS officials are also encouraged to select specialist fields where they would like to learn more, and pair-up with that specialist during field surveys and workshops. This programme has been updated during the project following each training session with final participants and comments from the Departmental participants.

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

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

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

1.4 Capacity Building Participants

The DWS members which were all invited to the specialist workshops, capacity building initiatives and water resource in-field surveys are listed in Table 1-1. Other than the surveys, all capacity building events were held virtually on Microsoft Teams.

Table 1-1: Trainees from DWS invited to all capacity building events

Trainee	Email address
Ms Awodwa Magingi	MagingiA@dws.gov.za
Ms Adaora Okonkwo	OkonkwoA@dws.gov.za
Ms Basetsana Mokonyama	MokonyamaB@dws.gov.za
Mr Byron Fortuin	FortuinB@dws.gov.za
Ms Christa Thirion	ThirionC@dws.gov.za
Mr Carlo Schrader	SchraderC@dws.gov.za
Mr Elijah Mogakabe	Mogakabe1E@dws.gov.za
Ms Gerda Venter	VenterGA@dws.gov.za

Trainee	Email address
Mr Henry Maluleke	MalulekeH@dws.gov.za
Mr James Berkland	BerklandJ@dws.gov.za
Mr Jan Makhetha	MakhethaJ@dws.gov.za
Ms Keamogetse Molefe	MolefeK@dws.gov.za
Mr Kgotso Mahlahlane	MahlahlaneK@dws.gov.za
Mr Kwazikwakhe Majola	MajolaK@dws.gov.za
Ms Koleka Makanda	MakandaC@dws.gov.za
Mr Karabo Segage	SegageK@dws.gov.za
Mr Luckson Machingambi	MachingambiL@dws.gov.za
Mr Mkhevu Mnisi	MnisiM2@dws.gov.za
Mr Mfundi Biyela	BiyelaM@dws.gov.za
Ms Mawethu Ndiki	NdikiM@dws.gov.za
Ms Mmaphefo Thwala	ThwalaM@dws.gov.za
Mr Neo Innocent Hlalele	HlaleleN@dws.gov.za
Mr Noxolo Yoko	SekgotaT@dws.gov.za
Mr Ntuthuko Mthabela	MthabelaN@dws.gov.za
Ms Nsovo Mhlarhi	MhlarhiN@dws.gov.za
Ms Nolusindiso Jafta	JaftaN@dws.gov.za
Ms Ndivhuwo Netshiendeulu	NetshiendeuluN@dws.gov.za
Mr Philani Khoza	KhozaP@dws.gov.za
Ms Pule Liatile	LiatileP@dws.gov.za
Ms Rendani Makhwedzha	MudzananiR@dws.gov.za
Mr Stanley Nzama	NzamaS@dwa.gov.za
Mr Terrence Ngilande	NgilandeT@dws.gov.za
Mr Tichatonga Gona	GonahT@dwa.gov.za
Ms Tinyiko Mpete Neswiswi	MpeteT@dws.gov.za
Mr Vernon Blair	BlairV@dws.gov.za

Trainee	Email address
Mr Velile Sam Dywili	DywiliS@dws.gov.za
Ms Winnie Nedzingahe	NedzingaheW@dws.gov.za
Yoko Noxolo	YokoN@dws.gov.za

2. TECHNICAL WORKSHOPS / TRAINING AND STAKEHOLDER TRAINING

This chapter provides an encompassing overview of diverse specialist workshops had, whereby colleagues from DWS were invited to participate. These workshops had a dual purpose, being to deliver targeted training on the multifaceted components relevant to the studies process and fostering an environment conducive to crucial discussions among specialists and DWS colleagues. The principal aim of these workshops was to elevate the skills and knowledge of DWS colleagues through focused training sessions on essential components crucial to their roles. The overarching goal was to empower participants with a profound understanding of the intricate aspects of their work, ensuring they were well-prepared to address challenges and excel in their respective capacities.

Going beyond traditional training methodologies, these workshops also functioned as forums for meaningful and essential discussions. The integration of specialists alongside DWS colleagues created a dynamic environment for the exchange of catchment knowledge, experiences, and insights. This collaborative approach not only facilitated the sharing of best practices, but also encouraged the cross-pollination of knowledge specifically to the study's objectives.

In essence, a holistic training approach that not only imparts knowledge on various components, but also establishes a collaborative space for sharing experiences. It cultivates a culture of continuous learning, fortifying the collective expertise within the Department.

2.1 Resource Unit Prioritisation Workshop

Capacity building topic:	Resource Unit prioritisation workshop
Date:	31 August 2021
Invitees:	As per Section 1.4
Attendees:	Mr Kwazikwakhe Majola Ms Ndivhuwo Netshiendeulu Ms Adaora Okonkwo Mr Fanus Fourie Mr Kgotso Mahlahlane Mr Vernon Blair Ms Mmaphefo Thwala Mr Stanley Nzama Mr Tichatonga Gonah Mr Mkhevu Mnisi Mr Henry Maluleke Mr Philani Khoza Ms Rendani Makhwedzha Ms Tinyiko Mpete

Presenter (s):	Dr Mark Graham, Ms Retha Stassen, Ms Kylie Farrell, Mr Regan Rose, Mr Craig Cowden

Outputs:	• Approaches per component to obtain approval from DWS:
	  • Surface water
	  • Groundwater
	  • Wetlands
	• Discussion on the identified river RUs and levels of determination; and
	• Integration of rivers RUs with groundwater and wetlands.

Please refer to **Appendix B** for the presentation.

2.2 Wetland Technical Workshop

Capacity building topic:	Wetland Technical Workshop: Approach and Refinement of Resource Units
Date:	9 December 2021
Invitees:	As per Section 1.4 and the wider wetland specialists/NGOs/SANBI, etc.
Attendees:	Ms Tinyiko Mpete Neswiswi Ms Ndivhuwo Netshiendeulu Mr Jurgo Van Wyk Ms Barbara Weston Ms Jackie Jay Mr Kwazikwakhe Majola *Others* Ms Nancy Jobs Mr Donovan Kotze Mr Nacelle Collins Ms M Letsaba Ms M Lowies
Presenter (s):	Mr Craig Cowden
Outputs:	• Project background and proposed wetland approach • Wetland study area • Information gaps • Prioritised wetlands • Discussion and input from attendees on the proposed approach and on potential wetland areas for consideration • Working for wetlands strategic planning • General discussion

Please refer to **Appendix C** for the presentation.

2.3 Ecological Water Requirements Workshop

Capacity building topic:	Ecological Water Requirements (EWR) workshop for all Intermediate EWR sites
Date:	19 July 2023
Invitees:	As per Section 1.4
Attendees:	Mr Kwazikwakhe Majola Ms Ndivhuwo Netshiendeulu Mr Kgotso Mahlahlane Ms Mmaphefo Thwala Mr Stanley Nzama Mr Tichatonga Gonah Mr Mkhevu Mnisi Mr Philani Khoza Ms Rendani Makhwedzha Ms Tinyiko Mpete Ms Joyce Machaba Ms Barbara Weston Mr Yoko Noxolo
Presenter (s):	Dr Mark Graham, Ms Retha Stassen, Mr Trevor Pike, Ms Khwezi Mncwabe, Mrs Kylie Farrell, Mr Gary de Winnaar, Mr Bennie van der Waal and Mr Byron Grant
Outputs:	• Quantification of the EWR for all Intermediate EWR river sites within the Upper Orange Catchment area; • Presentation and discussion on the Habitat Flow Model (HabFlo); • Discussion on the Flow-Stressor Response model; • With a focus on the Lower Kraai EWR site, discussion around the responses form a geomorphological, riparian vegetation and instream biota perspective; • Illustration of the Desktop Reserve Model (DRM) within SPATSIM which was used for the integration of data produced from the surveys and the eco-categorisation to quantify the EWRs (as what was done for the Rapid 3 EWR sites quantification); and • Presentation on the hydraulic modelling (cross-sectional profile and discharge) will also be used to evaluate the DRM requirements.

3. CAPACITY BUILDING / TRAINING TOPICS

Similarly, to Chapter 2, the Department was offered a range of capacity building initiatives and opportunities. These endeavours were aimed at augmenting their expertise, skills, and practical experience in the diverse steps and processes associated with Reserve determination.

3.1 Resource Unit Prioritisation

Capacity building topic:	Resource Unit prioritisation capacity building
Date:	31 August 2021
Invitees:	As per Section 1.4
Attendees:	Mr Kwazikwakhe Majola Ms Ndivhuwo Netshiendeulu Ms Adaora Okonkwo Mr Fanus Fourie Mr Kgotso Mahlahlane Mr Vernon Blair Ms Mmaphefo Thwala Mr Stanley Nzama Mr Tichatonga Gonah Mr Mkhevu Mnisi Mr Henry Maluleke Mr Philani Khoza Ms Rendani Makhwedzha Ms Tinyiko Mpete
Presenter (s):	Dr Mark Graham, Ms Retha Stassen, Mrs Kylie Farrell

Outputs:	• Assess Resource Units (RUs) and river level approaches, including the Integrated Water Use Index (IWUI) (resource stress) and the Integrated Ecological Index (IEI). Assessment of the resource stress.
	• Approaches per component:
	  • Surface water
	  • Groundwater
	  • Wetlands

Please refer to **Appendix B** for the presentation.

3.2 Wetland and Groundwater Resource Units

Capacity building topic:	Wetland and Groundwater RU Capacity Building
Date:	4 February 2022
Invitees:	As per Section 1.4
Attendees:	*Attendance register not recorded.*
Presenter (s):	Mr Craig Cowden and Mr Regan Rose

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

Please refer to **Appendix D** for the presentations.

3.3 Site Selection for Rivers, Wetlands and Groundwater

Capacity building topic:	Site Selection – rivers, wetlands and groundwater capacity building
Date:	23 March 2022
Invitees:	As per Section 1.4
Attendees:	*Attendance register not recorded.*
Presenter (s):	Dr Mark Graham, Mr Trevor Pike, Mrs Kylie Farrell, Ms Retha Stassen, Mr Craig Cowden and Mr Regan Rose

Outputs:	• Rivers:
	  • Site selection and specific consideration:
	    • Locality of priority RUs (stressed areas, hotspots), gauging weirs with good quality hydrological data, characteristics of tributaries);
	    • Representivity of the river reach, ecoregions, geomorphic zones;
	    • Sampling suitability (i.e. hydrology, habitats, accessibility, safety); and
	    • Hydraulic profiles i.e. discharge calculations at the site, assessment of bends, islands, bridges, bars, slope which affects the confidence in the results or whether the channel is straight (high confidence results).
	• Wetlands:
	  • Wetland complexes;
	  • Assessment of the different hydrogeomorphic unit (HGM) categorisations of wetlands;
	  • Representivity of the wetland system to be assessed; and
	  • Critical habitats within wetlands.
	• Groundwater:
	  • Existing DWS monitoring points – WMS data and Hydstra data;
	  • Site selection mainly based on active sites, representative of aquifer or part of aquifer;
	  • Long term historical data an advantage;
	  • Spatial distribution within the catchment; and
	  • Unimpacted vs impacted condition, ideally need to have a bit of both.

Please refer to **Appendix E** for the presentation.

3.4 Wetland Resource Unit In-field Survey

Capacity building topic:	Wetland Resource Unit In-field Survey and on-site capacity building
Date:	10 – 14 April 2022
Invitees:	As per Section 1.4
Attendees:	Ms Ndivhuwo Netshiendeulu; Mr Kwazikwakhe Majola; and Ms Tinyiko Mpete
Presenter (s):	Mr Craig Cowden and Mr Steven Ellery
Outputs:	• An important component of the wetland resource unit survey was to share expert knowledge and wetland survey methodologies with members of the DWS; • During the field survey, the DWS colleagues went through the WET-Health (MacFarlane et al. 2020) assessment tool field datasheets with the survey team, which formed the primary form of data captured for these wetland resource unit surveys; • In addition, the survey team shared a number of wetland delineation tips and tricks with the DWS officials using soils, vegetation and landscape position to quickly be able to tell if one is standing within or outside the wetland boundary; • Furthermore, general discussions were had about groundwater/surface water interactions in depression wetlands, different hydroperiods of wetlands across the study area, defining HGM units, vegetation classification in wetlands, soil chemistry in wetlands and the different assessment techniques that will be used for the wetland component of the reserve study; and • Overall, the enthusiasm and willingness to learn and ask questions made for a positive learning experience for all involved. Please refer to **Figure 3-1** for some capacity building pictures during the field survey.

Figure 3-1: Capacity building moments during the wetland survey

3.5 Groundwater Hydrocensus

Capacity building topic:	Groundwater Hydrocensus capacity building
Date:	25 – 29 April 2022
Invitees:	As per Section 1.4
Attendees:	Ms Ndivhuwo Netshiendeulu; Mr Kwazikwakhe Majola; Mr Stanley Nzama; and Mr Mfundi Biyela.
Presenter (s):	Mr Regan Rose and Mr Mfundo Ntuzela

Outputs:	• An important component of the Groundwater Hydrocensus was to engage with DWS personnel from the regions and head office, share expert knowledge and groundwater survey methodologies with the members;
	• The objectives of the capacity building initiative was to:
	  • Describe the groundwater Reserve process;
	  • Gain an understanding of institutional arrangements and challenges; and
	  • Seek ways to synergize activities between the regions and service provider for mutual benefit.

	• The engagement with DWS personnel allowed for detailed discussions relating to the High Confidence Reserve Determination Study. The discussions focussed on several key elements as follows:
	  • Data requirements and future data collection;
	  • Regional Office duties and database management;
	  • Existing and future groundwater licenses and compliance monitoring; and
	  • Groundwater supply at towns and the responsibility of the Water Services Provider to comply with groundwater monitoring and reporting.
	• Overall, the enthusiasm and willingness to learn, ask questions, guidance as to where to obtain groundwater data made for a positive learning experience for all involved.
	
	Please refer to **Figure 3-2** for some capacity building pictures during the field survey.

Figure 3-2: Groundwater hydrocensus capacity building images

3.6 Rivers Survey 1

Capacity building topic:	Rivers Survey 1 capacity building
Date:	4 to 15 July 2022
Invitees:	As per Section 1.4
Attendees:	Ms Ndivhuwo Netshiendeulu Mr Jan Makhetha Ms Tinyiko Mpete Ms Keamogetse Molefe Ms Pule Liatile Mr Basetsana Mokonyama *Citizen Scientists* Mr Hendrik Sithole (SanParks)
Presenter (s):	Ms Retha Stassen, Dr Bennie Van Der Waal, Mr Byron Grant and Mrs Kylie Farrell

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

	• Fish - the various flow-velocity-depth classes were discussed and examples illustrated on site. Fish identification exercises were held; • Geomorphology – features, zones, sediment regime, various geomorphological drivers were deliberated and examples at the sites shown; and • Furthermore, the suitability of the sites for accurate hydraulic modelling, where the range of possible flows, especially low flows, was discussed and how discharge is measured. • Overall, the enthusiasm and willingness to learn and ask questions made for a positive learning experience for all involved. Please refer to **Figure 3-3** for some capacity building pictures during the field survey.

Figure 3-3: Rivers survey 1 capacity building

3.7 Rivers Eco-categorisation Tools: Part 1

Capacity building topic:	Rivers Eco-categorisation Capacity Building: Part 1
Date:	28 July 2022
Invitees:	As per Section 1.4
Attendees:	Ms Nolusindiso Jafta Mr Philani Khoza Mr Mkhevu Mnisi Mr Elijah Mogakabe Mr Kgotso Mahlahlane Ms Tinyiko Mpete Neswiswi Mr Kwazikwakhe Majola Mr Luckson Machingambi Ms Nsovo Mhlarhi Ms Koleka Makanda Ms Basetsana Mokonyama Ms Mawethu Ndiki Ms Ndivhuwo Netshiendeulu Ms Winnie Nedzingahe Ms Christa Thirion
Presenter (s):	Mrs Kylie Farrell and Mr Byron Grant

Outputs:	• Provided an overview of the background to the rives eco-categorisation process
	• Described the approach in accordance with the 8-step Reserve determination process and Step 3 as outlined in the Establishment of a Water Resource Classification System (WRCS) as per Regulation 810 (Government Gazette 33541) dated 17 September 2010
	• Example used for the capacity building session was the Lower Kraai (UO_EWR08_I) whereby the following was guided upon:
	  • Site location and site characteristics
	  • Index of habitat integrity (IHI): instream and riparian criteria were described and the thought process when rating each criteria;
	  • The significance of incorporating aquatic macroinvertebrates within the eco-categorisation process and how these organisms provide valuable insights into the health and ecological dynamics of the river system.
	  • Macroinvertebrate response assessment index (MIRAI)
	  • DWS were taken through the excel model with each metric described
	  • The importance of assessing fish and their valuable input in understanding the health and integrity of a river system

	• Fish response assessment index (FRAI) • DWS were taken through the excel model with each metric described • Eco-Status Level 4: using the ecological category results from the MIRAI, FRAI and the riparian score from the IHI as a surrogate to the Riparian Vegetation Response Assessment Index (VEGRAI); and • Overall results and conclusion of the Lower Kraai

Please refer to **Appendix F** for the presentation.

3.8 Rivers Eco-categorisation Tools: Part 2

Capacity building topic:	Rivers Eco-categorisation Capacity Building: Part 2
Date:	28 November 2022
Invitees:	As per Section 1.4
Attendees:	Ms Nolusindiso Jafta Mr Philani Khoza Mr Mkhevu Mnisi Mr Elijah Mogakabe Mr Kgotso Mahlahlane Ms Tinyiko Mpete Neswiswi Ms Rendani Makhwedzha Mr Kwazikwakhe Majola Ms Awodwa Magingi Mr Luckson Machingambi Ms Nsovo Mhlarhi Ms Koleka Makanda Ms Basetsana Mokonyama Ms Mawethu Ndiki Ms Ndivhuwo Netshiendeulu Ms Winnie Nedzingahe Ms Christa Thirion Ms Mmaphefo Thwala Mr Noxolo Yoko
Presenter (s):	Dr Mark Graham, Ms Retha Stassen, Mr Gary de Winnaar, Mrs Kylie Farrell, Dr Bennie van der Waal
Outputs:	• Overview of the river surveys that were/to be conducted and the different Reserve levels (Intermediate, Rapid 3 and field verification),

	including the driver and response components surveyed for the different levels;
	• Re-capped on the background to the rives eco-categorisation process
	• Re-capped on the approach in accordance with the 8-step Reserve determination process and Step 3 as outlined in the Establishment of a Water Resource Classification System (WRCS) as per Regulation 810 (Government Gazette 33541) dated 17 September 2010
	• Example used for the capacity building session was the Lower Kraai (UO_EWR08_I) whereby the following was guided upon:
	  ◦ Hydrological Driver Assessment Index (HAI)
	  ◦ Geomorphology Driver Assessment Index (GAI);
	  ◦ Physical-chemical Driver Assessment Index (PAI):
	    ▪ Although the PAI was not run for this study owing to a considerable lack of surface water quality data in the catchment – the model was trained upon and illustrated;
	  ◦ Approach/guidance how to address catchment wide water quality issues;
	  ◦ Presentation on background to diatoms, the laboratory technique in identifying the species, and their associated response to water quality, providing the study with valuable insight into the water quality of the river systems; and
	  ◦ Riparian Vegetation Response Assessment Index (VEGRAI).

Please refer to **Appendix G** for the presentation.

3.9 Rivers Survey 2

Capacity building topic:	Rivers Survey 2 capacity building
Date:	29 May to 4 June 2023
Invitees:	As per Section 1.4
Attendees:	Ms Tinyiko Mpete Ms Rendani Mudzanani Ms Koleka Makanda Ms Nolusindiso Jafta Ms Basetsana Mokonyama Mr Mawethu Ndiki *Citizen Scientists* From the Directorate: Water Use and Irrigation Development under the Department of Agriculture Land Reform and Rural Development: • Ms Mosibudi Sekgala • Ms Nomsa Masemola

Presenter (s):	Mr Trevor Pike, Ms Khwezi Mncwabe, Mr Gary de Winnaar, Mr Byron Grant and Mrs Kylie Farrell

Outputs:	• All topics included in Section 3.7 were revisited and recapped during this second survey;
	• In addition to this survey, the riparian vegetation specialist and engineers were on site, providing many opportunities to discuss the following in more detail, compared to the first survey:
	  ◦ Riparian vegetation and the different zones associated with the assessment;
	  ◦ Riparian vegetation identification exercises; and
	  ◦ Further detail around accurate hydraulic modelling, site selection purely from a hydraulic perspective and the characteristics of the cross-sections.
	• Similarly to the first river survey, the overall enthusiasm and willingness to learn made for another positive learning experience for all involved. Thank you to those DWS members for your participation, involvement and more importantly, your support.
	
	Please refer to **Figure 3-4** to **Figure 3-5** for some capacity building pictures during the field survey.

Figure 3-4: Morning of introductions during the start of the second survey

Figure 3-5: River survey 2 capacity building moments

3.10 Scenario and Consequences

Capacity building topic:	Scenario and Consequences capacity building
Date:	29 November 2023
Invitees:	As per Section 1.4
Attendees:	Ms Ndivhuwo Netshiendeulu Ms Tinyiko Mpete Neswiswi Ms Rendani Makhwedzha Mr Philani Khoza Mr Mkhevu Mnisi Ms Awodwa Magingi Mr Luckson Machingambi Ms Winnie Nedzingahe Mr Noxolo Yoko Ms Mmaphefo Thwala Mr Ntuthuko Mthabela Ms Nsovo Mhlarhi
Presenter (s):	Mrs Kylie Farrell, Ms Retha Stassen and Ms Michelle Brown
Outputs:	• Purpose of assessing the scenarios and consequences; • The process whereby the operational scenarios are defined;

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

Please refer to **Appendix H** for the presentation.

3.11 Final Capacity Building – Holistic Overview of the Reserve Determination Process for all water resources

Capacity building topic:	Final Capacity Building – Holistic Overview of the Reserve Determination Process for all water resources
Date:	30 January 2024
Invitees:	As per Section 1.4
Attendees:	Ms Ndivhuwo Netshiendeulu Ms Tinyiko Neswiswi Mr Byron Fortuin Mr Vernon Blair Ms Gerda Venter Ms Nolusindiso Jafta Mr James Berkland Ms Koleka Makanda Mr Mfundi Biyela Mr Mawethu Ndiki Mr Karabo Segage Mr Carlo Schrader Mr Velile Sam Dywili Ms Mmaphefo Thwala Mr Elijah Mogakabe Ms Winnie Nedzingahe Mr Neo Innocent Hlalele Mr Henry Maluleke Mr Mawethu Ndiki Mr Terrence Ngilande

	Mr Carlo Schrader
Presenter (s):	Kylie Farrell, Retha Stassen, Steven Ellery and Regan Rose

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

Please refer to **Appendix I** for the presentation.

4. PROFESSIONAL SERVICE PROVIDER: TEAM CONTRIBUTION

The following PSP team members contributed to the capacity building events held:

- Dr Mark Graham;
- Mr Trevor Pike;
- Ms Khwezi Mncwabe;
- Mr Gary de Winnaar;
- Mr Craig Cowden;
- Mr Steven Ellery;
- Ms Michelle Brown
- Ms Retha Stassen;
- Mrs Kylie Farrell;
- Dr Bennie van der Waal;
- Mr Byron Grant;
- Mr Regan Rose;
- Mr Mfundo Ntuzela; and

5. A THANK YOU NOTE

Thank you to all DWS members for your participation, involvement and more importantly, your support during all the specialist workshops, training, capacity building initiatives and groundwater, wetland and rivers surveys for this study (**Figure 5-1**).

Figure 5-1: DWS colleauges that joined the second river survey

6. APPENDICES

Appendix A: Capacity Building programme

INTEGRATED VAAL RIVER COMPREHENSIVE RESERVE DETERMINATION STUDY: PROJECT MANAGEMENT UPDATED PROGRAMME

	Activities	Final Participants	Comments from trainees	2021					2022												2023						
				AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
1	Approach for RU delineation and level of assessment			◆																							
2	Selection of priority wetland and groundwater RUs								◆																		
3	EWR site selection and river survey 1 (intermediate sites)										◆																
4	Wetland surveys									◆																	
5	Groundwater surveys										◆																
6	River survey 2 (rapid 3 and biological sites)													◆													
7	Socio-economic outline and Socio-Cultural Importance (SCI)						◆																				
8	River ecoclassification (ecostatus models)														◆												
9	River EWR quantification workshop (DRM, RDRM, HFSR)																◆										
10	Groundwater workshop (PES, quantification and setting RQOs)															◆											
11	Wetlands workshop (WET-Health, functioning, EIS)																	◆									
12	Stakeholder workshop 1 (Citizen Science)															●											
13	Scenarios and Water Resource Modelling																		◆								
14	Ecological consequences, ecospecs and monitoring																				◆						
15	Integration between components (rivers, wetlands & groundwater)																					◆					
16	Stakeholder workshop 2 (Citizen Science)																				●						
17	1-day Wrap-up training (all components)																						◆				

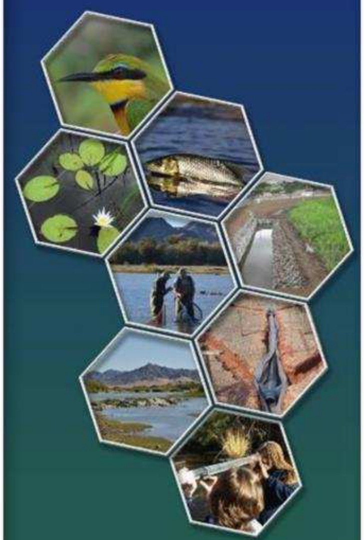
◆ = Training workshop

▲ = Individual training

● = Awareness creation/ Citizen science

Appendix B: RU Approach Technical Presentation

Resource Units



31 August 2021

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment (WP11343)

GroundTruth

1

Generic process for EWR determination

1. INITIATE STUDY
Define study area
Select level and eco-system components
Select study team

2. DEFINE RESOURCE UNITS
& SELECT EWR SITES

3. FIELD SURVEYS & ASSESSMENTS
Undertake specialist field surveys
Assess the present state and recommend future state

4. QUANTIFICATION
Quantify the EWR, including quality

5. ANALYSIS
Impacts of development scenarios
Ecological and socio-economic consequences

6. DECISION-MAKING PROCESS
Include EWRs in catchment models, trade-offs

7. SELECT BEST DEVELOPMENT OPTION & DEVELOP A MONITORING PROGRAMME

8. IMPLEMENTATION PLAN

2

Resource Units (RUs - rivers)

Define Resource Units….

are sections of the river that have the same natural flow patterns and reactions to stress,

similar biophysical and geographic features,

each of these sections has its own specification of EWRs.

Purpose of Resource Units…..

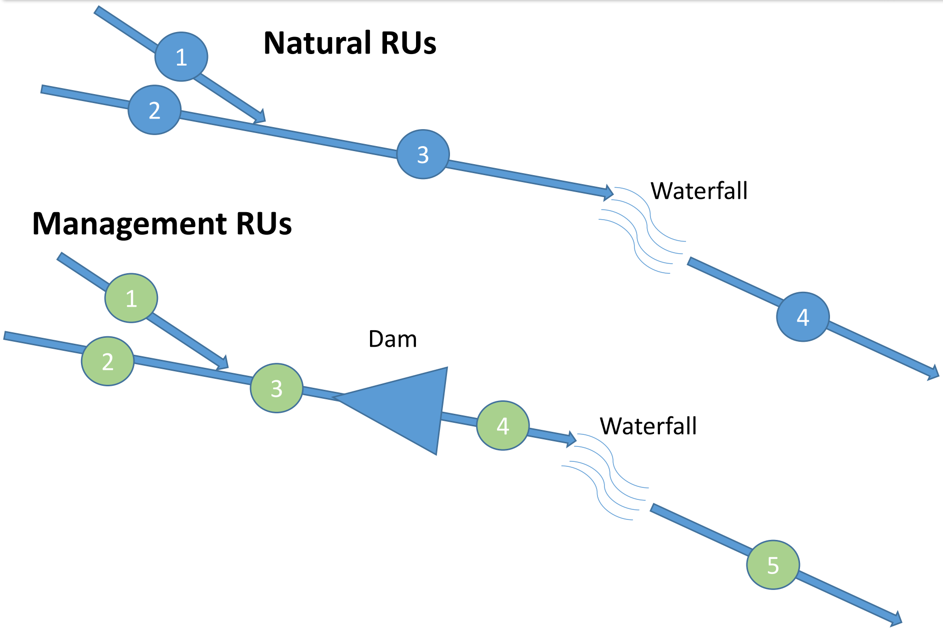
delineate the catchment into units which are relatively homogenous on an ecological basis,

can be further resolved into smaller/larger reaches which are suited to management requirements,

considering a variety of factors, namely eco-regions, geomorphologic classification, water quality, land use, habitat integrity, physical system constraints, local knowledge.

3

Example of Resource Units



4

Process for RUs (rivers)

Desktop PES/EI/ES information per sub-quaternary reach

Integrated Water Use Index (IWUI) (Resource Stress)

0	None
1	Small
2	Moderate
3	Large
4	Serious
5	Critical

IWUI = Highest score (Flow modification, Quality modification)

Ecological Importance and Sensitivity

EI/ES
Very low
Low
Moderate
High
Very high

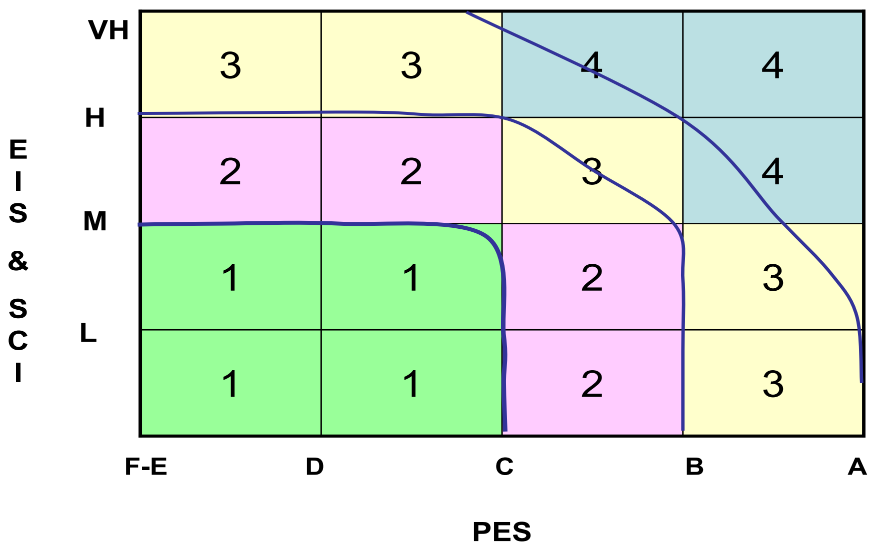
EIS = Highest score (Ecological Importance, Ecological Sensitivity)

Present Ecological State (PES)

PES
A
B
C
D
E/F

5

Integrated Ecological Index (IEI)



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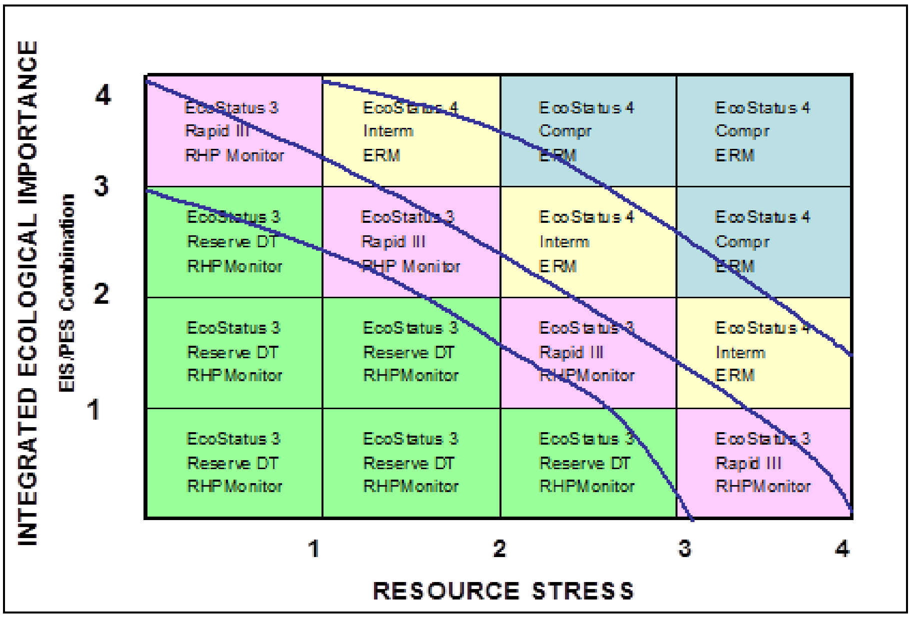
Level of EWR assessment



7

Example

			Resource stress			Ecological					IWUI+IEI
Sub-quat	Quat	River	Water Use	Quality	IWUI	PES	EI	ES	EIS	IEI	Level
C51A-04263	C51A	Leeuspruit	1	2	2	C	MODERATE	MODERATE	Moderate	1	Biological
C51A-04269	C51A	Fouriespruit	3	3	3	D	HIGH	MODERATE	High	2	Rapid 3
C51A-04297	C51A	Un-named tributary	3	2	3	C	MODERATE	MODERATE	Moderate	1	Biological
C51A-04323	C51A	Fouriespruit	1	2	2	C	MODERATE	MODERATE	Moderate	1	Biological
C51A-04336	C51A	Fouriespruit	1	2	2	C	MODERATE	LOW	Moderate	1	Biological
C51A-04352	C51A	Kroonspruit	1	2	2	C	MODERATE	MODERATE	Moderate	1	Biological

Rationale/ Motivation
Extensive agriculture in the upper catchment and tributaries

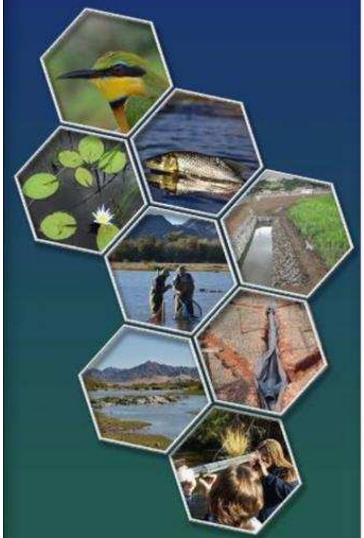
8

Questions

9

Appendix C: Wetland Technical Workshop

DWS Upper Orange Reserve Determination



9 December 2021

A High Confidence Reserve Determination Study for the Upper Orange Catchment -

Wetland Workshop

(WP11343)

GroundTruth

1

Agenda

1. WELCOME & INTRODUCTIONS	15min
2. APOLOGIES	5min
3. PROJECT BACKGROUND AND PROPOSED APPROACH	60min
BREAK (15min)	
4. DISCUSSION AND INPUT FROM ATTENDEES ON THE PROPOSED APPROACH AND ON POTENTIAL WETLAND AREAS FOR CONSIDERATION	60min
5. GENERAL DISCUSSION/ITEMS	15min
6. CONCLUSION OF THE MEETING	5min

2

2

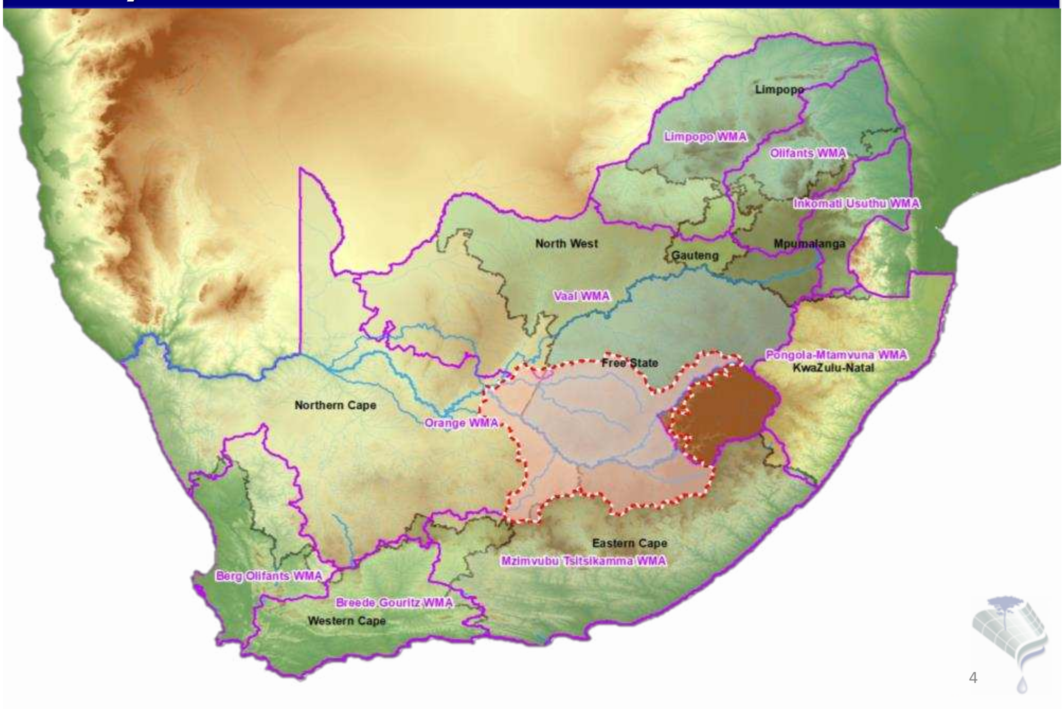
Project Background

- Upper Orange System is a working catchment under increasing stress from a water quality/quantity perspective.
- The Department needs to ensure that the water supply remains sufficient to meet the requirements of both current and future users.
- Upper Orange Catchment therefore prioritised for reserve determination
- Guide the Department to:
  - Meet the objectives of maintaining/improving the state of the water resources within this catchment.



3

Study Area



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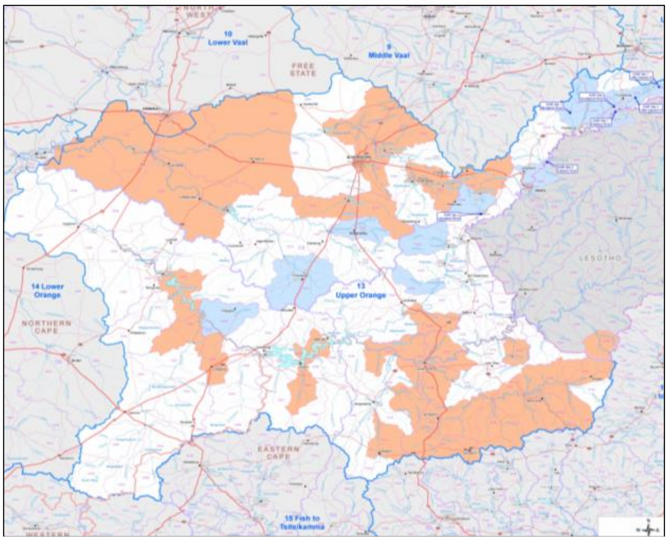
Project Background

- The Department has overall responsibility for and authority over water resource management
  - Equilibrium between basic human needs (BHN) and ecological water requirements (EWR) for the water resources
- Previously, mainly desktop and rapid Reserve determinations undertaken for DWS
  - Desktop Reserves
  - Rapid Reserves
- ORASECOM, intermediate EWR
  - Kraai (1 site)
  - Caledon (2 sites)
  - Orange (site at Hopetown)



5

Overall Study Objectives

- Identify the gaps to be addressed in the Upper Orange catchment.
- To determine the Reserve (quantity/quality of the EWR and BHN for the rivers at various EWR sites).
- Determine the water quantity/quality component of the EWR and BHN for the priority wetlands/wetland clusters where applicable.
- Determine the groundwater quality/quantity component of the BHN and the groundwater quantity component of the EWR for each resource unit/quaternary catchment in the study area.
- Address priority water resources identified to be investigated.
- Assess and evaluate operational scenarios, considering water transfers and developments in Lesotho.
- Determine ecological specifications/protection measures to support the Reserve requirements.
- Prepare the EWR and BHN templates for the Upper Orange Reserve.

6

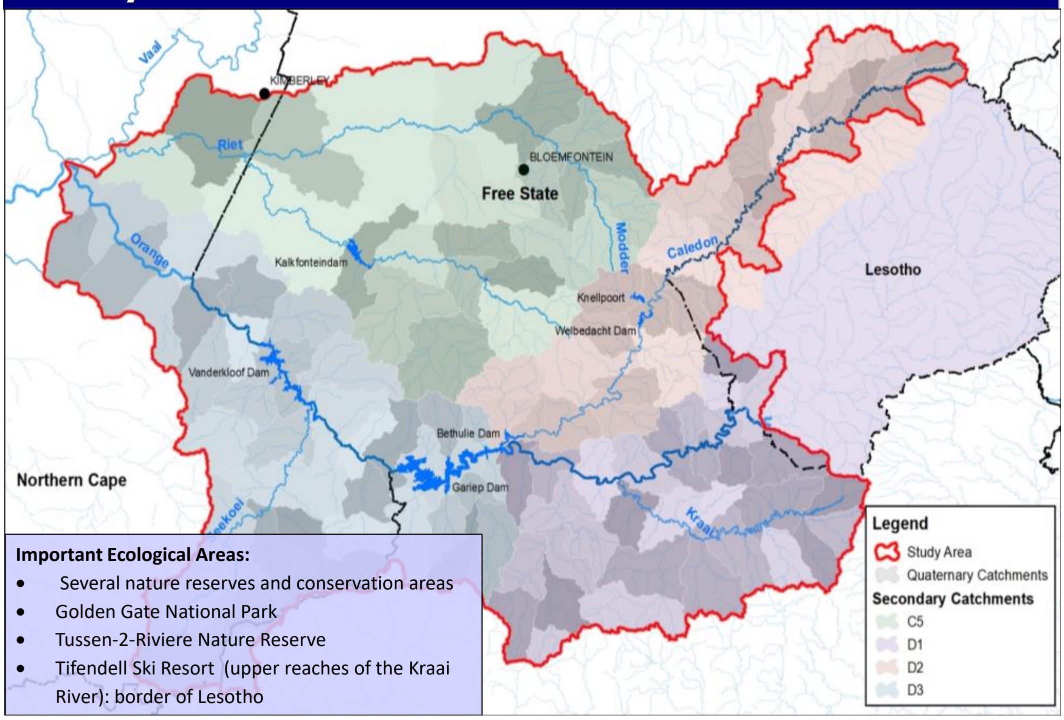
6

Project Background

- A High Confidence Reserve Determination Study for the Upper Orange Catchment
- In tandem:
  - Joint Basin Survey (JBS3) for the Orange-Senqu River Basin (previous/current data obtained for the Upper Orange will be significant contributor to this project)
  - Currently in the Inception Phase for the setting of transboundary Resource Quality Objectives for the Orange-Senqu River Basin (draw from information/data/delineated RU for this project).

7

Study Area

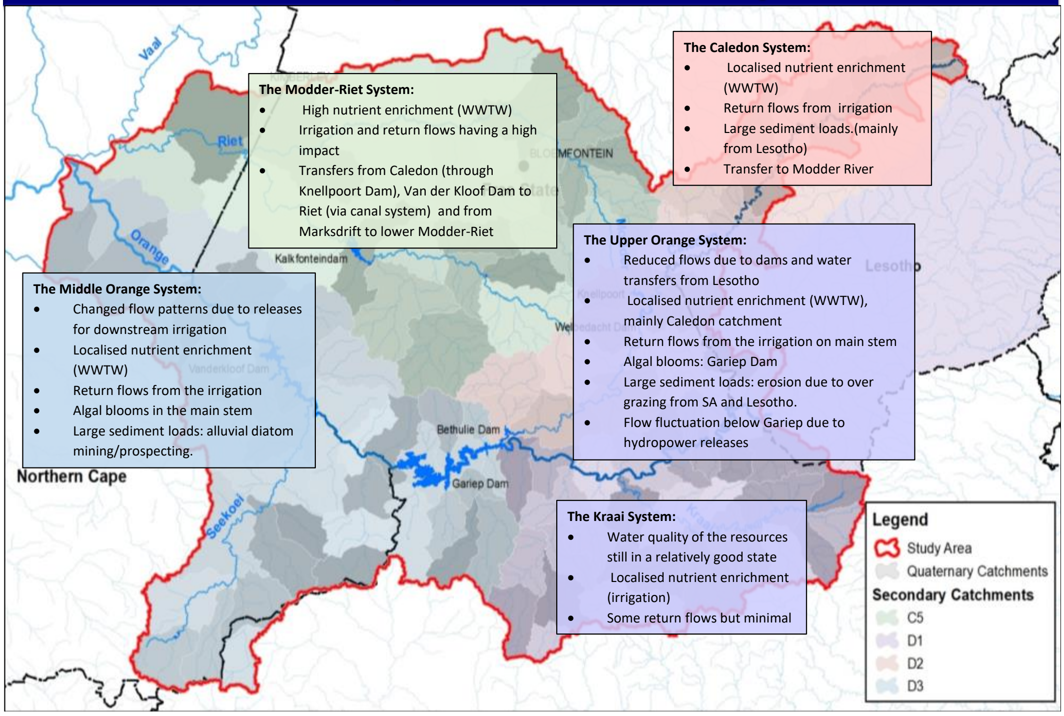


Important Ecological Areas:

- Several nature reserves and conservation areas
- Golden Gate National Park
- Tussen-2-Riviere Nature Reserve
- Tifendell Ski Resort (upper reaches of the Kraai River): border of Lesotho

8

Freshwater Ecosystems: Main Impacts



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General Approach for Determining the Reserve

- Task 1 and task 2 concurrent
- Review of water resource information and data gathering:
  - ORASECOM technical studies
  - Desktop PES/EI-ES (DWS, 2014)
  - National Wetlands Map 5
  - Previous Reserve results
  - Water resource availability and planning studies
  - Various water quality studies
  - Reconciliation strategies

- Socio-economic information to inform possible scenarios
- Obtaining the latest water resource models for updating
- Prioritisation of reaches/sites/wetlands
- Gap analysis Report
- All the above will take place between September 2021 and January 2022

10

10

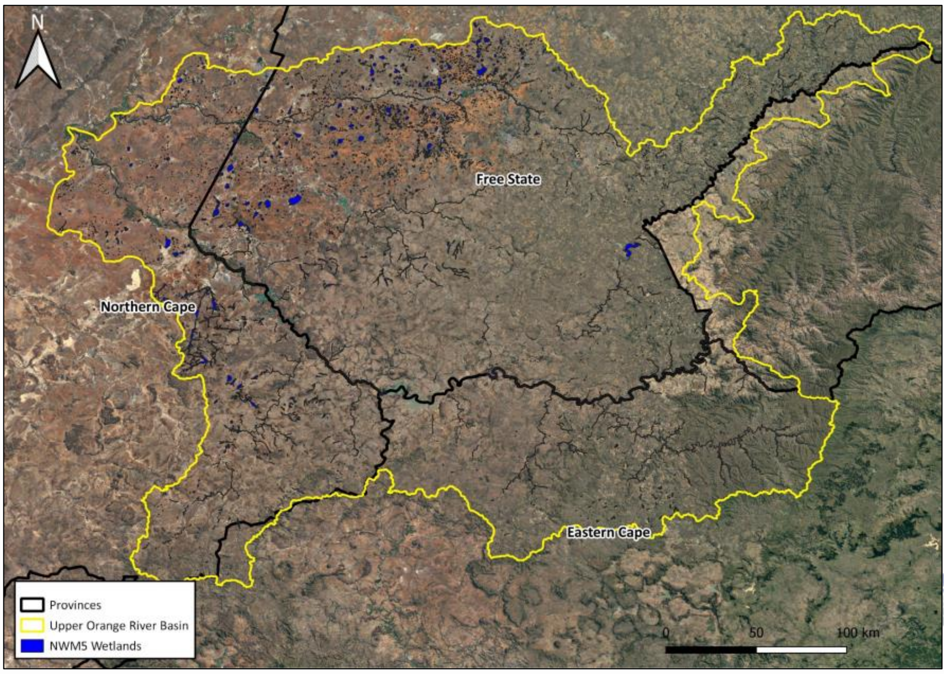
Wetland Study Approach

- Majority of the wetlands are located in:
  - The northern and north-eastern areas of the Free State;
  - Western portions of the Northern cape;
  - And scattered throughout the upper reaches of the Eastern Cape.
- The wetland priority sites are currently being selected using available data and study sites (wetlands) will be selected accordingly.

11

11

Wetlands: NWM5



12

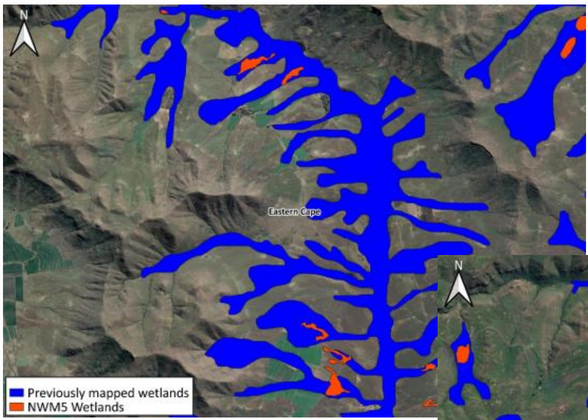
Wetlands: Information Gaps

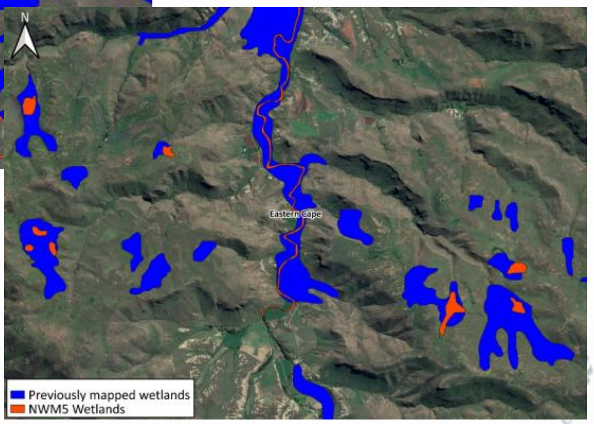
- Main area of concern – southern reaches of Free State and northern Eastern Cape
  - Limited to no wetland coverages within the national layers (NWM5)
  - The NFEPA coverage does includes additional features but not necessarily adding significant data
- With wetland mapping at a national scale, many wetlands have not been mapped and the collection of additional wetland coverages would be a huge benefit.

13

13

Wetlands: Information Gaps





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Wetland Prioritisation

Top-down approach using desktop derived data with the following wetland related data would be used to inform the wetland site prioritisation:

- KEY ATTRIBUTES:
  - Wetlands with PES A/B;
  - Wetlands “Critically Endangered” / “Endangered”;
  - Crane breeding sites;
  - Expert ID (According to NFEPA/ specialist input); and
  - WfWetlands rehabilitation sites (these were considered but are largely limited within the Upper Orange catchment area with some rehabilitation sites within the Golden Gate rehabilitation project area)

- These sites further refined based on:
  - Linked to ground/surface water SWSAs;
  - Upstream of water supply dams;
  - Wetlands >50ha
  - HGM Unit type and associated services:
    - Used the assumption that various HGM units provide different water quality and quantity services
  - Located in water stress areas in terms of quantity and quality (derived from river information)

15

15

Wetland Prioritisation – Preliminary

- All attributes were provided a score of 0-1, based on a presence-absence scale.

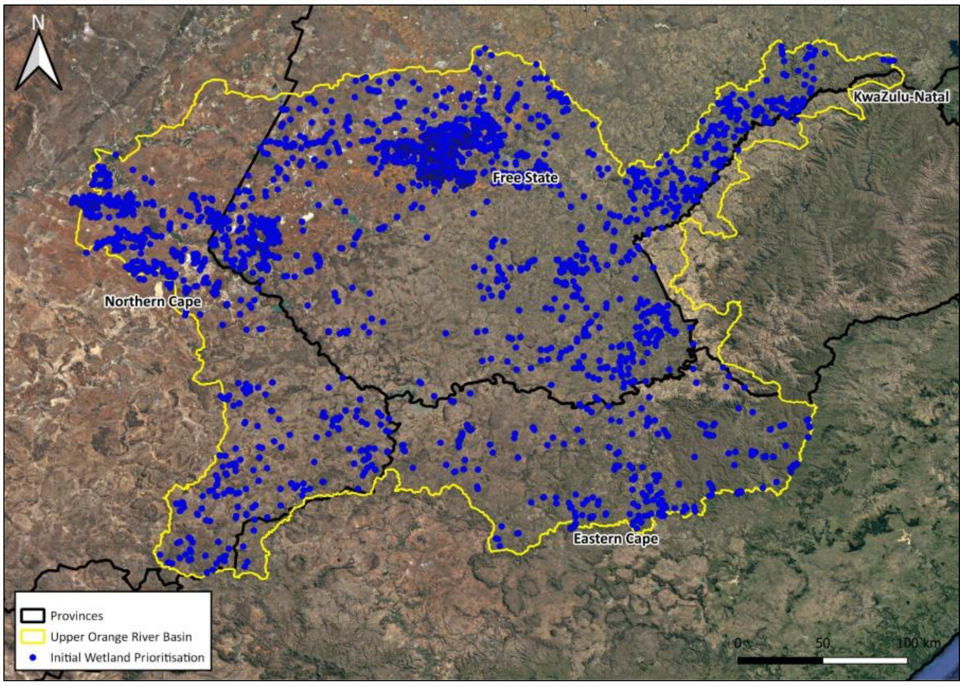
- The wetlands were then ranked accordingly, highest scores being the more important systems.

- Total of 3679 wetland systems identified.

16

16

Wetlands: Prioritised Wetland Systems



17

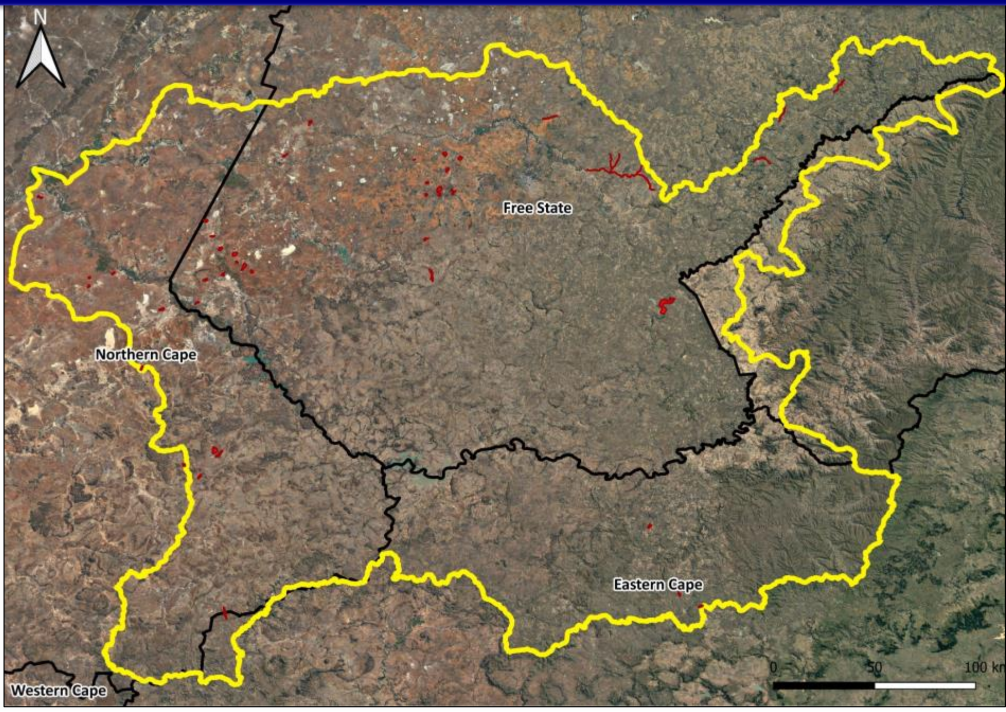
Wetland Prioritisation – Preliminary

- Initial ranking = 3679 wetlands
- If sites are then selected using an additional 'filters', the results vary widely:
  - PES: A/B = 2043 wetlands
  - Area >100 = 47 wetlands
  - UCVB HGM unit = 227 & Floodplain HGM unit = 38 wetlands
- Significant variation in number of wetlands prioritised, depending on the type of layers used to screen further. Therefore, motivation for which layers to use is critical.
- Input from stakeholders therefore critical for
  - Criteria that are important in the catchment area; and
  - For priority sites that have been identified from the ground (bottom-up approach)

18

18

Wetlands: Wetlands >100ha



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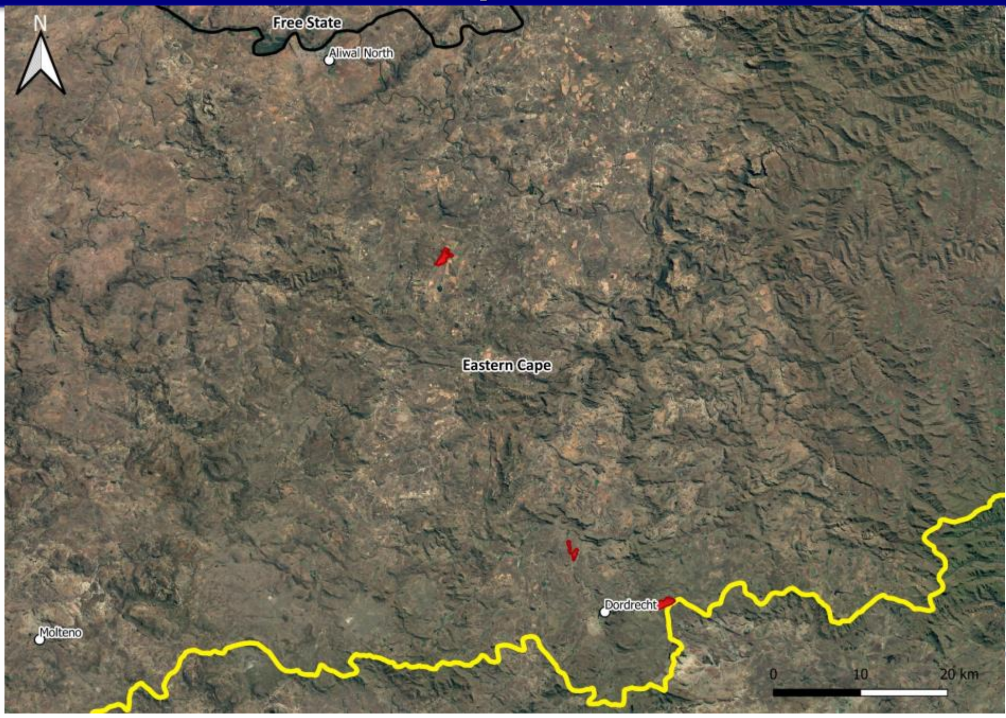
Wetlands: Eastern Cape

Type	Ha	WETCON2	ETS2018	EPL2018	Total	Province
DEPR	200.5197	A/B	LC	Poorly protected	8	Eastern Cape
FLOOD	105.4999	D/E/F	CR	Poorly protected	8	Eastern Cape
FLOOD	186.8695	C	CR	Not protected	8	Eastern Cape

20

20

Wetlands: Eastern Cape



21

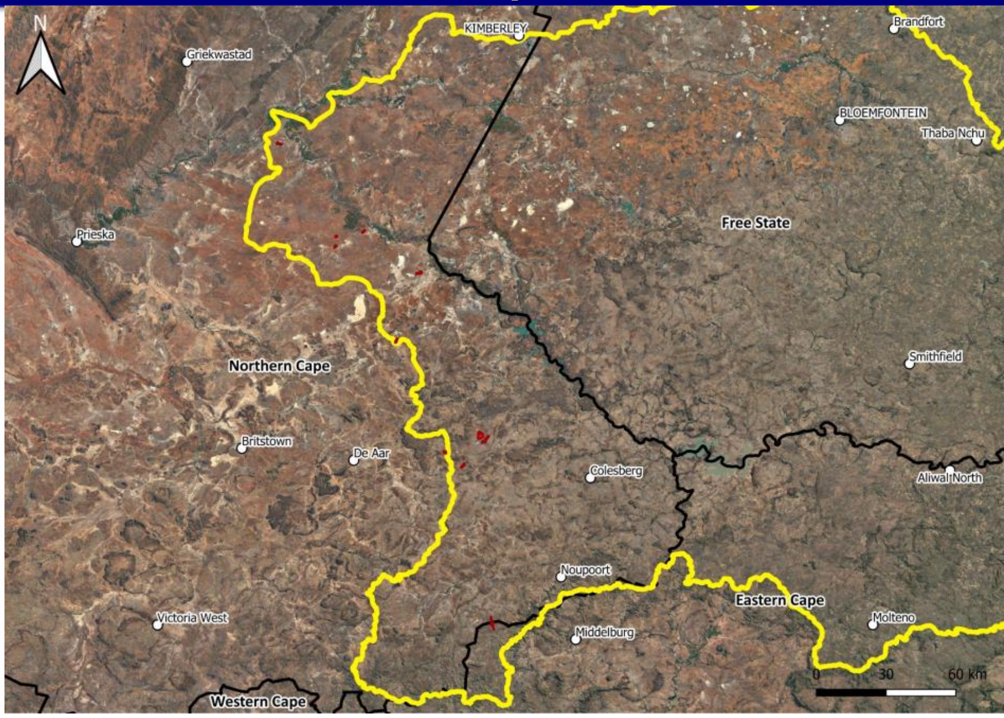
Wetlands: Northern Cape

Type	Ha	WETCON2	ETS2018	EPL2018	Total	Province
DEPR	646.1702	A/B	VU	Not protected	6	Northern Cape
DEPR	216.6754	A/B	VU	Not protected	6	Northern Cape
DEPR	141.1878	A/B	VU	Not protected	5	Northern Cape
DEPR	327.4027	A/B	VU	Not protected	6	Northern Cape
DEPR	168.732	A/B	VU	Not protected	5	Northern Cape
DEPR	244.1543	A/B	VU	Not protected	6	Northern Cape
DEPR	106.6576	A/B	VU	Not protected	5	Northern Cape
DEPR	112.3541	A/B	VU	Not protected	5	Northern Cape
DEPR	136.7647	A/B	VU	Not protected	5	Northern Cape
DEPR	190.0981	A/B	VU	Not protected	5	Northern Cape
CVB	349.9465	D/E/F	CR	Not protected	10	Northern Cape

22

22

Wetlands: Northern Cape



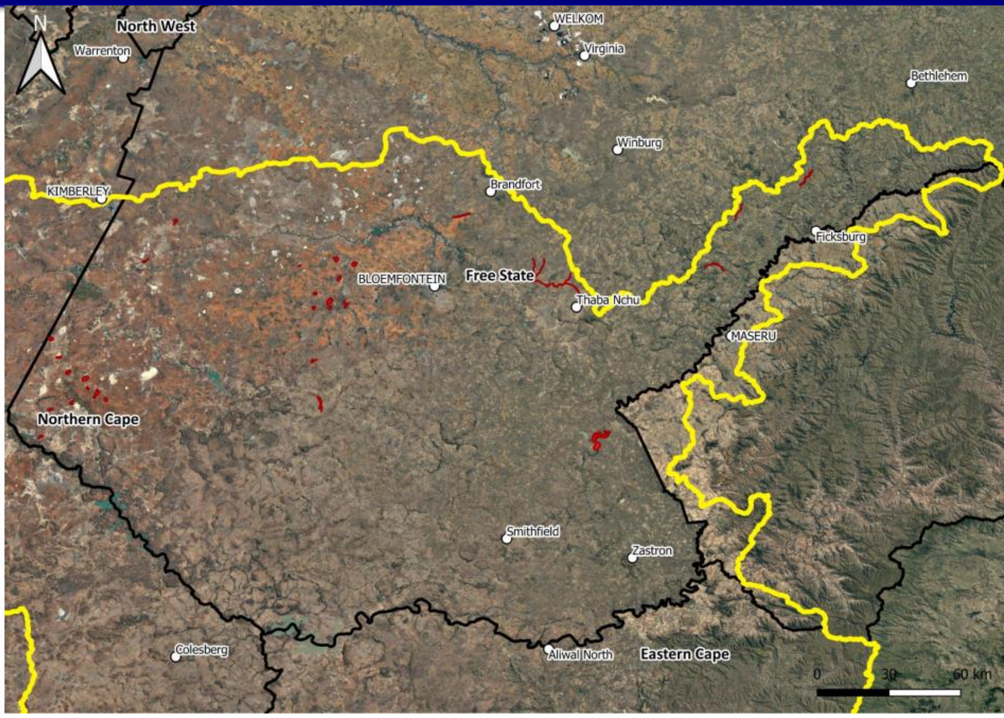
23

Wetlands: Free State

Type	Ha	WETCON2	ETS2018	EPL2018	Total	Province
SEEP	166.48	A/B	CR	Not protected	9	Free State
DEPR	264.0542	A/B	LC	Poorly protected	6	Free State
DEPR	126.2008	A/B	LC	Poorly protected	6	Free State
DEPR	202.8509	A/B	LC	Poorly protected	6	Free State
DEPR	243.0452	A/B	LC	Poorly protected	6	Free State
DEPR	277.5289	C	LC	Poorly protected	5	Free State
DEPR	289.4004	A/B	LC	Poorly protected	6	Free State
DEPR	499.7089	A/B	LC	Poorly protected	6	Free State
DEPR	128.548	A/B	LC	Poorly protected	6	Free State
DEPR	154.53	A/B	VU	Not protected	6	Free State
DEPR	149.5843	A/B	VU	Not protected	6	Free State
DEPR	196.3862	A/B	VU	Not protected	8	Free State
DEPR	478.5998	A/B	VU	Not protected	6	Free State
DEPR	100.6671	A/B	VU	Not protected	6	Free State
DEPR	257.9367	A/B	VU	Not protected	7	Free State
DEPR	403.3733	A/B	LC	Poorly protected	5	Free State
DEPR	222.6371	A/B	VU	Not protected	5	Free State
DEPR	516.2411	A/B	VU	Not protected	5	Free State
FLOOD	2455.1	C	CR	Not protected	10	Free State
FLOOD	231.92	D/E/F	CR	Not protected	8	Free State
SEEP	132.4143	D/E/F	CR	Not protected	7	Free State
SEEP	138.6491	A/B	CR	Not protected	9	Free State
SEEP	138.5459	A/B	CR	Not protected	11	Free State
SEEP	221.1824	C	CR	Not protected	7	Free State
CVB	1688.027	D/E/F	CR	Not protected	10	Free State
CVB	410.7382	A/B	CR	Not protected	9	Free State
CVB	137.7787	D/E/F	CR	Not protected	8	Free State
CVB	357.7044	D/E/F	CR	Not protected	8	Free State
UVB	252.9316	D/E/F	CR	Not protected	10	Free State
CVB	117.1763	C	CR	Not protected	8	Free State

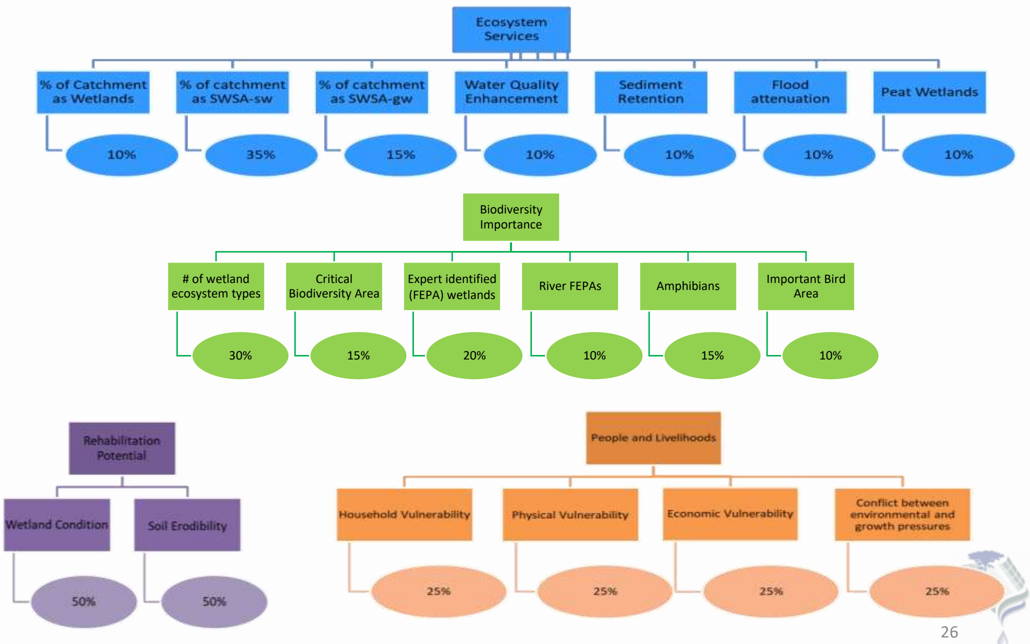
24

Wetlands: Free State



25

WfWet Strategic Planning Process



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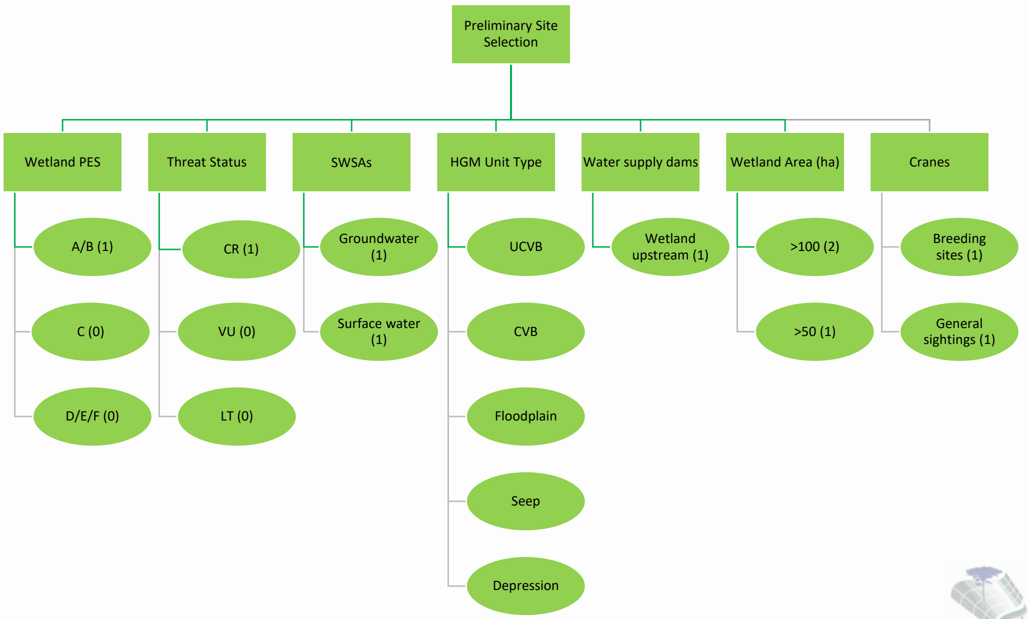
Upper Orange Reserve: Wetland Prioritisation



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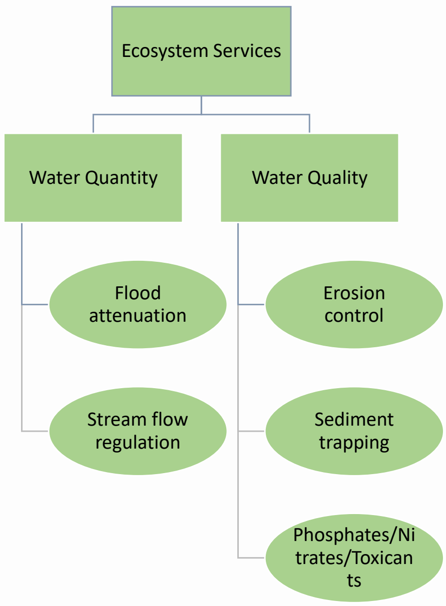
Upper Orange Reserve: Wetland Prioritisation



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HGM Unit & Provision of Ecosystem Services

WETLAND HYDRO-GEO-MORPHIC TYPE	REGULATORY BENEFITS POTENTIALLY PROVIDED BY WETLAND							
	Flood attenuation		Stream flow regulation	Enhancement of water quality				
	Early wet season	Late wet season		Erosion control	Sediment trapping	Phos-phates	Nitrates	Toxicants[2]
1. Floodplain	++	+	0	++	++	++	+	+
2. Valley-bottom - channelled	+	0	0	++	+	+	+	+
3. Valley-bottom - unchannelled	+	+	+?	++	++	+	+	++
4. Hillslope seepage connected to a stream channel	+	0	+	++	0	0	++	++
5. Isolated hillslope seepage	+	0	0	++	0	0	++	+
6. Pan/ Depression	+	+	0	0	0	0	+	+

29

29

Integration with Rivers and Groundwater

- Study sites that integrate all aspects (rivers, wetlands and groundwater) will also need to be considered.
- This will occur once the different disciplines have done a preliminary level of prioritisation and semi-final rankings exist.

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Further Discussion Points

- Input needed into:
  - Criteria considered important
  - Important wetlands for consideration

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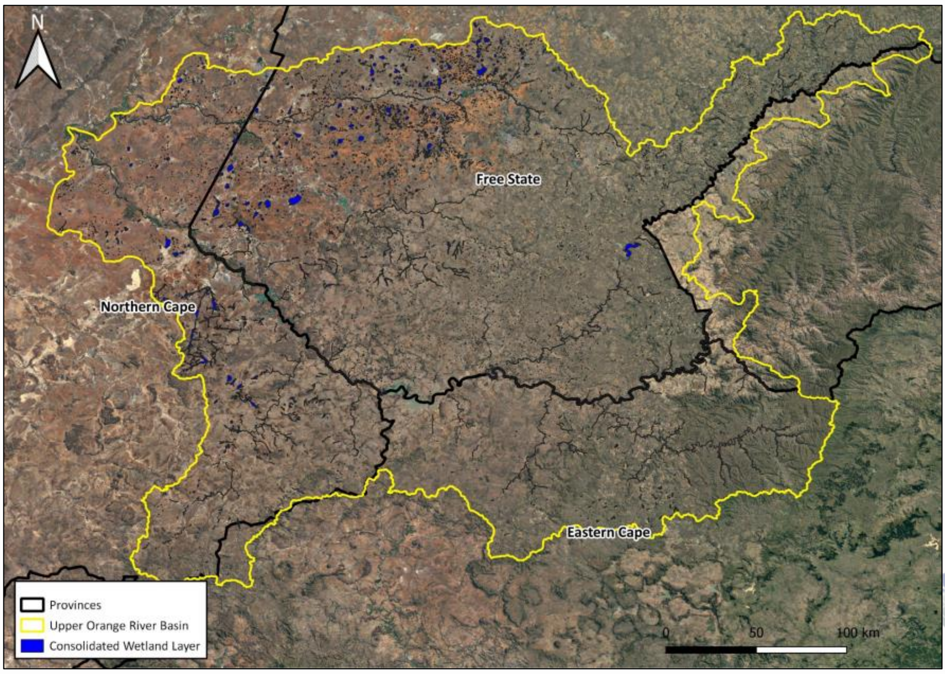

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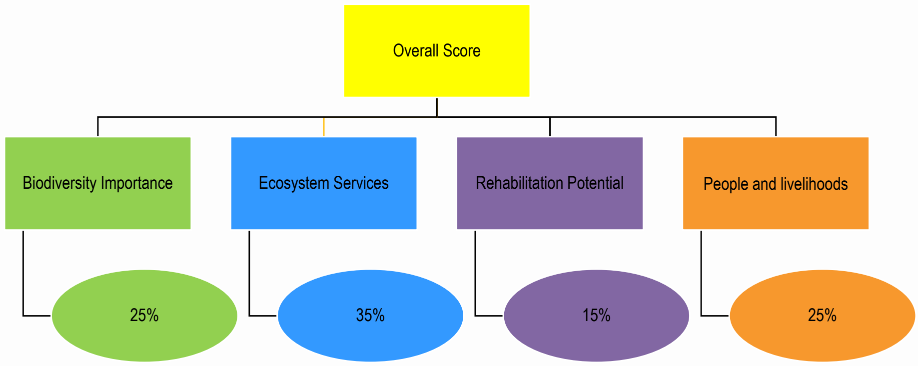
WfWet Strategic Planning



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Appendix D: Groundwater RU and Wetland RU Capacity Building Presentation

Upper Orange

Groundwater Resource Unit Capacity Building:

4 February 2023

CITY OF CAPE TOWN ISIXEKO SASEKAPA STAD KAAPSTAD

JG AFRIKA

1

GRU Approach

- WRC (2007) manual as guidance for GRU delineation
- Primary, Secondary and Tertiary delineations
- Primary
  - » Quaternary catchment by definition
- Secondary
  - » Aquifer type
    - Subsurface conditions play an important role in controlling geohydrological conditions
    - 4 Main types of aquifers
      - Intergranular (primary)
      - Fractured (secondary)
      - Fractured & Intergranular
      - Karst (dolomitic)
- Tertiary
  - » No formal method for delineating GRU beyond the 2nd level , expert judgment required based on conceptual understanding
  - » Physical Criteria
  - » Management Criteria
  - » Functional Criteria

JG AFRIKA

2

GRU for Upper Orange Catchment

- Primary
  - » Quaternary catchment (WR2012)
- Secondary
  - » Aquifer type
    - 4 Main types of aquifers
      - Intergranular (primary)
      - Fractured (secondary)
      - Fractured & Intergranular
      - Karst (dolomitic)
- Tertiary
  - » Physical Criteria (WR2012)
    - Borehole Yield (2.0l/s)
    - Groundwater Quality (EC below and above 70mS/m)
    - Recharge (20mm per annum)
    - Stressed Catchments (where Re < GW(baseflow) + BHN + GW(use)
  - » Management Criteria
    - Political boundaries (Provinces)
  - » Functional Criteria
    - Maintaining system integrity, discharge integrity or ecological integrity (mainly for prioritizing)

JG AFRIKA

3

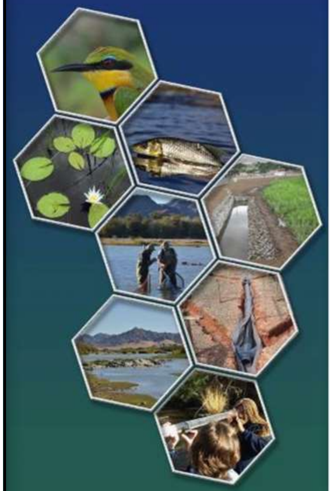
Prioritisation of GRUs

- Abstraction (WARMS)
  - » Hotspots identified
- Wetlands
  - » Major systems identified and overlayed
- Strategic Groundwater Resources
- If yes to all above, the GRU has been prioritised

JG AFRIKA

4

DWS Upper Orange Reserve Determination



4 February 2022

A High Confidence Reserve Determination Study for the Upper Orange Catchment -

Wetland & Groundwater RUs Workshop

(WP11343)

GroundTruth

1

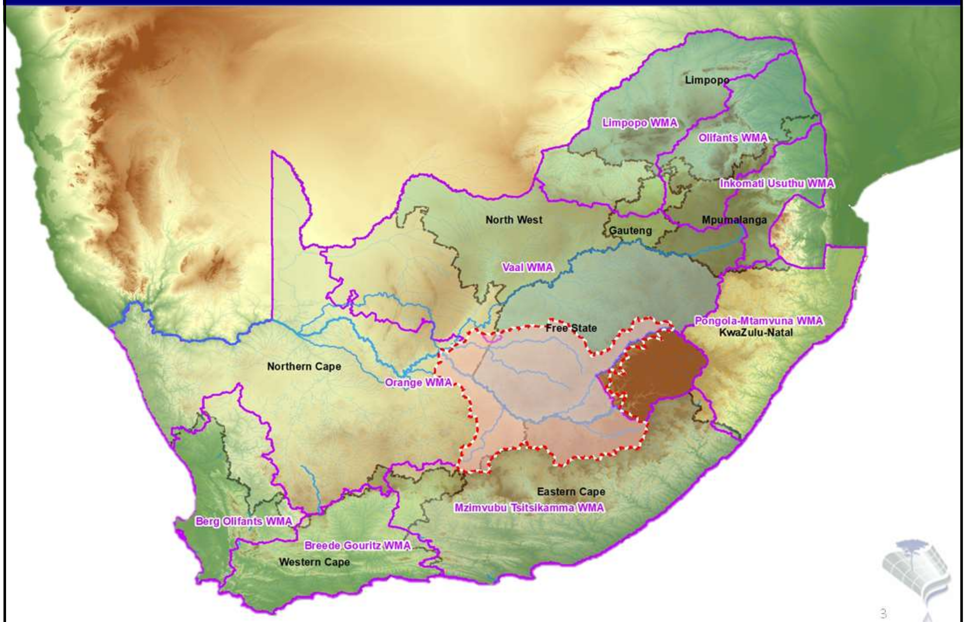
Agenda

1.	WELCOME & INTRODUCTIONS	15min
2.	APOLOGIES	5min
3.	PROJECT RECAP	5min
4.	PRESENTATION OF IDENTIFIED GROUNDWATER RESOURCE UNITS	60min
5.	PRESENTATION OF IDENTIFIED WETLAND RESOURCE UNITS	60min
	BREAK (15min)	
6.	DISCUSSION REGARDING INTERGRATION OF COMPONENTS (RIVERS, WETLANDS AND GROUNDWATER) AT SELECTED SITES (KRAAI / SEEKOEI / LOWER MODDER)	30min
7.	GENERAL DISCUSSION/ITEMS	15min
8.	CONCLUSION OF THE MEETING	5min

2

2

Study Area



3

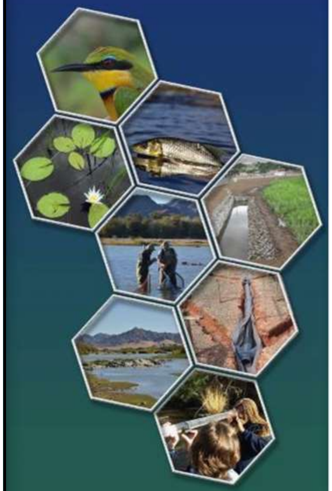
3

Overall Study Objectives

- Identify the gaps to be addressed in the Upper Orange catchment.
- To determine the Reserve (quantity/quality of the EWR and BHN for the rivers at various EWR sites).
- Determine the water quantity/quality component of the EWR and BHN for the priority wetlands/wetland clusters where applicable.
- Determine the groundwater quality/quantity component of the BHN and the groundwater quantity component of the EWR for each resource unit/quaternary catchment in the study area.
- Address priority water resources identified to be investigated.
- Assess and evaluate operational scenarios, considering water transfers and developments in Lesotho.
- Determine ecological specifications/protection measures to support the Reserve requirements.
- Prepare the EWR and BHN templates for the Upper Orange Reserve.

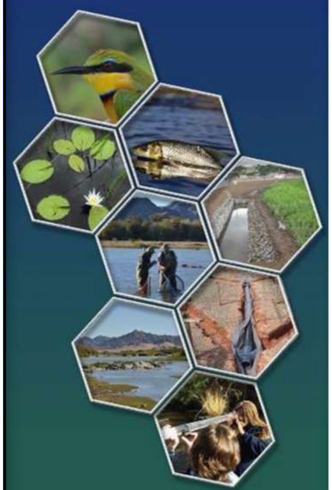
4

4



Groundwater RUs

5



Wetland RUs

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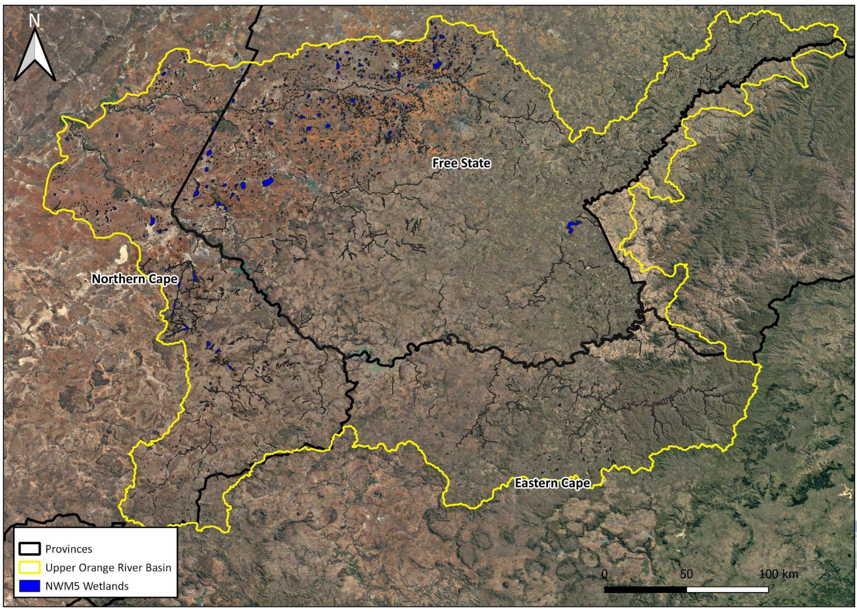
Wetlands: NWM5



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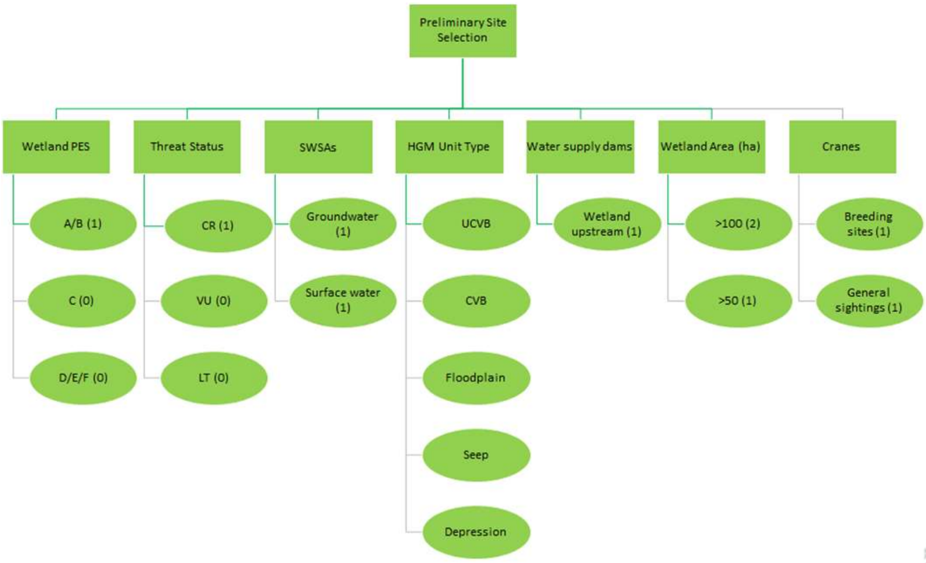
Wetland Prioritisation – Multi-criteria Analysis



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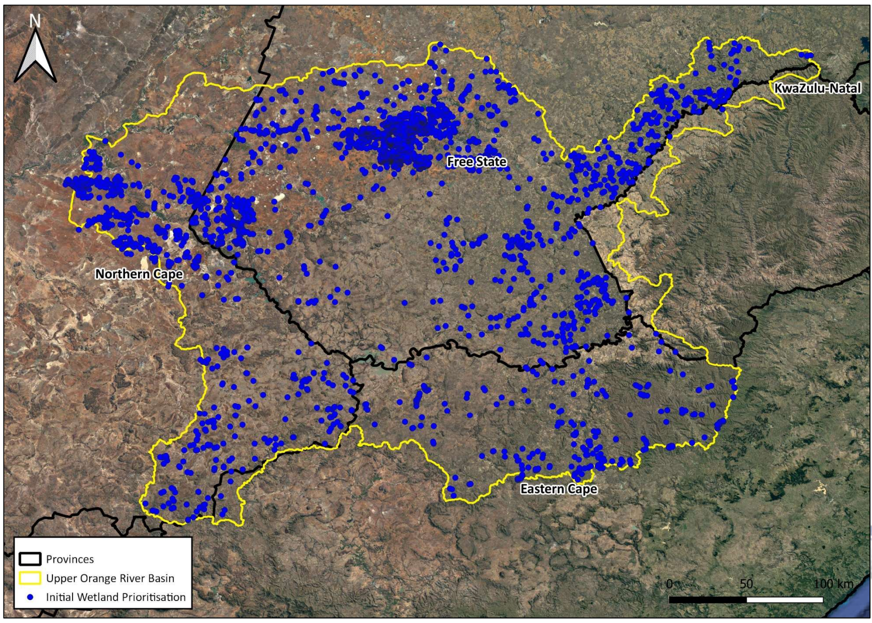
Wetlands: Prioritised Wetland Systems



9

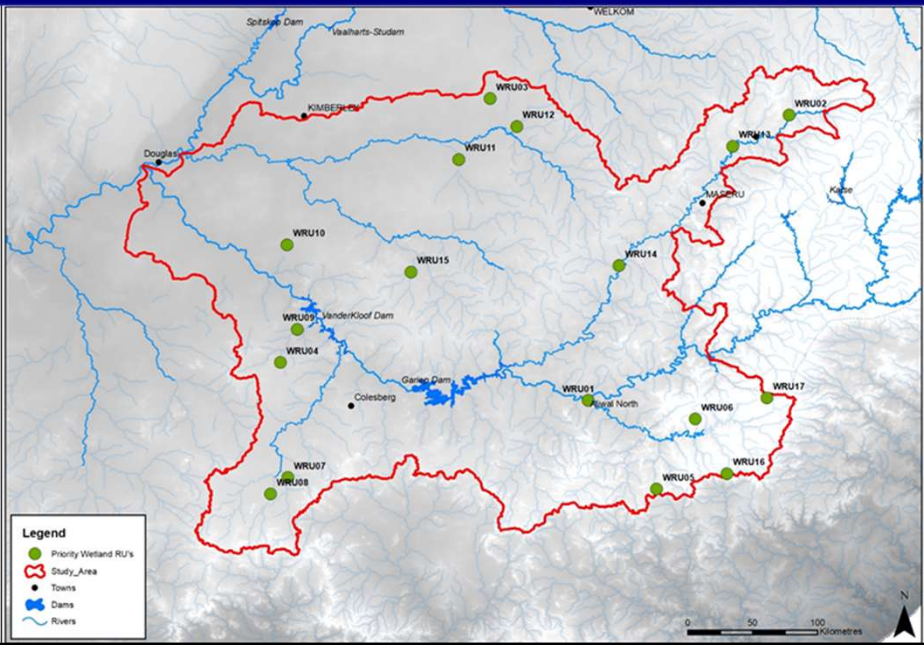
Finalised Wetland RUs

- Following the MCA, a manual review of the entire study area was undertaken
- The following spatial layers were used to inform the desktop prioritisation:
  - Presence of surface and/or groundwater SWSAs;
  - Preliminary River RU quaternary catchments;
  - Top 10% of quaternary catchments identified through the WfWets strategic planning for the Eastern Cape, Northern Cape and Free State provinces;
  - Specific important wetland areas identified by individual stakeholders; and
  - Quaternary catchments identified with the highest recorded water uses (water quantity).

10

10

Overview of the Finalised Wetland RUs



11

Appendix E: Site Selection for Rivers, Wetlands and Groundwater Capacity Building Presentation

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

NATIONAL DEVELOPMENT PLAN
Our Future - make it work

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment (WP11343)

Capacity building
Site selection and survey preparation (rivers, wetlands, groundwater)

23 March 2022

WATER IS LIFE - SANITATION IS DIGNITY

1

Rivers: Site Selection

2

Rivers: Site Selection

- Consists of a river length which can include one or more cross-section for hydraulic modelling and ecological evaluation/ assessment
- Sites are selected through a multi-disciplinary process by the evaluation of Google Earth images to identify possible sites, and ground-truthing during surveys to select final site
- The sites are selected to provide information about the variety of conditions in a river reach related to the available habitats

Detail process described in BBM Manual, 1999 RDM Methods and adapted in DWA, 2013

3

Rivers: Site Selection Considerations

Locality of:

- Priority RUs (stressed areas, hotspots)
- Gauging weirs with good quality hydrological data
- Characteristics of tributaries

Ecological :

- Level II EcoRegions (one site per ecoregion)
- Geomorphological zones
- Habitat diversity for aquatic organisms, marginal and riparian vegetation or critical for ecosystem functioning
- Suitability of the sites for accurate hydraulic modelling (range of possible flows, especially low flows)

4

Rivers: Site Selection

Specific Considerations

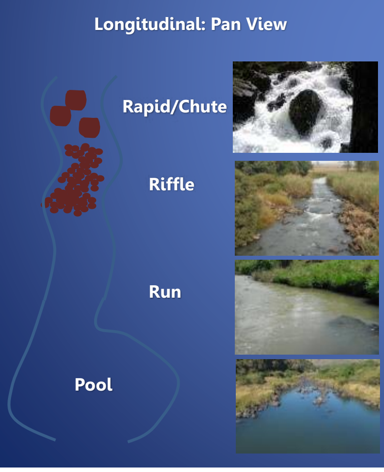
- **What is the critical habitat within the system/ reach?**
- **Is the site representative of the system/ reach?**
- **Is the site suitable for sampling?**
- **Other considerations**

5

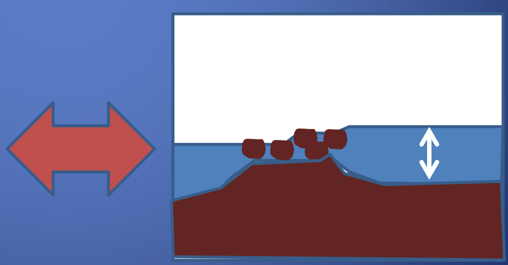
Site selection: Representivity

What is the critical habitat within the system/ reach?

If flow increase/ decrease, which habitat will be most affected?



Pools in perennial rivers are not considered as critical as they are still able to function as refuge habitats during periods of no flow.



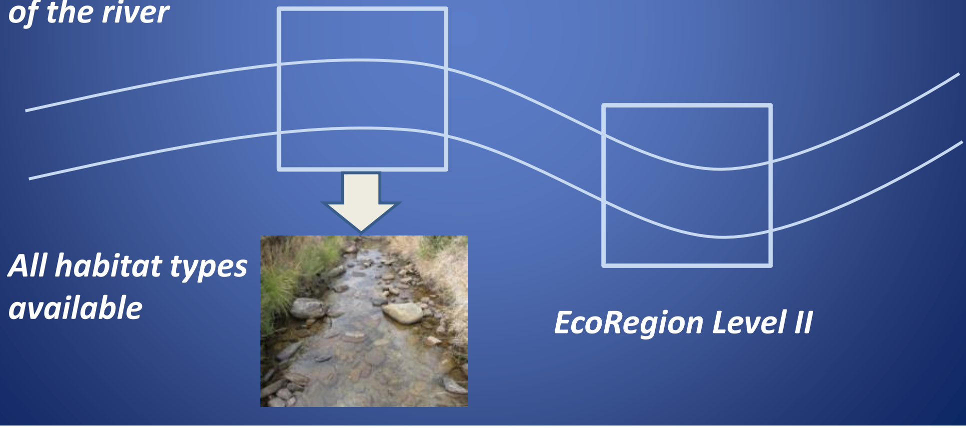
Pools are considered as important/ critical for seasonal/ intermittent rivers

6

Site Selection: EcoRegions

Is the site representative of the system?

Representivity: Results from the EWR site can be extrapolated to the rest of the river reach because the site is representative of the river



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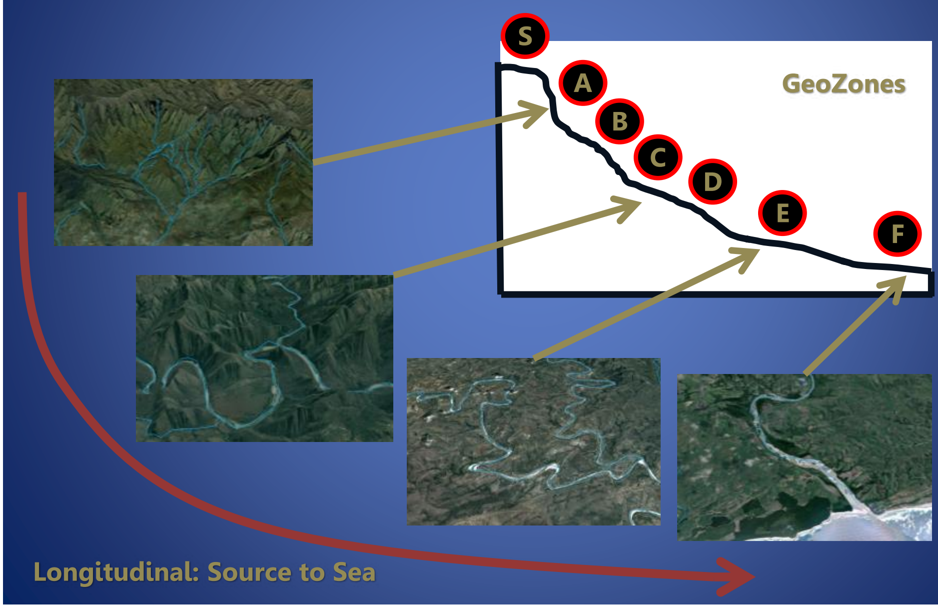
Site Selection: Geomorphic zones



8

Site Selection: Geomorphic examples

9

Site Selection: Sampling suitability

Is the site suitable for sampling?

- *Hydrology (gauges)*
- *Hydraulics*
- *Fish (habitats, velocity-depth-classes)*
- *Macroinvertebrates (habitats)*
- *Vegetation (Intermediate and Comprehensive)*
- *Geomorphology (Intermediate and Comprehensive)*
- *Safety*

10

Site Selection

Is the site suitable for sampling?

- *Hydrology*
  - *e.g. how high up in the catchment are we?*
  - *e.g. is there a gauging weir that we can use?*
  - *Ideal? good quality hydrological data*

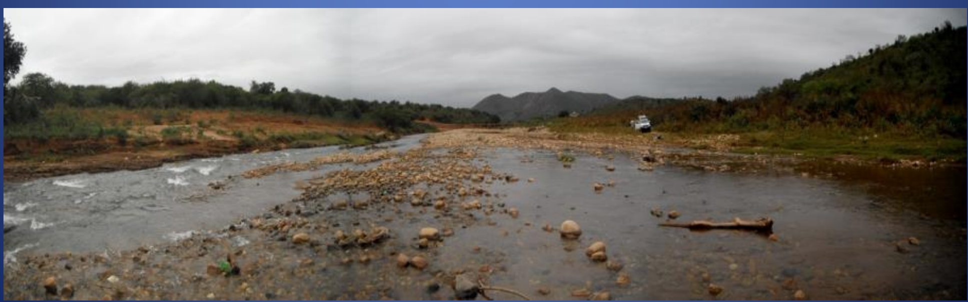
vs

11

Site Selection

Is the site suitable for sampling?

- *Hydraulics*
  - *Can we accurately calculate the discharge of the river at the site?*
  - *Bends, islands, side/ multiple channels, bridges and bars, slope, inundation – confidence of modelled results*
  - *Ideal? U-shaped cross section in a straight channel*

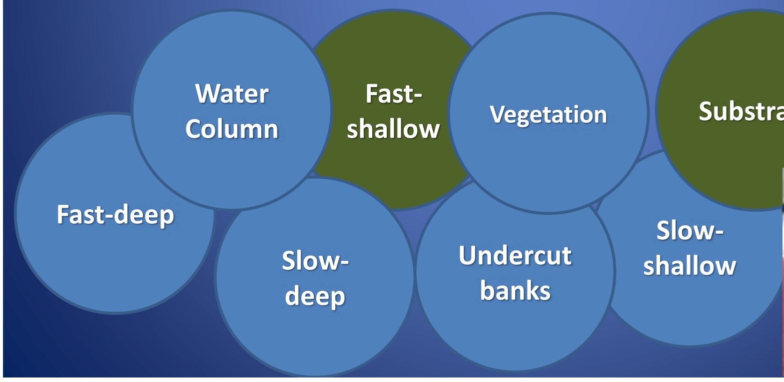


12

Site Selection

Is the site suitable for sampling?

- ***Fish***
  - ***What fish habitats are available at the site?***



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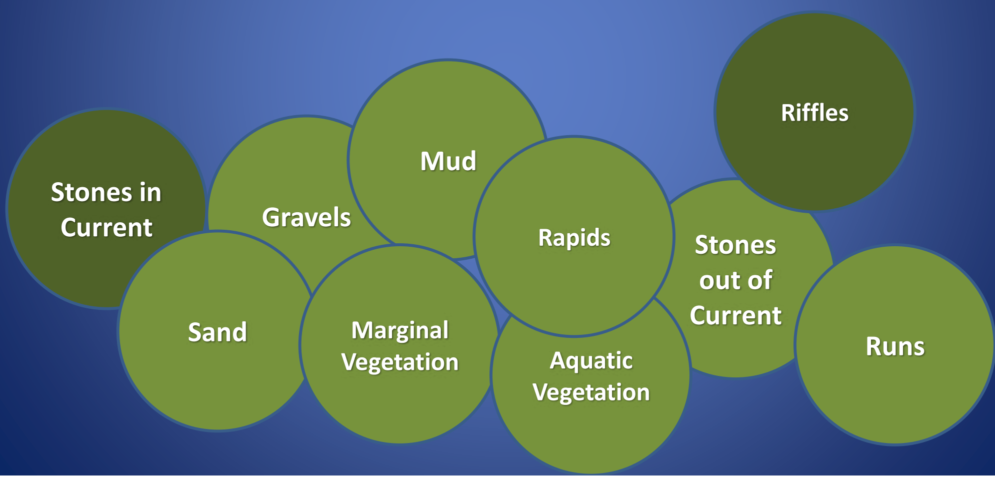
Site Selection

Is the site suitable for sampling?

- ***Macroinvertebrates***
  - ***What biotopes are available at the site?***



14

Site Selection

Other considerations

- *Availability of historical data (e.g. REMP, existing EWR Site, previously baseline studies)*
- *Suitability of the site for follow-up monitoring*
- *Direct dependence of people on the river or ecosystem*
- *Accessibility of the site*
- *Safety (both high flows and theft)*
- *Sites can be excellent ecological sites, but poor hydraulic sites or visa versa*

15

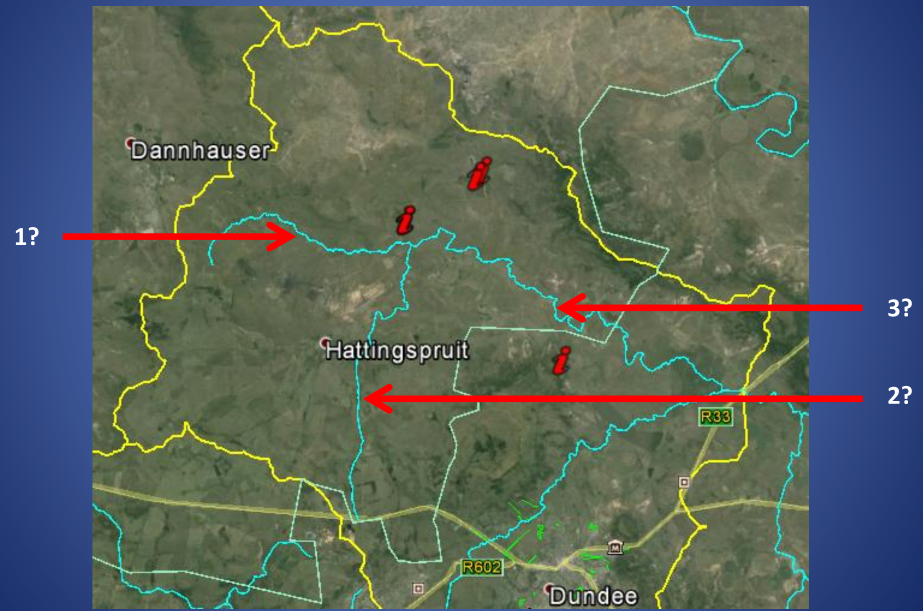
Site Selection

Does the ideal site exist?

Generally a trade-off and we need to select the best option

16

Site Selection: Potential sites



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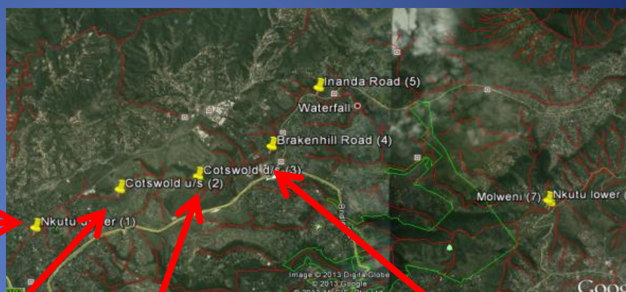
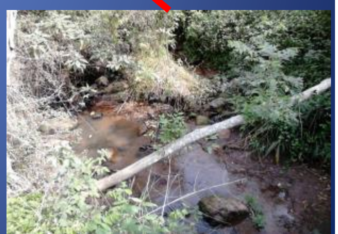
Site Selection

Potential sites





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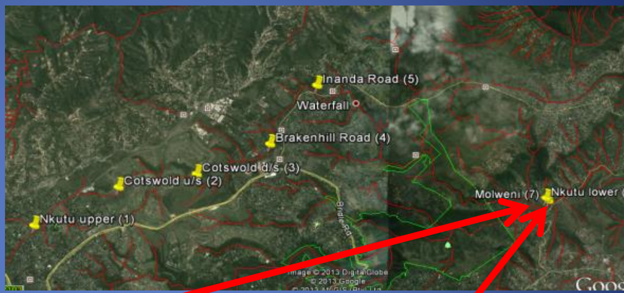
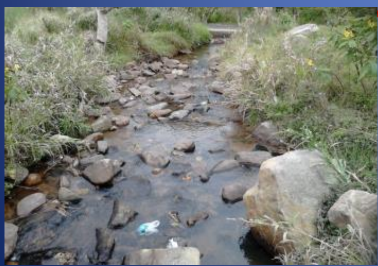
Site Selection

Potential sites





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Site Selection

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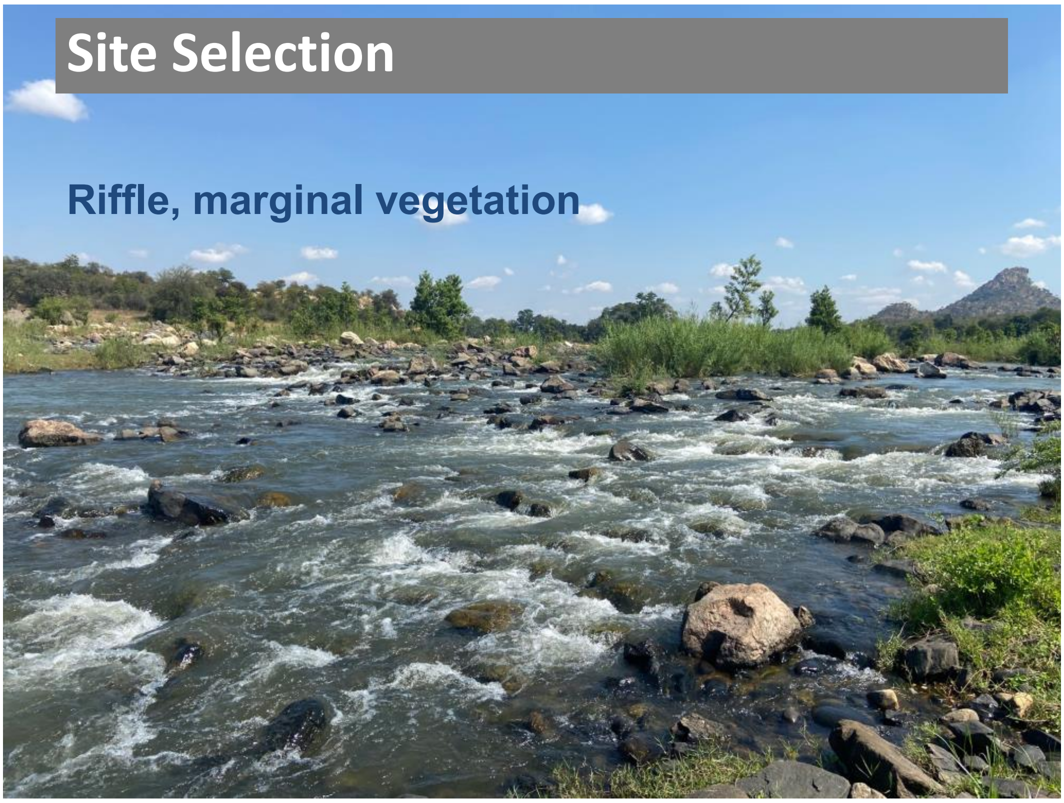
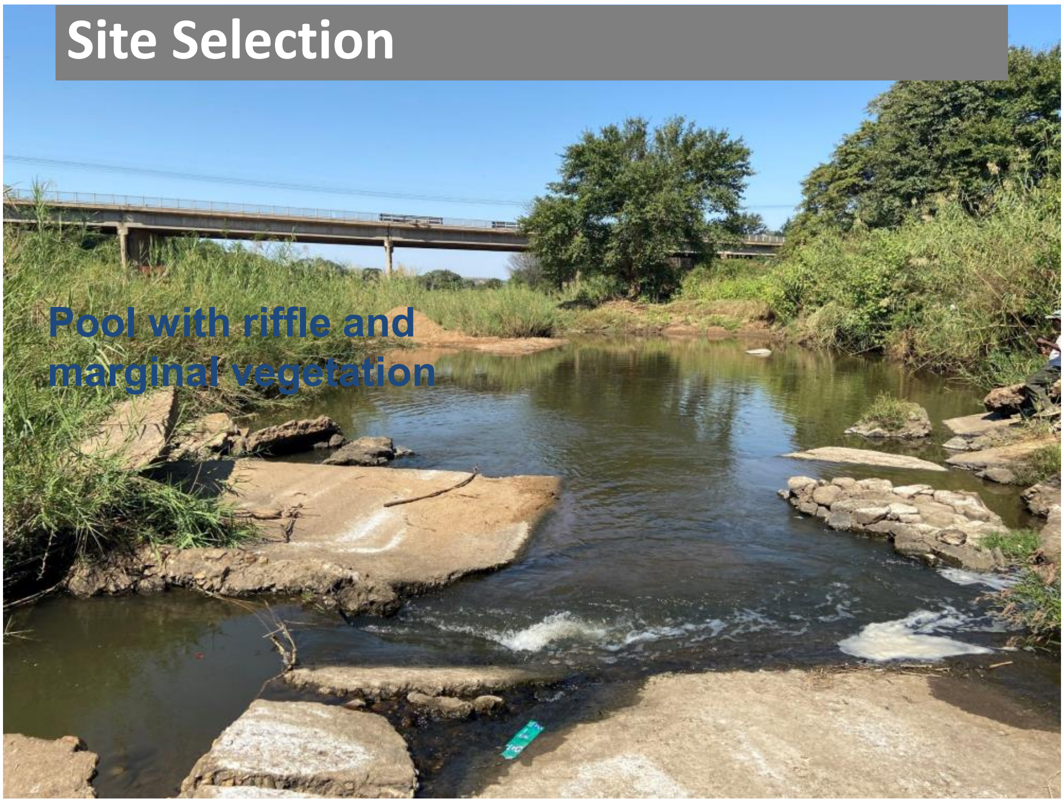

Site Selection
Riffle, marginal vegetation

21


Site Selection
Pool with riffle and
marginal vegetation

22

23

Wetland RUs

- MCA of the NWM5 coverage based on selected criteria e.g. PES, Threat Status, HGM Unit type, Water supply dams etc.
- Followed by a manual review of the prioritised wetlands considering additional spatial data:
  - Presence of surface and/or groundwater SWSAs;
  - Preliminary River RU quaternary catchments;
  - Top 10% of quaternary catchments identified through the WfWets strategic planning for the Eastern Cape, Northern Cape and Free State provinces;
  - Specific important wetland areas identified by individual stakeholders; and
  - Quaternary catchments identified with the highest recorded water uses (water quantity).

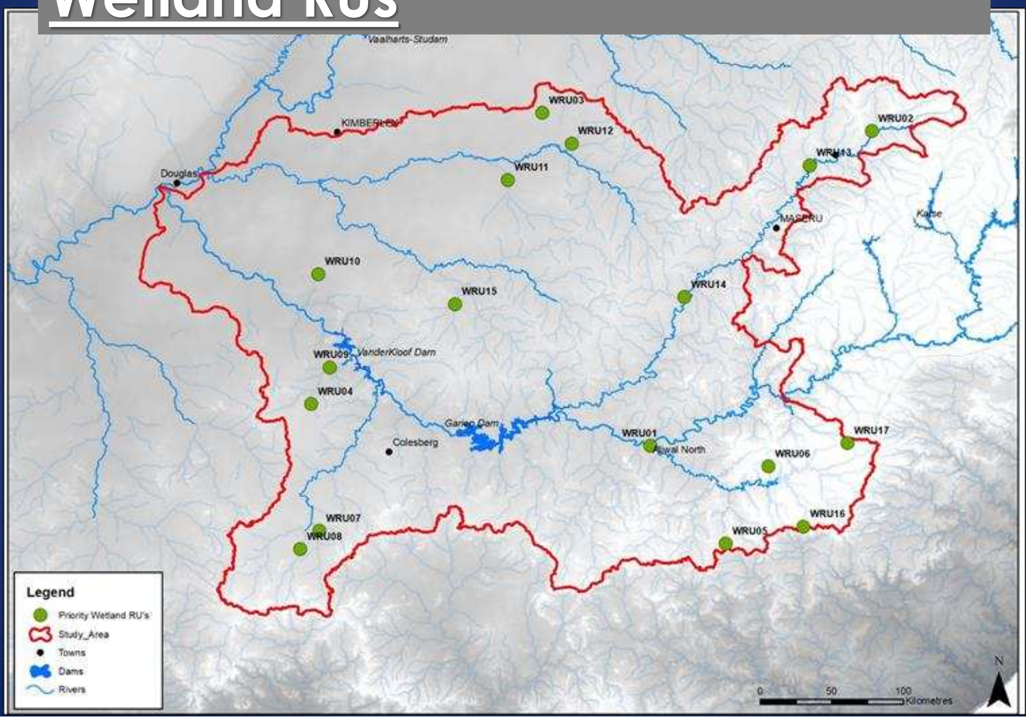
24

Desktop Refinement of RUs

- Further refinement of the selected wetlands, included the desktop review of aerial imagery:
  - Verification of HGM unit type
  - Review of landscape context
  - In-system impacts - overall integrity of the wetland
  - Catchment related impacts
- Results: 17 RUs spread across the 3 provinces

25

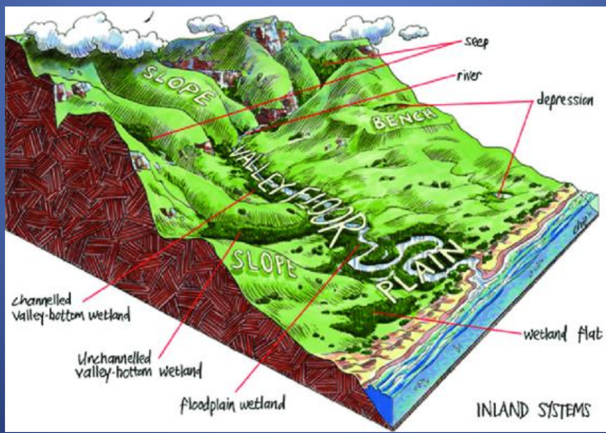
Wetland RUs



26

Wetlands: Site Selection

- Many of the RUs comprise of **wetland complexes** (i.e. multiple HGM units
- Fieldwork will serve to **finalise** the extent and nature of the wetland systems included in the complex/RU



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Wetlands: Site Selection

- Site selection will look to consider :
  - Is the site representative of the wetlands within the broader landscape in terms of HGM unit type, wetness regimes and vegetation characteristics?
  - What is the critical habitat within the wetland complex and is there a diversity of habitats e.g. zones of wetness, emergent or short vegetation?
  - Accessibility and/or existing data/research

28

Groundwater Field Verification

- Verification of existing DWS monitoring points
  - WMS data
    - > 1900 monitoring sites with groundwater quality data, but need to be selective
  - Hydstra data
    - Seasonal fluctuation in water levels
- Verification of WARMS (municipal mainly)
  - > 20 towns are dependent on groundwater
  - Status to be verified
- Surface flow data and groundwater levels at selected sites in close proximity to significant GDEs

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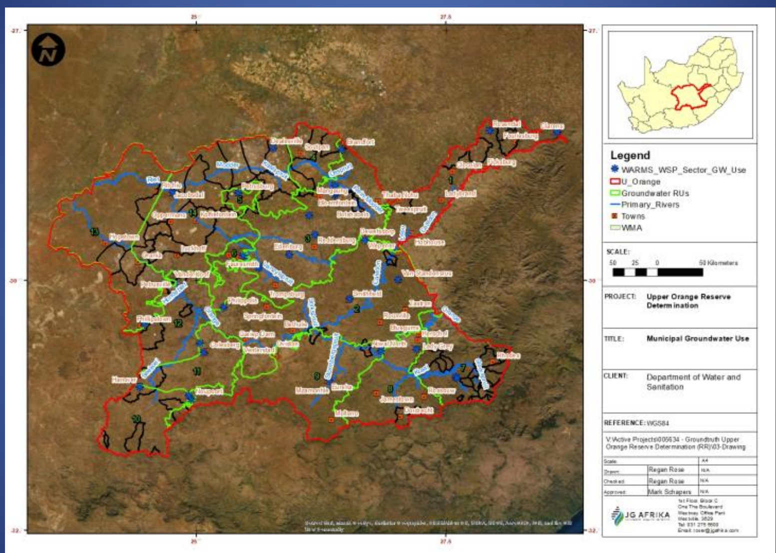

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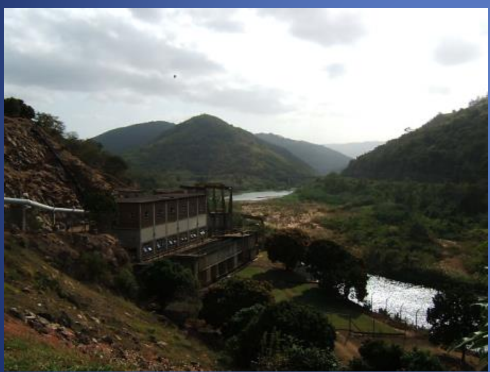
Groundwater Field Verification

- Site selection based on:
  - Active sites mainly that are easily verifiable in the field
  - Representative of aquifer or part of aquifer
  - Long term historical data an advantage
  - Spatial distribution within the catchment
  - Unimpacted vs impacted condition, ideally need to have a bit of both
- Analyses required for:
  - Recharge determination (Chloride mass balance/Isotopes/SVF)
  - Groundwater Contribution to Baseflow (Baseflow separation techniques)
  - GDE systems (Groundwater elevation model)

31

Discussion

- Preparation for site visit



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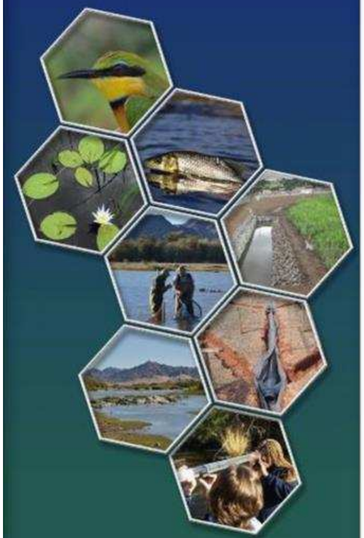
Appendix F: River's Eco-categorisation Capacity Building Presentation – Part 1

Eco-Categorisation Capacity Building



28 July 2022

A High Confidence Reserve Determination Study for Surface Water, Groundwater, and Wetlands in the Upper Orange WP11343

GroundTruth

1

Agenda

- Purpose of capacity building workshop
- Ecological Categorisation
- Capacity building workshop example: LOWER KRAAI (rapid 3)
  - Site description
  - Index of habitat integrity (IHI)
  - Macroinvertebrate response assessment index (MIRAI)
  - Fish response assessment index (FRAI)
  - Eco-Status Level 4

2

2

Purpose of the Capacity Building Workshop

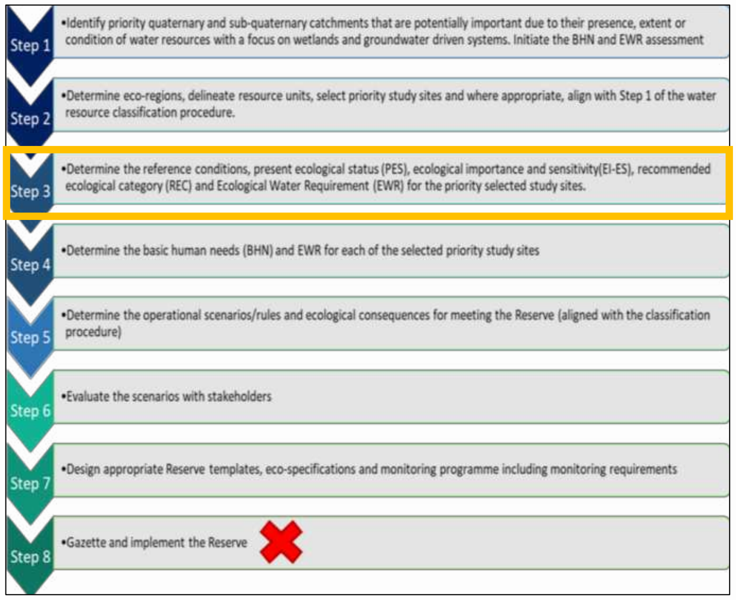
- Dry season river field survey: 4 – 15 July 2022
- Intermediate, Rapid 3 and field verification sites
- Driver components included:
  - Geomorphology
  - *In situ* water quality
  - Hydrology (cross-sections and discharge)
- Response components included:
  - Fish
  - Aquatic macroinvertebrates
  - Index of habitat integrity
  - Diatoms

Specialist team	DWS team	Additional capacity building colleagues
Retha Stassen	Ndivhuwo Netshiendeulu	Hendrik Sithole (SanParks)
Dr Bennie Van Der Waal	Jan Makhetha	
Byron Grant	Tinyiko Mpete	
Kylie Farrell	Keamogetse Molefe	
	Pule Liatile	
	Basetsana Mokonyama	

3

Ecological Categorisation

- Ecological Categorisation (Eco-Categorisation) phase of the study



- Accordance with the 8-step Reserve determination process
- Step 3
- Outlined in the Establishment of a Water Resource Classification System (WRCS) as per Regulation 810 (Government Gazette 33541) dated 17 September 2010

4

4

Ecological Categorisation

- Eco-categorisation is the determination and categorisation of the PES (health and/or integrity) of various biophysical attributes of rivers relative the natural or close to the natural reference condition.
- These results then provide the information needed to derive desirable and attainable future ecological objectives for the rivers
- Document the results of all identified EWR sites within the Upper Orange catchment
- Based on available data (PES, 2014, JBS2, JBS3, ORASECOM EFR 2010 (Kraai, 2 sites on Caledon, 1 on Orange River), high confidence study on 4 sites on Seekoei River)
- Compared with present data: Rapid3 (July 2022) and Intermediate (July and November 2022)
- All relevant to the gazetting of the Reserve.

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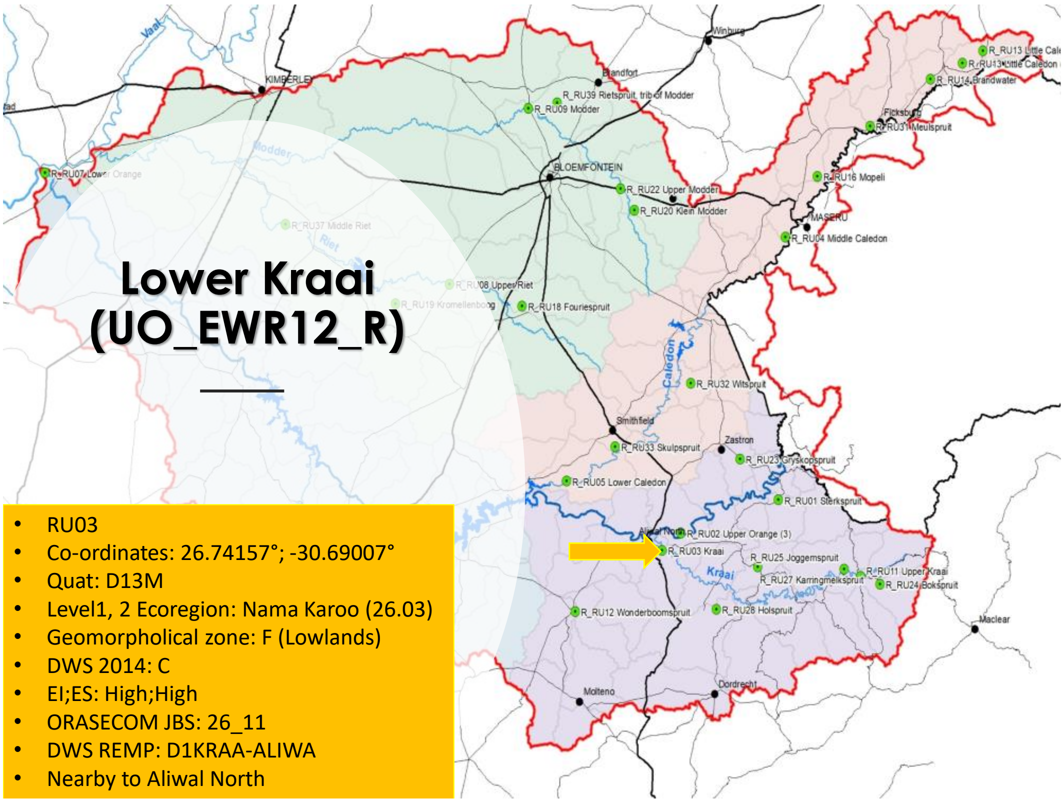
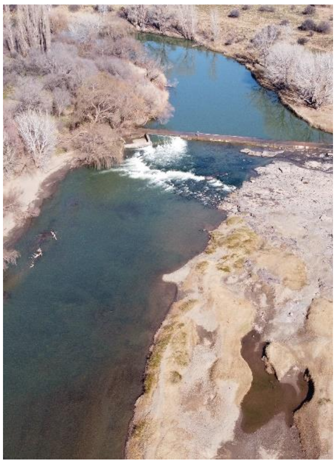
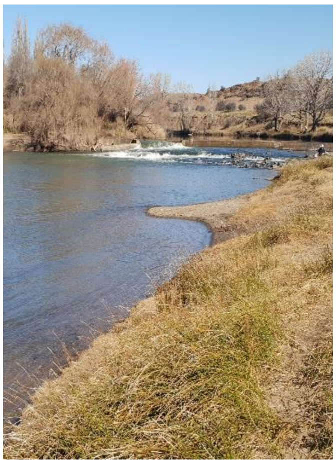


Lower Kraai (UO_EWR12_R)

- RU03
- Co-ordinates: 26.74157°; -30.69007°
- Quat: D13M
- Level1, 2 Ecoregion: Nama Karoo (26.03)
- Geomorphological zone: F (Lowlands)
- DWS 2014: C
- EI;ES: High;High
- ORASECOM JBS: 26_11
- DWS REMP: D1KRAA-ALIWA
- Nearby to Aliwal North

6

LOWER KRAAI (Rapid 3)

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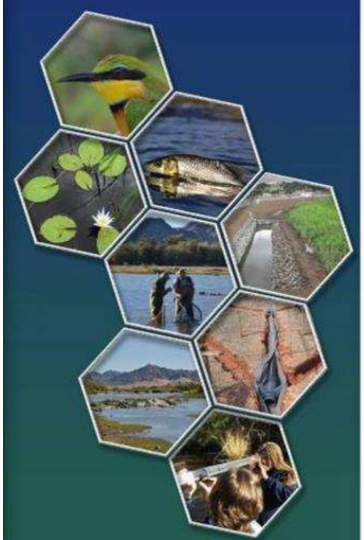
Index of habitat integrity
(IHI)



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GroundTruth

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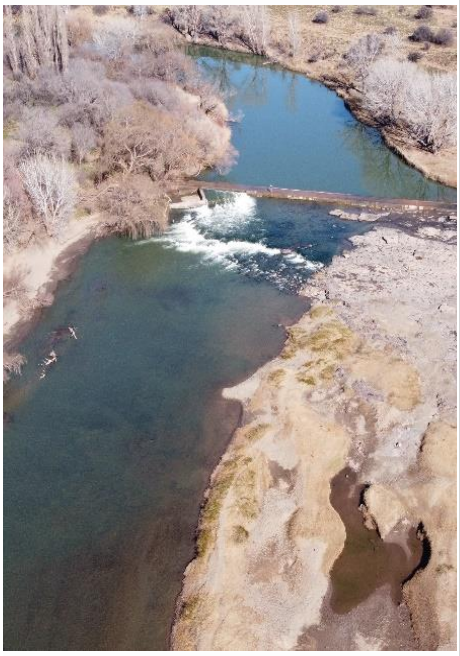
IHI

- Module G: Index of Habitat Integrity, Section 2: Model Photo Guide
- Microsoft Word - IHI_Instreamphoto.doc (dws.gov.za)
- Instream (1-25): Instream integrity score and class
  - Water abstraction
  - Flow modification
  - Bed modification
  - Channel modification
  - Physical-chemical modification
  - Inundation
  - Alien macrophytes
  - Introduced aquatic fauna
  - Rubbish dumping
- Riparian (1-25): Riparian integrity score and class
  - Vegetation removal
  - Exotic vegetation
  - Bank erosion
  - Channel modification
  - Water abstraction
  - Inundation
  - Flow modification
  - physical-chemical

9

9

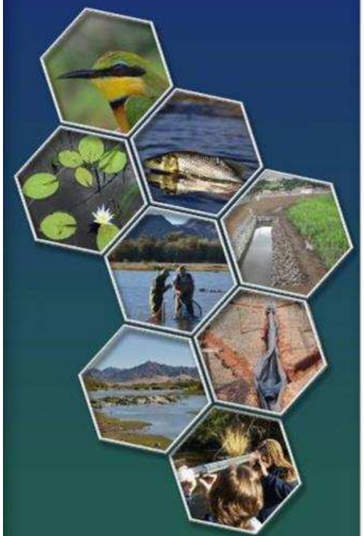
IHI: Lower Kraai



Instream		
Criteria	**Score**	**Rationale**
Water abstraction	9	Irrigation
Flow modification	2	
Bed modification	6	Low water causeway at site, rest of reach less impacted
Channel modification	4	Widening because of causeway at site, sand mining
Physical-chemical modification	5	Algae instream only
Inundation	7	During high flows/ floods in Orange Low causeway results in inundation upstream
Alien macrophytes	0	
Introduced aquatic fauna	6	Carp present, some trout from upstream
Rubbish dumping	2	Localised
Instream PES	**81**	**B/C**
Riparian		
Vegetation removal	6	Roads, tracks
Exotic vegetation	9	Salix, poplars
Bank erosion	8	Some erosion at site, weir/ causeway
Channel modification	6	Localised – cutting for road, sand mining
Water abstraction	3	
Inundation	4	Upstream of causeway
Flow modification	1	
Physical-chemical modification	2	
Riparian PES	**80**	**B/C**

10

Macroinvertebrate Response Assessment Index *(MIRAI)*



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GroundTruth

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Recap: Aquatic macroinvertebrates

- Why aquatic macroinvertebrates:
  - Act as indicators of overall ecological condition
  - Responses to environmental impacts/localised disturbances is detectable in terms of the community as a whole
  - Habitat, water quality, river conditions driven, thus:
    - Communities offer a good reflection of the prevailing flow regime and water quality in a river.
  - Easy to sample and identify
  - Relatively sedentary
  - Rapid results
- Sampling and modeling aquatic macroinvertebrate communities:
  - Macroinvertebrates are samples using the standard SASS5 (Dickens and Graham, 2002), published method (ISO 17025 accredited)
  - Modelled using the Macroinvertebrate Response Assessment Index (MIRAI)) (Thirion, 2008)

12

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Tool Showcase – MIRAI Model

- Thirion C. 2008. Module E: *Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report no. TT 332/08*
  - MIRAI is used to determine the macroinvertebrates ecological condition (EC)
  - Done through the integration of the ecological requirements of the invertebrate taxa in a community and their response to modified habitat conditions.
- Aim of the MIRAI:
  - To provide a habitat-based cause-and-effect foundation to interpret the deviation of the macroinvertebrate community from the reference condition.

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MIRAI Model

- Information required for the model:
  - Reference conditions
  - Data collected (present data or 1 hydrological year's worth of data if REMP site)
  - Habitat/biotope assessment
- Determining the EC
  - 4 metric groups that measure the deviation of the macroinvertebrate community from the reference community
    - Flow modification
    - Habitat modification
    - Water quality modification
    - System connectivity and seasonality (only used for migratory taxa (Paleomonidae and *Varuna*) are expected to occur under reference conditions)

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MIRAI Model

- Determining the EC
  - Each macroinvertebrate taxon has been assigned a velocity, habitat, water quality preference score
  - Ratings:
    - 0 = No change from reference
    - 1 = Small change from reference
    - 2 = Moderate change from reference
    - 3 = Large change from reference
    - 4 = Serious change from reference
    - 5 = Extreme change from reference
  - The metric ranked 1 (most important) is weighted 100%. Other metrics are then ranked as a percentage relative to the most important metric.
- SASS5 score and ASPT value rating and ranking (present vs reference)

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MIRAI Model

- The 4 metric groups are combined to derive the EC

Which of these measures will best indicate the response of invertebrates (*in this system at this site*)

		INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS					
INVERTEBRATE EC METRIC GROUP		METRIC GROU CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCO OF GROUP	RANK OF METR GROUP	% WEIGHT FOR METRIC GROU	COMMENTS
FLOW MODIFICATION	FM	#DIV/0!	#DIV/0!	#DIV/0!			
HABITAT	H	#DIV/0!	#DIV/0!	#DIV/0!			
WATER QUALITY	WQ	#DIV/0!	#DIV/0!	#DIV/0!			
CONNECTIVITY & SEASONALITY	CS	60.0	#DIV/0!	#DIV/0!			
						0	
INVERTEBRATE EC				#DIV/0!			
INVERTEBRATE EC CATEGORY				#DIV/0!			
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F							

- Which of these metrics best indicate the response of invertebrates in this system at this particular site/reach
- Rank of metric 0 - 5 (1 = most responsive and (5 = least responsive)
- Give 100% to rank 1, then how big the impact of each of the others is as a % of that
- Lowest metric group calculated score indicates the primary driver of change
- EC: >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

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MIRAI Showcase

- LINK to MIRAI Model

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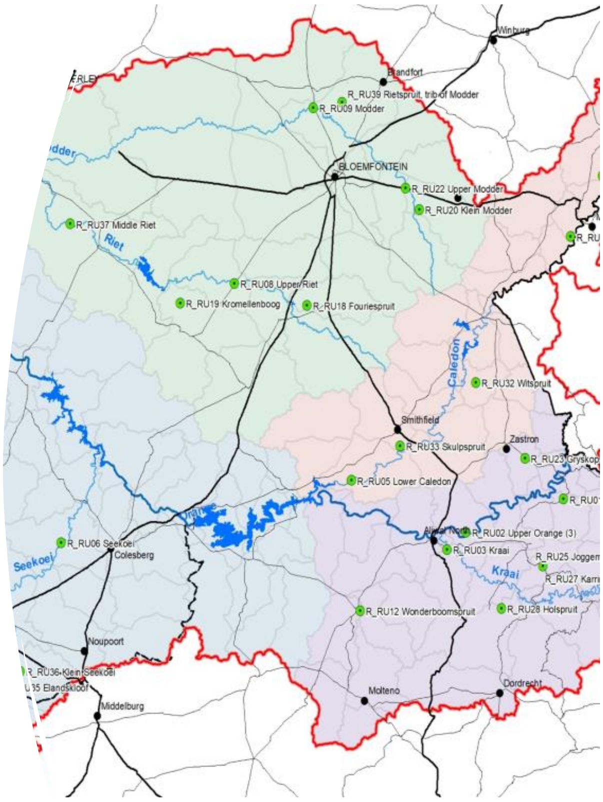
What is the MIRAI telling us



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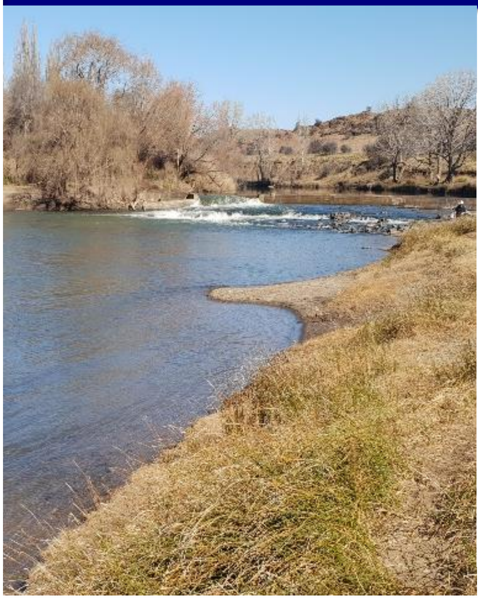
MIRAI: Lower Kraai



INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	62.9	0.230	14.4267	3	70
HABITAT	H	56.5	0.328	18.5229	1	100
WATER QUALITY	WQ	58.1	0.279	16.1921	2	85
CONNECTIVITY & SEASONALITY	CS	80.0	0.164	13.1148	4	50
						305
INVERTEBRATE EC				62.2566		
INVERTEBRATE EC CATEGORY				C		

- Driver of change: habitat and water quality was the most impacted metric, followed by flow modification
  - Limited to no marginal vegetation – representative of the dry season (vegetation die back and undercut banks)
  - Algae
- EC of community: C (moderately modified)
- Perlidae, Baetidae>2spp. Leptophlebiidae were the only sensitive to moderately sensitive taxa present
- Majority of the taxa had a preferences for cobbles, low velocities (<0.1m3/s) and low requirements for unmodified water quality

- Increased flow velocities due to channel restriction as a result of the low-level crossing reduced preferential habitat for several of the expected taxa
- Increased nutrients (algal growth) further reduced available habitat and taxa preference

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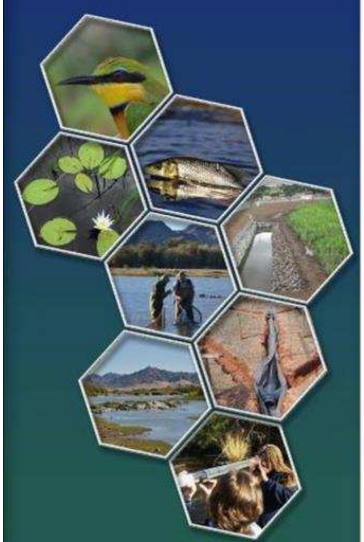
Fish response assessment index *(FRAI)*



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GroundTruth

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Recap: Fish

- Why Fish:
  - Act as indicators of overall ecological condition
  - Long-lived
  - Highly mobile
  - Wide range of preferences in terms of flow, habitat, water quality, etc.
  - Assemblages include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores).
  - They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.
  - Easy to sample and identify
- Sampling and modeling fish communities:
  - Fish can be sampled using a variety of methods, including electro-fishing, gill nets, seine nets, fyke nets, cast nets, angling, snorkeling surveys, etc.
  - Modelled using the Fish Response Assessment Index (FRAI)) (Kleynhans, 2008)

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21

Tool Showcase – FRAI Model

- Kleynhans CJ. , 2008. *Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08*
- FRAI is used to determine the Fish ecological condition (EC)
  - Done through an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions
  - Allows for determination of EC under present state, target state and scenario state
- Aim of the FRAI:
  - To provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived reference condition

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FRAI Model

- Information required for the model:
  - Reference conditions
  - Data collected (present data or 1 hydrological year's worth of data if REMP site)
  - Habitat cover assessment
- Determining the EC
  - 5 metric groups that measure the deviation of the present-day fish community from the reference community
    - Velocity-depth
    - Flow modification
    - Cover
    - Physico-chemical
    - Migration
  - Modifying determinant: Introduced Species

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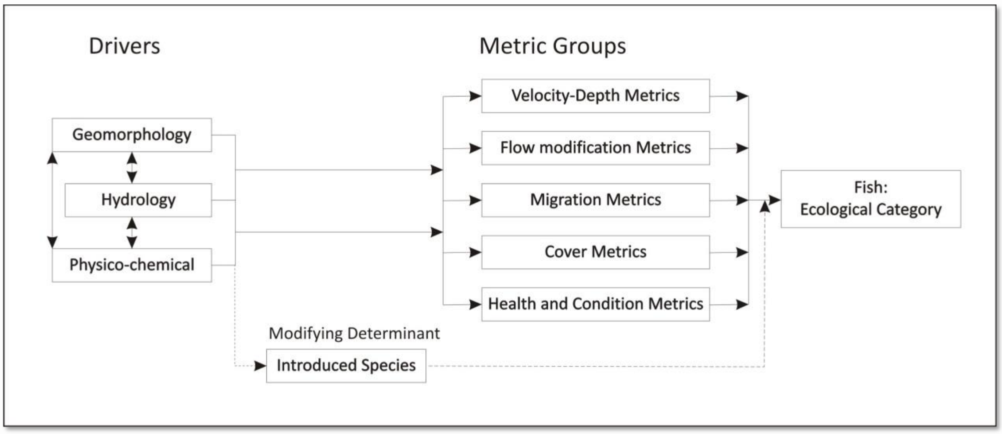
FRAI Model



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FRAI Model

- Determining the EC
  - Each fish species has a has been assigned a velocity-depth, flow, cover and water quality preference score as well as a migration value
  - Within a reach, each species is also assigned a Frequency of occurrence (FROC) rating
  - Each metric is ranked – which metric (if it changed from worst to best) would best indicate good integrity
  - The metric ranked 1 (most important) is weighted 100%. Other metrics are then ranked as a percentage relative to the most important metric.
  - Ratings: 0 = No change from reference · 1 = Small change from reference · 2 = Moderate change from reference · 3 = Large change from reference · 4 = Serious change from reference · 5 = Extreme change from reference

25

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FRAI Model

- Consideration also given to the presence of introduced fish species as an impacting factor
  - Different introduced species have different impacts and different degrees of impact
- Metric Group Weighting exercise
  - According to an Analytical Hierarchical Procedure
  - Goal is to provide a reasonably objective way to determine the weights of metric groups. Consideration in this regard is given to:
    - The natural characteristics of the fish assemblage and its habitat, and
    - When comparing a pair of fish metric groups, which member in the pair would contribute most to a decline or improvement in the fish assemblage integrity if it was to change for whatever reason

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FRAI Model

VELOCITY-DEPTH METRIC GROUP	
VELOCITY-DEPTH VERSUS	COVER
VELOCITY-DEPTH VERSUS	FLOW MODIFICATION
VELOCITY-DEPTH VERSUS	PHYSICO-CHEMICAL
PRESENT VELOCITY-DEPTH VERSUS ->	PRESENT: MIGRATION
5.00	5.00
PRESENT: VELOCITY-DEPTH VERSUS ->	PRESENT: IMPACT OF INTRODUCED
5.00	5.00
TARGET VELOCITY-DEPTH VERSUS ->	TARGET: MIGRATION
5.00	5.00
TARGET: VELOCITY-DEPTH VERSUS ->	TARGET: IMPACT OF INTRODUCED
5.00	5.00
SCENARIO: VELOCITY-DEPTH VERSUS ->	SCENARIO: MIGRATION
5.00	5.00
SCENARIO: VELOCITY-DEPTH VERSUS ->	SCENARIO: IMPACT OF INTRODUCED
5.00	5.00

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FRAI Model

FRAI	PRESENT
FRAI (%)	
EC: FRAI	
	TARGET
FRAI (%)	
EC: FRAI	
	SCENARIO
FRAI (%)	
EC: FRAI	

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)	TARGET WEIGHTS (%)	SCENARIO WEIGHTS (%)
VELOCITY-DEPTH				
COVER				
FLOW MODIFICATION				
PHYSICO-CHEMICAL				
MIGRATION				
IMPACT OF INTRODUCED				

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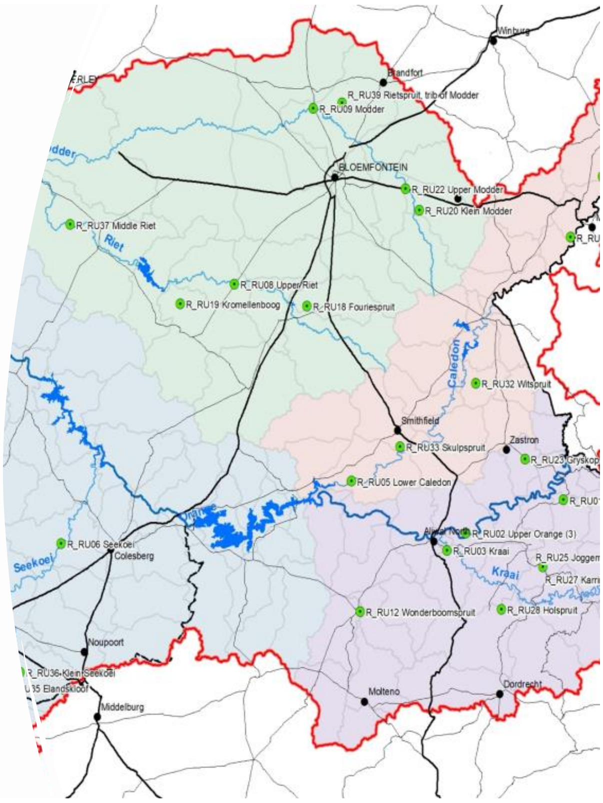
FRAI: Lower Kraai

- LINK to FRAI Model

What is the FRAI telling us



FRAI: Lower Kraai

FRAI	PRESENT
FRAI (%)	73.7
EC: FRAI	C

METRIC GROUP	REFERENCE WEIGHTS (%)	PRESENT WEIGHTS (%)
VELOCITY-DEPTH	100.00	97.54
COVER	99.06	100.00
FLOW MODIFICATION	64.03	77.48
PHYSICO-CHEMICAL	57.74	70.98
MIGRATION		62.64
IMPACT OF INTRODUCED		38.78

- Cover metric remains the metric contributing the most weight to the PES determined, followed by Velocity-Depth Metric
- Increased weight relative to Reference noted for flow modification and water quality metrics:
- Importance of migration also contributing a fair amount to PES - Site is located downstream of a weir that would influence upstream migration of species moving up from the Orange River
- Impact of introduced species is contributing the least to the ecological state of the reach in question

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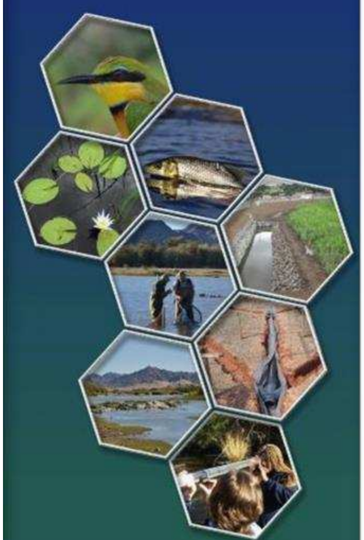
Eco-Status Level 4



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GroundTruth

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EcoStatus

- Totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services.
- Integrated ecological state combining all the components' ecological states
- Approach to determine EcoStatus therefore based on:
  - Biological fitness & survival (biological responses) in an aquatic ecosystem determined through drivers (layers) → processes → habitat effects
  - i.e. the direct assessment of the biological response (using a biological indicator) identifies why and how ecosystems are impacted on

33

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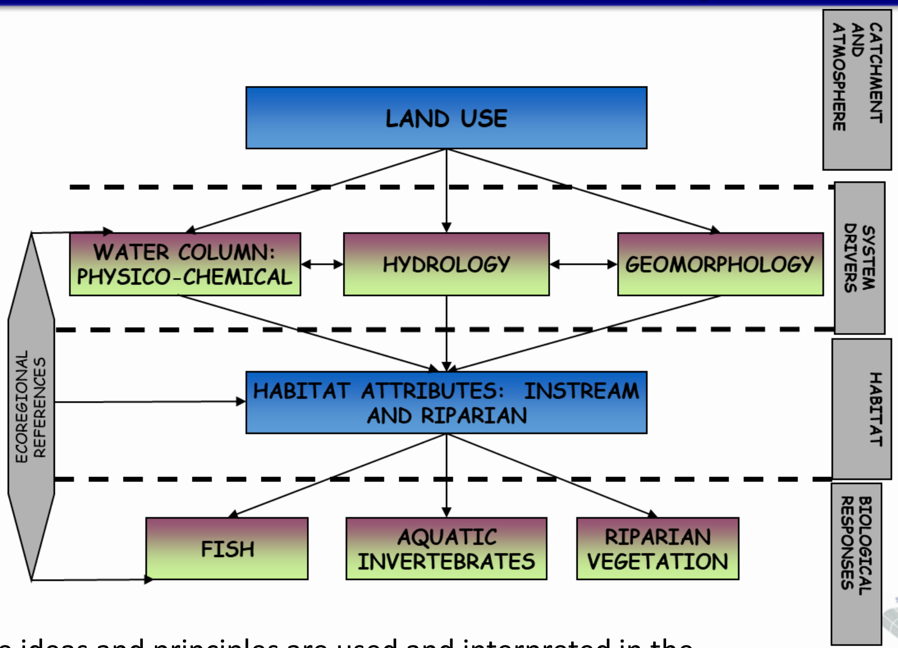
Illustration of the EcoStatus concepts



These ideas and principles are used and interpreted in the EcoStatus models

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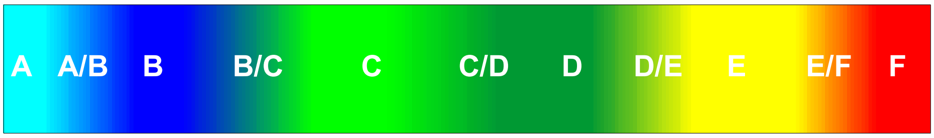
EcoStatus: how to determining the EC for the components and EcoStatus

- ECs are described for each component as follows:
  - DRIVERS: physico-chemical, geomorphology, hydrology
  - RESPONSES: fish, invertebrates, riparian vegetation *(riparian IHI as a surrogate for Rapid3 sites, VEGRAI for intermediates)*
- Therefore, each component is described in terms of ecological categories (A – F)
- Then the integrated ecological state for the river is termed the ECOSTATUS



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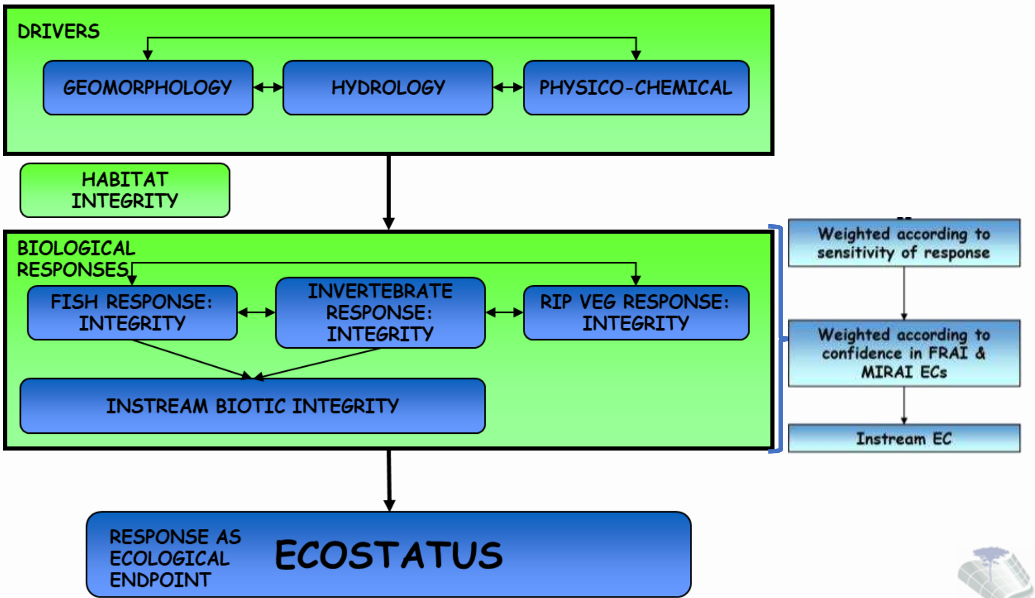
Determination of the EcoStatus (through assessing each component ECs)



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EcoStatus: Lower Kraai

•LINK to EcoStatus Model

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EcoStatus: Lower Kraai

Driver Components	Component EC
HYDROLOGY	
WATER QUALITY	
Response components	**Component EC**
FISH	C
AQUATIC INVERTEBRATES	C
RIPARIAN VEGETATION	B/C
ECOSTATUS	C

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EcoStatus Conclusion

- Current EcoStatus: C
- PES, 2014: C
- Trend remains stable
- Main impacts remain:
  - Agriculture
  - Cattle activity
  - Irrigation
- No new developments in the past 10 years, to have considerably affects on the PES
- Main drivers:
  - Water quality
  - Flow (weir)
- Consider newly proposed upstream dam and how that can affect the ecology of the system and thus PES

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Thank You!

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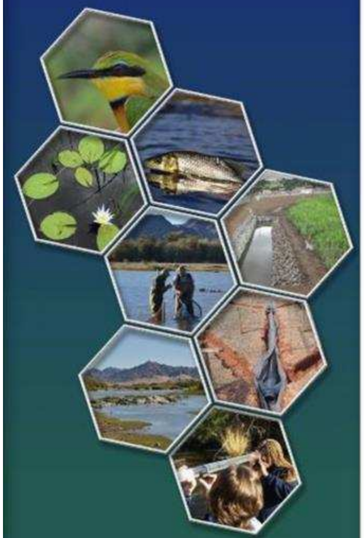
Appendix G: River's Eco-categorisation Capacity Building Presentation – Part 2

Eco-Categorisation Capacity Building



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GroundTruth

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Agenda

- Purpose of capacity building workshop
- Ecological Categorisation
- Capacity building workshop example: LOWER KRAAI
  - Site description *(Retha Stassen)*
  - Hydrological Driver Assessment Index (HAI) *(Retha Stassen)*
  - Physico-chemical Driver Assessment Index (PAI) *(Mark Graham)*
  - Geomorphological Driver Assessment Index (GAI) *(Bennie Van Der Waal)*
  - Riparian Vegetation Response Assessment Index (VEGRAI) *(Gary De Winnaar)*

2

2

Purpose of the Capacity Building Workshop

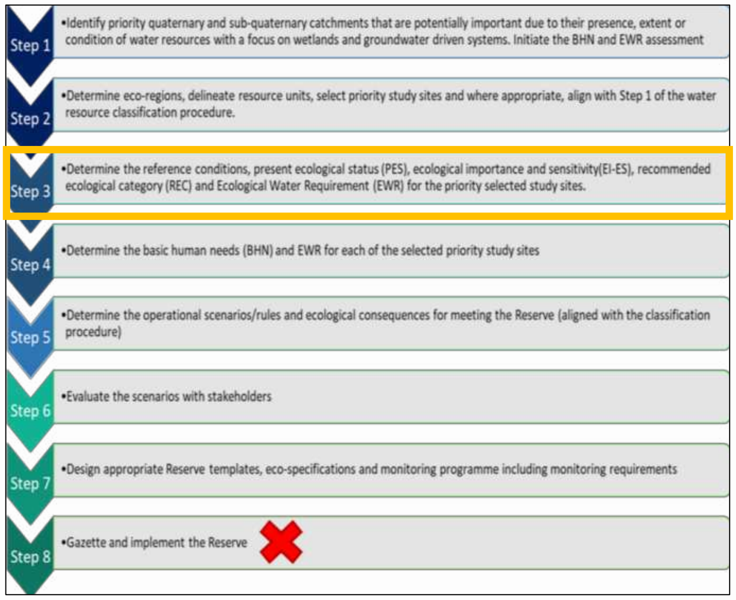
- Dry and post-wet season river field surveys:
  - 4 – 15 July (dry) and April 2023 (post-wet)
- Intermediate, Rapid 3 and field verification sites
- Driver components included:
  - Geomorphology
  - *In situ* water quality
  - Hydraulics (cross-sections and discharge)
- Response components included:
  - Fish
  - Aquatic macroinvertebrates
  - Index of habitat integrity / riparian vegetation
  - Diatoms

3

3

Ecological Categorisation

- Ecological Categorisation (Eco-Categorisation) phase of the study



- Accordance with the 8-step Reserve determination process
- Step 3
- Outlined in the Establishment of a Water Resource Classification System (WRCS) as per Regulation 810 (Government Gazette 33541) dated 17 September 2010

4

4

Ecological Categorisation

- Eco-categorisation is the determination and categorisation of the PES (health and/or integrity) of various biophysical attributes of rivers relative to the natural or close to the natural/ reference condition
- These results then provide the information needed to derive desirable and attainable future ecological objectives for the rivers (ecological categories)
- Document the results of all identified EWR sites within the Upper Orange catchment
- Based on available data (PESEIES 2014, JBS2, JBS3, ORASECOM EFR 2010, Seekoei 2010, other rapid studies)
- Compared with present data from field surveys undertaken as part of this study

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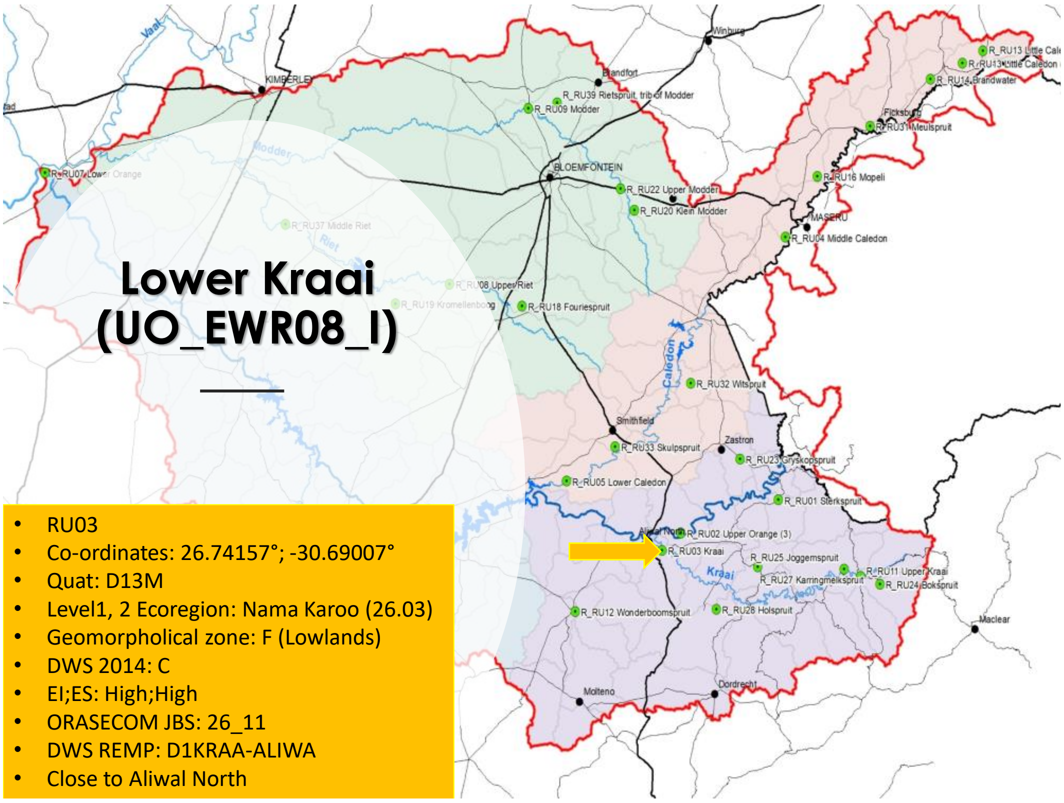
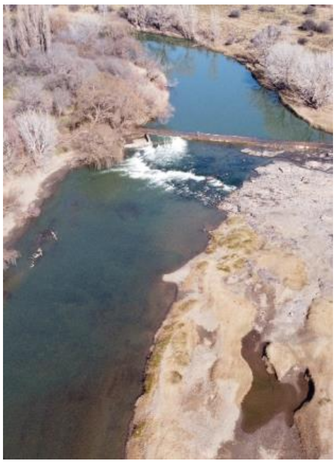
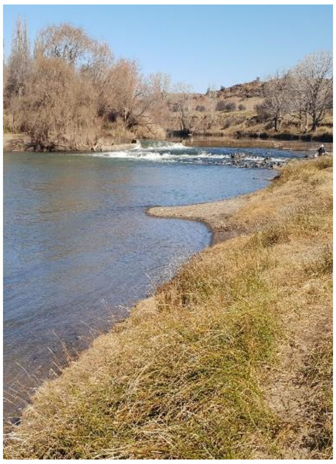


Lower Kraai (UO_EWR08_I)

- RU03
- Co-ordinates: 26.74157°; -30.69007°
- Quat: D13M
- Level1, 2 Ecoregion: Nama Karoo (26.03)
- Geomorpholical zone: F (Lowlands)
- DWS 2014: C
- EI;ES: High;High
- ORASECOM JBS: 26_11
- DWS REMP: D1KRAA-ALIWA
- Close to Aliwal North

6

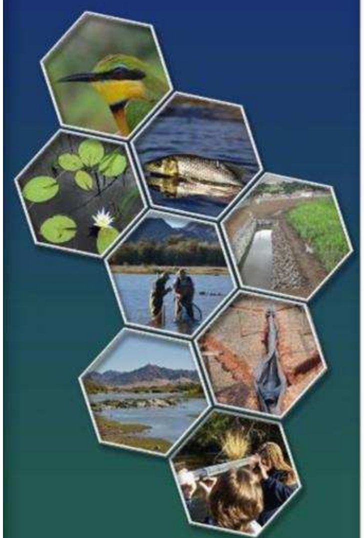




LOWER KRAAI

7

7

Hydrological Driver Assessment Index **(HAI)**



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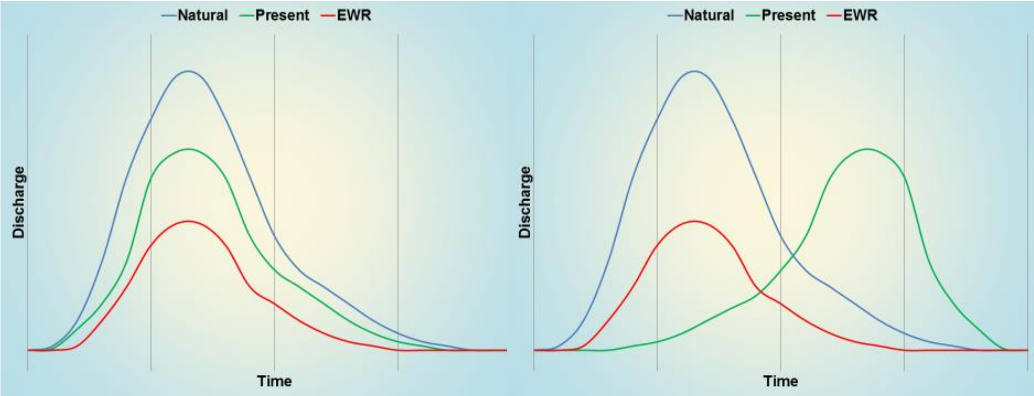
HAI

- Provides an indication of the changes in hydrology from reference
- Based on monthly long term natural and present day flow time series
- Used by ecologists to interpret changes in habitats using the hydraulics (depths, velocities, wetted perimeter, etc.)
- Explain some changes in the response components (fish, macroinvertebrates, vegetation)



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HAI – hydrological metrics

- Based on long-term changes in 5 metrics:

LOW FLOWS
ZERO FLOW/ DURATION
SEASONALITY
MODERATE EVENTS
EVENT HYDROLOGY (HIGH FLOWS/ FRESHETS/ FLOODS)

- Each metric is weighted and ranked

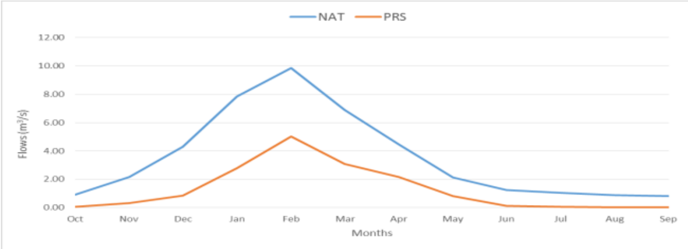
10

10

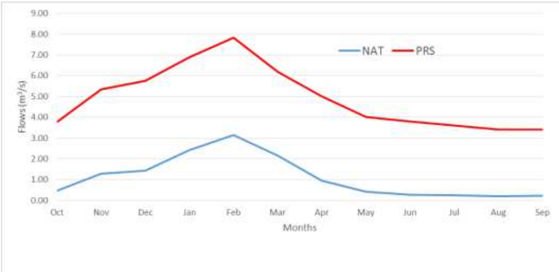
HAI – low flows

- Mainly changes to the baseflows during the low flow months
- Changes in low flows can be:

Less than natural



More than natural/ Constant flows



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HAI – zero flows/ duration

- No zero flow months in natural, but in present day flows
- Percentage of zero flow months increased in present day flows

%zero flows	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Natural	4	3	0	0	1	2	3	3	3	4	4	4
Present day	76	55	30	25	34	40	51	68	76	77	80	81
Natural	0	0	0	0	0	0	0	0	0	0	0	0
Present day	13	7	8	4	2	4	2	5	7	8	12	14

12

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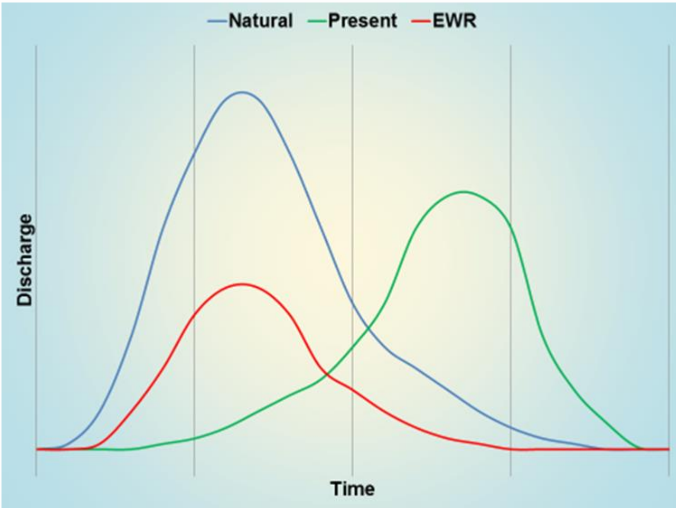
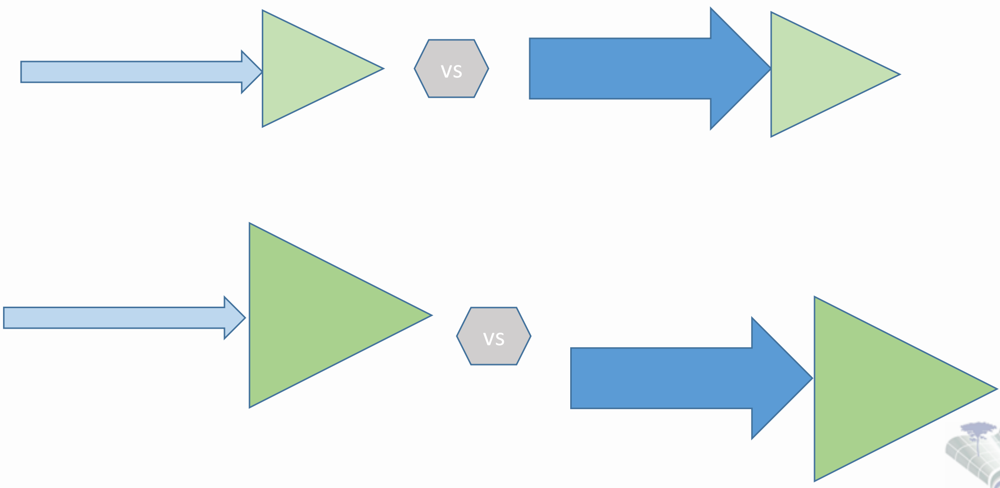
HAI – seasonality

- Typically downstream dams
- Store water during wet months, releases during low flow months



HAI – moderate/ flood events

- Reduced floods due to storage in dams
- Size of dam important for impacts on downstream floods



HAI – excel spreadsheet

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	Rank	%wt	RATING	CONFIDENCE
LOW FLOWS	2.00	95.00	1.00	4.00
ZERO FLOW DURATION	1.00	100.00	0.00	4.00
SEASONALITY	3.00	80.00	0.50	4.00
MODERATE EVENTS	3.00	80.00	0.50	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	60.00	0.50	4.00
HYDROLOGY SCORE	**90.12**			
HYDROLOGY ECOLOGICAL CATEGORY	**A**			

Consider range from 5 to 0 per metric
Which one would affect overall habitat if change from 0 (none) to 5 (large)
Input from ecologists

Rating:
0 – no change from reference to 5 (extreme change from reference)

100% to rank 1
Impact of other metrics as a percentage of 100% weight

Confidence that change will have an impact on the metric:
0 – no likelihood 5 (very high likelihood)

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HAI model: Lower Kraai (UO_EWR08_I)

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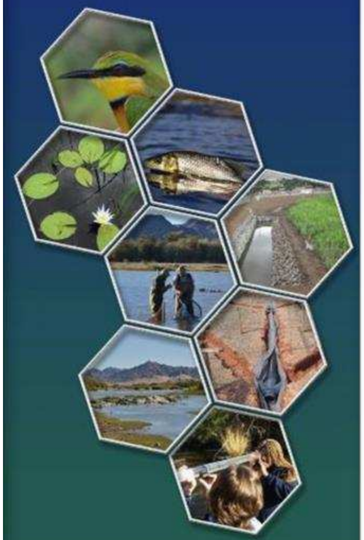
Physico-chemical Driver Assessment Index
(PAI)



28 November 2022

A High Confidence Reserve Determination Study for Surface Water, Groundwater, and Wetlands in the Upper Orange WP11343

GroundTruth

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Steps for an Intermediate Reserve study

Step 1
- Initiation of study and scoping
- Select list of water quality variables

Step 2
- Delineation of Water Quality Sub-Units
- Including site visit and data collection

Step 3
- Data analysis and input to EC categorization or EcoStatus

Step 4
- Quantify quality component of EWR Scenarios

Step 5
- Water quality consequences of operational scenarios and selected flows

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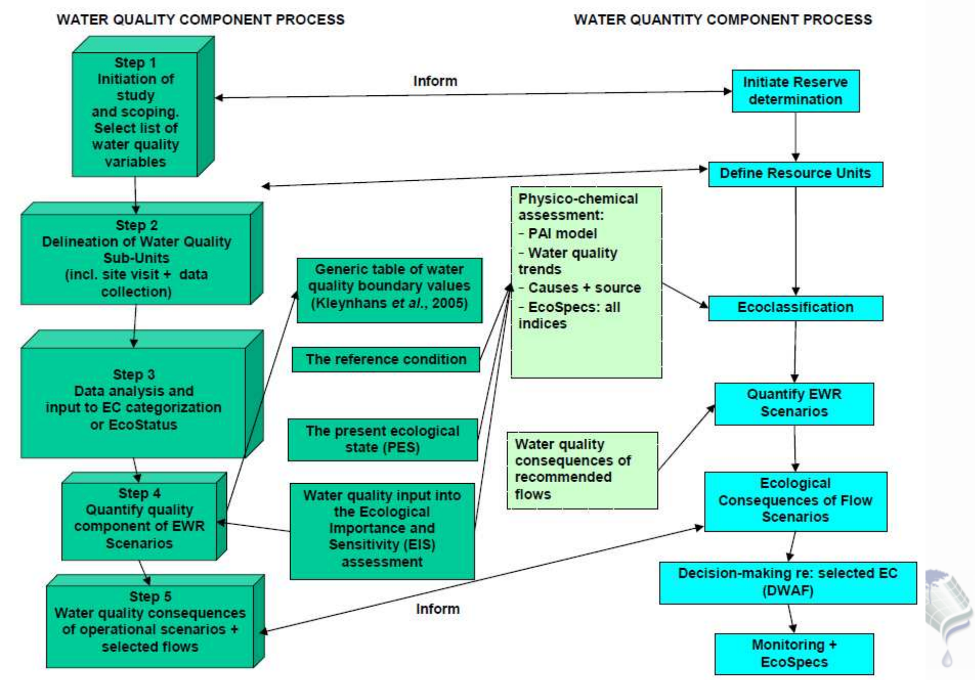
Link between flow and quality



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Background

- The Physico-Chemical driver Assessment index (PAI)
  - Used to determine the present status of the physical and chemical water quality for a resource unit or specific site
  - Used in EcoStatus Level 4 (i.e. Intermediate and Comprehensive Reserve methods)

Table 1.1 Tools used for different EcoStatus levels

ECOSTATUS LEVELS	TOOLS											
	GAI	PAI	HAI	VEGRAI	FRAI	MIRAI	IHI	DERIVED VEG EC	DESKTOP FISH RATING	DESKTOP INVERT RATING	DESKOP HI	DERIVED VEG RATING
4	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
3	N	N	N	N*	Y	Y	Y	Y*	N	N	N	N
2	N	N	N	N*	N	Y	Y	Y*	Y	N	N	N
1	N	N	N	N	N	N	Y	Y	Y	Y	N	N
DT#	N	N	N	N	N	N	N	N	Y	Y	Y	Y

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Background

- The model considers
  1. How much have individual components of water quality changed from reference conditions (the rating)
  2. How important each component is in terms of biotic response (rank and weight)
- The water quality specialist is responsible for determining the rating for each group, and biotic specialists the weight
- Can be applied with other driver models as a stand-alone assessment, or it can be applied as the water quality contribution to a Reserve determination
- Guiding document: River EcoClassification: Manual for EcoStatus Determination (Kleynhans *et al*., 2055).
- However, has been updated by P. Scherman (2008) – however this is still in draft and very data dependent

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EcoStatus Boundary Values

- The A-F values are translated to numeric ratings of 0-5 to facilitate input of numeric data into the model

Rating	Deviation from reference conditions	A-F categories	Natural – Poor categories
0	No change	A	Natural
1	Small change	B	Good
2	Moderate change	C	Fair
3	Large change	D	
4	Serious change	E	Poor
5	Extreme change	F	

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Data Requirements

- For an Intermediate/Comprehensive Reserve assessment, the following data is required:
  - Map of the catchment showing location and names of DWAF monitoring sites, gauging weirs towns and quaternary catchment boundaries
  - A list of DWAF monitoring stations in the study area showing the length of the data record at each station
  - Literature and reports regarding water quality conditions, land-use, geological information, and a field survey to verify delineation of Water Quality Sub-Units (WQSUs)
  - Knowledge of dam operations (including size and if releases are from the top (epilimnetic), bottom (hypolimnetic) or mixed

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Data Requirements

- It is important to consider tributaries with water quality that is naturally anthropogenically different from the mainstem of the river
  - Poor water quality can cause hotspots, good quality can provide refugia

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Data Collection

- Each resource unit must be described by a set of water quality data.
- Need to assess how much water quality has deviated from "Natural" conditions – i.e. need reference and present state sites
- Considerations in selecting appropriate reference and present state sites:
  1. The ability of a single monitoring point to represent the whole water quality resource unit. Assessed qualitatively by comparing, such as land-use, up-and downstream of a monitoring point
  2. The occurrence and frequency of biomonitoring data near the chemical monitoring point increases the confidence of the wate quality Reserve determination

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Data Collection

- Sites for data collection are identified and mapped
  - All water quality monitoring points in each resource unit are identified
  - Where data is inadequate, select from equivalent resource units or implement short-term monitoring programme
  - A table is compiled for each site with a narrative
    - Land use
    - Geology
    - Point sources
    - Any other features relevant to water quality
    - Reference to the DWAF WQ site number and co-ordinates of the PES
    - Reference to an reference sites in the resource unit
  - All existing water quality and biomonitoring data is collated

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Data Collection

- Sites for data collection are identified and mapped
  - Number of samples and length of data recorded for each sample site
    - Remove points with few data records, or where no data has been recorded in the last five years
    - From remaining sites, identify those that can serve as unimpacted reference sites, and those that can be used to characterize the PES
  - If there are resource units with no biomonitoring data, collect at least one SASS sample near the water quality monitoring site

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Data Collection

- An assessment of the following variables in required as part of the Intermediate Reserve study:
  - **Inorganic salts**
    - Sodium chloride (NaCl)
    - Sodium sulphate (Na2SO4)
    - Magnesium chloride (MgCl2)
    - Magnesium sulphate (MgSO4)
    - Calcium chloride (CaCl2)
    - Calcium sulphate (CaSO4)
    - If data on inorganic salts is not available, EC may be used as a surrogate.
  - **Nutrients**
    - Total inorganic nitrogen (*Note:* NH3-N is not included)
    - Phosphate (PO4 3- -P) – also referred to as SRP (Soluble Reactive Phosphorous) or ortho-phosphate

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Data Collection

- An assessment of the following variables in required as part of the Intermediate/Comprehensive water Quality Reserve study:
  - **System variables**
    - pH
    - Temperature
    - Dissolved oxygen
    - Turbidity/clarity
  - **Toxic substances**
    - Those listed in SA WQ guidelines for Aquatic Ecosystems – ammonia, toxic metal ions, toxic organic substances, and/or substances selected from the chemical inventory of an effluent/discharge

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Data Collection

- An assessment of the following variables in required as part of the Intermediate/Comprehensive water Quality Reserve study:
  - **Response variables**
    - Biotic community composition (macroinverts and fish)
    - Algal abundance (chlorophyll-a and diatoms)
    - In-stream toxicity (if anticipated in the catchment)

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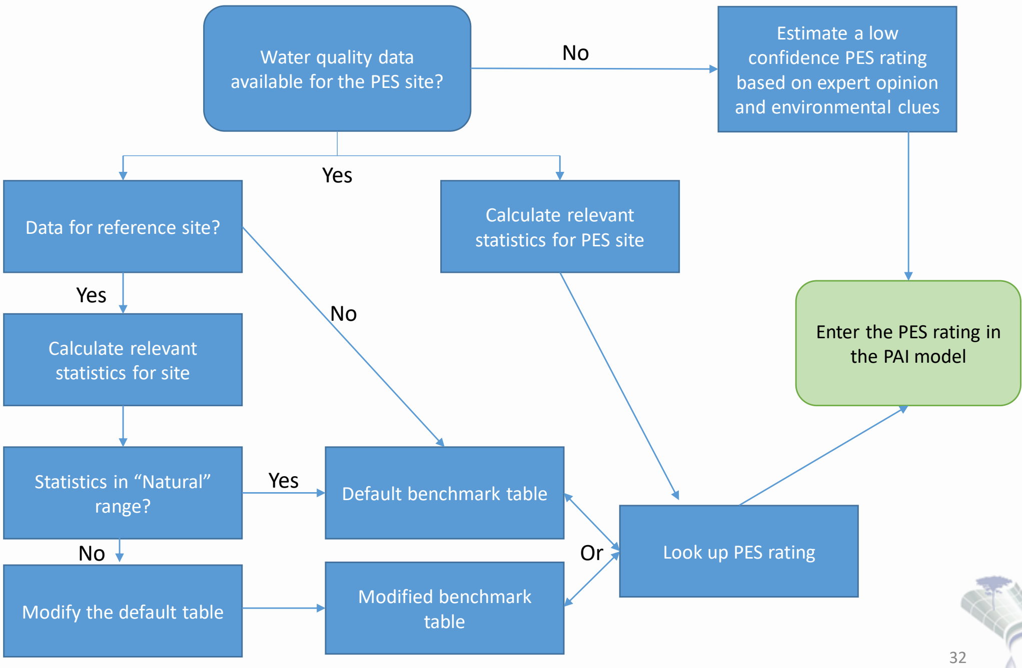
PAI Process



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Water Quality Data Required

- Inorganic salts
  - If no data are available, this cannot be visually assessed
  - Low-confidence assessment can be based on knowledge of catchment (e.g. presence of saline discharges).
  - High confidence assessment requires 60 samples over earliest three years
  - If data is available, refer to reference site data to determine if default boundary values need to be adjusted

PES	Deviation from reference condition	Water quality category	$MgSO_4$ (mg/L)	Na_2SO_4 (mg/L)	$MgCl_2$ (mg/L)	$CaCl_2$ (mg/L)	NaCl (mg/L)
0	No change	A	16	20	15	21	45
1	Small change	B	23	33	30	57	191
2	Moderate change	C	28	38	36	69	243
3	Large change	D	37	51	51	105	389
4	Serious change	E	45	64	66	141	535
5	Extreme change	F	>45	>64	>66	>141	>535

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Water Quality Data Required

- Inorganic salts
  - Boundary values are adjusted by calculating the 95th percentile values for the reference site's inorganic salt data using the Stoichiometric Salt Model. This is necessary in rivers/streams with naturally high inorganic salt concentrations
  - To calculate the PES:
    - Use the default or modified rating table
    - Calculate the 95th percentile values at the PES site using the Salt Model
    - Use the relevant table to look up the rating between 0 and 5
    - Select the highest rated (worst) salts for the inorganic salts present and enter into PAI

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Water Quality Data Required

- Inorganic salts
  - If sufficient data on inorganic salts is not available, electrical conductivity (EC) may be used

Category	A-F Category	Rating	mS/m
Natural	A	0	≤30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

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Water Quality Data Required

- Nutrients
  - If no nutrient or algal concentration data are available, use expert judgement and algal growth to derive a low confidence present state rating
  - High confidence assessment requires 60 samples over earliest three years
  - If data are available, refer to reference site to determine if the default boundaries need to be adjusted

Rating	Deviation from reference condition	Environmental clue	PO_4 (mg/L)	TIN (mg/L)	Phytoplankton Chl a (ug/L)	Periphyton Chl a (mg/,m^2)
0	No change	Oligotrophic	<0.005	<0.25	<10	<1.7
1	Small	Oligo-mesotrophic	0.005-0.015	0.25-0.70	10-15	1.7-12
2	Moderate	Mesotrophic	0.015-0.025	0.7-1.0	15-20	12-21
3	Large	Eutrophic	0.025-0.125	1.0-4.0	20-30	21-84
4	Serious	Eutrophic	>0.125	<4.0	>30	>84
5	Extreme	Hyper-eutrophic				

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Water Quality Data Required

- Nutrients
  - Confirm reference site is largely unimpacted by examining response variables
  - Calculate median values for orthophosphate, Total Inorganic Nitrogen
  - If median value is higher than default table, the adjust boundaries for A, B, and C. D boundary value remains unchanged.
  - This procedure is necessary to adjust the boundary values for rivers and streams with naturally elevated nutrient concentrations.

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Water Quality Data Required

- Nutrients
  - To determine the PES
    - Calculate median for orthophosphate, TIN and chlorophyll *a*.
    - Refer to benchmark table to look up the rating from 0 to 5 for orthophosphate and TIN
    - Select the highest rated (worst condition) nutrient rating and enter the value into PAI
    - If chlorophyll *a* data indicates a higher rating, or if there is visual evidence of excessive algal growth, and the nutrient rating is low, increase the PES by 1 to indicate poorer state than when only nutrient concentrations were considered.

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Water Quality Data Required

- pH
  - If no pH data available, then determining pH by environmental clues is difficult. The exception is the tea-coloured headwater streams (indicative of high fulvic/humic acid content – generally acidic
  - If pH data is available, refer to reference site to assess whether default boundary values need to be adjusted

Rating	Deviation from reference condition	pH (5th percentile)	pH (95th percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small	5.9-6.5	8.0-8.8
2	Moderate	5.6-5.9	8.8-9.2
3	Large	5.0-5.6	9.2-10
4	Serious	4.0-5.0	10-11.0
5	Extreme	<4	>11

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Water Quality Data Required

- pH
  - Reference condition is derived by calculating the 5th and 95th percentiles of the pH data from a reference site (i.e. one with high biotic integrity and that is "Natural", or one where there is evidence of no significant anthropogenic impact)
    - If 5th and 95th percentiles fall within "Natural" boundary, or if no reference site is available, use the default benchmark table
    - Otherwise, adjust values according to Palmer (2005)
  - To determine the PES:
    - Calculate 5th and 95th percentile values
    - Use default or modified table to look up rating
    - Select the highest rated (worst condition) pH rating as the present state pH rating and enter the value in PAI model
    - **Note:** the default rating table is not applicable to WC acidic streams and swamp forest

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Water Quality Data Required

- Dissolved oxygen (DO)
  - If no data available, use expert judgement and environmental clues to derive low confidence PES
  - Fish and invert specialists can help provide insights based on community composition
  - If data are available, refer to reference site to determine if default boundary values need to be adjusted for streams with natural low DO

Rating	Deviation from reference condition	Environmental clues	DO (mg/L)
0	No change	Pristine river, all oxygen sensitive spp. Present	>8
1	Small	Some man-made modifications, most oxygen sensitive spp. present	7-8
2	Moderate	Mostly oxygen tolerant spp. Some sensitive	6-7
3	Large	Mostly low DO tolerant spp.	4-6
4	Serious	Anoxic odours possible. Only low DO tolerant spp.	2-4
5	Extreme	Anoxic odours, discoloured water, bacterial films, no biota	0-2

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Water Quality Data Required

- Dissolved oxygen (DO)
  - Calculate 5th percentile concentration to set the “Natural” boundary. If the calculated boundary is <6mg/L, then use default boundary
  - If no data available, use benchmark values
- To determine the PES
  - Calculate the 5th percentile of the PES data and look up the rating in the benchmark or modified table and enter into the PAI model
- Good DO record seldom available, often have to rely on a single measurement and expertise of biotic specialists – the latter should take preference

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Water Quality Data Required

- Temperature
  - If no data available, use expert judgement and temperature descriptions to derive a low confidence PES
    - Fish and invert specialists can provide input based on community composition
  - If data is available, sort data by month and calculate 10^{th} and 90^{th} percentile for each month – natural reference temperature range for each month
  - To calculate PES:
  - Jooste & Rossouw (2003) to calculate a monthly temperature distribution, represented by 10^{th} and 90^{th} percentiles for each month
  - Calculate the deviation from natural monthly range – the difference between the reference and present state temperatures

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Water Quality Data Required

- Temperature

Rating	Deviation from reference condition	Environmental clues	Deviation from natural monthly temperature range
0	No change	Pristine river, all temp sensitive spp present in abundances and frequencies similar to reference	Natural temperature range, measured or estimated from air temperature
1	Small	Minor man-made changes, some highly temp sensitive spp in lower abundance and frequency	Natural temperature range, measured or estimated from air temperature
2	Moderate	Moderate change to temp occurs infrequently. Most highly temp sensitive spp in lower abundances and frequency	Vary by no more than 2°C
3	Large	Large change to temp regime occurs often. Most moderately temp sensitive species in lower abundances and frequencies	Vary by no more than 4°C
4	Serious	Serious changes to temp regime most of the time. All moderately temp sensitive spp in lower abundances and frequency	Vary by no more than 4°C
5	Extreme	Extreme changes to temp regime all the time. Only temp. insensitive spp present, often in low abundances and frequency	Vary by no more than 5°C, up to a max of 30°C

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Water Quality Data Required

- Inorganic turbidity
  - Not routinely recorded by DWAF
  - Present state is based on expert opinion

Rating	Deviation from reference condition	Environmental clues
0	No change	Pristine river, changes in turbidity related to natural catchment processes such as rainfall runoff
1	Small	Minor man-made modifications. Very minor effects of silting or scouring – largely temporary
2	Moderate	Moderate change in land use have created high sediment loads and high turbidity during runoff
3	Large	Erosion and/or urban runoff causes high sediment loads. Habitat often silted. Low amounts periphyton algae or phytoplankton
4	Serious	Serious erosion problems, increased turbidity most of the time, large silt deposits. Low amounts periphyton algae or phytoplankton
5	Extreme	Serious erosion problems, increased turbidity most of the time. Large silt deposits lead to almost total loss of habitat

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Water Quality Data Required

- Toxic substances
    - Listed in South African Water Quality Guidelines for Aquatic Ecosystems (incl. toxic metal ions and toxic organic substances etc). Benchmarks also defined in this document
    - Toxicity investigation triggered by concerns over chemical discharges or biotic response indicating deteriorated conditions
  - PES:
    - Calculate the 95th percentile of data
    - Use the toxic substances rating table (available in the manual) to look up present state rating
    - Select the highest-rated (worst) toxic substance as the rating for the toxic substances in the PAI model

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Water Quality Data Required

- Rule of thumb: Select the Reference data as the first 3-5 years of the data record, and the PES as the last 3-5 years of data
  - High confidence = 60 samples
  - Moderate confidence = 25 samples
  - Low confidence = 12 samples
  - The samples should ideally be spread across the hydrological cycle
- Reference site should be on an unimpacted tributary, or very early in the data record, before notable anthropogenic impacts

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Water Quality Data Required

- In the real world, however, a sufficient data record is seldom available
  - This is particularly relevant given the current lack of data from DWS monitoring stations within the country and lab analysis problems at RQIS
    - Necessary variables may not be available
    - May not be sufficient data points

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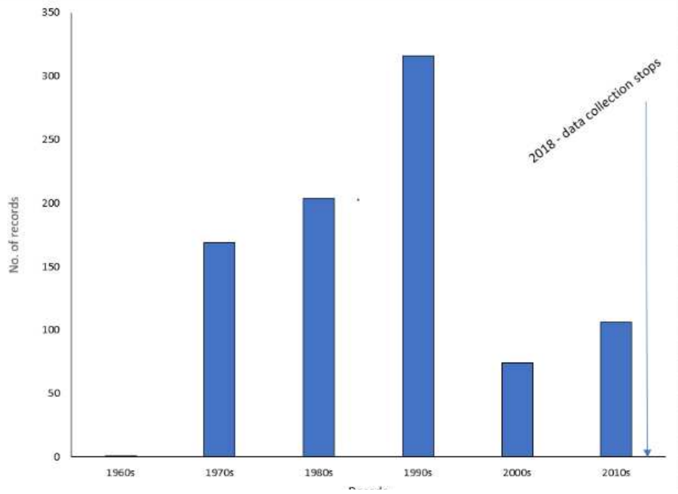
The Lower Kraai

- Data record 1967 – 2018
  - No data available for the last 3 – 5 years
  - Lab analyses stop 2018
  - Insufficient data for the first three years of monitoring to establish a Reference condition



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The Lower Kraai

- Data available:
  - pH ✓
  - Salts ×
  - Nutrients ×
  - Temperature ×
  - Turbidity/clarity ×
  - Dissolved oxygen (DO) ×
- Based on this, would have to use the default benchmark table for reference

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The Lower Kraai

- Although we lack the required data, we may have the necessary surrogates:
  - Salts → Electrical Conductivity ✓
  - Nutrients → Algal observations ✓
  - Turbidity → Clarity ✓
- Biotic information, such as SASS and diatoms, can be hugely useful and help infer water quality trends
  - E.g. saline tolerant diatom species indicate elevated salts in water
  - Biotic data critical as it provides an insight into the historical water quality in the absence of long-term monitoring data
- In the absence of long-term data, confidence will be reduced, but PES can still be determined
- Understanding the catchment and site can help categorise water quality parameters

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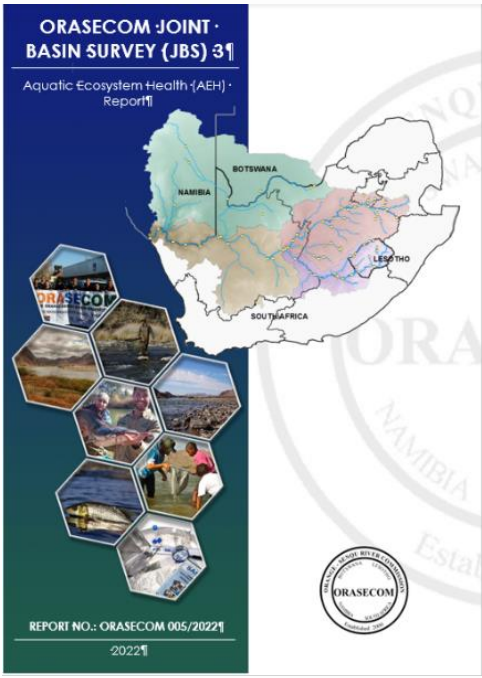
The Lower Kraai

- Additional data sources?
  - Regional offices?
  - FBIS
  - Other surveys etc.
  - E.g. ORASECOM JBS



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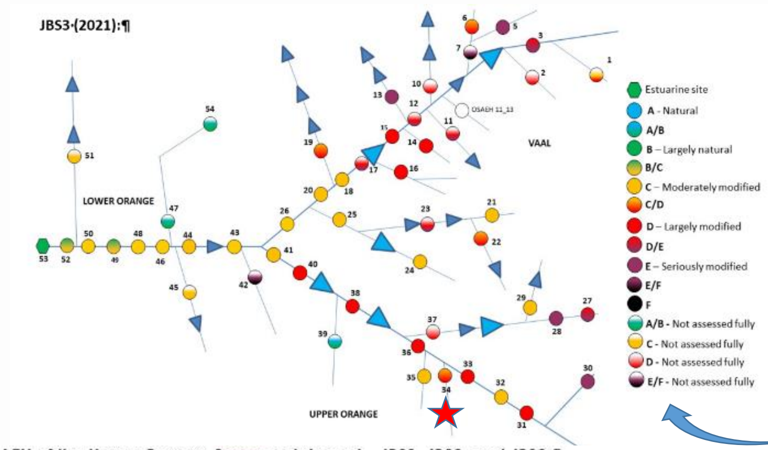
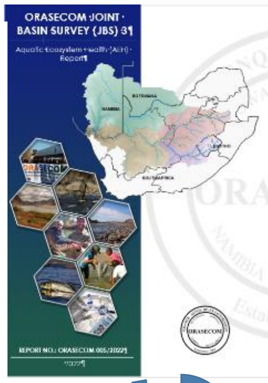
The Lower Kraai





AEH of the Upper Orange-Sengu catchment – JBS1, JBS2, and JBS3:

Site ID	Site Code	River Name	IHI: Instream			IHI: Riparian			Diatoms			Riparian Veg			Inverts			Fish			EcoStatus		
			JBS1	JBS2	JBS3	JBS1	JBS2	JBS3	JBS1	JBS2	JBS3	JBS1	JBS2	JBS3	JBS1	JBS2	JBS3	JBS1	JBS2	JBS3	JBS1	JBS2	JBS3
Upper Orange/Senqu Catchment																							
30	OSAEH_15_02	Matsuko		B/C	C		D	D		B	B		E	F	D	C/D	C/D		E	F	C	D	E
31	OSAEH_15_03	Renoster		C	C		C	C		C	C		C/D	E		C	C		D	D		C	D
32	OSAEH_15_05	Senqunyane		B	B		A/B	B		B	B		B	B/C		C	C/D		D	D		C	C
33	OSAEH_11_22	Orange		B/C	B/C		C	D		C/D	C		D	E		D	D		D	D		D	D
34	OSAEH_26_11	Kraai	C	B	B		C/D	C/D	C	B	C	C	D	D	C	B/C	D	C	D	C	C	C	C/D
35	OSAEH_26_13	Stormbergspruit		B/C	B/C		C	B/C		C	C		C	C		C/D	C		C	C		C	C
36	OSAEH_26_14	Orange		B/C	B/C		B/C	B/C		C	C		C/D	D		D	D		D	C		D	D
27	OSAEH_15_01	Caledon	D	A/B	B/C		D	D	B	B/C	C	C	E	F	C	B/C	C/D	D	C/D	D/E	C	D	D/E
28	OSAEH_15_06	Caledon		D	D		D	D		F	D/E		D	E		D	D		E	E		D	E
29	OSAEH_11_20	Leeuspruit	C	C	C		C	C	C	C/D	C	C	C	C	C	C	C	C	D	D	C	C	C
37	OSAEH_26_08	Caledon	D	C	C		C	C	C	D		B	C/D	D	D	D		D	C		C	C/D	D*
38	OSAEH_26_15	Orange		D	C		D	D		C	C		D	D		C/D	C		C/D	C/D		C/D	D
39	OSAEH_26_12	Seekoei		B	A		A	A		C	A		A	A		C/D			D			C	A/B*

The Lower Kraai

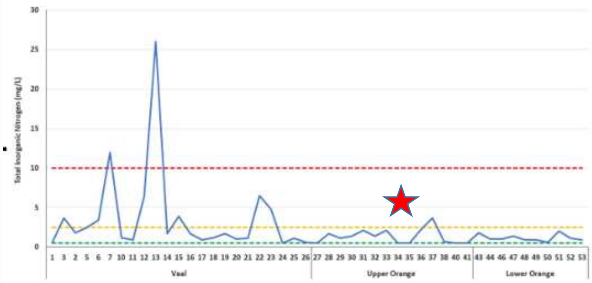
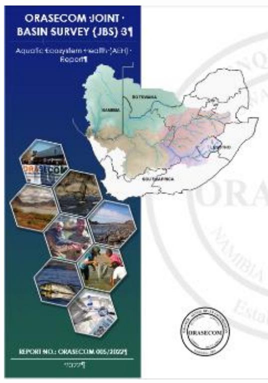


Figure 4-4 → Concentrations of Total Inorganic Nitrogen (TIN) within the basin. The green dotted line shows the target water quality range (TWQR) limit, orange dotted line the chronic effect value (CEV) limit, and red dotted line the acute effect value (AEV) limit.

Figure 4-5 → Concentrations of Total Phosphorous (P) within the basin. The green dotted line shows the target water quality range (TWQR) limit, orange dotted line the chronic effect value (CEV) limit, and red



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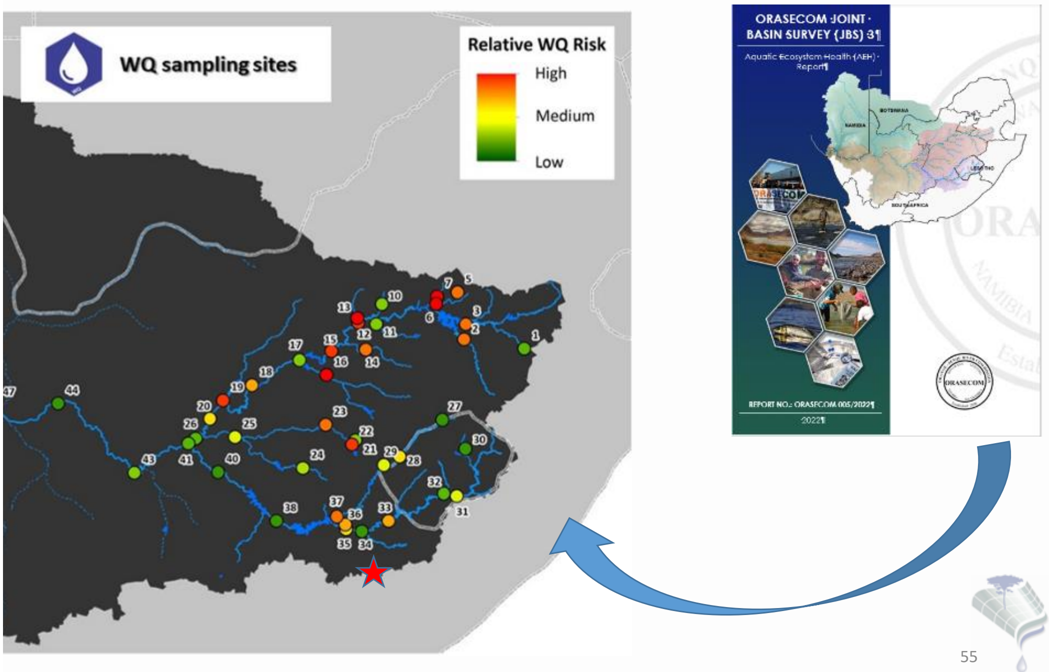
The Lower Kraai



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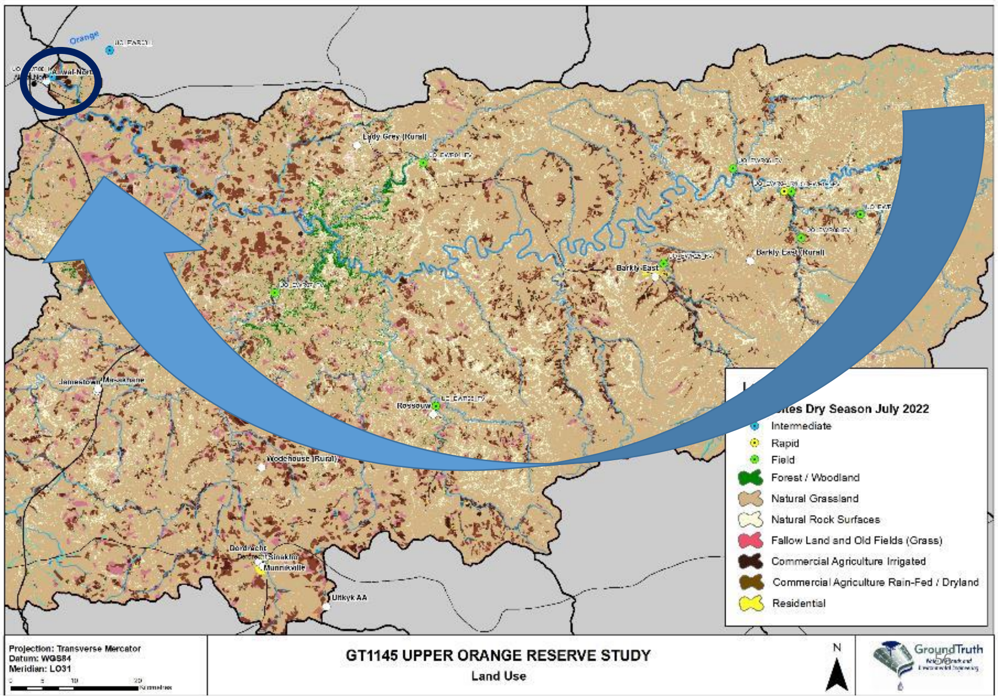
The Lower Kraai



56

The Lower Kraai

- Catchment largely dominated by natural grassland
- There is some irrigated agriculture above the monitoring point → possibility of nutrient inputs
- Interestingly diatom results (JBS 3 survey) show *Gomphonema pumilum, Navicula reichardtiana* and *Nitzschia dissipata* to be most abundant – indicate polluted water, high electrolytes and some siltation

- Congruent of some of the catchment drivers that we note in the catchment (settlements/failing WWTW/irrigation agriculture)

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The Lower Kraai: Results

- pH – 8.6

Rating	Deviation from reference condition	pH (5th percentile)	pH (95th percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small	5.9-6.5	8.0-8.8
2	Moderate	5.6-5.9	8.8-9.2
3	Large	5.0-5.6	9.2-10
4	Serious	4.0-5.0	10-11.0
5	Extreme	<4	>11

- EC – 21.8 mS/m

Category	A-F Category	Rating	mS/m
Natural	A	0	≤30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

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The Lower Kraai: Results

- Nutrients – presence of algae, but lack of filamentous algae indicates some nutrient enrichment

Rating	Deviation from reference condition	Environmental clue	PO_4 (mg/L)	TIN (mg/L)	Phytoplankton Chl a (ug/L)	Periphyton Chl a (mg/,m^2)
0	No change	Oligotrophic	<0.005	<0.25	<10	<1.7
1	Small	Oligo-mesotrophic	0.005-0.015	0.25-0.70	10-15	1.7-12
2	Moderate	Mesotrophic	0.015-0.025	0.7-1.0	15-20	12-21
3	Large	Eutrophic	0.025-0.125	1.0-4.0	20-30	21-84
4	Serious	Eutrophic	>0.125	<4.0	>30	>84
5	Extreme	Hyper-eutrophic				

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The Lower Kraai: Results

- DO – 10.1 mg/L
- Clarity – 68cm
- Temperature – 9.1°C

Rating	Deviation from reference condition	Environmental clues	DO (mg/L)
0	No change	Pristine river, all oxygen sensitive spp. Present	>8
1	Small	Some man-made modifications, most oxygen sensitive spp. present	7-8
2	Moderate	Mostly oxygen tolerant spp. Some sensitive	6-7
3	Large	Mostly low DO tolerant spp.	4-6
4	Serious	Anoxic odours possible. Only low DO tolerant spp.	2-4
5	Extreme	Anoxic odours, discoloured water, bacterial films, no biota	0-2

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PAI model: Lower Kraai (UO_EWR08_I)

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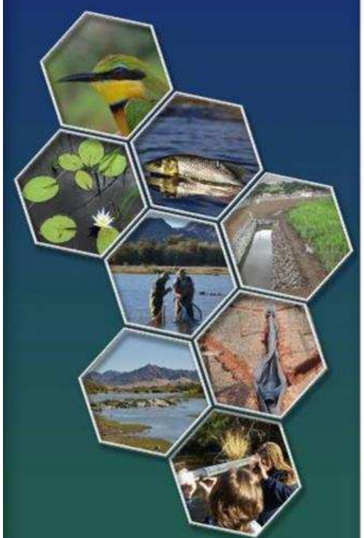
Geomorphological Driver Assessment Index
(GAI)



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GAI

- Geolorphological Driver Assessment Index – Rowntree 2013
- Reference condition
- It rates the deviation in system drivers (flow and sediment) and site condition from natural/reference
- It rates the flow-relatedness of the deviation (flow or land use?)
- Rule based model used to determine the PES
- Confidence in the score

- Setting geomorphological flow requirements

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Field Observations

- Reach and channel classification – site description
- Reference condition
- Score metric groups – GAI (21 page form)
  - Hillslope-channel; longitudinal, lateral and vertical connectivity
  - Sediment supply
  - Bed, bank and flood zone stability
  - Present channel condition
  - Morphological change
- Site photos
- Survey cross-section and describe substrate and morphological features
- Sediment measurement

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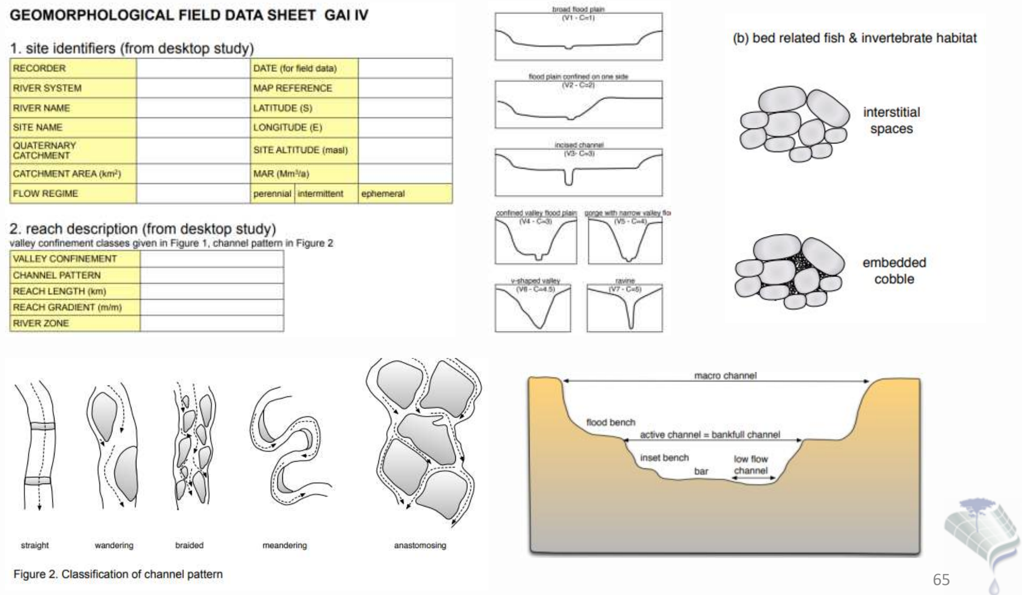
Site Description



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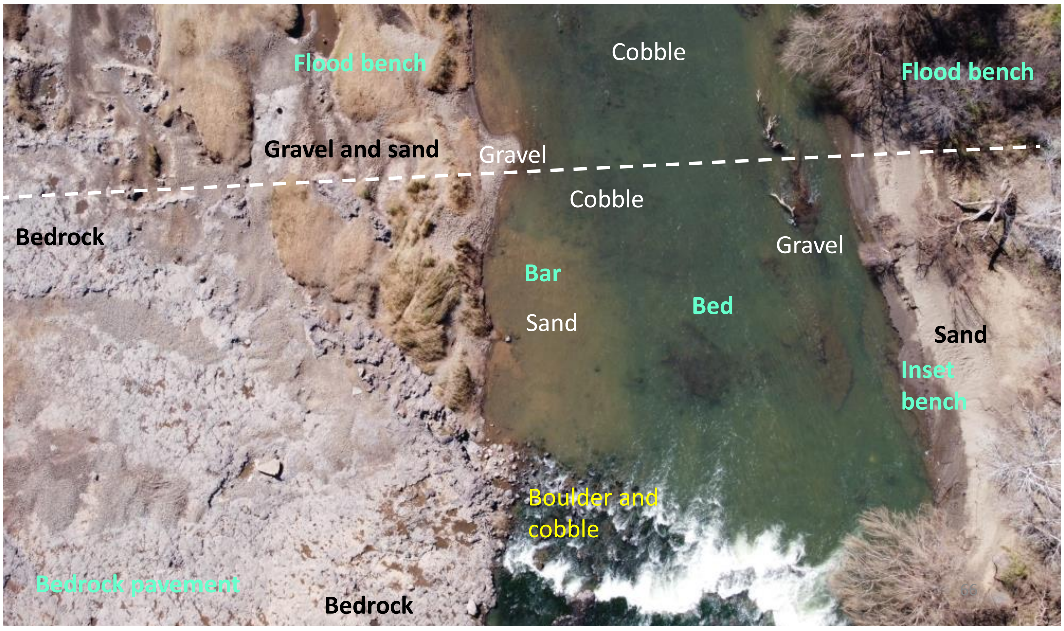
Site Description



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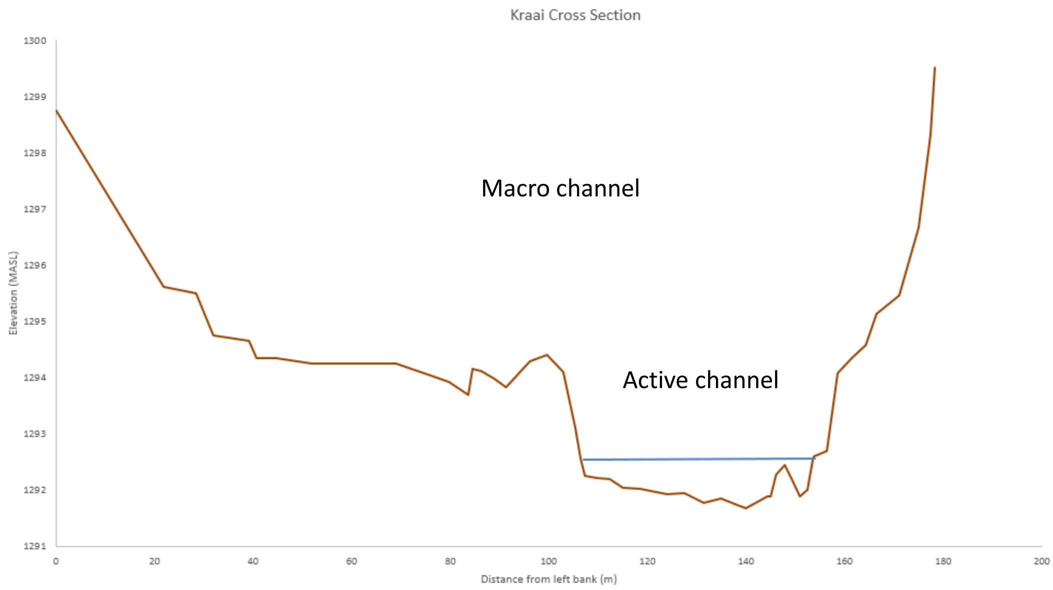
Cross-section



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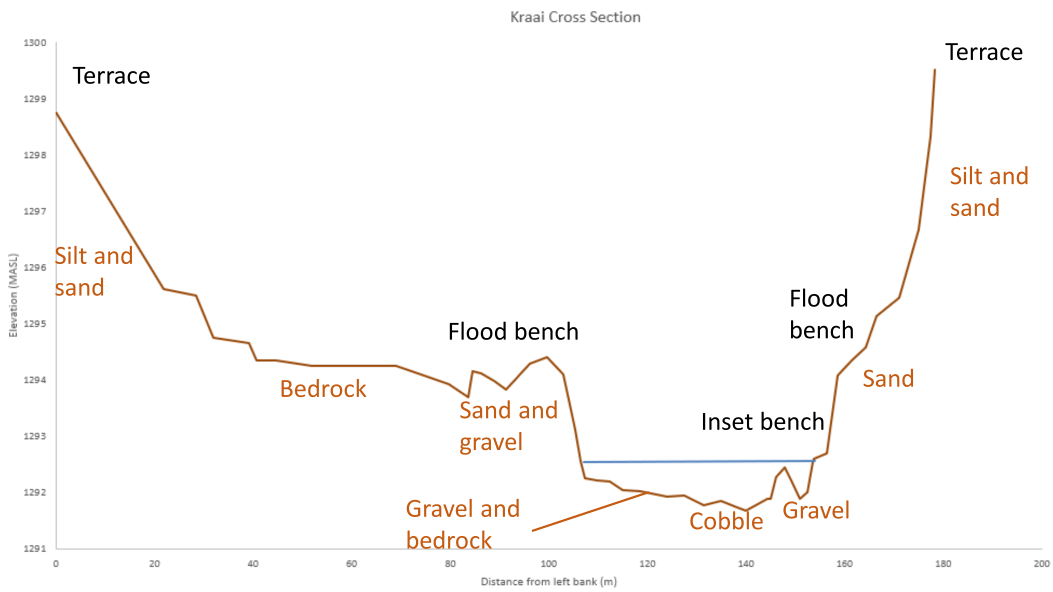
Cross-section and morphological features



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Reference Conditions

River slope – 0.001 E Lower foothills

Longitudinal zone	Macro-reach characteristics			Characteristic channel features
	Valley form	Gradient class	Zone class	
A. Zonation associated with a 'normal' profile				
Source zone	V1	not specified	S	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
Mountain headwater stream	V6, V7	> 0.1	A	Very steep gradient streams dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
Mountain stream	V6, V7	0.04 - 0.99	B	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Transitional	V4, V6	0.02 - 0.039	C	Moderately steep stream dominated by bedrock or boulder. Reach types include plain-bed, pool-rapid or pool riffle. Confined or semi-confined valley floor with limited flood plain development.
Upper Foothills	V4	0.005 - 0.019	D	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present.
Lower Foothills	V4, V2	0.001 - 0.005	E	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
Lowland river	V1, V2 V3	0.0001- 0.001	F	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.

Steep and rocky

↓

Mixed character

↓

Low gradient with fine sediment

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Changes to connectivity

- Increase in gully erosion
- Localised roads
- Localised weirs
- Localised farm dams
- Channel on bedrock and no berms
- Low occurrence of silt and clay deposition

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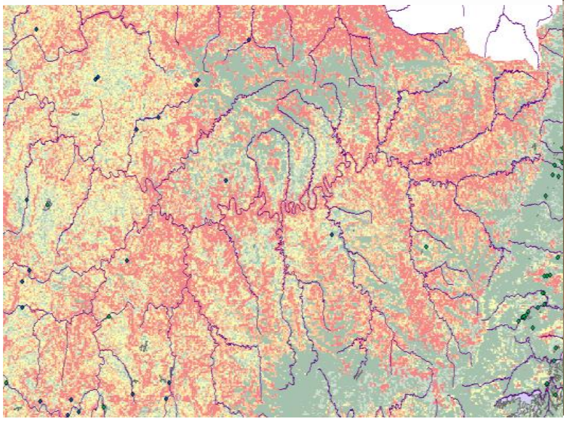
Changes to sediment supply

- Moderate levels of grazing
- Localised agriculture
- Localised, but intense gully erosion



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Bed, bank and flood zone stability

Changes to vegetation, trampling, fire frequency, cultivation

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Present channel condition and morphological change

- Infilling of interstitial spaces
- Silt drape covering bedrock and sediment
- Erosion of bed and bank material
- Deposition in channel and along banks
- Changes to width and depth – velocity and depth in relation the discharge
- Secondary channels – gain or loss?
- Shift in deposited sediment – increase in silt?
- Change in sedimentation rate?

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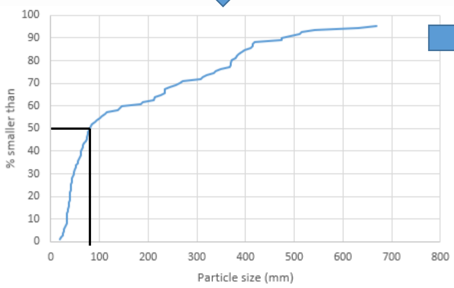
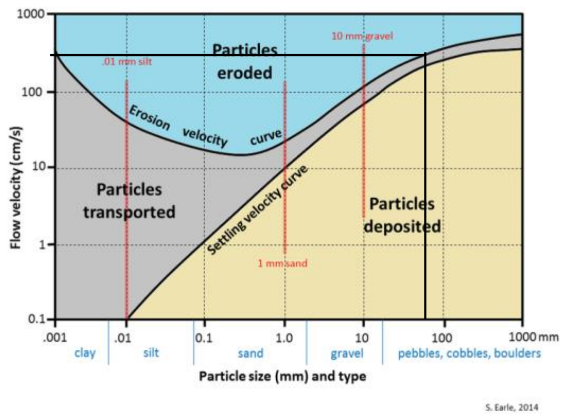
Setting flows – mobile bed material

What velocity is needed to mobilise this sediment?





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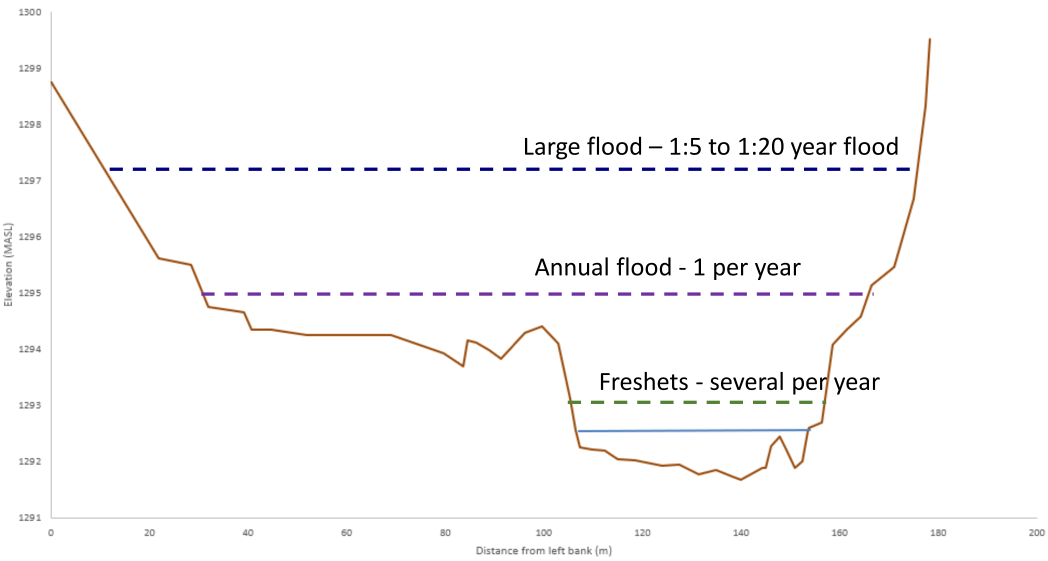
Setting flows – morphological features

Kraai Cross Section



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GAI model: Lower Kraai (UO_EWR08_I)

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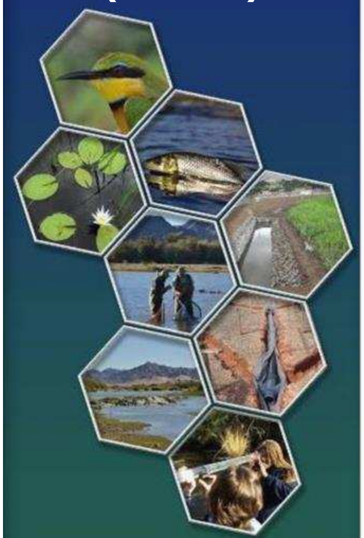
Riparian Vegetation Response Assessment Index **(VEGRAI)**



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VEGRAI: Riparian Vegetation Condition

Riparian Vegetation Response Assessment Index

Natural → Critically modified

100% — 0%

VEGRAI Ecological Category

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VEGRAI: Key Steps

- Define the **reference state** – the natural state or condition of the riparian habitat
- Identify and delineate riparian **vegetation zones**
- Identify **key/dominant/indicator plant species** in each zone – indigenous and exotic/ invasive alien plants (IAPs)
- Assess vegetation in each zone according to vegetation components, namely **woody and non-woody plant forms**
- Estimate cover and abundance of **indigenous woody and non-woody vegetation** in each zone
- Estimate cover of **exotic vegetation/IAP** cover
- Assess population structure and recruitment of **indigenous woody plants** (L4)
- Assess species composition of woody and non-woody **vegetation** within each zone taking into account both indigenous and exotic plant species (L4)

Run the VEGRAI Model

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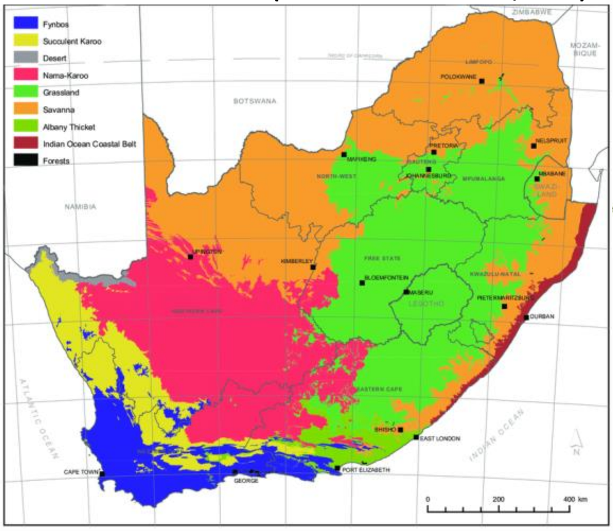
VEGRAI: Determine Reference State

Biomes of South Africa (Mucina & Rutherford, 2006)



What is the dominant state?

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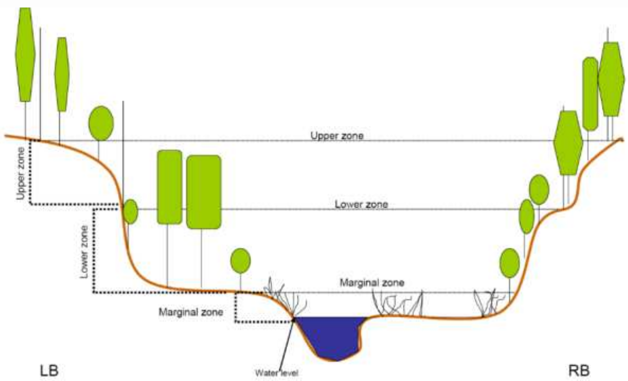
VEGRAI: Riparian Zones

Riparian vegetation is described in the Water Act (Act No 36 of 1998) as follows:

“riparian habitat'' includes the physical structure and **associated vegetation** of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to **support vegetation of species with a composition and physical structure distinct from those of adjacent land areas**.



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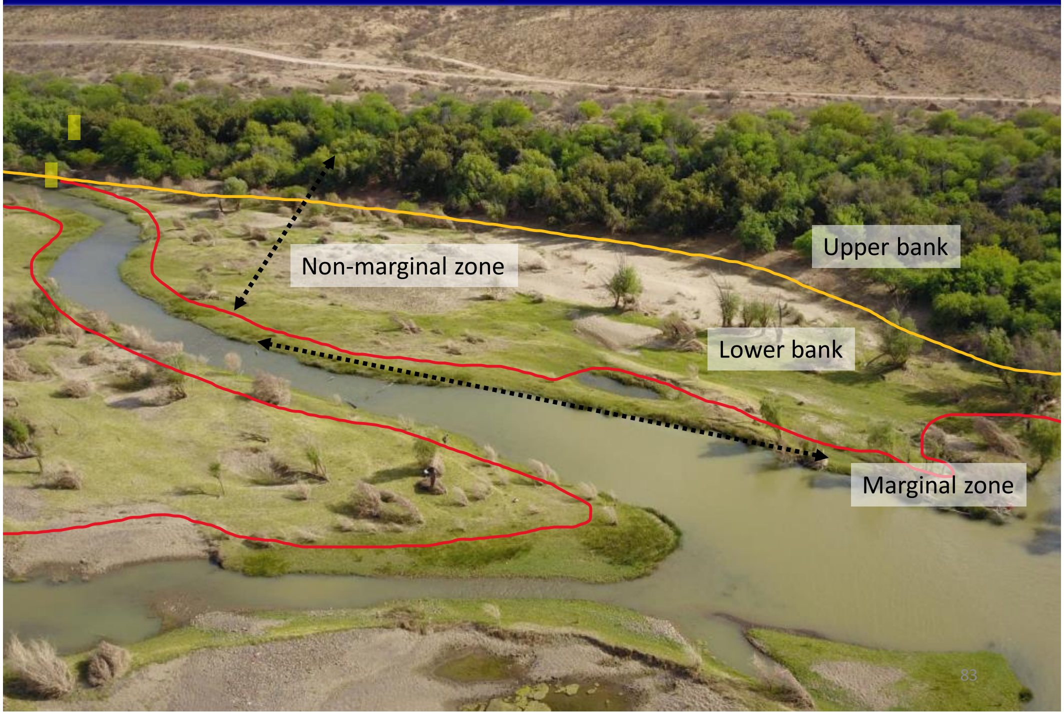
VEGRAI: Delineate Riparian Zones



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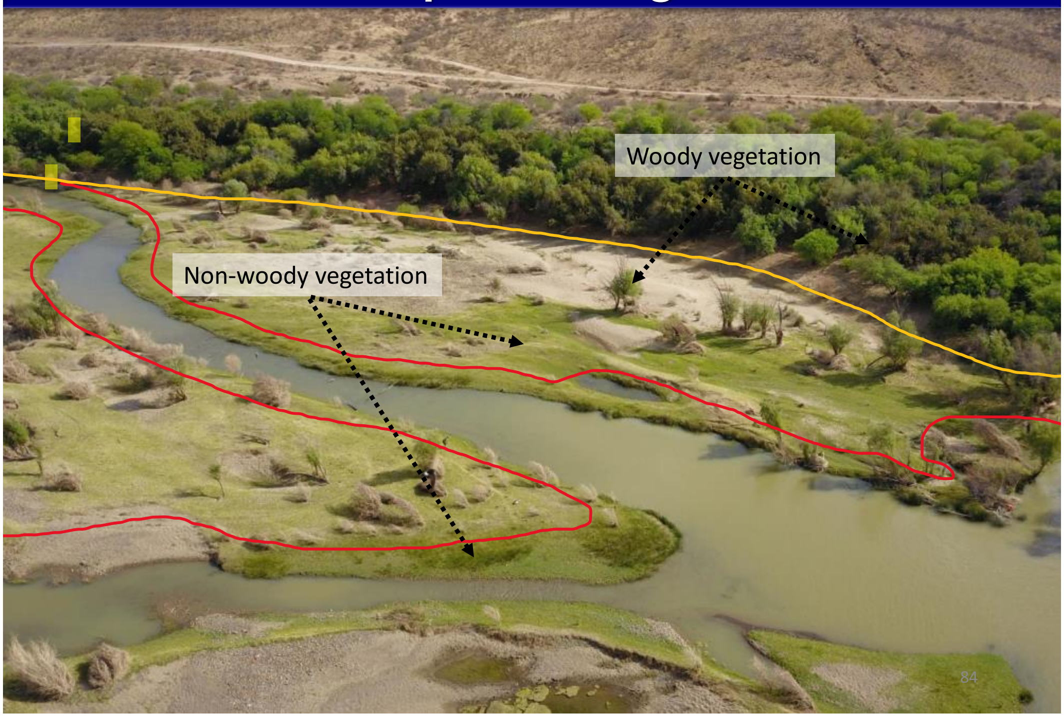
VEGRAI: Assess Riparian Vegetation



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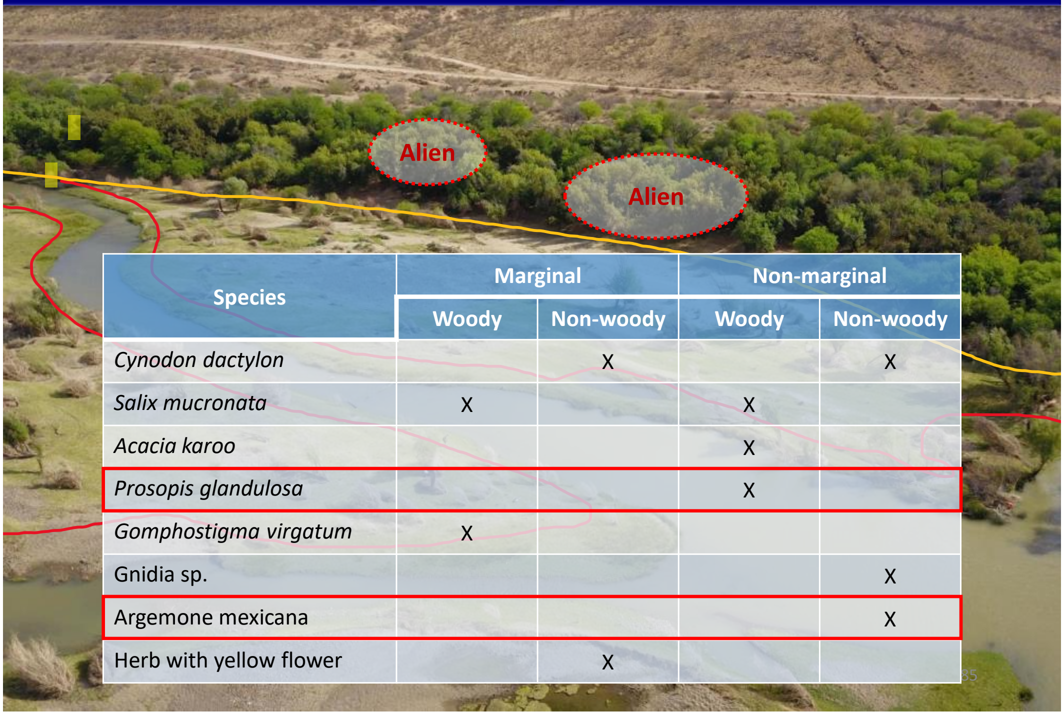
VEGRAI: Identify Plant Species



Species	Marginal		Non-marginal	
	Woody	Non-woody	Woody	Non-woody
Cynodon dactylon		X		X
Salix mucronata	X		X	
Acacia karoo			X	
Prosopis glandulosa			X	
Gomphostigma virgatum	X			
Gnidia sp.				X
Argemone mexicana				X
Herb with yellow flower		X		

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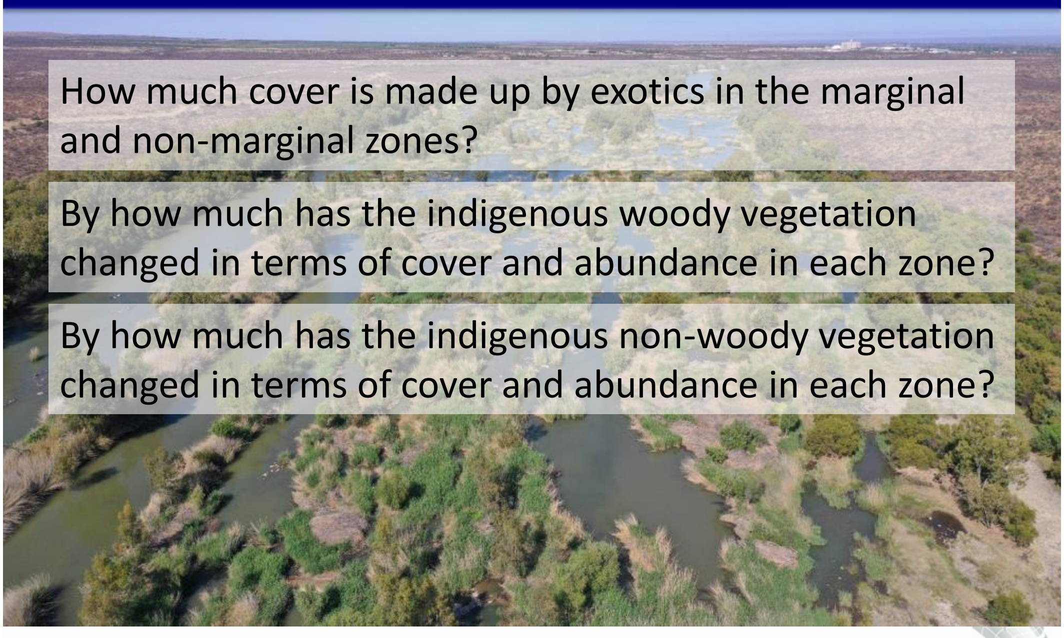
VEGRAI: Estimate Cover & Abundance

How much cover is made up by exotics in the marginal and non-marginal zones?

By how much has the indigenous woody vegetation changed in terms of cover and abundance in each zone?

By how much has the indigenous non-woody vegetation changed in terms of cover and abundance in each zone?



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Find a shady spot!

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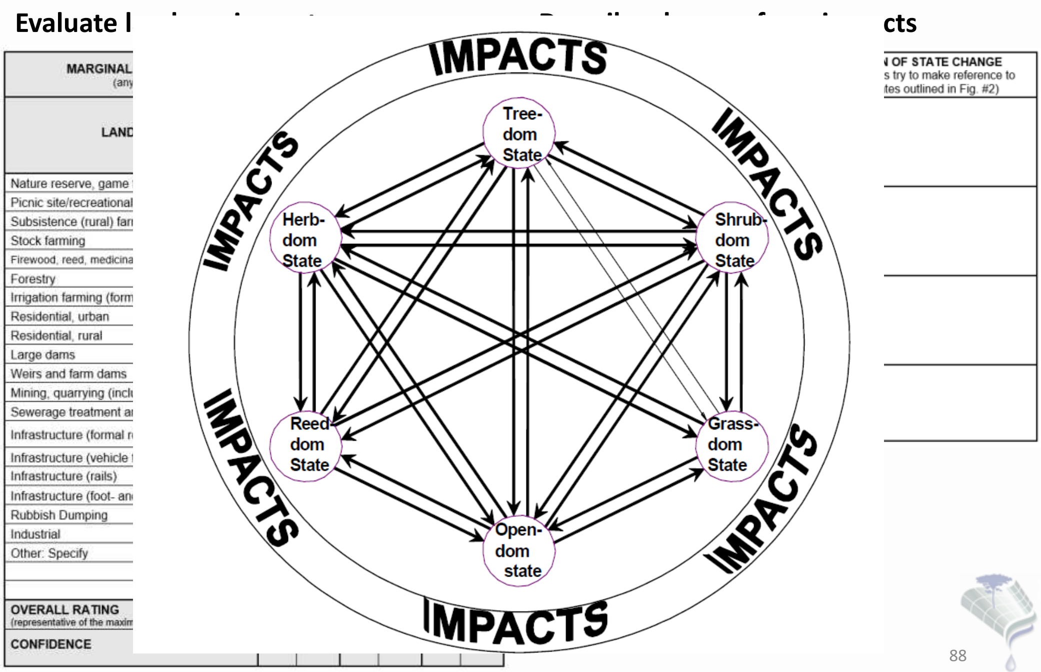
VEGRAI: Assess Impacts on Riparian Veg



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VEGRAI: Kraai River (UO_EWR08_I)

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Eco-Categorisation workshop

- Eco-Categorisation workshop: 29 November to 1 December 2022
- Team workshop attended by DWS colleagues
- Agenda has been circulated
- Objective:
  - Rapid 3 Reserve sites only
  - Summary of each site
  - Discuss the current EcoStatus and trend (decline, improvement or maintained)
  - Discuss the Recommended Ecological State
  - Ecological Water Requirements
- Hope to see you all there!

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THANK YOU FOR YOUR PARTICIPATION TODAY!

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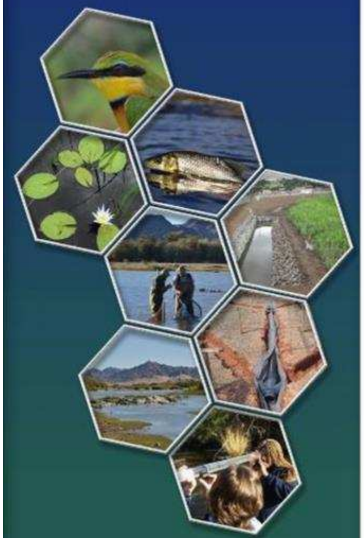
Appendix H: Scenario and Consequences Capacity Building Presentation

Scenario and Consequences Capacity Building



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A High Confidence Reserve Determination Study for Surface Water, Groundwater, and Wetlands in the Upper Orange WP11343

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Agenda

- Objective of todays capacity building;
- Purpose of assessing the scenarios and consequences;
- The process to define the operational scenarios;
- The approaches of assessing the ecological consequences of these scenarios for the rivers:
  - Hydrological modelling and interpretation
  - Water quality
  - Geomorphology
  - Riparian vegetation
  - Instream Biota (fish and macroinvertebrates)
  - Socio-economics
- Determining and ranking of scenarios per EWR site; and
- Working example: Upper Orange (UO_EWR03_I)

2

2

Objective of the Capacity Building

- Training on the scenarios and consequences process
  - Regulation 810 (Government Gazette 33541), 17 September 2010;
- Improve the understanding of:
  - The process whereby the operational scenarios are defined;
  - The approach to assessing the ecological consequences of these scenarios for the rivers, and
  - The qualitative approach to assessing the socio-economic consequences of the defined scenarios.
- End off with a working example.

3

3

OPERATIONAL SCENARIOS

4

4

What are operational scenarios?

What are operational scenarios?

- Scenarios, in context of water resource management and planning, are plausible definitions (settings) of all the factors (variable) that influence the water balance and water quality in a catchment and the system as a whole;
- Scenarios come in the form of proposed:
  - Dams
  - Weirs
  - Transfer schemes
  - Pipelines between catchments etc.
- Different levels of water use and protection are evaluated with the aim to find a balanced scenario.

ECOLOGICAL AND SOCIO-ECONOMIC CONSEQUENCES

7

Determining Ecological Consequences of Scenarios?

- Need to answer the 'what if' questions;

CONSEQUENCE: COMES AFTER…. OR A RESULT OR EFFECT OF SOMETHING…

- **Altering the natural flow of a river, can have severe ecological consequences**
  - Disrupt habitats
  - Decline water quality
  - Affect the biota
  - Affect the overall biodiversity of an area
- **Construction/development and the adverse effects on the rivers:**
  - Water quality
  - Affect the biota
  - Affect the overall biodiversity of an area

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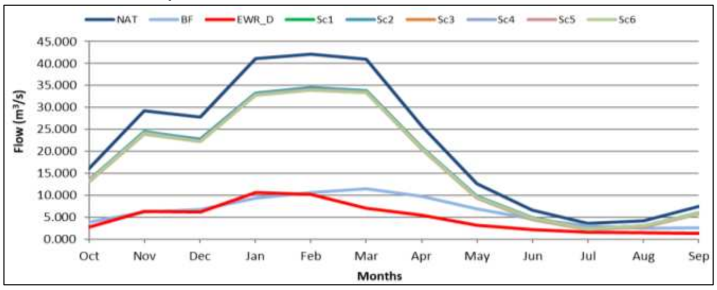
Determining Ecological Consequences of Scenarios?

- Express in terms of change in Ecological Category & degree to which the REC is met;
- Use the Eco-categorisation models to predict changes in the driver and response components at each EWR site for each scenario;
- Drivers:
  - Hydrology
    - Seasonal distribution of scenarios
    - Reduced freshets/ floods - might have significant impact even with good seasonality



Scenario hydrology.xlsx

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Determining Ecological Consequences of Scenarios?

- Drivers:
  - Water quality
    - Based primarily on diatoms, macroinvertebrates and any available physical-chemical data (limited)
    - Scenario 2 (current) and Scenario 7 (future); and
    - Evaluation of scenario 7 pertaining to water quality with insights derived from diatom results, macroinvertebrate data and the Green Drop Reports (GD score of <31% non-compliance, dysfunctional). Biotic response was based on these results for Sc7.
  - Geomorphology
    - Scenarios were assessed using the GAI
    - Where additional dams are proposed to be constructed in the catchment
    - Changes to freshets, flood flows and longitudinal sediment transport (main geomorphological drivers)

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Determining Ecological Consequences of Scenarios?

- Responses:
  - Riparian vegetation
    - Scenarios were assessed using the VEGRAI
    - Only for systems where future planned developments would occur;
    - Significant effects on the flow regime and/or geomorphological changes
    - Changes to freshets, flood flows (important for the marginal riparian vegetation reset)
  - Biota
    - Assessment of all drivers (hydrology, water quality and geomorphology) and the response from the riparian vegetation
    - Fish Invertebrate Flow Habitat Assessment Model (FIFHA) (as per ToR)
    - Limitations:
      - Does not account for the effects of increased flows, alteration to flow patters (e.g: dry season – WWTW releases, increased baseflows) or water quality
      - Rheophilic fish and invert limitations
      - At times, needed to make use of expertise and understanding the changes and responses of the biota to happen

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FIFHA example

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Determining Socio-economic Consequences of Scenarios?

- Contextual background
  - Review of altered flows to meet EWR;
  - Guided by the WRCS Socio-Economic Guidelines (DWAF, 2007, DWS, 2016);
  - Existing socio-economic data;
  - Spatial visualization (maps);
  - Visual reflection of potential areas of relative greater vulnerability; and
  - Overall, analysis based on socio-economic context from Socio-Economic Baseline Report (Report No. RDM/WMA13/00/CON/COMP/1123).

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Determining Socio-economic Consequences of Scenarios?

- Scale of assessment:
  - Socio-economic baseline at local municipality scale; and
  - Interpretation of EWR site based on local municipality baseline.

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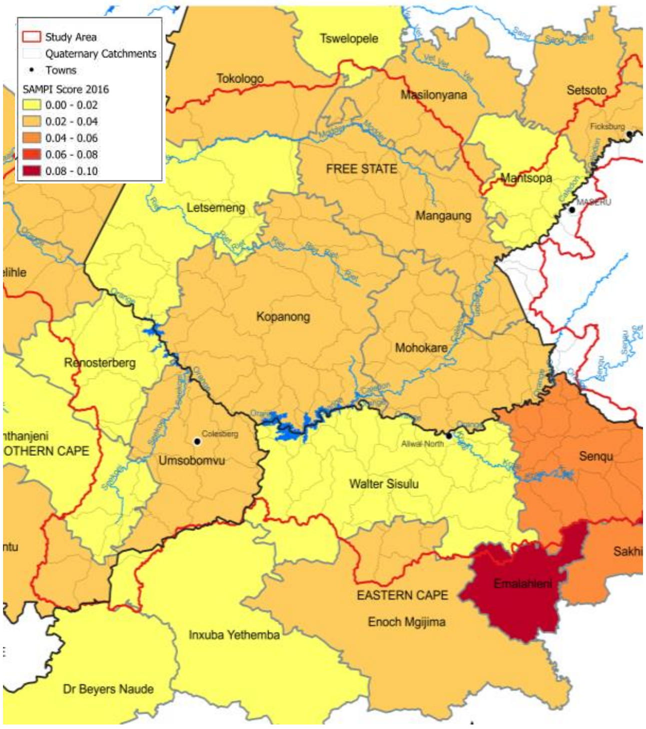

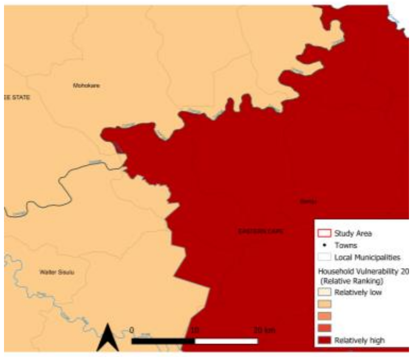

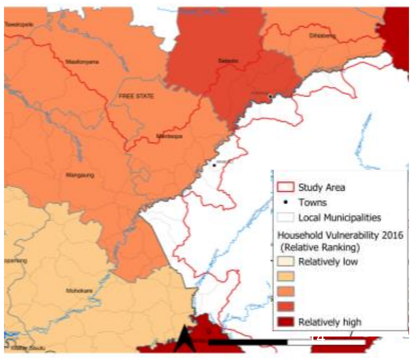

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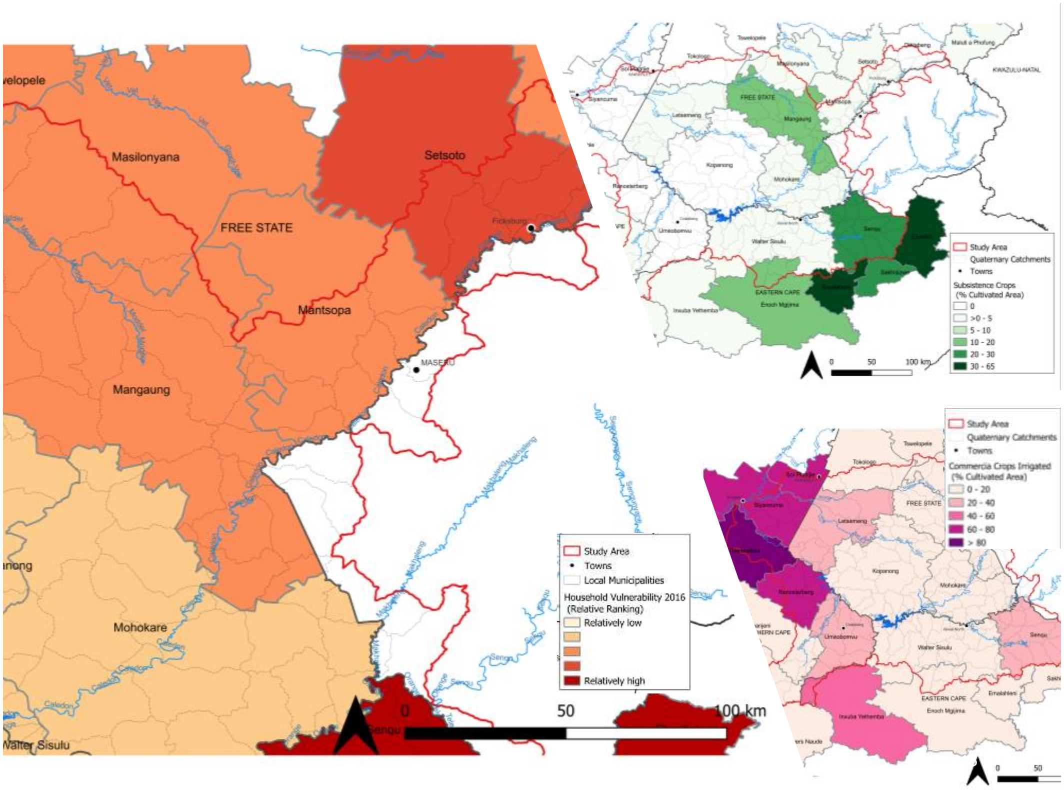

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Determining Socio-economic Consequences of Scenarios?

- System Drivers and Response Elements Reviewed:
  - Water quantity
  - Water quality
  - Geomorphology
  - Riparian vegetation
  - Fish and macroinvertebrates
- Consideration of Socio-economic Outcomes:
  - Comparison between 'with EWR' and 'without EWR' scenarios.
  - Analysis across five key socio-economic aspects:
    - Household vulnerability
    - Domestic (treated) water use
    - Subsistence cultivation
    - Commercial irrigated agriculture
    - Local economy

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Determining Socio-economic Consequences of Scenarios?

- Predictive Methodology:
  - Qualitative prediction of socio-economic outcomes under altered flow regimes.
  - Narrative statements for scenarios with identified likely outcomes.
  - Indicator levels described as a range from low to high based on the Upper Orange catchment.
- Scope and Limitations:
  - Socio-economic evaluation based on predicted driver and state responses at EWR sites.
  - Indication of socio-economic outcomes for the site and local municipalities.
  - Exclusion of potential socio-economic outcomes related to changes upstream for EWR.
  - Flow modeling interpreted considering present human water use and growth projects.

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Determining the ranking of scenarios per EWR site

- Step 1: The degree to which the scenario meets the PES per component

Ecological Category	≥PES/ component	½EC < PES/ component	1 EC < PES/ component	>1 EC PES component
Colour key	Green	Yellow	Orange	Red

- Step 2: The relative ecological significance of the sites:
- Step 3: Rank the scenarios in a system context based on assumptions
- Step 4: Interpretation of Sc7 from a biotic perspective

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Determining the ranking of scenarios per EWR site

Ecological Category	≥PES/ component	½EC < PES/ component	1 EC < PES/ component	>1 EC PES component
Colour key	Green	Yellow	Orange	Red

Component	PES	REC	Sc1	Sc3	Sc3	Sc4	Sc5	Sc6
Geomorphology	C	D	C/D	C/D	D	D	D/E	D/E
Riparian Vegetation	D		D	D	D	D	D/E	D/E
Fish	D		A	A	B	B	B	B
Macroinvertebrates	C/D		A	A	B	B	B	A
EcoStatus	D							
Meeting Overall REC			√	√	X	X	X	X

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UO_EWR03_I Upper Orange

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UO_EWR03_I: Upper Orange

Recap on the scenario's…

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

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UO_EWR03_I *(D12F)*

Hydrological modification due to upstream impoundments within Lesotho

Diatoms: elevated nutrient concentrations prevalent at the site because of the Sterkspruit discharging untreated sewage upstream. Other contaminants and toxins were also picked up given the untreated effluent discharged upstream.

Widespread overgrazing and soil erosion in the catchment (largely Lesotho and communal land) elevating fine sediment loads)

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

Poor habitat availability for both fish and aquatic macroinvertebrates

Extensive alien invasive plants

(High)-Moderate (riparian-wetland zone habitat integrity class / instream habitat integrity class)

(High)-Moderate (reduced macroinvertebrate sensitivity / riparian-wetland vegetation intolerance to water level changes)

EWR

Quaternary Catchment	R12F
nMAR at EWR site	4 259.5
Total EWR	1067.450 (25.06 %MAR)
Maintenance Low flows	554.061 (13.01 %MAR)
Drought Low flows	206.669 (4.85 %MAR)
Maintenance High flows	513.389 (12.05 %MAR)

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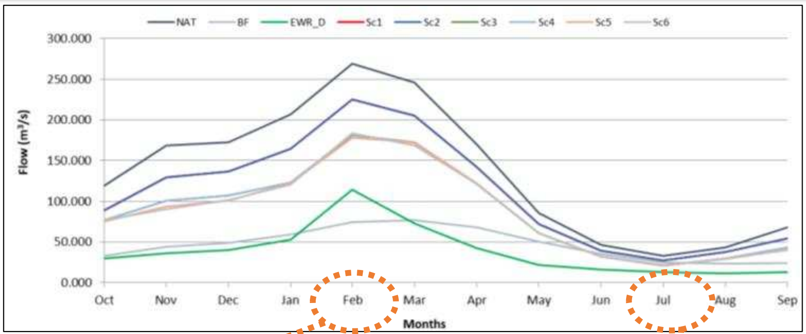
UO_EWR01_I: Upper Orange



Percentiles	Natural	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	EWR_D
0.1	1001.244	920.673	920.673	728.350	728.349	727.654	727.654	206.949
1	875.691	772.627	772.627	725.324	725.313	726.334	726.334	206.949
5	711.070	611.777	611.778	526.404	526.404	525.559	525.291	206.937
10	562.898	510.494	510.493	441.747	441.747	440.953	440.953	205.648
15	516.934	443.862	443.862	376.697	376.697	374.522	374.523	191.458
20	470.439	382.324	382.325	280.330	280.301	270.909	270.105	180.968
30	286.068	239.098	239.098	187.760	187.862	185.188	186.834	160.079
40	214.979	178.692	178.692	137.304	137.409	133.168	146.556	139.156
50	174.796	138.820	138.820	110.317	110.605	104.785	117.470	106.945
60	157.113	122.337	122.336	91.962	92.118	88.978	97.928	92.259
70	136.245	100.617	100.617	77.034	77.033	76.077	84.838	72.474
80	105.099	85.176	85.248	63.354	63.424	62.870	68.943	48.805
85	83.165	69.121	69.121	49.466	49.465	48.181	56.397	37.743
90	65.408	53.666	53.666	37.309	37.479	37.272	43.798	30.363
95	42.130	37.660	37.658	28.847	28.847	28.009	27.965	23.134
99	24.164	24.375	24.375	16.288	16.572	11.884	19.844	20.054
99.9	22.328	22.409	22.408	15.653	15.937	11.266	18.356	20.054

Percentiles	Natural	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	EWR_D
0.1	167.017	128.680	128.680	108.424	108.423	108.954	108.366	18.624
1	153.111	122.640	122.639	91.772	91.771	92.108	86.222	18.624
5	121.242	95.143	95.143	67.766	67.766	66.553	66.553	18.611
10	75.059	65.053	65.053	45.840	45.840	44.848	44.683	18.545
15	61.015	47.186	47.186	35.017	35.017	36.180	34.921	18.411
20	48.777	41.649	41.648	30.511	30.510	32.901	32.868	18.195
30	35.990	28.919	28.918	22.016	22.016	23.628	22.980	17.575
40	22.982	19.410	19.410	15.806	15.806	18.021	18.021	16.003
50	18.551	16.258	16.259	13.212	13.440	12.791	14.589	14.214
60	15.374	13.959	14.013	11.353	11.351	10.885	13.445	11.057
70	12.223	10.225	10.314	8.580	8.623	8.942	10.073	8.835
80	9.059	8.421	8.419	7.220	7.220	6.325	7.494	6.695
85	7.165	7.031	7.106	6.117	6.204	5.447	6.661	5.982
90	6.598	5.701	5.702	4.661	4.964	4.152	5.614	5.495
95	5.908	5.014	5.152	3.998	4.131	2.896	5.179	5.219
99	2.932	3.138	3.159	2.700	2.894	2.069	4.331	2.932
99.9	2.848	2.551	2.674	2.362	2.869	1.564	3.094	2.847

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Which scenarios were evaluated?

Present day with EWR for REC

Present day with EWR for REC (Sc2) with progressive water quality decline

Component	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
Quality							
Geomorphology							
Riparian Vegetation							
Biota							
Socio-economics							

All aspects on Socio-economics

Impacts from Polihali Dam (Lesotho) upstream of EWR site (Sc3 and Sc4) Verbeeldingskraal on upper Orange upstream of EWR site (Sc5 and Sc6)

Biotic responses to wq declines

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UO_EWR03_I: Water Quality

- Scenario 2:
  - Maintenance of the typical summer/wet season volume
  - Thus, water quality will be reset during the rainfall season
    - Benthic algal growth from nutrient enrichment will be scoured out
    - System refreshed.
  - Low flows during the winter/dry season (June – August) will be when the discharge from WWTW contribute some additional base flow to this system
    - Thus base / low flow period being when the nutrients, bacteria, and other WWTW associated outputs dominate the water quality in the system.
- Scenario 7:
  - Critical degradation of water quality
  - Expected to worsen significantly in the future
  - Significant decline in health and functionality
  - Impaired ability to deliver ecosystem goods and services (i.e. clean water)
  - Major cause: impacts from Lesotho and failing WWTW
  - Implications of Worsening Water Quality: increased frequency and persistence of waterborne diseases, seasonal risk

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UO_EWR03_I: Geomorphology

Geomorphology							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
C		C/D	C/D	D	D	D/E	D/E

Polihali Dam (Lesotho) (Sc3–Sc4)

Verbeeldingskraal Dam (Sc5–Sc6)

- Let's discuss the consequences ……

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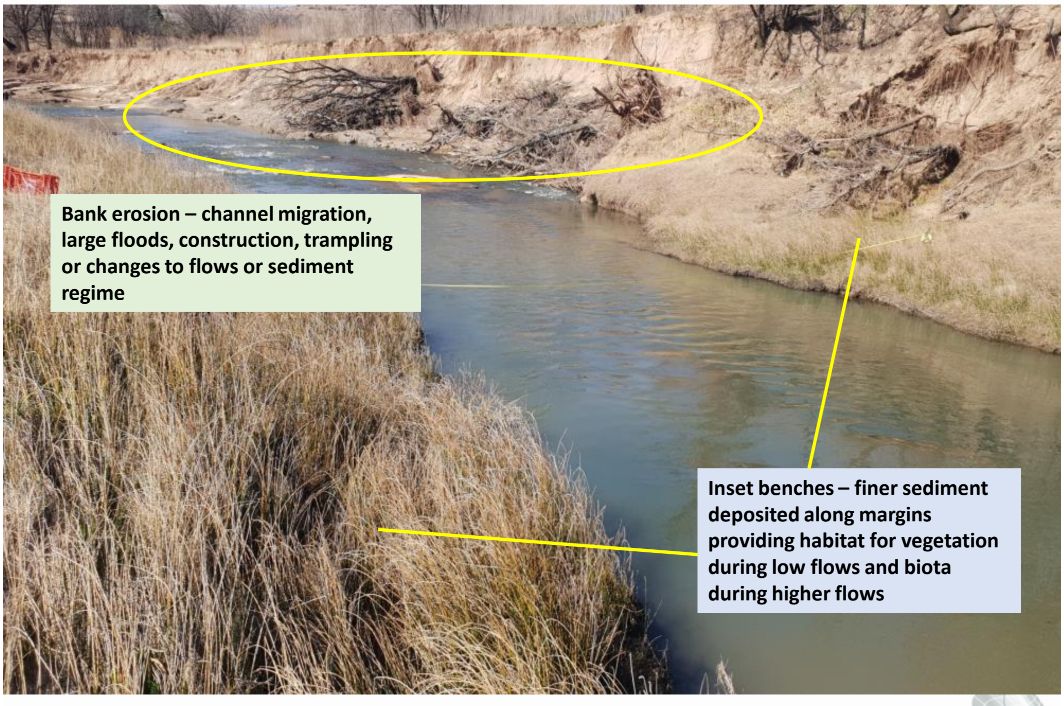

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Sedimentation – high sediment loads lead to high sedimentation rates. Fine sediment often covers larger substrates, making them unavailable for biota. This leads to reduced habitat diversity

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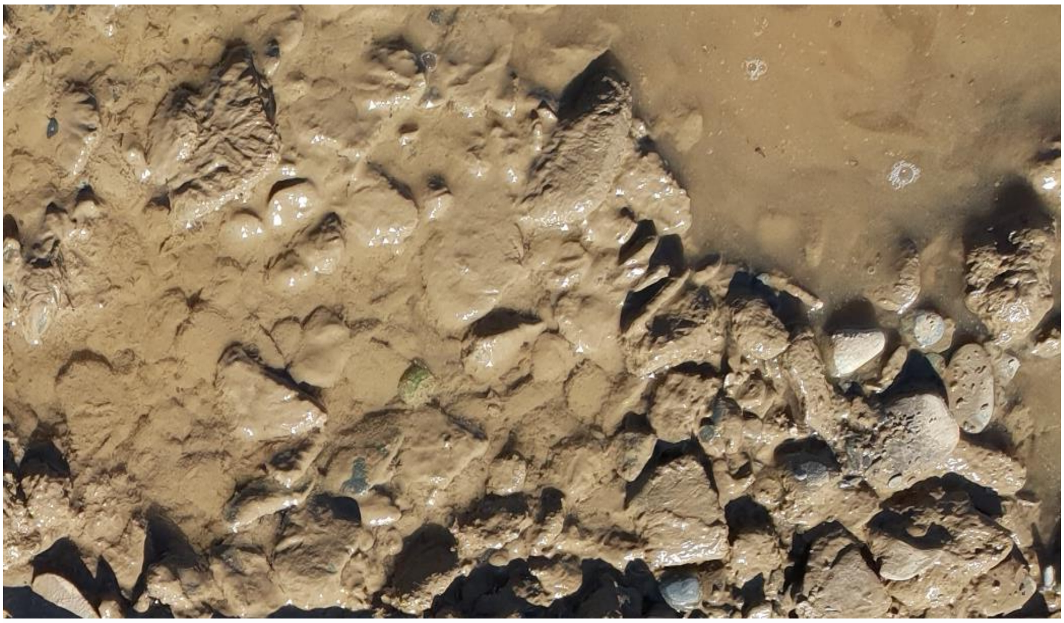

Embedded coarse sediment – fine sediment filling voids between coarse sediment particles – coarse sediment not available to biota

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Armoured bed – bed sediment trapping upstream (mostly large dams), leading to a reduction in finer and more mobile sediment reaching the site. A static bed dominated by large sediment is the result – reduced habitat diversity

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UO_EWR03_I: Geomorphology

Geomorphology							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
C		C/D	C/D	D	D	D/E	D/E

- Sc3/Sc4: reductions in sediment and flow, freshets reduced, thus increased embeddedness due to smaller events. Polihali Dam will trap bedload – moderate sand supply
- Sc5/Sc6: large impact on the sediment regime, trapping suspended sediments. Change in longitudinal connectivity – thus the current alluvial channel will be starved of bed sediment - channel incision, bank erosion. The bed sediment coarser (less sediment deposited on flood features).

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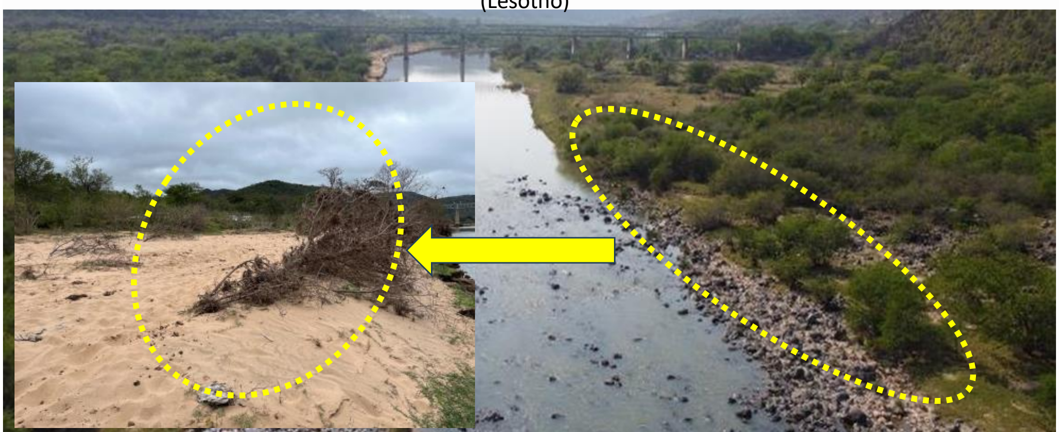
UO_EWR03_I: Riparian vegetation

Riparian Vegetation							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
D		D	D	D	D	D/E	D/E

Polihali Dam (Lesotho)

Verbeeldingskraal Dam



- Let's discuss the consequences ……

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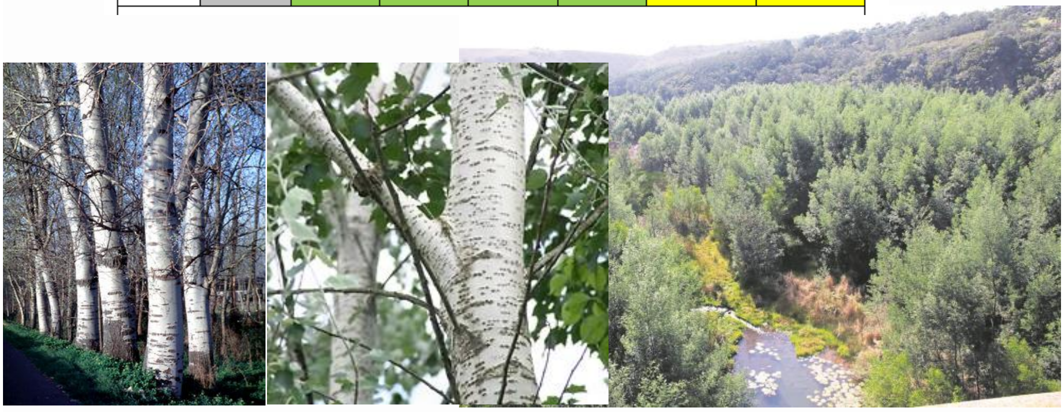
UO_EWR03_I: Riparian vegetation

Riparian Vegetation							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
D		D	D	D	D	D/E	D/E



- What do you see here – lets discuss the consequences …

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UO_EWR03_I: Riparian vegetation

Riparian Vegetation							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
D		D	D	D	D	D/E	D/E

- Sc3/Sc4: flood peaks will be reduced, baseflows more constant. Lead to increased terrestrialisation and increased dominance of reeds in the marginal zone

- Sc5/Sc6: Flood magnitude and frequency will be further reduced, freshets will become less frequent. The channel incision and bank erosion will further degrade riparian vegetation (along the margins and lower banks). It is expected that the marginal zone will become more degraded, with terrestrial species encroaching and increase alien invasive plants.

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UO_EWR03_I: Biotic

Fish and Macroinvertebrates									
	PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
Fish Dry	D		A	A	A	A	A/B	A	D/E
Inverts Dry	C/D		A	A	A	A	A	A	D
Fish Wet	D		A	A	B	B	B	B	D/E
Inverts Wet	C/D		A	A	B	B	B	A	D

- FIFHA model did not yield accurate results;
- Thus, the team reverted to fundamental principles and incorporated additional metrics into their interpretations;
- These metrics included factors like increased flows, siltation, erosion, incision, and/or limited habitat availability.
- Macroinvertebrates:
  - Homogenous system with limited habitat – however reduced marginal vegetation and the alluvial system starved of sediment (only habitats available for inverts), the indicator taxon Caenidae relies on the GSM.
  - NB to note: the macroinvertebrate community is not significantly influenced by alterations in flow currently. Instead, showed significant responses to low to very low requirements for unaltered physical-chemical conditions. As a result, the primary factor shaping the macroinvertebrate PES, which was assessed to be moderately to largely modified was water quality.

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UO_EWR03_I: Biotic

Fish and Macroinvertebrates									
	PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
Fish Dry	D		A	A	A	A	A/B	A	D/E
Inverts Dry	C/D		A	A	A	A	A	A	D
Fish Wet	D		A	A	B	B	B	B	D/E
Inverts Wet	C/D		A	A	B	B	B	A	D

- Fish:
  - Lack of true rheophilic species, large semi-rheophilic fish species were selected to act as flow-dependent indicators.;
  - The reach has no critical habitat
    - For early-life stages
  - Primary focus in this respect was given the faster flowing velocity-depth classes, notably fast-intermediate and fast-deep classes.
  - The indicator species have a wide diversity of habitat preferences, thus the changes in flow wouldn't affect them;
  - Nevertheless, loss of seasonal high-flow events and/or unseasonal releases following the development of various dams proposed is likely to impact the migratory cues for the indicator fish species, and result in a loss of upstream connectivity and habitat fragmentation; and
  - Water quality concerns.

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UO_EWR03_I: Summary

Component	PES	REC		Sc1	Sc3	Sc3	Sc4	Sc5	Sc6
Geomorphology	C			C/D	C/D	D	D	D/E	D/E
Riparian Vegetation	D			D	D	D	D	D/E	D/E
Fish	D	D		A	A	B	B	B	B
Macroinvertebrates	C/D			A	A	B	B	B	A
EcoStatus	D								
Meeting Overall REC				√	√	X	X	X	X

Should one/more of the components not meet their PES by a whole category/more, ultimately, that scenario will not meet the requirements of the overall REC for the EWR site.

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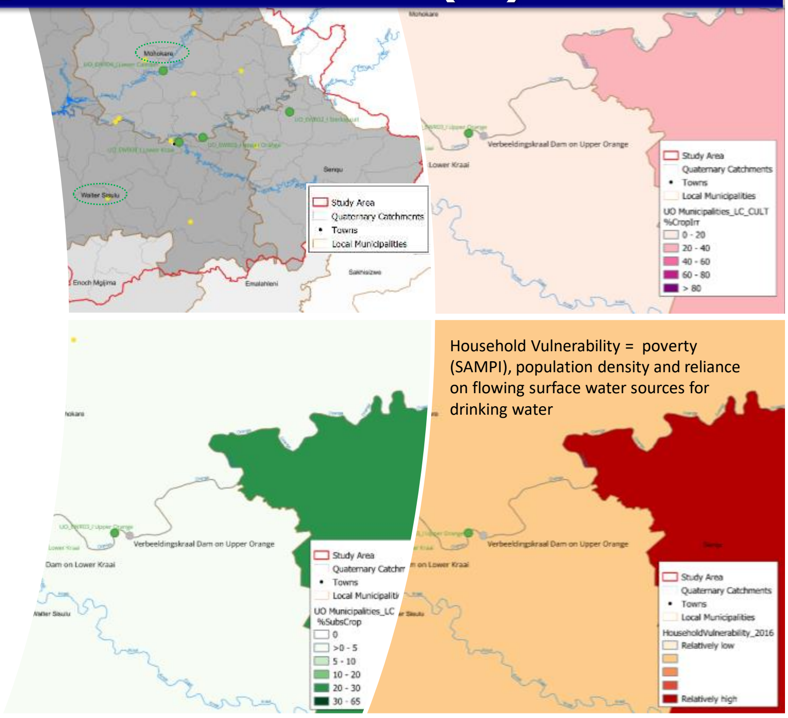
UO_EWR03_I: Socio-Economic (SE)

Present SE state

- Little irrigated commercial agriculture
- Limited subsistence agriculture
- Low relative incidence of vulnerable households



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UO_EWR03_I: Socio-Economic (SE)

Present SE state

- Basic Human Needs Reserve – River sources

Basic human needs surface water (river/stream) Reserve required, by quaternary catchment, Upper Orange study area

Quaternary drainage region	Population (current requirement)	Per capita need (litres / day)	NMAR (MCM)	Basic human needs surface water Reserve required*	
				MCM / annum	% NMAR
D12F	4	25	24.500	0.00003	0.00014
D14A	29	25	21.800	0.00026	0.00121

The BHN Reserve aims to ensure that the essential needs of individuals served by the water resources in question are provided for.
River Reserve - people directly dependent on surface water (rivers) abstraction to meet their basic needs.

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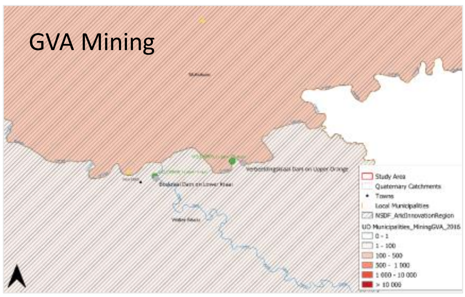
UO_EWR03_I: Socio-Economic (SE)

Present SE state

- Local economy

Local municipality	Three major economic sectors 2016	Local economic development focus areas Latest available IDP Report
Walter Sisulu	Government and community services. Finance, insurance, real estate and business services. Wholesale and retail trade, catering and accommodation.	Agriculture and land reform. Tourism (Gariep Dam, Game reserves). Renewable energy. Fishing (development of infrastructure).
Mohokare	Wholesale and retail trade, catering and accommodation. Government and community services. Finance, insurance, real estate and business services.	Agriculture (irrigated). Tourism (Orange River, heritage sites, nature reserves (Vulture Conservation Area, Tussen-die-Riviere and Oviston), game lodges).

- Arid Innovation Region - vulnerable to changes in water resources
- GVA – primary sectors



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UO_EWR03_I: SE Summary Results

Ecological/biophysical analysis and consequences

Component	PES	REC		Sc1	Sc3	Sc3	Sc4	Sc5	Sc6
Meeting Overall REC				√	√	X	X	X	X

- Indicate inadequate flow and compromised water quality for Sc3 to Sc6

SE Summary Results

Together, the Present State & Ecological Outcomes

- ➢ Suggests, for Sc3 to Sc6, there may be a risk to the ability of the system to meet socio-economic water-use
- ➢ However, the low relative incidence of vulnerable households and limited subsistence agriculture and commercial agriculture limits the likely extent of the risk

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UO_EWR03_I: Conclusion

Ecological consequences

Component	PES	REC		Sc1	Sc3	Sc3	Sc4	Sc5	Sc6
Geomorphology	C	D		C/D	C/D	D	D	D/E	D/E
Riparian Vegetation	D			D	D	D	D	D/E	D/E
Fish	D			A	A	B	B	B	B
Macroinvertebrates	C/D			A	A	B	B	B	A
EcoStatus	D								
Meeting Overall REC				√	√	X	X	X	X

Socio-economic consequences

Component	PES	REC		Sc1	Sc3	Sc3	Sc4	Sc5	Sc6
Meeting Overall REC				√	√	X	X	X	X

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Thank You!

Any Questions please don't hesitate to contact the team!

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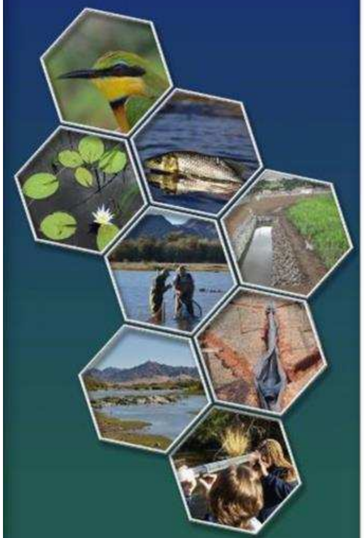
Appendix I: Final Capacity Building – Holistic Overview of the Reserve Determination Process for all water resources

Final Capacity Building



30 January 2024

A High Confidence Reserve Determination Study for Surface Water, Groundwater, and Wetlands in the Upper Orange WP11343

GroundTruth

1

Agenda and Purpose

- Purpose of capacity building workshop:
  - Provides a recap on the approaches and main steps to assess and determine the Reserve for the:
- Rivers – main steps/ tasks undertaken
- Wetlands – overview of steps for assessment
- Groundwater – approach for groundwater Reserve

2

2

RIVERS

3

Rivers - approach

- Step 1 •Identify priority quaternary and sub-quaternary catchments that are potentially important due to their presence, extent or condition of water resources with a focus on wetlands and groundwater driven systems. Initiate the BHN and EWR assessment
- Step 2 •Determine eco-regions, delineate resource units, select priority study sites and where appropriate, align with Step 1 of the water resource classification procedure.
- Step 3 •Determine the reference conditions, present ecological status (PES), ecological importance and sensitivity(EI-ES), recommended ecological category (REC) and Ecological Water Requirement (EWR) for the priority selected study sites.
- Step 4 •Determine the basic human needs (BHN) and EWR for each of the selected priority study sites
- Step 5 •Determine the operational scenarios/rules and ecological consequences for meeting the Reserve (aligned with the classification procedure)
- Step 6 •Evaluate the scenarios with stakeholders
- Step 7 •Design appropriate Reserve templates, eco-specifications and monitoring programme including monitoring requirements
- Step 8 •Gazette and implement the Reserve

- Outlined in the Establishment of a Water Resource Classification System (WRCS) as per Regulation 810 (Government Gazette 33541) dated 17 September 2010
- Reserve determination process as outlined in the study, 'Development of Procedures to operationalise Resource Directed Measures' (DWS, 2017)

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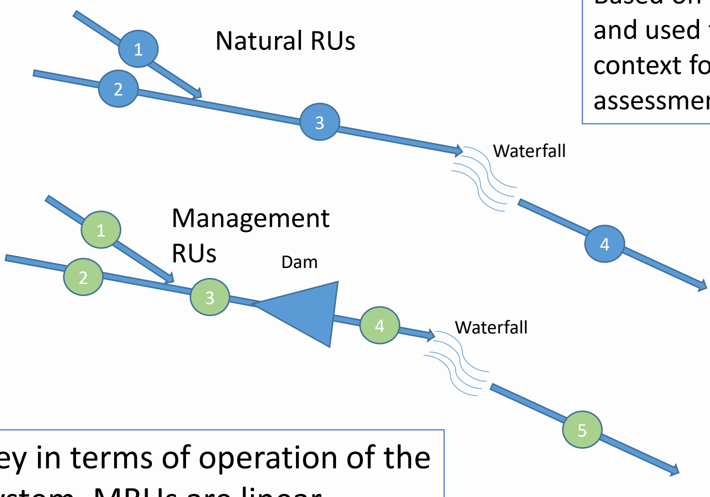
Resource Units (RU)

Step 2

Based on mostly EcoRegions and used for providing context for biophysical assessments.



Key in terms of operation of the system. MRUs are linear sections of key river reaches for which a Reserve is set

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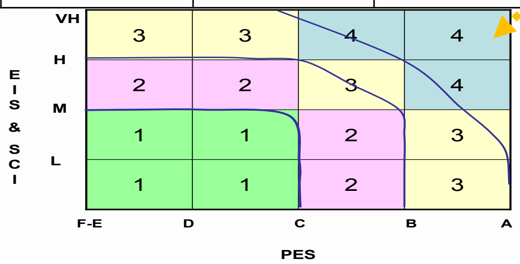
Delineating and Prioritising River RU – Approach (1)

Resource Stress		
Water use impact	***Water quality impact***	***Integrated Water Use Index (IWUI)/ Resource stress***
Scoring: 1 – None; 4&5 – critical		Maximum of the 2

Ecological Stress/protection						
PES	***EI***	***ES***	***FEPA***	***SWSA***	***EIS***	***Integrated Ecological Importance (IEI)***
Per SQ (A – F)	1 – Very low/ low 2 – Moderate 3 – High 4 – Very high		1 - no FEPA 2 - Ph2FEPA/US 3 - FSA/Corridor free flowing 4 - FEPA/ flagship/ IUCN	1 - no SWSA 2 - SW 3 - SW-GW 4 – SW & SW-GW	Max of EI, ES, FEPA, SWSA	Integrate EIS&SCI and the PES graph



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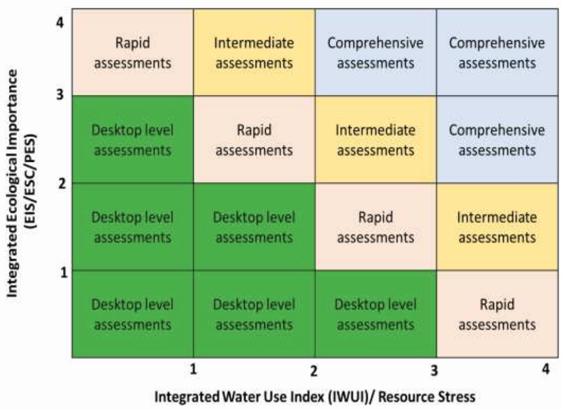
Delineating and Prioritising River RU – Approach (2)



Integrate IWUI + IEI = Level of Reserve study	
Resource stress (IWUI): x-axis	Ecological stress (IEI): y-axis

IWUI + IEI	
Level of Reserve study	**River Priority Rating**
• Intermediate / comprehensive • Rapid 3 • Desktop	• 1 – Priority (intermediate / comprehensive) • 2 – Rapid 3 • 3 – Desktop

Other considerations:

- Socio-cultural Importance
- Fish sanctuaries
- IUCN red listed fish species
- Sensitive macroinvertebrates
- Protected riparian vegetation species
- Invasive plants

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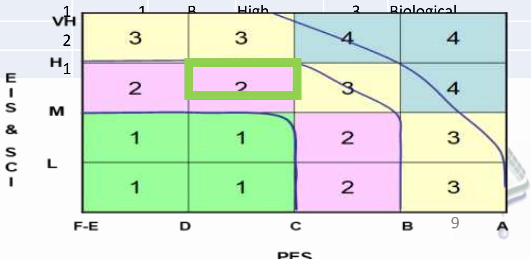
Example – Kraai River

Sub-quat	Quat	River	Water Use	Quality	IWUI	PES	EIS	IEI	Level
D13A-05712	D13A	Bokspruit	1	1	1	B	High	3	Biological
D13B-05474	D13B	Kraai	3	1	3	C	High	2	Rapid 3
D13C-05672	D13C	Sterkspruit	2	2	2	C	High	2	Biological
D13D-05766	D13D	Langkloofspruit	2	3	3	C	High	2	Rapid 3
D13E-05438	D13E	Joggemspruit	3	1	3	C	High	2	Biological
D13E-05604	D13E	Kraai	2	1	2	B	High	3	Rapid 3
D13F-05664	D13F	Kraai	1	1	1	B	High	3	Biological
D13G-05918	D13G	Wasbankspruit	1	1	1	B	High	3	Biological
D13H-06067	D13H	Holspruit	2	2	2	C	Moderate	1	Biological
D13J-05741	D13J	Holspruit	1	1	1	B	High	3	Biological
D13K-05454	D13K	Karringmelkspruit	0	0	0	B	High	3	Biological
D13K-05718	D13K	Kraai	1	1	1	B	High	3	Biological
D13L-05650	D13L	Kraai	1	1	1	B	High	3	Biological
D13M-05442	D13M	Kraai	2	2					
D13M-05591	D13M	Klipspruit	2	1					



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EWR Site Selection

Considerations (1)

Step 2

- Priority RUs (stressed areas, hotspots)
- Gauging weirs with good quality hydrological data
- Characteristics of tributaries
- Level II EcoRegions (one site per ecoregion)
- Geomorphological zones
- Habitat diversity/ critical habitats for aquatic organisms, marginal and riparian vegetation
- Suitability of the sites for accurate hydraulic modelling (range of possible flows, especially low flows)
- Accessibility and safety

Longitudinal view

Rapid/Chute

Run

Riffle

Pool

Critical habitats: ***If flow increase/ decrease, which habitat will be most affected?***

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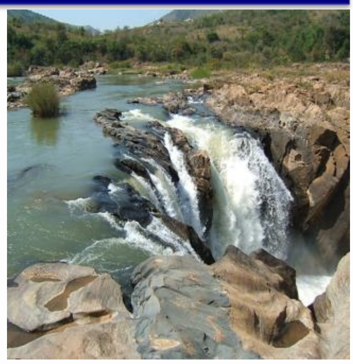
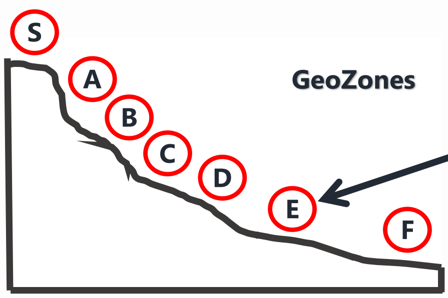
Considerations (2)

EcoRegions:
Is the site representative of the reach?
Can be used for extrapolation to other sites within reach



Availability of habitat types

Geomorphic zones:



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Considerations (3)

Is the site suitable for sampling?

- ***Hydrology (availability of gauges in vicinity of EWR site)***
- ***Hydraulics***
  - *Can we accurately calculate the discharge of the river at the site?*
  - *Bends, islands, side/ multiple channels, bridges and bars, slope, inundation – confidence of modelled results*
  - *Ideal? U-shaped cross section in a straight channel*

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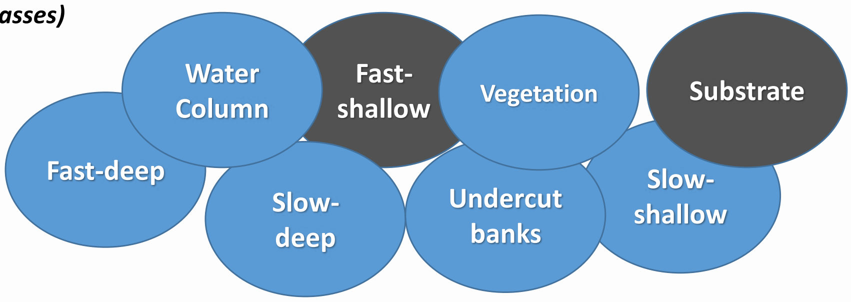
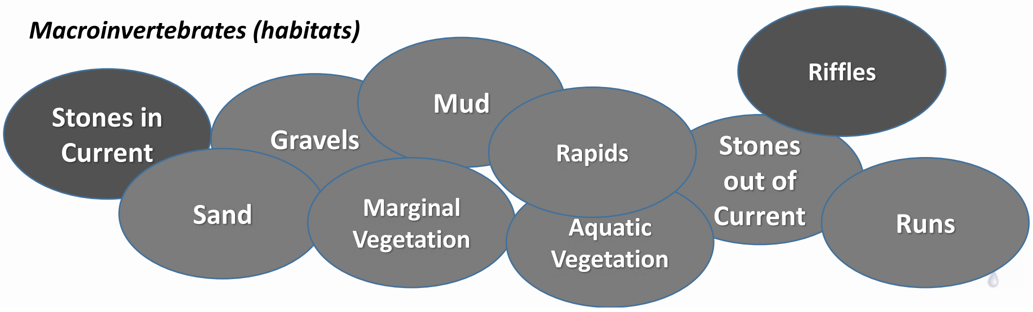
Considerations (4)

Is the site suitable for sampling?

- ***Fish (habitats, velocity-depth-classes)***



- ***Macroinvertebrates (habitats)***



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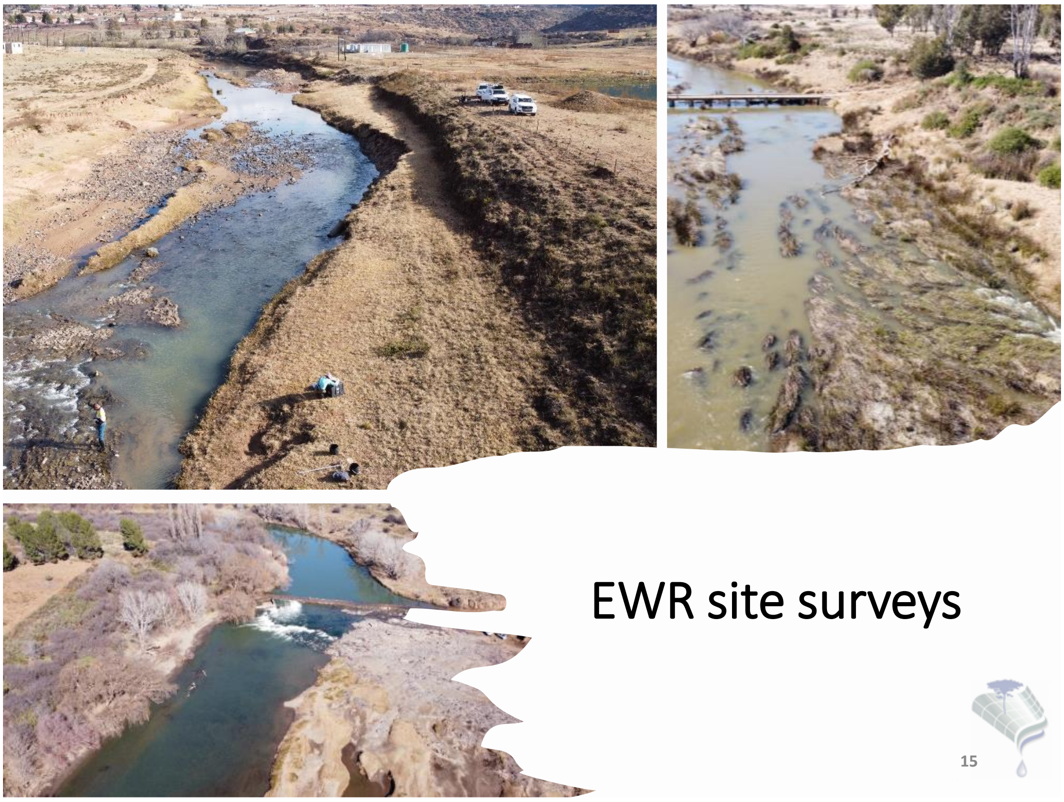

EWR site surveys

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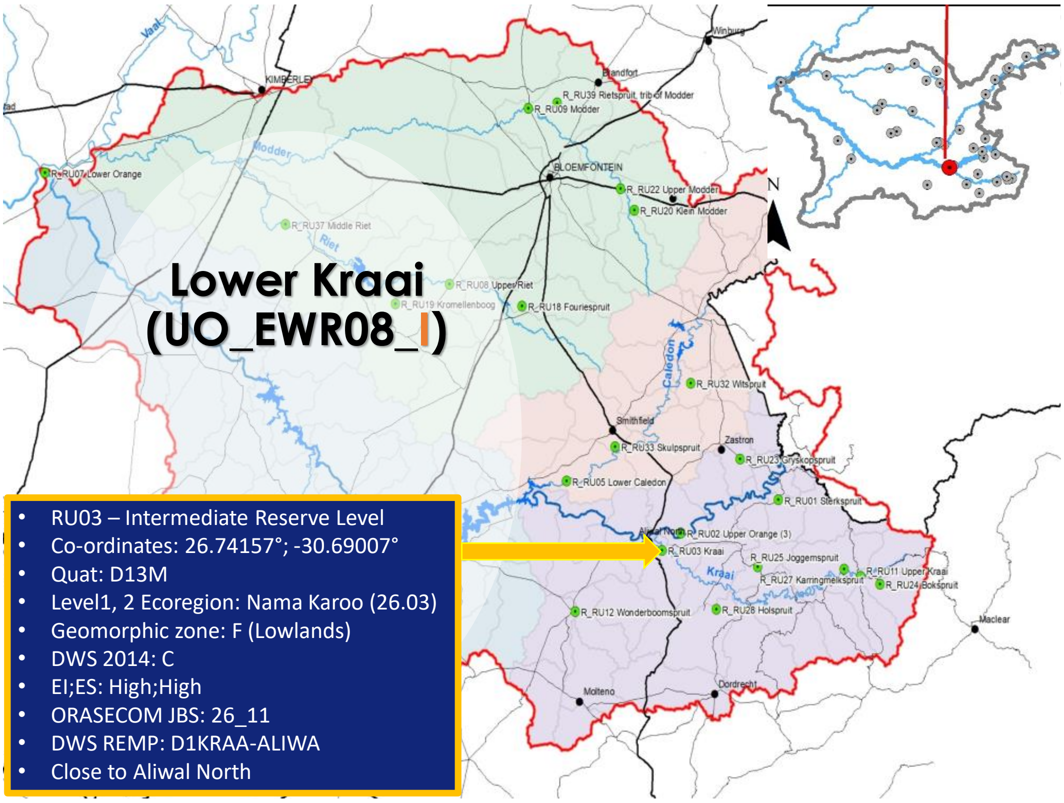

- RU03 – Intermediate Reserve Level
- Co-ordinates: 26.74157°; -30.69007°
- Quat: D13M
- Level1, 2 Ecoregion: Nama Karoo (26.03)
- Geomorphic zone: F (Lowlands)
- DWS 2014: C
- EI;ES: High;High
- ORASECOM JBS: 26_11
- DWS REMP: D1KRAA-ALIWA
- Close to Aliwal North

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LOWER KRAAI

Characteristics

- Site description
- Impacts
- Photos!!!
- *In-field results: In situ* water quality, discharge

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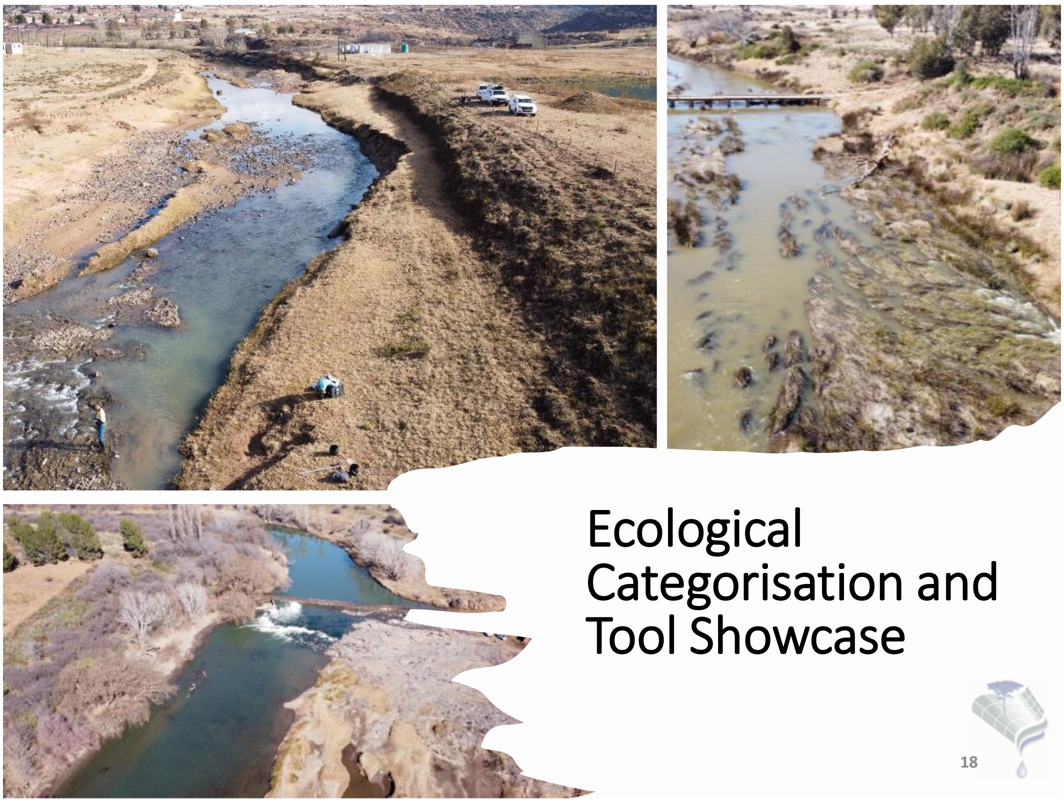

Ecological Categorisation and Tool Showcase

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Ecological Categorisation

Step 3

- Eco-categorisation is the determination and categorisation of the PES (health and/or integrity) of various biophysical attributes of rivers relative to the natural or close to the natural/ reference condition
- These results then provide the information needed to derive desirable and attainable future ecological objectives for the rivers (ecological categories)
- Based on available data from previous and current surveys
- Various models available for **drivers** and **responses** to determine present state (PES) per component
- Review desktop Ecological Importance and Sensitivity with survey information
- Ecostatus/ PES for the river reach by integrating response components
- Identify the REC for EWR quantification

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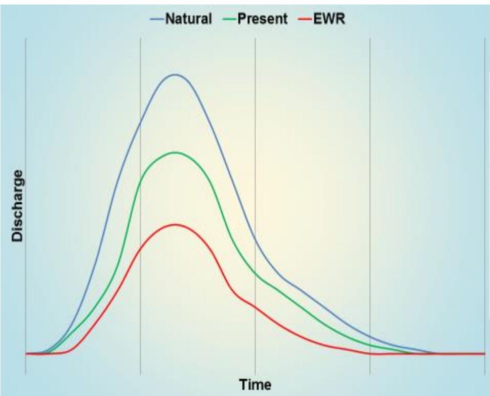
Hydrology: Hydrological Assessment Index (HAI)

- Provides an indication of the changes in hydrology from reference
- Based on monthly long term natural and present day flow time series
- Used by ecologists to interpret changes in habitats using the hydraulics (depths, velocities, wetted perimeter, etc.)
- Explain some changes in the response components (fish, macroinvertebrates, vegetation)



%zero flows	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Natural	4	3	0	0	1	2	3	3	3	4	4	4
Present day	76	55	30	25	34	40	51	68	76	77	80	81
Natural	0	0	0	0	0	0	0	0	0	0	0	0
Present day	13	7	8	4	2	4	2	5	7	8	12	14

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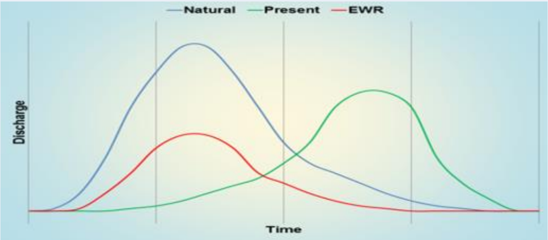
HAI

LOW FLOWS - changes to the baseflows during the low flow months

ZERO FLOW/ DURATION - no zero flow months in natural, but in present day flows or percentage of zero flow months increased in present day flows

SEASONALITY



MODERATE FLOWS/ FRESHETS AND FLOOD EVENTS - Reduced flows mainly due to storage in dams

Size of dams important for impacts on downstream river reaches

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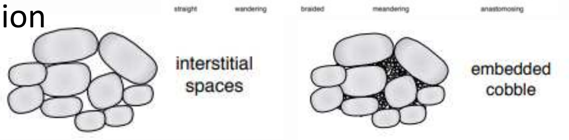
Geomorphology: Geomorphological Driver Assessment Index (GAI)

- Rowntree, 2013: rule-based model to determine the PES
- It rates:
  - The deviation in system drivers (flow and sediment) and site condition from **natural/reference (geomorphic/longitudinal zones)**
  - The flow-relatedness of the deviation (flow or land use?)
- Score metric groups – GAI (21 page form)
  - ➢Hillslope-channel; longitudinal, lateral and vertical connectivity
  - ➢Sediment supply / transport
  - ➢Bed, bank and flood zone stability
  - ➢Present channel condition
  - ➢Morphological change



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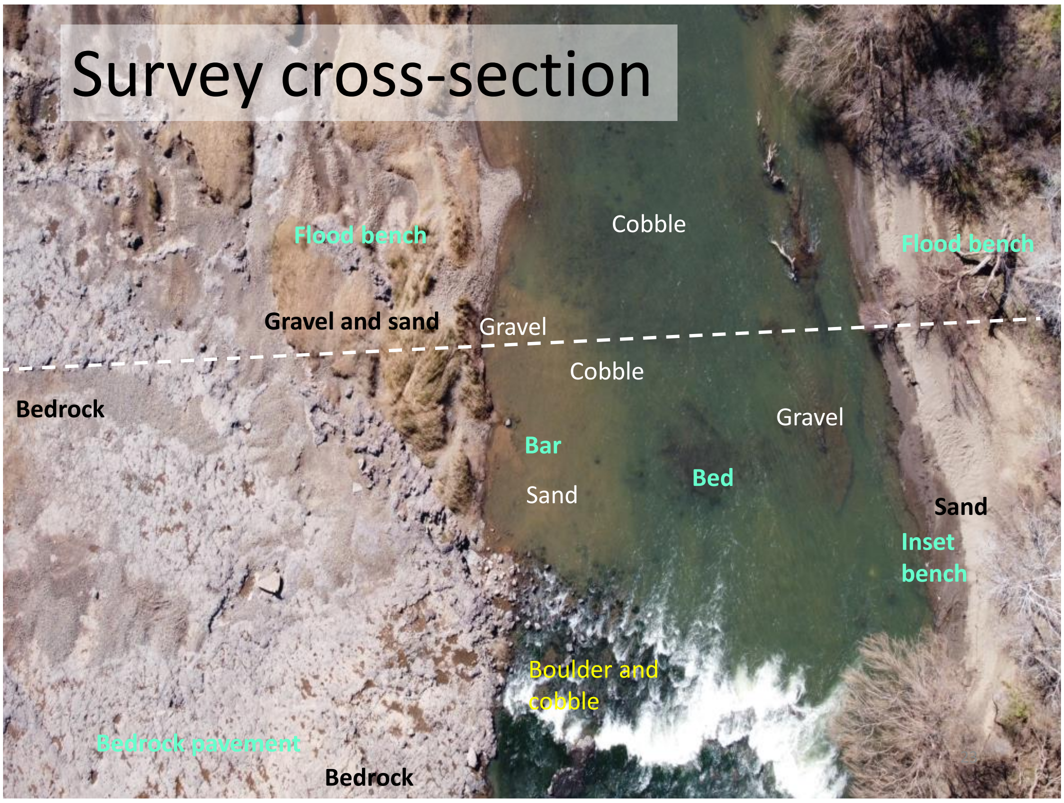

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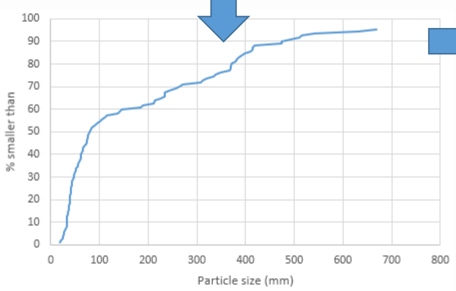
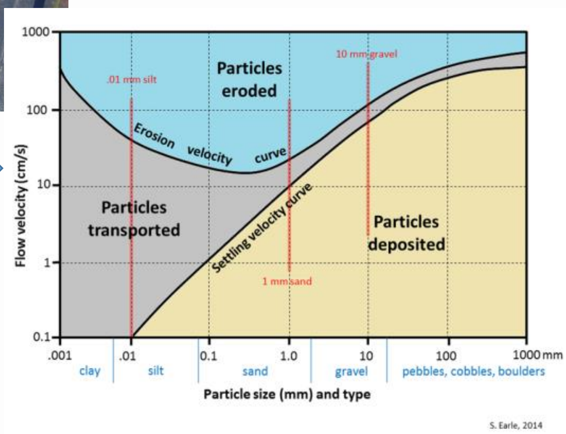
GAI

- Sediment measurement



- What velocity is needed to mobilise this sediment?
- Setting geomorphological flow requirements



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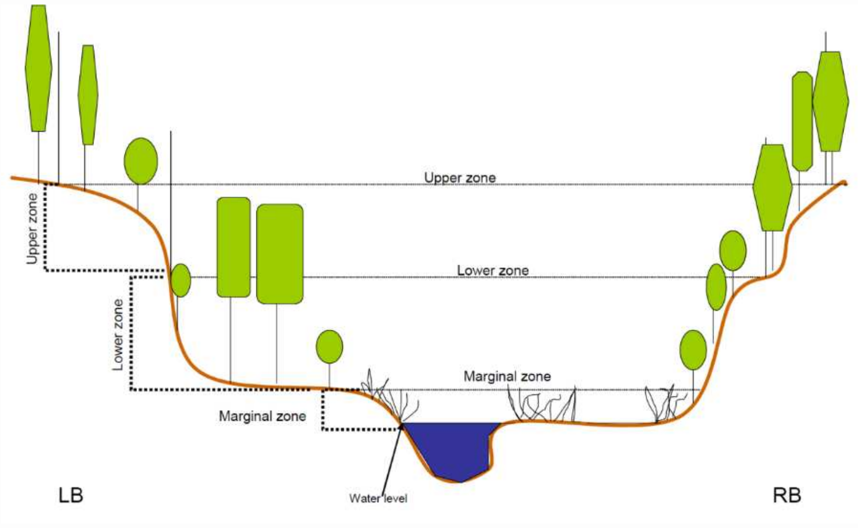
Riparian Vegetation: Riparian Vegetation Response Assessment Index (VEGRAI)

- Define the **reference state** (natural state/condition of riparian habitat)
- Identify and delineate riparian **vegetation zones**



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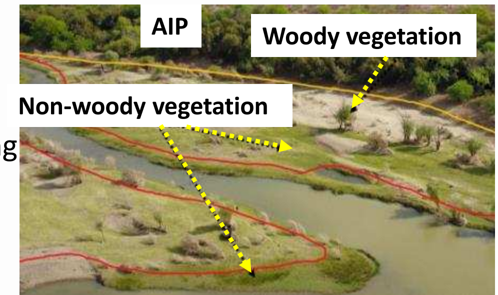
VEGRAI

- Identify **key/dominant/indicator plant species** in each zone – indigenous and exotic/ alien invasive plants (AIPs)
- Assess vegetation in each zone according to vegetation components, namely **woody and non-woody plant forms**



- Estimate cover and abundance of **indigenous woody and non-woody vegetation** in each zone
- Estimate cover of **exotic vegetation/AIP** cover
- Assess population structure and recruitment of **indigenous woody plants** (L4)
- Assess species composition of **woody and non-woody vegetation** within each zone taking into account both indigenous and exotic plant species (L4)

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VEGRAI: Level 4

- Level 4 Model
- Rate, weight and provide confidence for the various sub-zones i.e. marginal, flood bench

IMPACTS
REMOVAL
ALIEN SPECIES
WATER QUANTITY
WATER QUALITY
EROSION

VEGETATION COMPONENTS	RESPONSE METRIC
WOODY	COVER
	ABUNDANCE
	POPULATION STRUCTURE
	VERTICAL STRUCTURE
	RECRUITMENT
	SPECIES COMPOSITION
	MEAN
SPECIAL CATEGORY (eg Reeds, Palmiet)	COVER
	ABUNDANCE
	MEAN
NON-WOODY (Excl Reeds)	COVER
	ABUNDANCE
	SPECIES COMPOSITION
	MEAN

LEVEL 4 VEGRAI (%)	73.2
VEGRAI Ecological Category	**C**
AVERAGE CONFIDENCE	2.7

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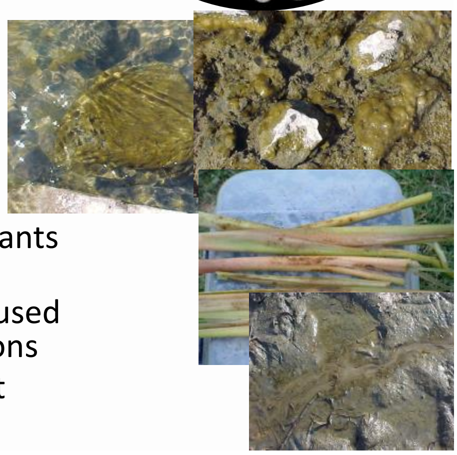
Water Quality - Diatoms

- Microalgae with siliceous skeleton (frustule)
- Form important part of the aquatic food chain
- Their ecology provides information on water quality – makes them ideal bioindicators
  - Found in almost every aquatic ecosystem – not limited to habitat
  - Rapid cell cycle and response to perturbation
  - Integrate nutrients and other pollutants in the water
  - Their silica frustule remains can be used to determine historic water conditions
  - Often and currently one of the most reliable integrators of WQ



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Macroinvertebrate: Macroinvertebrate Response Assessment Index (MIRAI)

- Why aquatic macroinvertebrates:
  - Act as indicators of overall ecological condition
  - Responses to environmental impacts/localised disturbances is detectable in terms of the community as a whole
  - Habitat, water quality, river conditions,flow driven, thus:
    - Communities offer a good reflection of the prevailing flow regime and water quality in a river.
  - Easy to sample and identify
  - Relatively sedentary
  - Rapid results
- Sampling and modeling aquatic macroinvertebrate communities:
  - Macroinvertebrates are samples using the standard SASS5 (Dickens and Graham, 2002), published method (ISO 17025 accredited)
  - Modelled using the Macroinvertebrate Response Assessment Index (MIRAI)) (Thirion, 2008)

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MIRAI

Aim of the MIRAI:

To provide a habitat-based cause-and-effect foundation to interpret the deviation of the macroinvertebrate community from the **reference condition**

- Done through the integration of the ecological requirements of the macroinvertebrate taxa in a community and their response to the various metrices (flow, habitat, water quality)
- Overall ecological category (condition) of the macroinvertebrate community
- Identify the driver of the community from the model

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MIRAI Model: Determine the EC

						Velocity metrics				Habitat metrics				Water Qaulity	
rt	Taxon	Reference Abundar	Reference Frequei	Present Abunda	Present Frequer	<0.1	0.1-0.3	0.3-0.6	>0.6	COBBLES	VEG	GSM	WATER	SENSITIVITY	SASS QV
1	Porifera					3	4.5	3	1	4.5	1	0	0	LOW	5
2	Coelenterata					4	3	1	0	2	4	0	0	VERY LOW	1
3	Turbellaria	A	3	A	5	2	4	4.5	4	4	1	3	0	VERY LOW	3
4	Oligochaeta	A	4	A	5	4.5	4	3.5	3.5	4	3	4.5	0	VERY LOW	1
5	Hirudinea	A	2			3	4.5	4	2.5	4	2.5	4	0	VERY LOW	3
6	Amphipoda					1.5	2.5	2.5	2.5	3	3	3.5	0	HIGH	13
7	Potamonautidae	A	2	A	4	4	4.5	4.5	4.5	4.5	0.5	4	0	VERY LOW	3
8	Atyidae	A	1			4	3.5	0.5	0	1	4.5	0.5	0	MODERATE	8
9	Paleomonidae					0.5	2	2	3	3	3	1	0	MODERATE	10
10	Hydracarina	A	2			3	3	3	3	3	2.5	2.5	0.5	MODERATE	8
11	Notonemouridae					0.5	2	3.5	4	4.5	1	0.5	0	HIGH	14
12	Perlidae	A	5	B	4	0.5	3	4	3.5	4	0.5	1.5	0	HIGH	12
13	Baetidae 1sp	A	1			3	3.5	4	4	4	4	4	0	LOW	4
14	Baetidae 2spp	B	2			3	3.5	4	4	4	4	4	0	LOW	6
15	Baetidae >2spp	B	4	B	5	3	3.5	4	4	4	4	4	0	HIGH	12
16	Caenidae	B	5	A	5	4.5	3.5	3	3	3	3	4.5	0	LOW	6
17	Ephemeridae					4.5	0.5	0	0	1	0.5	4.5	0	HIGH	15
18	Heptageniidae	B	5	A	5	1	4	4.5	3	4.5	0.5	1.5	0	HIGH	13
19	Leptophlebiidae	B	5	B	5	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE	9
20	Oligoneuridae	A	2			0	0	3	5	4.5	3.5	1	0	HIGH	15
21	Polymitarcyidae	A	1			4.5	1	0	0	0.5	0.5	5	0	MODERATE	10
22	Prosopistomatidae	A	3			0.5	1	2	4	4	0	3.5	0	HIGH	15
23	Telagonodidae	A	1			1	3	4.5	4	4.5	1	1	0	HIGH	12
24	Trichorythidae	B	4	B	4	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE	9

Reference taxa generator | Data | flowmod | habitat | wq | Con & Seas | EC | Refe

4 metric groups that measure the deviation of the present vs reference state

System connectivity and seasonality (only used for migratory taxa (Paleomonidae and Varuna) are expected to occur under reference conditions

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Fish: Fish Response Assessment Index (FRAI)

- Why Fish:
  - Act as indicators of overall ecological condition
  - Long-lived
  - Highly mobile
  - Wide range of preferences in terms of flow, habitat, water quality, etc.
  - Assemblages include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores).
  - They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.
  - Easy to sample and identify
- Sampling and modeling fish communities:
  - Fish can be sampled using a variety of methods, including electro-fishing, gill nets, seine nets, fyke nets, cast nets, angling, snorkeling surveys, etc.
  - Modelled using the Fish Response Assessment Index (FRAI)) (Kleynhans, 2008)

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Fish: Fish Response Assessment Index

Aim of the FRAI:

To provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived **reference condition**

FRAI is used to determine the Fish ecological category

- Done through an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions
- Allows for determination of ecological category under present state, target state and scenario state

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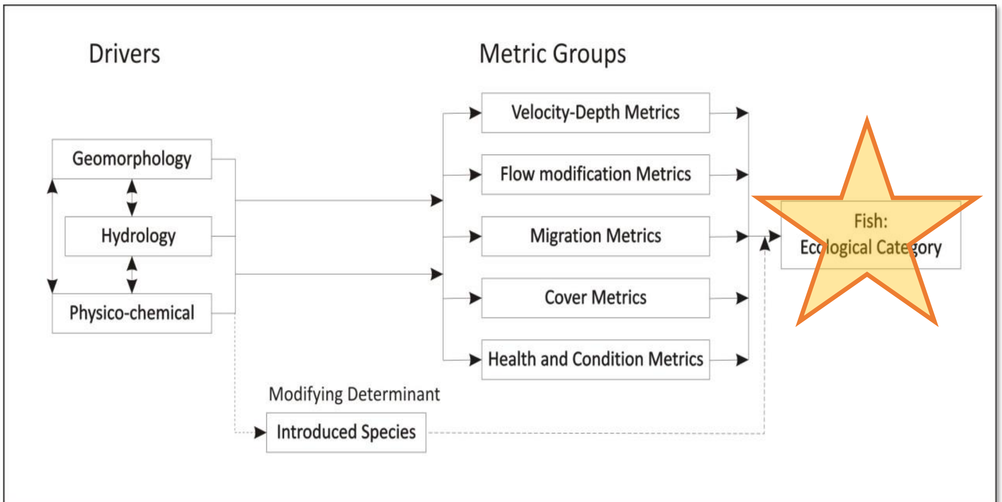
FRAI Model (2)



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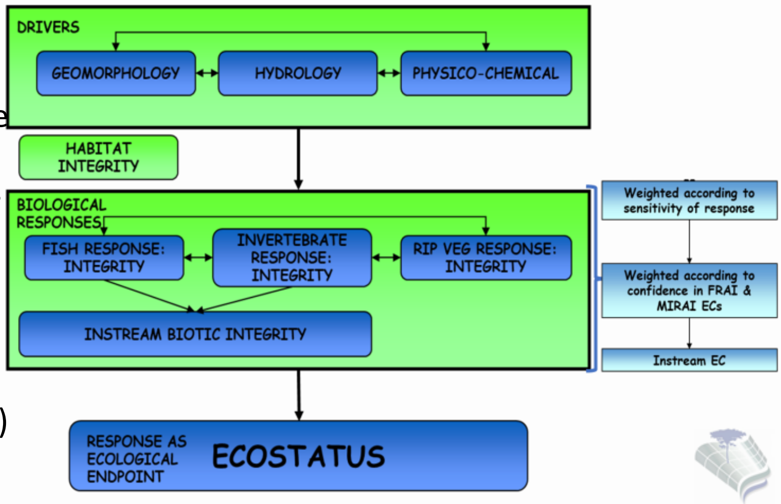
Determination of the EcoStatus

- Totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services
- Integrated ecological state combining all the **components' ecological states** and is termed the ECOSTATUS and is described in terms of ecological categories (A – F)



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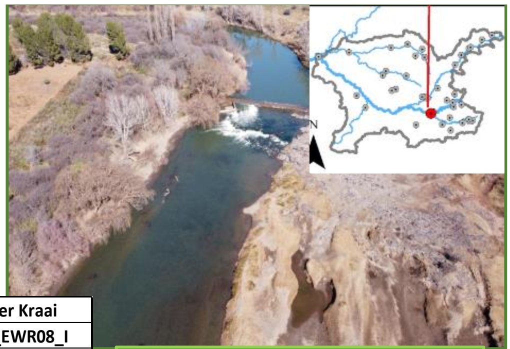
UO_EWR08_I *(D13M)*

Main impacts:

- Agriculture
- Cattle activity
- Irrigation

Limited hydrological modification – free flowing river



Diatoms: indicated elevated electrolyte concentrations and pollutants. Algae content over the stones biotope.

Widespread overgrazing and soil erosion in the catchment elevating fine sediment loads

REC ↑ WQ improvements through land use activities (irrigation, abstraction, return flows). Alien invasive vegetation to be managed. EWR quantification for a B/C 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

Good habitat availability for macroinvertebrates, although some algae smothering the biotopes. Presence of non-native fish species

Extensive alien invasive plants

EIES both remain *High*

Main drivers:

- Water quality
- Flow (weir)

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ECOLOGICAL WATER REQUIREMENTS

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Quantification of EWR

Step 4

- **What are EWRs?**

Flow and its associated characteristics (water quality, sediment and patterns) that should be left or provided in the river system for those biota dependent on it, as well as any people dependent on a natural functioning river (goods and services or Ecosystem Services)

- **Determining EWRs?**

Draw on results from the eco-categorisation:
- What state is the river in now and why? = PES
- Is the river ecological important = EIS
- If the river is important – is it in a present state that needs improvement?
- If Yes…? Is it attainable to improvement (ecologically)? = REC
- Then set flow regimes for the REC (ecologically)

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Quantification of EWR - Approaches

Primary focus is to quantify the EWR using various approaches depending on the specific conditions and impacts at the EWR sites. These include:

- Intermediate EWR sites: Habitat Flow Stressor Response (HFSR)
  - Where too much flow in a system – used first principles as HFSR not applicable, especially if no changes in flows in future due to releases from dams or WWTW
  - Results from the hydraulic modelling (cross-sectional profile and discharge) and output from HABFLO are used to determine the flow-stress relationships and to interpret the results within SPATSIM to finalise the EWR.
- Rapid 3: Verification of the Desktop Reserve Model (DRM)/ Revised DRM within SPATSIM for the integration of data produced from the surveys and eco-categorisation to quantify the EWRs
- Desktop EWRs for those EWR sites where little or no information is available from field surveys; and
- Field verification sites: extrapolation using the characteristics of Rapid 3 or Intermediate sites where desktop/FV sites are in the same Ecoregion level 2 and geozone.

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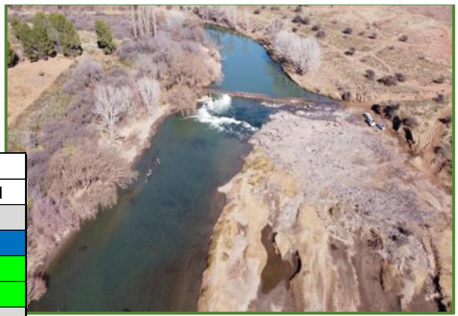
UO_EWR08_I *(D13M)*

Diatoms: indicated elevated electrolyte concentrations and pollutants. Algae content over the stones biotope.

Limited hydrological modification – free flowing river



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

Widespread overgrazing and soil erosion in the catchment elevating fine sediment loads

REC ↑ WQ improvements through land use activities (irrigation, abstraction, return flows). Alien invasive vegetation to be managed. EWR quantification for a B/C REC.

Good habitat availability for macroinvertebrates, although some algae smothering the biotopes. Presence of non-native fish species

Extensive alien invasive plants

EIES both remain *High*

EWR

Quaternary Catchment	D13M
nMAR at EWR site	719.0
Total EWR	334.513 (46.52 %MAR)
Maintenance Low flows	200.869 (27.94 %MAR)
Drought Low flows	40.997 (5.70 %MAR)
Maintenance High flows	133.644 (18.59 %MAR)

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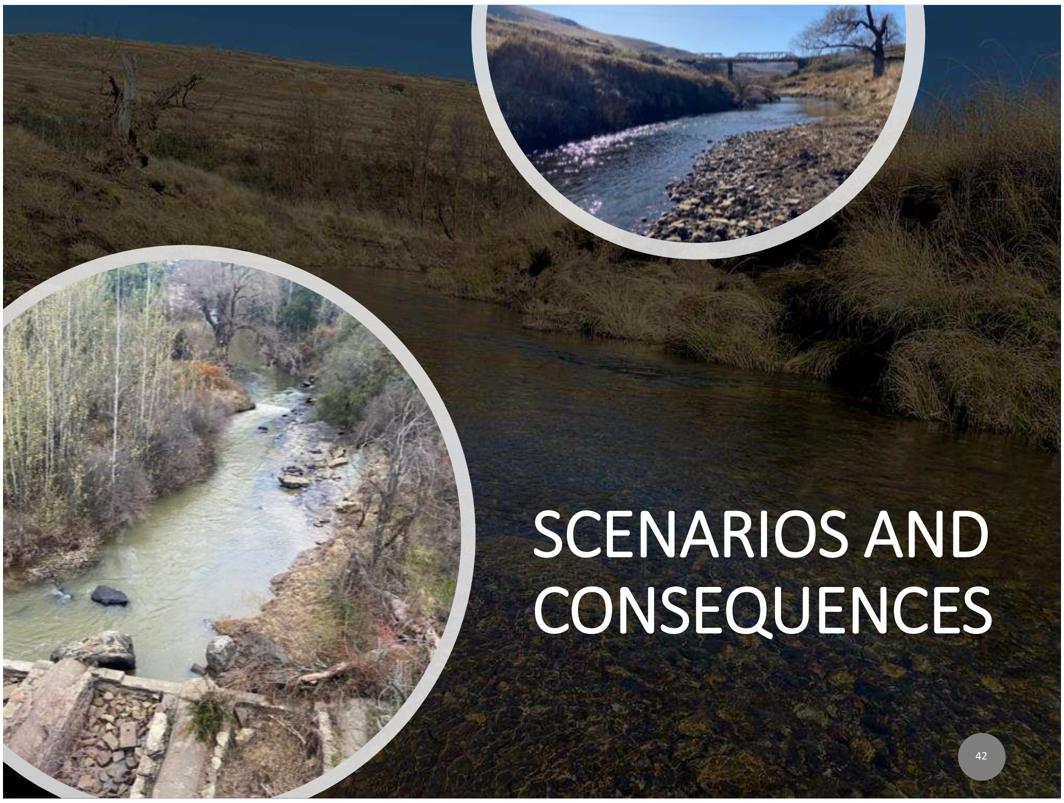

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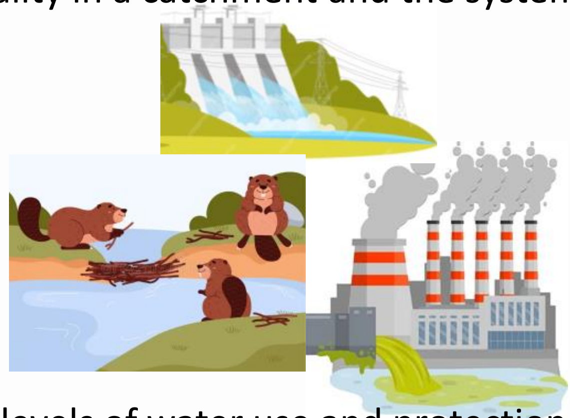
What are operational scenarios?

Step 5

- Scenarios, in context of water resource management and planning, are plausible definitions (settings) of all the factors (variable) that influence the water balance and water quality in a catchment and the system as a whole;



- Different levels of water use and protection are evaluated with the aim to find a balanced scenario.

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UO_EWR08_I: Lower Kraai

Recap on the scenario's…

Number	Description
Sc1	Present day without EWR
Sc2	Present day with EWR for REC
Sc3	2040 Polihali, Makhaleng Dam and pipeline to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs without EWR
Sc4	2040 Polihali, Makhaleng Dam and pipeline to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs with EWR for REC, estuarine requirements
Sc5	2060 Polihali, Makhaleng Dam, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on upper Orange, Vioolsdrift Dam on lower Orange, without EWR
Sc6	2060 Polihali, Makhaleng Dam, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on upper Orange, Vioolsdrift Dam on lower Orange, with EWR for REC, estuarine requirements
Sc7	Present day with EWR for REC (Sc2) with progressive water quality decline

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Determining Ecological Consequences of Scenarios?

Step 5

- Need to answer the 'what if' questions;

CONSEQUENCE: COMES AFTER…. OR A RESULT OR EFFECT OF SOMETHING…

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Ecological Consequences of Scenarios (2)

- Express in terms of change in Ecological Category & degree to which the REC is met;
- Use the Eco-categorisation models to predict changes in the driver and response components at each EWR site for each scenario;

- **Altering the natural flow of a river, can have severe ecological consequences**
  - Disrupt habitats
  - Decline water quality
  - Affect the biota
  - Affect the overall biodiversity of an area
- **Construction/development and the adverse effects on the rivers:**
  - Water quality
  - Affect the biota
  - Affect the overall biodiversity of an area

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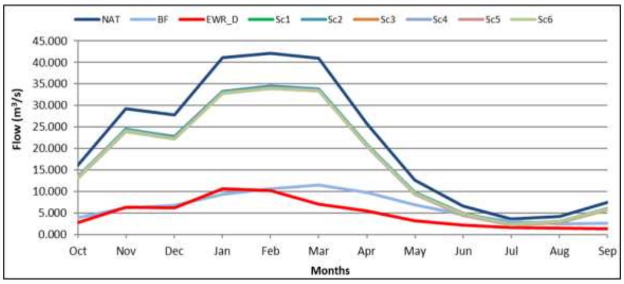
Ecological Consequences of Scenarios (3)

Drivers:

- *Hydrology:* changes in low flows, zero flows, freshets, floods or seasonal distribution of scenarios



- *Water quality*
  - Based on diatoms, macroinvertebrates and any physical-chemical data available
- *Geomorphology*
  - *Scenarios assessed using the GAI*
  - *Only for systems where future dams are proposed to be constructed in the catchment and the impacts on the sediment regime*
  - *Changes to freshets, floods and longitudinal sediment transport (main geomorphological drivers)*

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Ecological Consequences of Scenarios (4)

Responses:

- *Riparian vegetation*
  - Scenarios are assessed using the VEGRAI
  - Only for systems where future planned developments would occur and impact on riparian vegetation
  - Significant effects on the flow regime and/or geomorphological changes
  - Changes to freshets, floods (important for the marginal riparian vegetation reset)
- *Biota*
  - Assessment of all drivers (hydrology, water quality and geomorphology) and the response from the riparian vegetation
  - Fish Invertebrate Flow Habitat Assessment Model (FIFHA)
  - Limitations:
    - Does not account for the effects of increased flows, alteration to flow patters (e.g: dry season – WWTW releases, increased baseflows) or water quality
    - Rheophilic fish and invert limitations
    - At times, needed to make use of expertise and understanding the changes and responses of the biota

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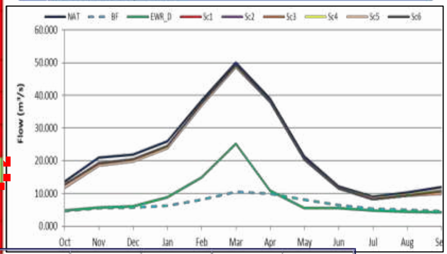
UO_EWR08_I: Lower Kraai

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

Sc1	Present day without EWR
Sc2	Present day with EWR for REC
Sc3	2040 Polihali, Makhaleng Dam and pipeline to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs without EWR
Sc4	2040 Polihali, Makhaleng Dam and pipeline to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs with EWR for REC, estuarine requirements
Sc5	2060 Polihali, Makhaleng Dam, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on upper Orange, Vioolsdrift Dam on lower Orange, without EWR
Sc6	2060 Polihali, Makhaleng Dam, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on upper Orange, Vioolsdrift Dam on lower Orange, with EWR for REC, estuarine requirements



Sc1-EWR												
Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	221.740	156.380	127.718	252.686	344.631	234.996	292.611	140.191	53.516	61.220	122.560	153.414
1	109.867	140.476	124.215	149.217	268.310	231.315	215.918	127.278	44.863	51.891	76.002	96.942
5	40.927	81.877	68.285	73.616	121.697	127.950	77.393	70.258	32.112	13.634	27.882	36.124
10	18.962	43.521	45.526	38.266	72.565	74.800	64.703	37.023	21.568	9.745	8.139	15.892
15	6.423	17.497	35.183	32.200	38.600	61.174	59.372	24.401	10.379	4.716	5.430	5.599
20	2.803	14.620	25.174	21.742	32.278	36.159	46.703	21.347	8.130	4.572	3.471	2.471
30	-0.169	5.289	9.781	11.169	11.541	8.493	30.641	10.035	2.882	1.581	1.054	0.349
40	-1.044	-0.144	3.247	1.440	-1.368	4.171	15.395	6.316	1.741	0.178	-0.334	-2.298
50	-1.381	-0.909	-2.820	-2.296	-1.975	-1.798	6.783	5.148	0.893	0.066	-0.806	-2.457
60	-1.628	-1.452	-2.593	-2.442	-1.883	-1.227	4.092	4.296	0.797	-0.282	-0.935	-2.141
70	-1.451	-1.292	-2.137	-1.752	-1.700	-1.672	3.017	3.885	1.518	-0.173	-0.880	-1.939
80	-1.493	-1.393	-1.295	-1.255	-1.784	-1.492	3.116	3.682	1.324	0.584	-0.203	-1.446
85	-1.412	-1.396	-0.915	-0.914	-1.713	-1.001	2.795	1.451	1.367	0.638	0.100	-1.326
90	-1.332	-1.089	-0.564	-0.686	-1.344	-0.362	1.644	1.332	1.003	0.704	0.065	-1.194
95	-0.956	-0.982	-0.371	-0.224	-0.930	-1.339	0.089	0.224	0.727	0.646	-0.065	-1.239
99	-0.744	-0.302	-0.190	-0.122	-0.121	-1.012	-0.833	-0.635	0.192	0.251	-0.306	-1.184
99.9	-0.691	-0.250	-0.126	-0.093	-0.087	-0.849	-0.603	-0.782	0.107	-0.050	-0.406	-1.141

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UO_EWR08_I: Lower Kraai – Results

Physical-chemical			
PES		Sc2	Sc7 (anticipated further deterioration in water quality)
C		Flows are virtually unchanged, thus the WQ would also not be impaired significantly during the wet season due to the flushing and dilution of return flows through the higher freshets and flood events	There may be some marginal deterioration, but with the reasonable EWR flows maintained here, the system can sustain the impacts with dilution and internal processing.

Geomorphology							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
C		C	C	*Not applicable due to no proposed development on the Lower Kraai*			

Riparian Vegetation							
PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
D/E		D/E	D/E	*Not applicable due to no proposed development on the Lower Kraai*			

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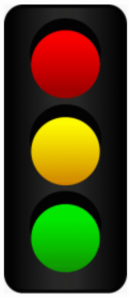
UO_EWR08_I: Lower Kraai – Results

Fish and Macroinvertebrates										
	PES		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7
Fish Dry	C		A	A	*Not applicable due to no proposed development on the Lower Kraai*				C
Inverts Dry	C		A	A					C
Fish Wet	C		C	B					C
Inverts Wet	C		C	B					C

Component	PES	REC		Sc1	Sc2	Sc3	Sc4	Sc5	Sc6
Geomorphology	C	B/C		C	C				
Riparian Vegetation	D/E			D/E	D/E				
Fish	C			C	B				
Macroinvertebrates	C			C	B				
EcoStatus	C								
Meeting Overall REC				√	√				



Ecological Category	≥PES/ component	½EC < PES/ component	1 EC < PES/ component	>1 EC PESR/ component
Colour key	Green	Yellow	Orange	Red

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Ecological Specifications-Monitoring

Step 7

What are EcoSpecs?

- Provide monitoring criteria to maintain the integrity of all river EWR sites, as well as prioritised RU for where key wetland-GW systems were identified
- Aim to safeguard the ecosystem in the Upper Orange catchment area
- EcoSpecs define quantifiable benchmarks, focusing on parameter values to achieve the REC (all water resources)
- Although must be quantifiable, measurement, verifiable and enforceable, ensuring comprehensive protection
- Rivers:
  - Covers hydrology, water quality, geomorphology, riparian vegetation, habitats, and biota of rivers
- Wetlands:
  - EcoSpecs based on the HGM unit and achieving the REC
- Groundwater:
  - EcoSpecs per quaternary catchment based on the GW i.e. GW quantity directive, quality status etc

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Ecological Specifications-Monitoring

What are TPCs?

- Represent upper/lower benchmarks along a continuum of change in selected environmental indicators
- Essentially, they are the triggers to change/negative trajectory
- This assessment serves as the foundation for deciding whether management actions are necessary or if recalibrating the TPC is warranted
- TPCs furnish management with strategic goals or endpoints for system management
- They serve as the foundation for an inductive approach to adaptive management, essentially functioning as hypotheses regarding the limits of acceptable change in ecosystem structure, function, and composition
  - Thus, TPCs should be adaptively modified as understanding and experience with the managed system evolve
  - The confidence in the validity of a TPC can be enhanced through more detailed monitoring surveys, effectively reducing uncertainty

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Ecological Specifications-Monitoring

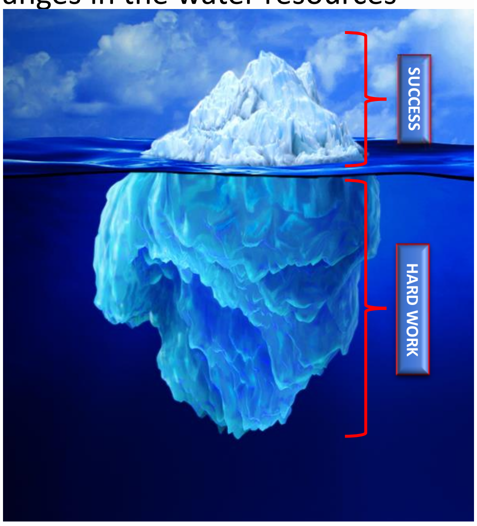
What is a monitoring programme?

- This programme entails the collection and analysis of data from routine monitoring events/surveys to assess changes in the water resources conditions

ICEBERG THEORY

- Don’t always assume by what you see
- If you don’t monitor…
- How do you know what's beneath the surface?
- What are the risks?
- How do you manage?

- If we are successful at implementing the proposed monitoring plan / measuring EcoSpecs
- Hard work
- Ultimately determine whether the EC is being achieved
- If any improvement/ maintenance/ reaching the REC



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Ecological Specifications-Monitoring

- Monitoring must be applied within an Adaptive Management Framework:
  - Important to conduct implementation monitoring:
    - Assess whether the activities are carried out as designed;
    - Further identify which variables are most likely to be causing a change in the resource and help eliminate from consideration some potential causes of change;
    - E.g: whether flows are released as was specified for the attainment of a particular EC;
- Thus, when/if TPCs are exceeded, more intensive monitoring or research may be needed.

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UO_EWR08_I: Ecospecs Results

Hydrology								
REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B/C	719.0	675.3	40.997	5.70	200.869	27.94	334.513	46.52
Metric		**EcoSpec**				**TPC**		
Water quality								
Diatoms		SPI Score: 13.8 Category (B): Good water quality				SPI Score: <12.8 Category C: Moderate water quality		
Geomorphology								
GAI level IV		C or higher				D or lower		
Channel pattern		Wandering channel (alternating bars)				Braided (overwhelmed with sediment) or straight channel (loss of mobile sediment)		
Channel width		100 m wide macro channel (away from engineered works)				Macro channel < 80 m or more than 120 m		
Median particle size of riffle/rapid		Coarse gravels (30 mm)				Loss of gravels, with sand or cobble dominating the riffle habitat		
Extent of bank erosion		~ 25%				More than 40% of banks eroding		

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UO_EWR08_I: Ecospecs Results

Riparian vegetation		
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 30% for entire riparian zone.	Alien species cover increases above 30% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 20%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Cyperus marginatus*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody and non-woody (*Cynodon dactylon* dominating) vegetation.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 20% of the cover.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 20%.
	Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of grasses and woody vegetation.	Diversity of indigenous species within the upper zone decreases below 10 species.

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UO_EWR08_I: Ecospecs Results

Fish			
Metric	**Indicator**[2]	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤4)
	Labeobarbus kimberlevensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites during summer (FROC ≤2)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

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UO_EWR08_I: Ecospecs Results

Macroinvertebrates			
MIRAI Score and category	-	MIRAI score: 65.3% (Category C). The MIRAI score to be maintained as a mid-C in the range >65 – 72%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤61% REC: MIRAI ≤78%
SASS5 and ASPT Score	-	PES: The SASS5 score was 157 with an ASPT of 6.3. Total SASS5 score should remain >160, with ASPT value >6.5. REC: SASS5 score ≥180, with ASPT value > 6.8.	PES: SASS5 scores <120 and ASPT <6.0. REC: SASS5 scores < 180, ASPT < 6.8.
Diversity of invertebrate community	-	PES: 25 families were collected during both surveys. Of these, 3 scored ≥ 10 sensitivity. More than 25 different families (taxa) should be present, with at least 4 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, with all indicator taxa recorded in ≥A abundances.	PES: Less than 20 taxa collected. Less than 1 taxa scoring ≥ 10. Some of the indicator taxon are not recorded. Any taxon (adults) with an abundance of D. REC: Less than 25 families, with less than 4 taxa scoring ≥ 10. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area upstream, from the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s, for longer than a week, water quality deterioration and SIC become exposed.

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UO_EWR08_I: Monitoring

Component	Monitoring programme to meet the specified EcoSpecs	Frequency
Flow/Quantity	Flows should be gauged at existing gauges as specified for the various sites, on a continuous time step	Continuous
Water quality	In situ water quality, other water quality parameters: monthly	Monthly
	Diatoms: biennually	Biennial
General habitat and site characteristics	Fixed upstream and downstream photos	Bi-annually
	The Rapid Habitat Assessment Method (RHAM)	Bi-annually
Riparian vegetation	Riparian vegetation should be assessed using the Riparian Vegetation Response Assessment Index (VEGRAI level 4) method to monitor the changes in vegetation	5 years autumn
	Conduct the IHI	Annually
Macroinvertebrates	DWS quarterly REMP monitoring and run the MIRAI	Annually
Fish	If possible, and if equipment is available (electro-shocker), ichthyofauna (fish) surveys and run the FRAI.	Annually
Geomorphology	Conduct GAI level IV during low flow conditions.	5 years
	Channel pattern during low flow – this can be done based on freely available satellite images	2 years
	Channel width –across the riffle/rapid with a long tape measure	
	Median particle size for mobile bed sediment along riffle/rapid.	
	Extent of bank erosion – this is a visual assessment	

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UO_EWR08_I: Monitoring

Component	Management programme as a result of the monitoring programme
Flow/Quantity	• Manage and maintain all active gauging weirs and stations throughout the study area • Investigate possible new gauging weirs close to EWR sites where no continuous flow data is available
Quality	• Vital and important that the management of compliance monitoring for water quality be undertaken • All DWS laboratories are encouraged to undertake assessments and implement interventions to improve analytical performance • Laboratories must aim to become accredited, if not already • The DWS to ensure enforcement and accountability within the municipalities (i.e. WWTW) • Allocation plans, water use licensees, directives must be reviewed and managed
Riparian vegetation	• Compile an alien plant control programme for riparian zones and adjacent buffers (up to 20m) • Eradication and control of exotic vegetation within riverine areas should be implemented
Overall	• Catchment management strategies must be developed to assist with the management of overgrazing and trampling
	• Riverine buffers must be implemented for all new applications, and grazing management within these buffer zones strictly controlled

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WETLANDS

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Wetlands - Approach

- Step 1 •Identify priority quaternary and sub-quaternary catchments that are potentially important due to their presence, extent or condition of water resources with a focus on wetlands and groundwater driven systems. Initiate the BHN and EWR assessment
- Step 2 •Determine eco-regions, delineate resource units, select priority study sites and where appropriate, align with Step 1 of the water resource classification procedure.
- Step 3 •Determine the reference conditions, present ecological status (PES), ecological importance and sensitivity(EI-ES), recommended ecological category (REC) and Ecological Water Requirement (EWR) for the priority selected study sites.
- Step 4 •Determine the basic human needs (BHN) and EWR for each of the selected priority study sites
- Step 5 •Determine the operational scenarios/rules and ecological consequences for meeting the Reserve (aligned with the classification procedure)
- Step 6 •Evaluate the scenarios with stakeholders
- Step 7 •Design appropriate Reserve templates, eco-specifications and monitoring programme including monitoring requirements
- Step 8 •Gazette and implement the Reserve

Reserve determination process as outlined in the study, 'Development of Procedures to operationalise Resource Directed Measures' (DWS, 2017)

Wetland specific approaches were adopted from the *Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)* (Rountree *et al.*, 2013)

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Resource Units

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Resource Unit Delineation

Step 2

- Multi-criteria analysis undertaken
  - Initial desktop screening process
  - Assessing various national spatial layers, wetland importance and associated ecosystem services.
- Wetland RU prioritisation based on key attributes:
  - NWM5 spatial dataset
  - National Freshwater Ecosystem Priority Areas wetland shapefile
  - Crane sightings and other Important Bird Areas
  - Crane sightings and nest sites
  - Wetlands that interacted with the surface and groundwater SWSAs
  - Wetlands with a PES of A/B
  - Hydrogeomorphic Unit type and ability to supply ecoservices
  - Systems categorized as Critically Endangered/Endangered
  - Wetlands located upstream of important water supply dams
  - Identified water-stressed catchments/basins from the river RU process
  - Located in water stress in terms of quantity and quality (River reserve information)

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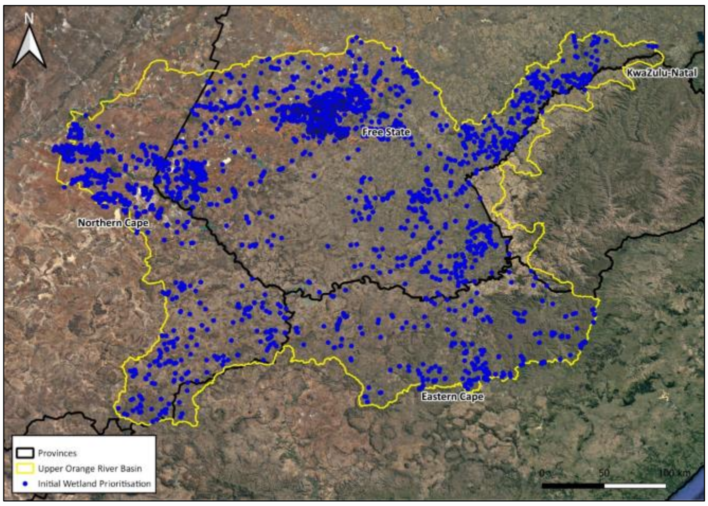
Resource Unit Delineation



- Total of 3 688 wetland systems identified using the NWM5 and expert identified wetlands
- The NWM 5 data was screened in detail to omit mis-mapped wetlands and wetlands not associated with the key attributes
- These sites have been further refined following a more vigorous review of the wetland characteristics

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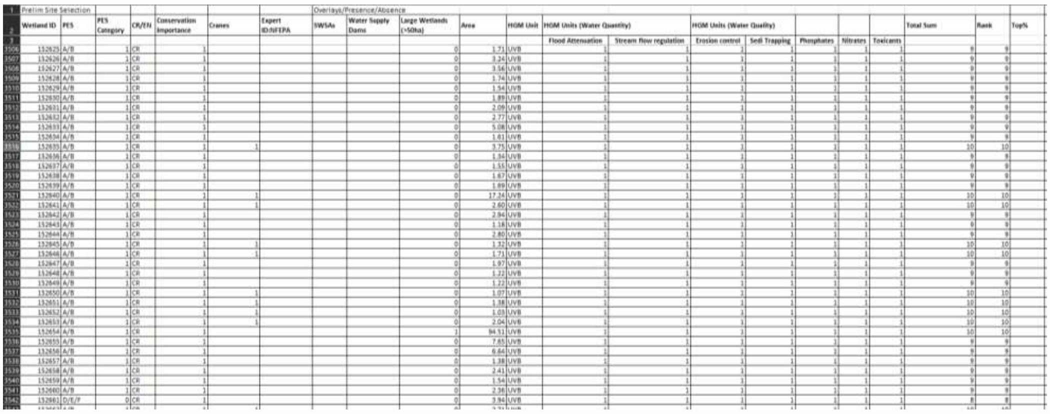
Resource Unit Delineation



	Prelim Site Selection							Overlays/Presence/Absence														
2	Wetland ID	PES	PES Category	CR/EN	Conservation Importance	Cranes	Expert ID:NFEPA	SWSAs	Water Supply Dams	Large Wetlands (>50ha)	Area	HGM Unit	HGM Units (Water Quantity)		HGM Units (Water Quality)					Total Sum	Rank	Top%
3													Flood Attenuation	Stream flow regulation	Erosion control	Sedi Trapping	Phosphates	Nitrates	Toxicants			
3506	152625	A/B	1	CR	1					0	1.71	UVB	1	1	1	1	1	1	1	9	9	
3507	152626	A/B	1	CR	1					0	3.24	UVB	1	1	1	1	1	1	1	9	9	
3508	152627	A/B	1	CR	1					0	3.56	UVB	1	1	1	1	1	1	1	9	9	
3509	152628	A/B	1	CR	1					0	1.74	UVB	1	1	1	1	1	1	1	9	9	
3510	152629	A/B	1	CR	1					0	1.54	UVB	1	1	1	1	1	1	1	9	9	
3511	152630	A/B	1	CR	1					0	1.89	UVB	1	1	1	1	1	1	1	9	9	
3512	152631	A/B	1	CR	1					0	2.09	UVB	1	1	1	1	1	1	1	9	9	
3513	152632	A/B	1	CR	1					0	2.77	UVB	1	1	1	1	1	1	1	9	9	
3514	152633	A/B	1	CR	1					0	5.08	UVB	1	1	1	1	1	1	1	9	9	
3515	152634	A/B	1	CR	1					0	1.61	UVB	1	1	1	1	1	1	1	9	9	
3516	152635	A/B	1	CR	1	1				0	3.75	UVB	1	1	1	1	1	1	1	10	10	
3517	152636	A/B	1	CR	1					0	1.34	UVB	1	1	1	1	1	1	1	9	9	
3518	152637	A/B	1	CR	1					0	1.55	UVB	1	1	1	1	1	1	1	9	9	
3519	152638	A/B	1	CR	1					0	1.67	UVB	1	1	1	1	1	1	1	9	9	
3520	152639	A/B	1	CR	1					0	1.89	UVB	1	1	1	1	1	1	1	9	9	
3521	152640	A/B	1	CR	1	1				0	17.24	UVB	1	1	1	1	1	1	1	10	10	
3522	152641	A/B	1	CR	1	1				0	2.60	UVB	1	1	1	1	1	1	1	10	10	
3523	152642	A/B	1	CR	1					0	2.94	UVB	1	1	1	1	1	1	1	9	9	
3524	152643	A/B	1	CR	1					0	1.18	UVB	1	1	1	1	1	1	1	9	9	
3525	152644	A/B	1	CR	1					0	2.80	UVB	1	1	1	1	1	1	1	9	9	
3526	152645	A/B	1	CR	1	1				0	1.32	UVB	1	1	1	1	1	1	1	10	10	
3527	152646	A/B	1	CR	1	1				0	1.71	UVB	1	1	1	1	1	1	1	10	10	
3528	152647	A/B	1	CR	1					0	1.97	UVB	1	1	1	1	1	1	1	9	9	
3529	152648	A/B	1	CR	1					0	1.22	UVB	1	1	1	1	1	1	1	9	9	
3530	152649	A/B	1	CR	1					0	1.22	UVB	1	1	1	1	1	1	1	9	9	
3531	152650	A/B	1	CR	1	1				0	1.07	UVB	1	1	1	1	1	1	1	10	10	
3532	152651	A/B	1	CR	1	1				0	1.38	UVB	1	1	1	1	1	1	1	10	10	
3533	152652	A/B	1	CR	1	1				0	1.03	UVB	1	1	1	1	1	1	1	10	10	
3534	152653	A/B	1	CR	1	1				0	2.04	UVB	1	1	1	1	1	1	1	10	10	
3535	152654	A/B	1	CR	1					1	94.51	UVB	1	1	1	1	1	1	1	10	10	
3536	152655	A/B	1	CR	1					0	7.85	UVB	1	1	1	1	1	1	1	9	9	
3537	152656	A/B	1	CR	1					0	6.64	UVB	1	1	1	1	1	1	1	9	9	
3538	152657	A/B	1	CR	1					0	1.38	UVB	1	1	1	1	1	1	1	9	9	
3539	152658	A/B	1	CR	1					0	2.41	UVB	1	1	1	1	1	1	1	9	9	
3540	152659	A/B	1	CR	1					0	1.54	UVB	1	1	1	1	1	1	1	9	9	
3541	152660	A/B	1	CR	1					0	2.36	UVB	1	1	1	1	1	1	1	9	9	
3542	152661	D/E/F	0	CR	1					0	3.94	UVB	1	1	1	1	1	1	1	8	8	

- All 3 688 wetland systems were put into an MCA spreadsheet and were ranked based on the key attributes considered beforehand
- A ranking system was created where systems were ranked between 1 and 10 with 1 being least important and 10 being of greatest importance

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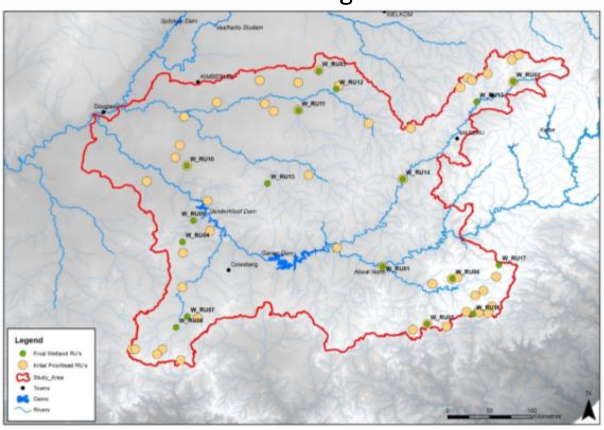
Resource Unit Delineation

- Using the data derived from the Multi-criteria analysis, a further review of the entire study area undertaken, and final RUs based on:
  - Presence of SW and/or GW SWSAs
  - Preliminary priority River RU quaternary catchments
  - The top 10% of quaternary catchments identified through the WfWets strategic planning (EC, NC and FS provinces)
  - Specific important wetland areas identified by individual stakeholders
  - Quaternary catchments identified with the highest recorded water uses (water quantity)



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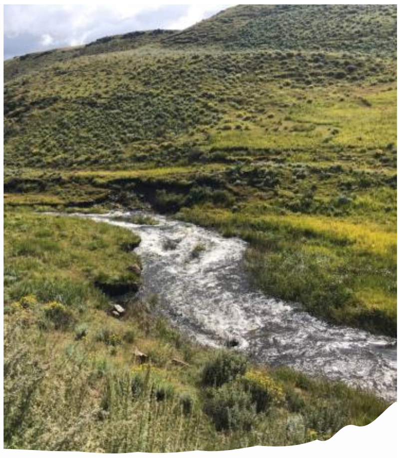


Eco-Categorisation

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Eco-Categorisation

Step 3

- The purpose of this step is to assess the current condition of the wetlands which comprises of the PES, EI-ES, REC and EWR (where necessary).
- What is Wetland Ecological Health?
- The ecological health or ecological condition, officially referred to by DWS as the "Present Ecological State" (PES) of a wetland, all refer to a wetland's **deviation from its theoretical reference or natural condition**
- The reference condition is defined as the unimpacted condition in which wetlands show little or no influence of human derived impacts
- Another way of phrasing it would be: the deviation is taken as a measure of the extent to which human impacts have caused the wetland to differ from its natural reference condition


Source: African Leadership Magazine


Source: European Environmental Agency

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How can we measure PES?

- The formation and functioning of wetlands are driven by four interrelated components, namely **hydrology**, **geomorphology**, **water quality** and **vegetation**
- The biota of a wetland (for which the **vegetation** is typically central) respond to the nature of the abiotic factors (i.e. **hydrology**, **geomorphology** and **water quality**)

Source: Macfarlane *et al.* (2020)

A useful approach for assessing the PES of a wetlands is to assess the degree to which each of these four components have been moved away from their natural reference condition by human impacts.

This is the approach applied by WET-Health Version 2, which has four individual modules for assessing the four components

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How can we measure PES?

For each of the four components, Impact is scored on a 0-10 scale, and PES is scored on a scale of 0% (where impacts are critical and natural habitat and biota have been completely lost) to 100% (unmodified, natural).

Table 1: Descriptions of the Ecological Categories typically used for PES assessments of inland aquatic ecosystems in South Africa, together with the applicable range of Impact Scores and PES Scores for each Category (Macfarlane *et al.* 2020)

	DESCRIPTION	IMPACT SCORE*	PES SCORE (%)
A	Unmodified, natural.	0 - 0.9	90 - 100
B	Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	1 - 1.9	80 - 89
C	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	2 - 3.9	60 - 79
D	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	4 - 5.9	40 - 59
E	Seriously modified. The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6 - 7.9	20 - 39
F	Critically modified. Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8 - 10	0 - 19

The natural or reference conditions used to measure PES against are inferred from conceptual models relating to the wetlands HGM type and knowledge of vegetation of similar wetlands which are minimally impacted.

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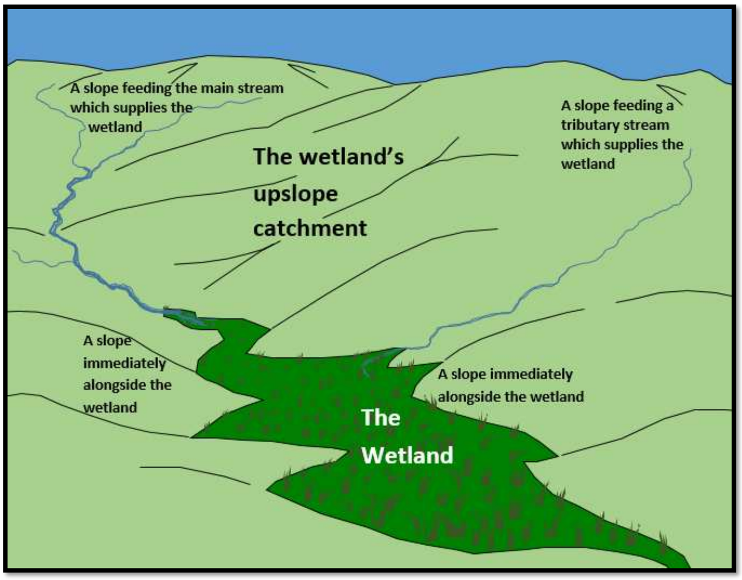
Wetland Impacts

Impacts to wetlands don't only occur directly within the wetland, but may arise from within the wetland's catchment



The wetland's catchment refers to that area upslope of the wetland from which water flows (both above- or below-ground) into the wetland, including the slopes immediately alongside the wetland as well as including slopes further away which feed any streams ultimately supplying the wetland.

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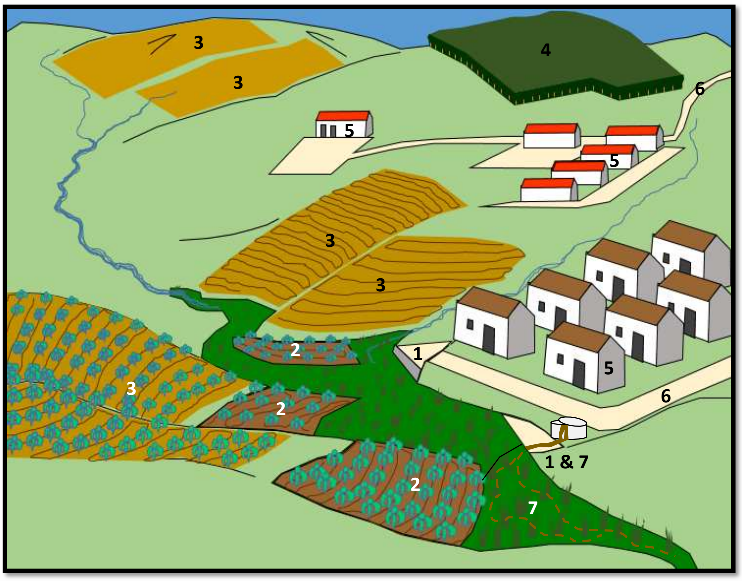
Wetland Impacts

An example of a wetland with extensive areas of natural vegetation which have been transformed in both the wetland (1=infilling with concrete rubble, 2=commercial annual crops, not irrigated) and in its upstream catchment



(3=commercial annual crops not irrigated, 4=tree plantations, 5=built-up areas, 6=roads). In addition, an area of natural wetland is affected by the point-source release of untreated wastewater (7). Each of these landuses has relevant impacts on **hydrology**, **geomorphology**, **water quality** and **vegetation**

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Calculating the PES Score

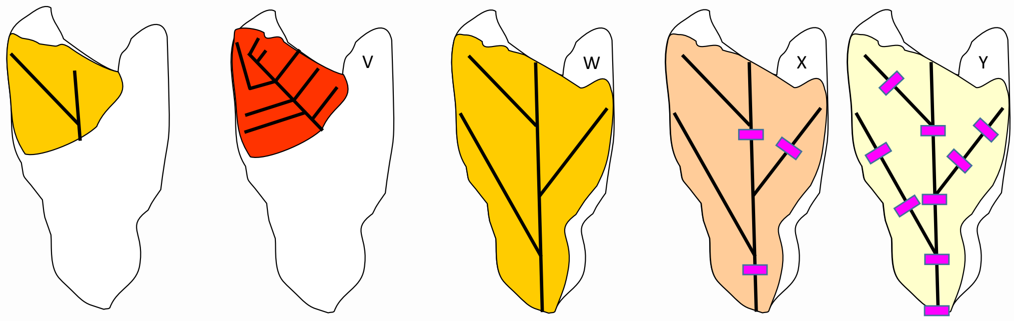
For all of the four components of ecological health, the impact on PES is assessed in terms of:

Extent affected (%/100) x Intensity (0 to 10) = **Magnitude of impact** on integrity (0 to 10)

Impact: | 0 | 1 | 3 | 5 | 7 | 9 |

Unmodified — Critical

Examples showing the effect of drainage furrows on the hydrology component:



Magnitude of impact score:

30/100 x 5 = **1.5**

30/100 x 9 = **2.7**

80/100 x 5 = **4.0**

80/100 x 3 = **2.4**

80/100 x 2 = **1.6**

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Calculating the PES Score

For each of the four wetland PES components, the magnitude scores of all impacts affecting that component are automatically combined to give an overall PES score for the component, representing the *current situation*.

To inform management it is also useful to know how the component is likely to change *in the future*. Thus, the projected trajectory of change over the next 5 years is also scored according to: ↑↑=large improvement, ↑= slight improvement, →= remains the same, ↓=slight decline and ↓↓=large decline.

Seen together, these provide a useful summary of the wetland's ecological health:

Kaalspruit – channeled valley-bottom wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	1.9	2.2	1.9	4.1
PES Score (%)	81%	78%	81%	59%
Ecological Category	B→	C→	B→	D→

Rantsho Unchannelled valley-bottom wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.7	2.8	3.4	7.0
PES Score (%)	53%	72%	66%	30%
Ecological Category	D↓	C↓	C↓	E↓

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Calculating the PES Score

Finally, the four components are automatically combined to give an overall score

Kaalspruit – channeled valley-bottom wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	1.9	2.2	1.9	4.1
PES Score (%)	81%	78%	81%	59%
Ecological Category	B→	C→	B→	D→
Combined PES Score (%)	75%			
Combined Ecological Category	C			

Rantsho Unchannelled valley-bottom wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.7	2.8	3.4	7.0
PES Score (%)	53%	72%	66%	30%
Ecological Category	D↓	C↓	C↓	E↓
Combined PES Score (%)	55%			
Combined Ecological Category	D			

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Ecological Importance and Sensitivity

Ecological importance and sensitivity

Ecological importance

- Biodiversity support
- Regulating and supporting services
- Provisioning and cultural services

Ecological sensitivity

- Sensitivity to altered water quantity & pattern
- Sensitivity to altered water quality
- Sensitivity to factors not related to flow

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ES – water quantity & pattern

Sensitivity to changes in floods	Can be inferred based on HGM type: Highest → Lowest Floodplain, Valley bottom, Seep

Sensitivity to changes in low flows/dry season flows	Can be inferred based on HGM type: Highest → Lowest UC V bottom/Seep, Floodplain

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ES – water quality

Sensitivity to altered water quality typically high in the following wetlands:

- With catchments having naturally low nutrient levels
- With sensitive native vegetation, e.g. which is diverse and short-growing
- Inward-draining wetlands
- Vegetation with a high PES
- Threatened vegetation type

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Ecological Importance

Not all wetlands are equal

Globally, wetlands are recognized as one of the most valuable ecosystem types for the many ecosystem services which they provide.

However, not all wetlands are equally important in terms of ecosystem services and biodiversity support - there are considerable differences across wetlands.

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Biodiversity Support

Biodiversity support is typically high in the wetlands with:

- Red-listed species
- Uncommonly large populations of wetland species
- Migration/breeding/feeding sites
- Protected ecosystem types
- Regional/landscape contribution, notably wetlands with relatively high PES & of a type subject to high cumulative impacts

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Regulating and supporting services

- Streamflow regulation
- Flood attenuation
- Sediment trapping
- Phosphate assimilation
- Nitrate assimilation
- Toxicant assimilation
- Erosion control
- Carbon storage

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Provisioning and cultural services

- Water for human use
- Harvestable resources
- Food for livestock
- Cultivated foods
- Tourism and recreation
- Education and research
- Cultural and spiritual heritage

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A Rapid EIS rating system

A quicker alternative to scoring the individual indicators is to apply the rapid EIS rating (also using 0 to 4 scale) of Rountree and Kotze (2013) available as a spreadsheet

	A	B	C	E	F
1		IMPORTANCE OF DIRECT HUMAN BENEFITS			
2			Score (0-4)	Motivation for site	Guideline
3	Subsistence benefits	Water for human use	1	No known water water use	The provision of water extracted directly from the wetland for domestic, agriculture or other purposes
4		Harvestable resources	1	No known harvesting	The provision of natural resources from the wetland, including livestock grazing, craft plants, fish, etc.
5		Cultivated foods	1	No known cultivated foods	Areas in the wetland used for the cultivation of foods
7	Cultural benefits	Cultural heritage	1	No known cultural heritage features	Places of special cultural significance in the wetland, e.g., for baptisms or gathering of culturally significant plants
8		Tourism and recreation	2.5	Currently there appears to be limited direct contribution of the wetland to tourism and recreation. However, the wetland contributes indrectly to tourism insofar as the wetland buffers water qulity in the Slang River, which is a notable tourist feature where it is crossed by the Otter Trail approximately 3 km downstream of the outlet of the wetland.	Sites of value for tourism and recreation in the wetland, often associated with scenic beauty and abundant birdlife
9–10		Education and research	1	Currently there appears to be limited contribution of the wetland to education and research	Sites of value in the wetland for education or research
11		TOTAL OVERALL SCORE:	1.25		

Rountree MW, Kotze DC, 2013. Specialist Appendix A3: EIS Assessment, in: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0). WRC Report No. 1788/1/13. Water Research Commission, Pretoria, pp. 42–46.

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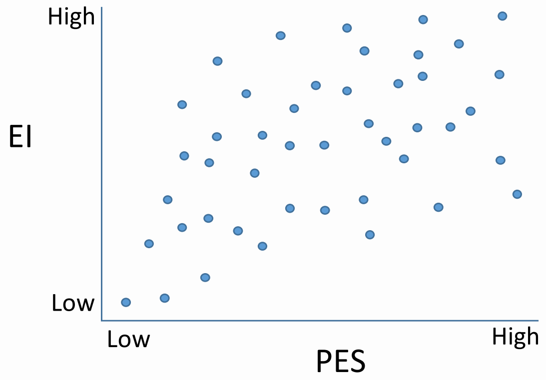
Relationship between PES and EI

Generally speaking, as PES of a wetland increases, the likelihood of that wetland being ecologically important will increase.

However, there are still many wetlands with a low PES which nonetheless have a high ecological importance, particularly in terms of regulating and provisioning services supplied by "hard-working wetlands"



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Recommended Ecological Category (REC)

Guidelines of Rountree et al. (2013) for setting the REC

Consider wetland's PES (Present Ecological State) and EI (Ecological Importance)

If PES is E or F category then the REC must be increased to a D.

If PES is D category or higher, check if any of the 3 main components of EI score is high (>2 and <=3) or very high (>3).

If so, evaluate the feasibility of increasing the PES, especially if the PES is in a C/D or D category.

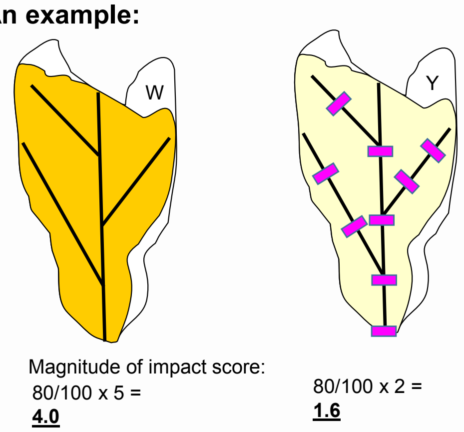
Rountree MW, Malan HL, Weston BC, 2013. Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0). Joint Department of Water Affairs and Water Research Commission report. WRC Report No. 1788/1/13. Water Research Commission, Pretoria.

Feasibility of increasing the PES

It is important to be realistic.

An assessment of the long-term ecological outcomes across 28 wetlands rehabilitated by Working for Wetlands (Kotze et al. 2019;2021) provides a useful reality check. The average improvement in PES was 17%, often not enough to move a wetland out of a C/D or D category despite the rehabilitation often costing > 1 million Rands.

An example:



Feasibility of increasing the PES

Generally most cost effective to focus on:

1. Illegal/non-compliant water/land-use activities impacting on the wetlands

2. Pre-emptive measures to avert degradation and prevent further decline in PES

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Ecological Water Requirements

Step 3

EWR quantification - estimate how much water and of what quality should remain in a given system using natural flows as a reference

- Specialist ecological insight is required to translate hydrological understanding into various biophysical/ecological impacts
- Not often clear **when** to select a wetland for EWR quantification
- The study team created a decision support system to assist the wetland team (and potentially future specialists doing wetland reserves)

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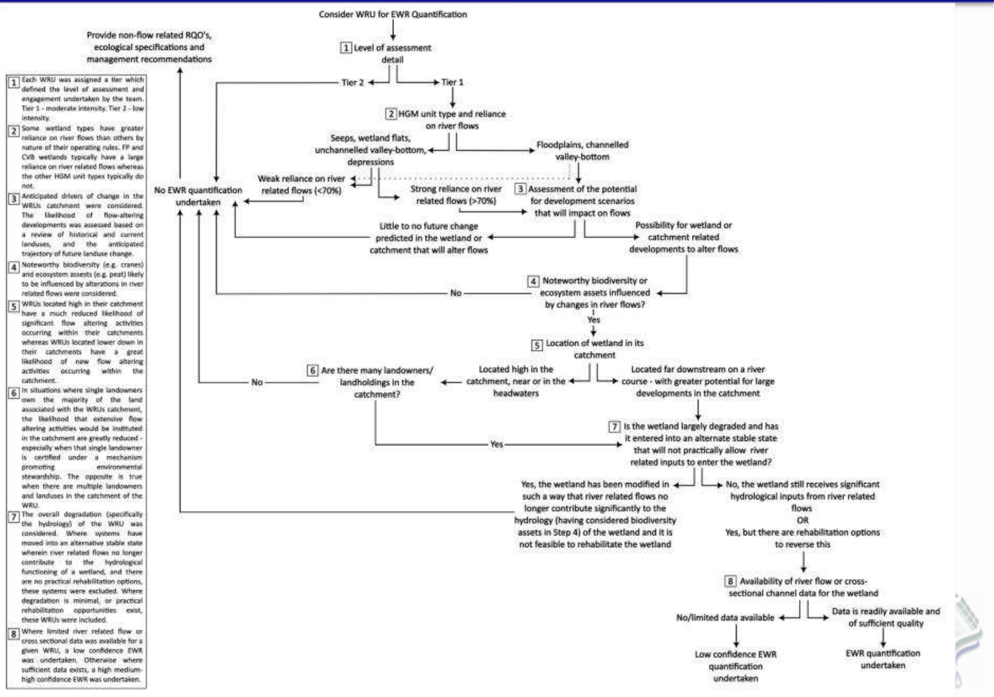
Decision Support System



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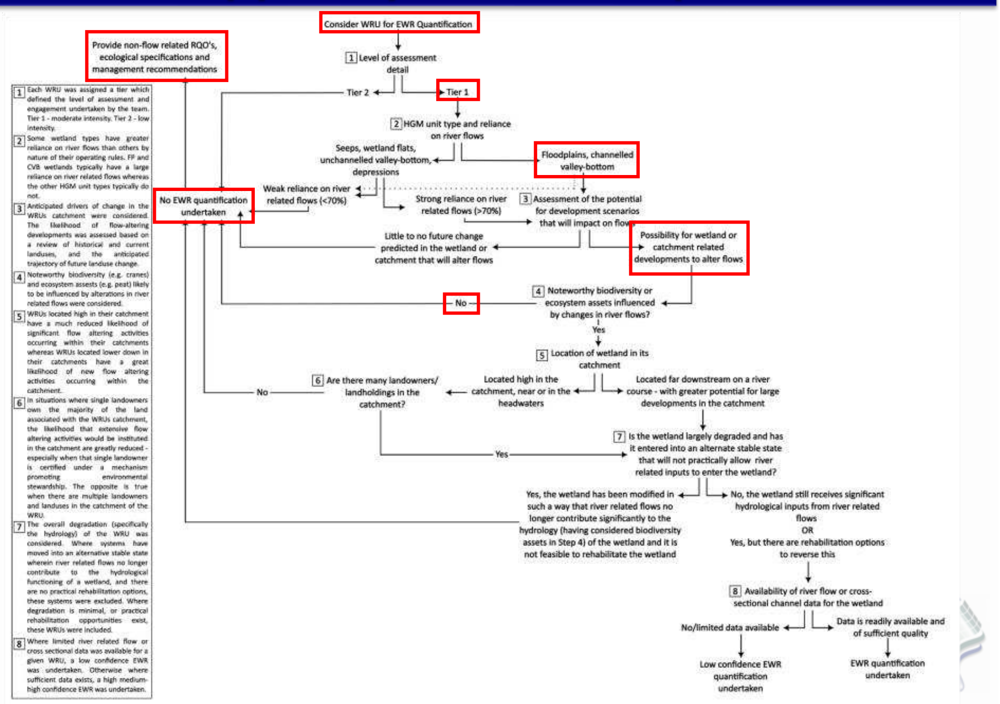
Decision Support System: Example



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Ecological
Consequences and
Operational Scenarios

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What are operational scenarios?

Step 5

- Scenarios, in context of water resource management and planning, are plausible definitions (settings) of all the factors (variable) that influence the **water balance** and **water quality** in a catchment and the system as a whole;
- Similar to the rivers, scenarios come in the form of proposed:
  - Dams
  - Transfer schemes
  - Pipelines between catchments
  - Large scale land use change in the catchment/wetland (e.g. would be irrigated agriculture)

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How are operational scenarios predicted?

- Hypothetical PES and EIS assessments are undertaken to assess the potential changes in **hydrology**, **geomorphology**, **water quality** and **vegetation** that the operational scenario may have on a given wetland
- This is predominantly predicted based on a landcover based assessment of a system
- For example, a floodplain wetland relies on floods flows to operate naturally
  - A dam directly upstream a floodplain wetland would drastically affect the **hydrology** and **geomorphology** of a floodplain wetland (i.e. **drivers**)
  - This would result in less frequent flooding and a decline in wetland **vegetation** within the floodplain (i.e. **response**)
- These scenarios were predicted for each wetland resource unit

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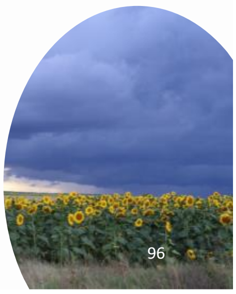
Ecological Specifications



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Ecological Specifications-Monitoring

Step 7

- Wetland condition was described in terms of biophysical components during the eco-categorisation process
- System drivers include hydrological, geomorphological and water quality components
- System responses predominantly include vegetation and hydrological components
- Low-cost desktop assessments of the WRUs were specified based on the following data:
  - Available wetland maps
  - Google Earth time series data
  - Invasive alien plant cover
  - Erosion
  - Land-use encroachment
  - Consultation with municipalities and landowners
- Some indicators can be observed from a desktop assessment, some require infield obsevations

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WRU 17 – Tiffindell Wetland Complex

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

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

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WRU 10 – Luckhof Depression Wetlands

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

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

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WRU 13 – Rantsho UCVB Wetland

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

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

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GROUNDWATER

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Groundwater – RU Delineation

- Resource Unit Definition: Water resources sufficiently different from one another are delineated into distinct units that have similar properties, with delineation being based on geohydrological, management or other criteria. Resource units can comprise part of a quaternary catchment, or a group of quaternary catchments.
- Primary Delineation
  - Quaternary Catchment
- Secondary Delineation
  - Geohydrological characteristics
    - Aquifer type
- Tertiary Delineation
  - Expert judgement & local knowledge
    - Conceptual Understanding
  - Physical criteria *(geology, climate, topography, recharge, gw levels & flow directions, temp hydrostatic response patterns, gw quality, gw use/stress, gw dependent ecosystems)*
  - Management criteria *(property, WUA, Catchment management, water management, political boundaries)*
  - Functional criteria *(role gw plays sustaining the environment, i.e. maintaining system integrity, discharge integrity or ecological integrity)*

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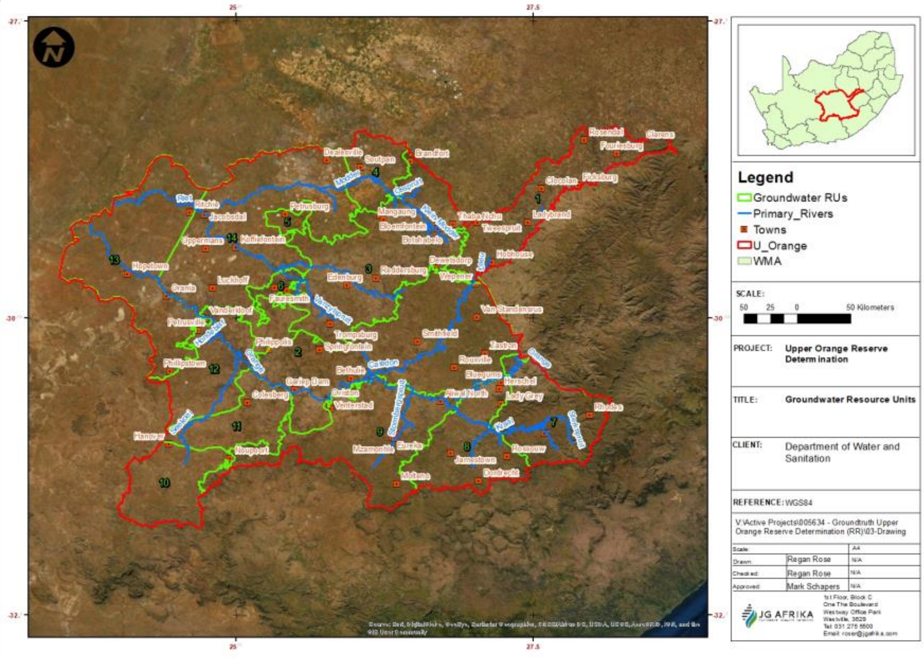
Groundwater – RU Delineation



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Groundwater – Prioritisation of GRUs

- Abstraction (WARMS)
  - Hotspots identified
- Wetlands
  - Major systems identified and overlayed
- Strategic Groundwater Resources
- If yes to all above, the GRU has been prioritised

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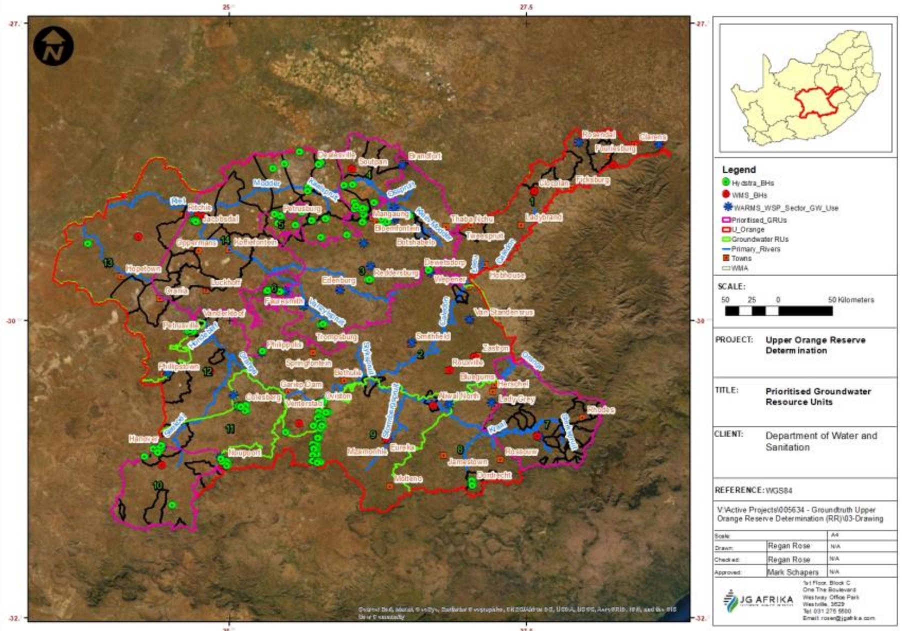
Groundwater – Prioritisation of GRUs



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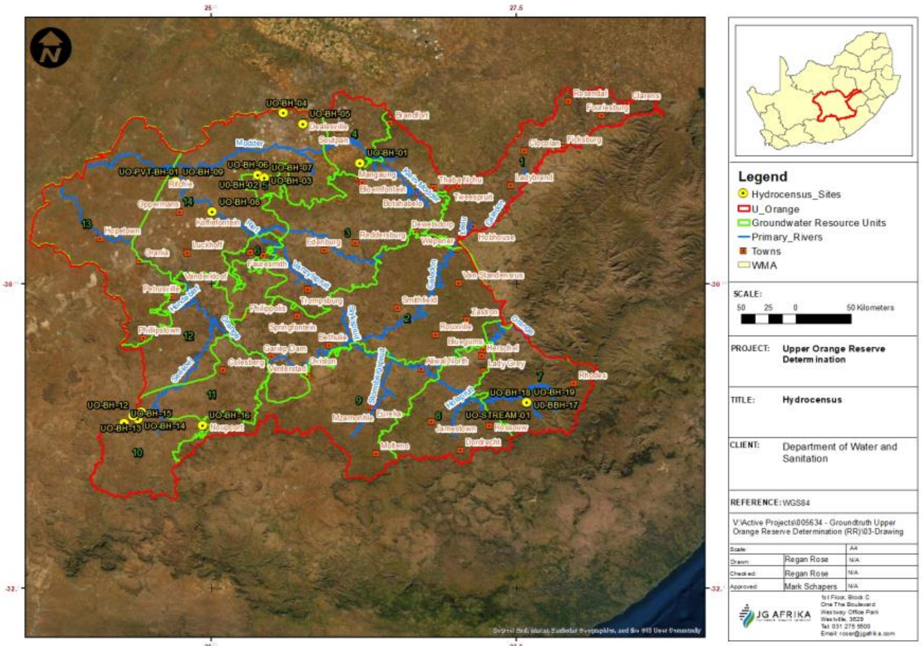
Groundwater – Hydrocensus



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Groundwater – Hydrocensus

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Groundwater – Reserve

- **Quantification of the Reserve (WRC, 2007)**
  - **Purpose**
    - To quantify the volume of groundwater that can be abstracted from a groundwater unit without impacting the ability of the groundwater system to contribute to the Reserve (basic human needs, ecological requirements)
  - **How**
    - Quantify recharge to the unit, using appropriate methods
    - Quantify the groundwater contribution to baseflow and groundwater dependent ecosystems, using appropriate methods
    - Quantify the basic human needs of the unit to be met from groundwater
  - **Key Outcomes**
    - GRDM assessment data sheet, in which recharge, groundwater contribution to baseflow and basic human needs are recorded
    - Calculation of the Reserve as a percentage of recharge and the groundwater allocation

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Groundwater – Reserve

- Quaternary Scale
- Groundwater Quantity Reserve
  - Recharge
    - Recharge Toolkit dependent on data availability
  - BHN
    - Population not linked to a formal water supply system and directly dependent groundwater abstraction to meet their basic needs.
  - Groundwater Baseflow
    - A desktop analysis using these lowest monthly flows as a proxy for baseflow.
- Groundwater Quality Reserve
  - Median groundwater quality determinands
  - 10% variation

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Groundwater – Reserve

- Using the available data, the latter components were estimated to determine the Groundwater Reserve.
  - Results:
    - The Groundwater Reserve varies from 0.01 – 223.80%.

Quaternary Catchment	Recharge (Mm3/a)	Basic human needs ground water Reserve required (Mm3/a)	Baseflow (Mm3/a)	Reserve (Mm3/a)	Reserve (%)
C51A	11.205	0.004	0.16	0.164	1.43
C51B	24.548	0.007	0.25	0.257	1.04
C51C	10.508	0.003	0.08	0.083	0.82
C51D	15.796	0.017	0.16	0.177	1.11
C51E	13.681	0.01	0.17	0.180	1.29

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Groundwater – PES

- PES for groundwater defined by Stress Index

$$\text{Stress Index (SI)} = GW_{use}/Re$$

Where:

Re = Recharge

GW_{use} = Groundwater Use

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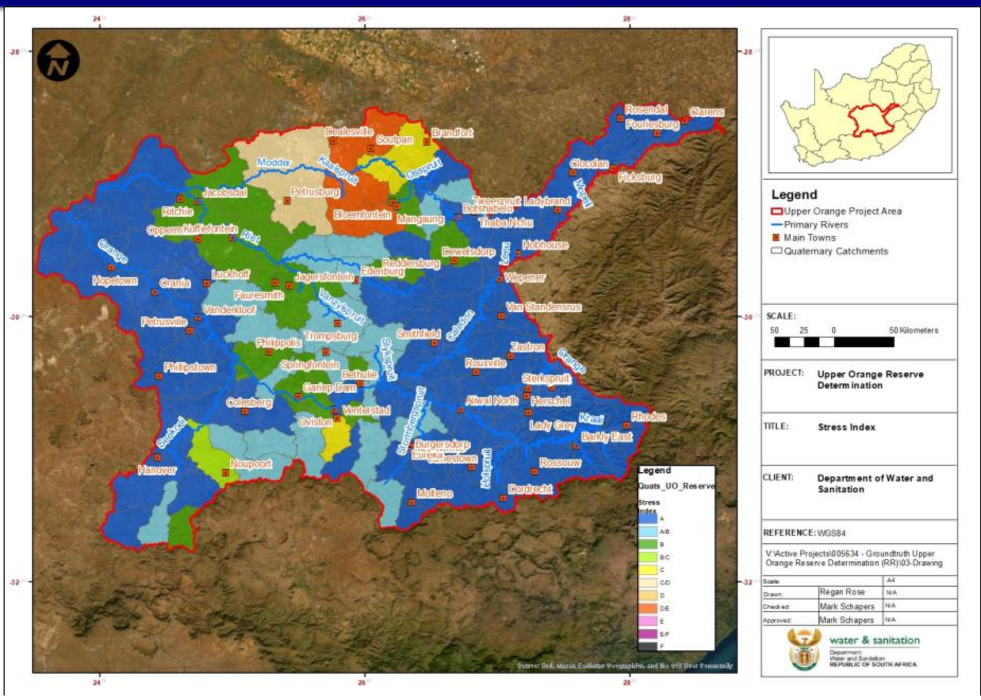
Groundwater – PES



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Groundwater – Ecospecs

- Based on outcomes of the Groundwater Reserve, groundwater quantity and quality indices for were derived for the Catchment
- The groundwater quantity directive
  - Minimum Stress Index Level
    - Groundwater investigation limited to local water balance estimation and hydrocensus
  - Moderate Stress Index Level
    - Groundwater investigation more detail in terms of hydrogeological conditions, hydrocensus, limited monitoring requirements, mapping of other abstractions and water balance
  - High Stress Index Level
    - High-level groundwater investigation, monitoring boreholes, specific license conditions, aquifer characterisation, recharge estimates, regional potential impacts and piezometric mapping

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Groundwater – Ecospecs

- The groundwater quality directive describes the time series component of the quaternary catchment's groundwater quality.
  - Long-term rising trends in salinity, i.e. EC/TDS, chloride, sodium, nitrate and nitrite, TALK and fluoride.
  - In this case the groundwater quality reserve should specify at least a marginal water quality in terms of the DWA (1998) Assessment Guide
    - Further deterioration should not be allowed without very strict mitigation measures.

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Groundwater – Ecospecs

- GRU 1

Quat	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Recommended Monitoring Programme
D21A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
D21C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
D21D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

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Groundwater – Ecospecs

- GRU 13 & 14

Quat	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Recommended Monitoring Programme
D33C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinitiy, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
D33D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinitiy, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
D33E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinitiy, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings

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Groundwater – Ecospecs

- GRU 3, 4 & 14

Quat	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Recommended Monitoring Programme
C51E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
C52J	Seriously Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
C52E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
C52F	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
C52G	Moderately Modified	Marginal, Class 2	Moderate Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
C52H	Seriously Modified	Marginal, Class 2	High Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings

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THANK YOU!

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