

DETERMINATION OF WATER RESOURCE CLASSES, RESERVE AND RQOs IN THE KEISKAMMA AND FISH TO TSITSIKAMMA CATCHMENTS WITHIN THE MZIMVUBU-TSITSIKAMMA WATER MANAGEMENT AREA (WP11354)

RQO Capacity Building: Wetlands, Groundwater and Estuaries

A collaboration with Steven Ellery (GroundTruth), Rob Schapers (JG Afrika) and Dr Lara Van Niekerk (CSIR)

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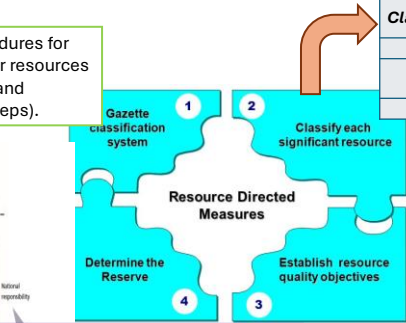
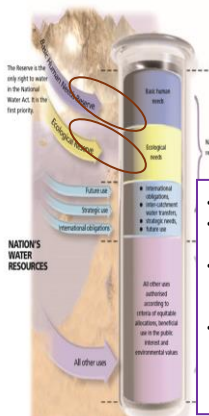
Protection of Water Resources

National system for classifying resources

- Gazetted on 17 September 2010, Gazette No. 33541, Regulation 810

Rivers, groundwater, wetlands and estuaries.

Defines and specifies the procedures for determining the classes of water resources (7 steps), the Reserve (8 steps) and resource quality objectives (6 steps).



Class	Description of use	Ecological Category	Description of resource
I	Minimally used	A-B	Minimally altered
II	Moderately used	C	Moderately altered
III	Heavily used	D	Heavily altered

Each class represents:

- a different **level of protection** that is required for the water resource, and the extent to which the water can be used.

Classification is used in two ways:

- To define the **present status** of the water resource
- To define the state towards which the water resource needs to be **managed** sustainably (**future state**).

- Only right in NWA
- The Reserve is an integral part of the RQO
- The Reserve is part of the water resource that is under the direct control of the Minister.
- It has priority over all other water use. Reserve must be met before water resources can be allocated to other water users

Targets or objectives/ management goals that provide statements about:

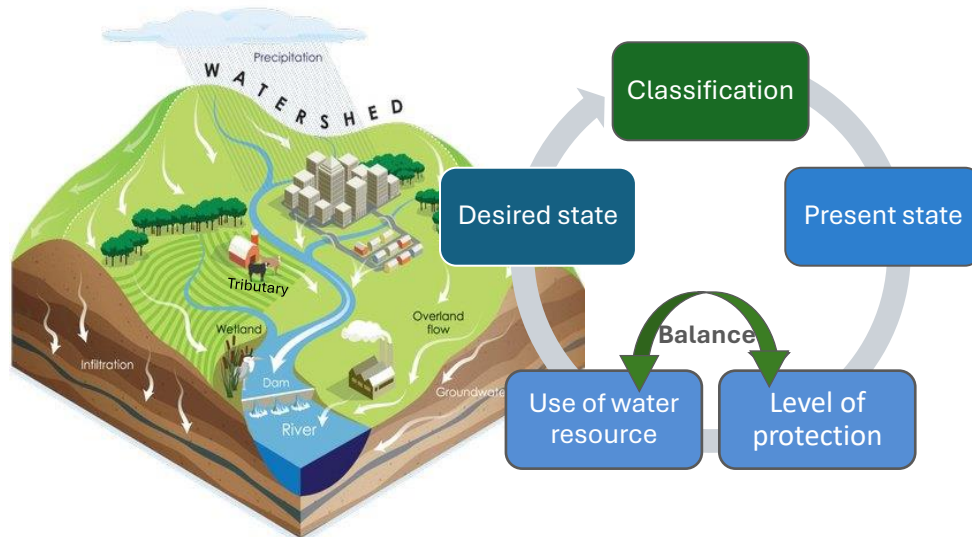
- what the **quantity** of the water should be (water level, pattern, timing)
- what the water **quality** should be (physical, chemical and biological)
- what the **condition of the instream and riparian** (riverbank) habitat should be
- what the **condition of the aquatic** (water) animal and plant life should be.



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Classification of Water Resources

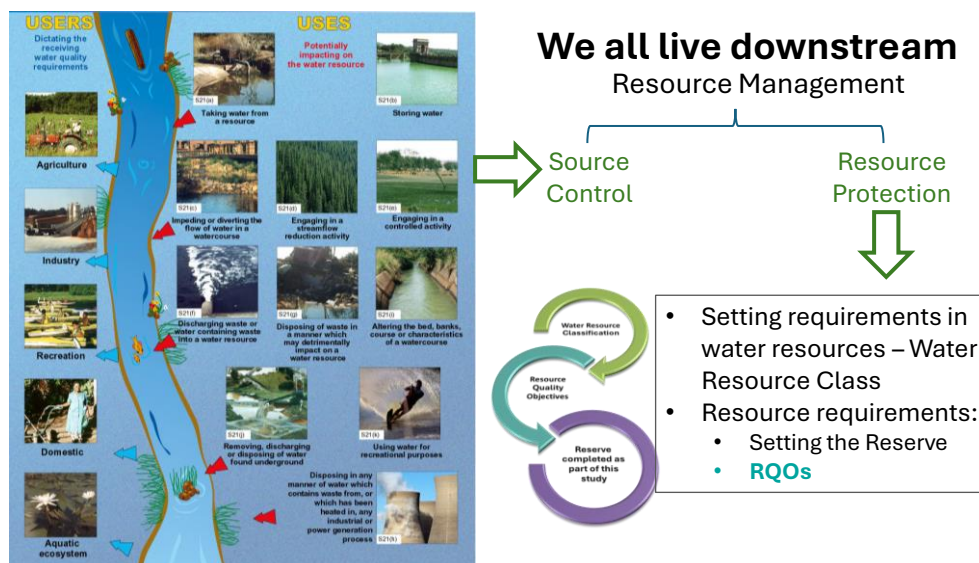
Integrated Water Resources Management (IWRM)



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Balancing Use and Protection

Integrated Water Resources Management (IWRM)



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RESOURCE QUALITY OBJECTIVES

- Purpose is to establish clear goals relating to the quality of the relevant water resources: provide limits or boundaries for the sustainable use of water resources
- In determining RQOs, a balance must be sought between the need to protect and sustain water resources and the need to use them
- Must take account of user requirements and the class of the resource
- Binding on all authorities and institutions
- The RQOs may inform decision-making relating to the use of the water in a specific water resource.

RQOs can be numerical and/or descriptive statements and may relate to the:

- **Quantity of water** (water level, pattern, timing)
- **Water quality** (physical, chemical, biological)
- **Instream and riparian (riverbank) habitat condition**
- **Aquatic (water) animal and plant life**



Major Dams



Estuaries



Groundwater

RQOs are determined for all water resources



Wetlands



Rivers

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Criteria for setting Resource Quality Objectives

- Simple, easily measured, understood, applied
- Use existing information where possible
- At appropriate scale and must detect change
- Comparable, repeatable, defensible
- May be drivers or response indicators
- Narrative and/or numeric
- Meaningful in terms of the Act



- RQOs cannot/do not:
 - Be applied to an individual licence
 - Replace the need for other monitoring programmes
 - Include every available indicator of resource quality
 - Be considered as absolute "truths"

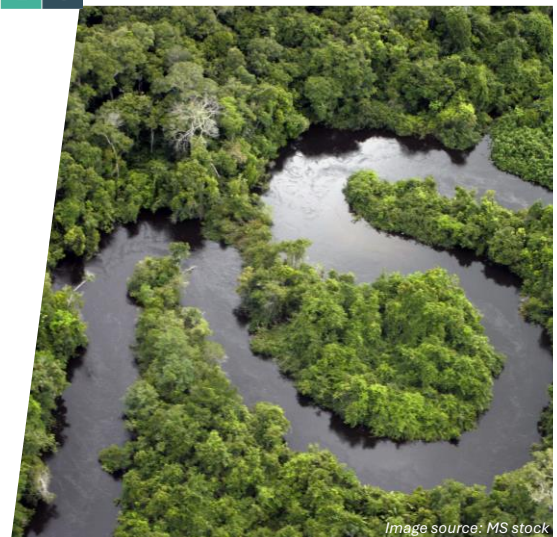
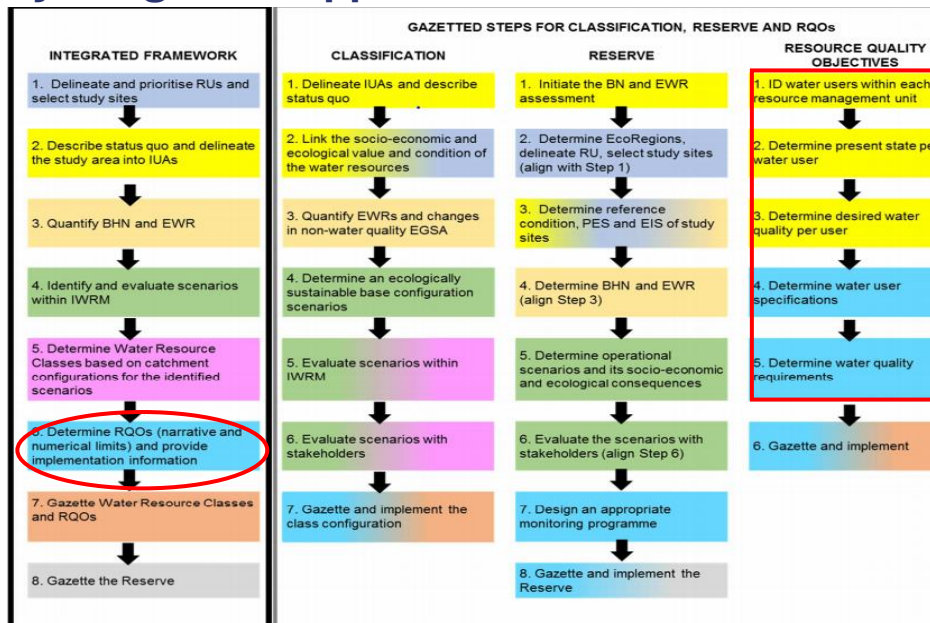


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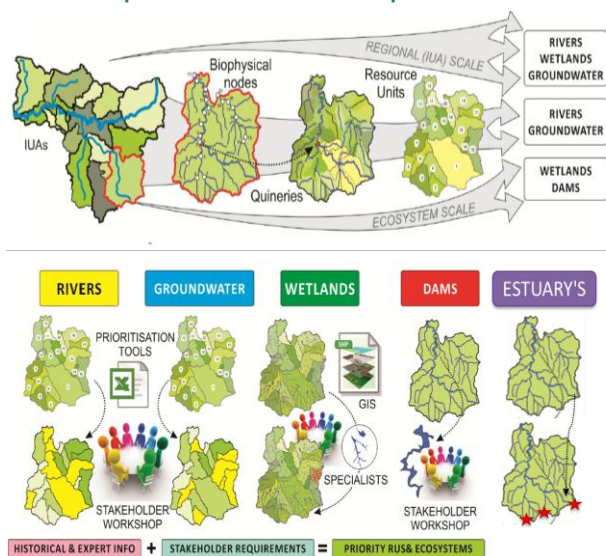
Study Integration Approach



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Resource Quality Objectives

Step: delineate and prioritise Resource Units



RQOs then set for all prioritised RUs for all water resources

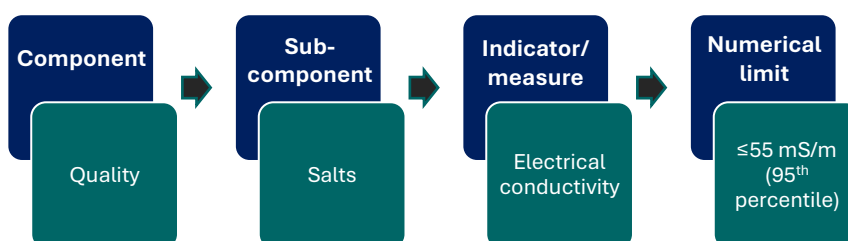
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Resource Quality Objectives

Step: use resource evaluation tool to select sub-components per prioritised Resource Unit

- DWS RU evaluation tool (rivers, wetlands and estuaries) – none for groundwater

Indicators and numerical limits for which RQOs should be set



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Resource Quality Objectives

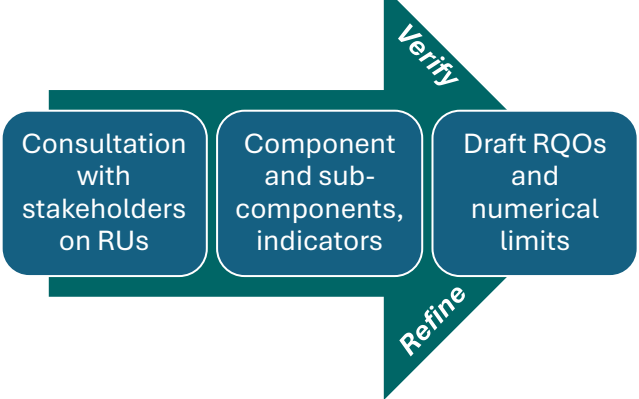
Step: use resource evaluation tool to select sub-components per prioritised Resource Unit

- RQOs for each resource unit:
 - May not always possible due the potentially large number of priority RUs that could be delineated for a catchment.
 - A rationalisation process has therefore been developed as part of the RQO Determination Procedure (DWA, 2011)
 - RU Evaluation Tool – to select the key indicators and sub-indicators appropriate and required per priority RU
 - Objective:
 - To evaluate and select the most useful indicators per priority RU for RQOs
 - Realistic and pragmatic: achievable and measurable
 - Rolcs Royce *versus* a Mahindra

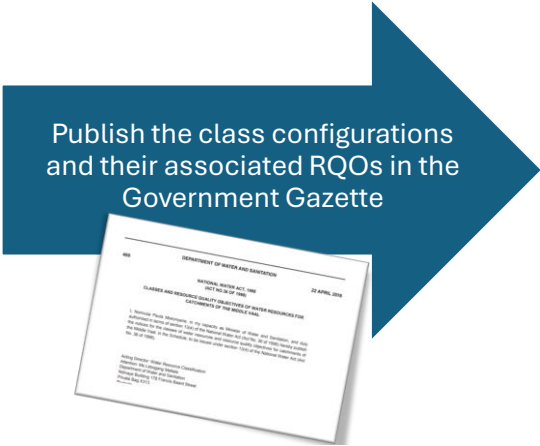
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Resource Quality Objectives

Step : Agree RUs, RQOs & numerical limits with stakeholders



Step: Finalise and Gazette



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WETLAND RESOURCE UNITS: APPROACH RECAP...

- The resource units (RUs) are the building blocks of any reserve study
- The delineation of the Wetland Resource Units (WRUs) was undertaken using a three-step approach:
 - Step 1: Identification of potential priority wetland areas
 - Step 2: Identification of criteria and scoring
 - Step 3: Final selected priority WRUs
- The identification of WRUs is focused on identifying systems at an ecosystem level and is strongly reliant on knowing where important wetland systems are.
- Existing wetland coverages/knowledge had to be leveraged for this process

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WRU APPROACH RECAP...

Step 1 – Identification of potential priority wetland areas

- Relied on existing wetland coverages as the base layer – which were limited (i.e. National Wetland Map, local knowledge, CMA databases, local governmental databases)
- These included:
 - National Wetland Map 5 spatial dataset (supplemented, especially in the western portions, with desktop review and local knowledge);
 - National Freshwater Ecosystem Priority Areas (NFEPA) wetland shapefile;
 - Important Bird Areas (IBAs);
 - Crane sightings and nest sites;
 - Wetlands that interacted with the surface and groundwater SWSAs (Lötter & Maitre, 2021);
 - Hydrogeomorphic (HGM) unit type, which was used to determine the level to which each system may provide services associated with:
 - Flood attenuation;
 - Stream flow regulation;
 - Erosion control;
 - Sediment trapping; and
 - Water quality enhancements (assimilation of nutrients).
- Wetlands that fall within Aquatic Critical Biodiversity Areas;
- Those systems that were classified as Critically Endangered or Endangered;
- Wetlands located upstream of important water supply dams;
- Identified water-stressed catchments/basins from the river RU process; and
- Landcover data

'Base
Layers'

'Overlay
Layers'

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WRU APPROACH RECAP...

Step 1 – Identification of potential priority wetland areas

- Where there were significant gaps in the available wetland datasets, wetland experts conducted GIS ‘flyovers’ of these areas and added point shapefiles where there were obvious wetlands



- Extensive gaps in the coverages with certain bioregions being underrepresented in the coverage
- Most of the spatial layers that were used were created at a national scale and were often not accurate at the fine scale required for this process

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WRU APPROACH RECAP...

• Step 2 – Identification of criteria and scoring

- As part of the initial wetland prioritisation process, specific criteria was identified for scoring on a sub-quaternary level (same sub-reaches as for the rivers). These criteria included the following:
 - Present Ecological State (PES)** – From A (largely natural) to E/F (serious/ critically modified);
 - Threat Status Score** (based on National Biodiversity Assessment 2011), with 4 = Critically Endangered, 3 = Endangered, 2 = Vulnerable, 1 = Least Concern;
 - Proximity to a known **crane** breeding or feeding site or if site falls within an **Important Bird Area**, with 4 = Crane Breeding Site, 3 = IBA, 2 = Crane Feeding Site, 1 = Crane sighting within 350m of wetland;
 - Critical Biodiversity Areas (CBA)**, with 4 = High Priority CBA, 2 = Low Priority CBA, 0 = No CBA;
 - Wetland Upstream of **Water Supply Dams**, with 4 = Wetland in same quaternary catchment, 2 = Wetland in quaternary catchment directly upstream of dam, 1 = Wetland in upstream quaternary catchment separated by one quaternary catchment;
 - Ability to **supply ecosystem services** based on HGM Unit type, with 4 = Unchannelled valley-bottoms, 3 = Channelled valley-bottoms, floodplains, 2 = Seep wetlands, 1 = Flats and depressions; and
 - FEPA Wetlands**, with 4 = FEPA Wetland and 2 = Low priority FEPA Wetland (Note: Due to inherent problems with the NFEPA wetland coverage, only FEPA wetlands that overlap with wetlands mapped in the NWM5 have been considered).

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WRU APPROACH RECAP...

Step 2 – Identification of criteria and scoring

- Scores for all wetlands within the study area were included within an Excel spreadsheet split up per IUA
- Based on the features of each wetland, it was possible to calculate a wetland priority score per wetland
- There were over 20 000 unique wetlands that were scored as part of this process
- Local stakeholders were requested to put forward priority wetlands and motivate for their inclusion
- Approximately 80 wetlands ended with equally high priority scores

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WRU APPROACH RECAP...

Step 3 – Final selected priority wetland resource units

- The wetland team manually reviewed the ~80 priority wetlands and further refined them on based on the following criteria/actions:
 - Presence of surface and/or groundwater SWSAs;
 - Preliminary priority River RU quaternary catchments;
 - Specific important wetland areas identified by individual stakeholders; and
 - Quaternary catchments identified with the highest recorded water uses (water quantity).
- There are 17 WRUs for this study. These were further refined into priority 1 and priority 2 wetland sites.
- Priority 1 sites required detailed fieldwork and priority 2 sites were predominantly desktop-based assessments with little fieldwork

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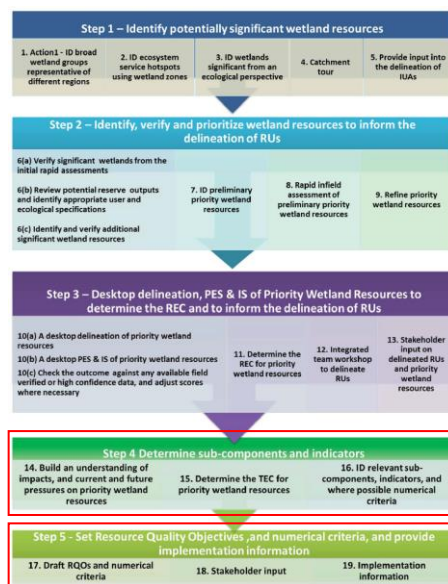
WETLAND RESOURCE QUALITY OBJECTIVES

- RQOs for wetlands are vital for a variety of reasons not limited to:



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WETLAND RESOURCE QUALITY OBJECTIVES

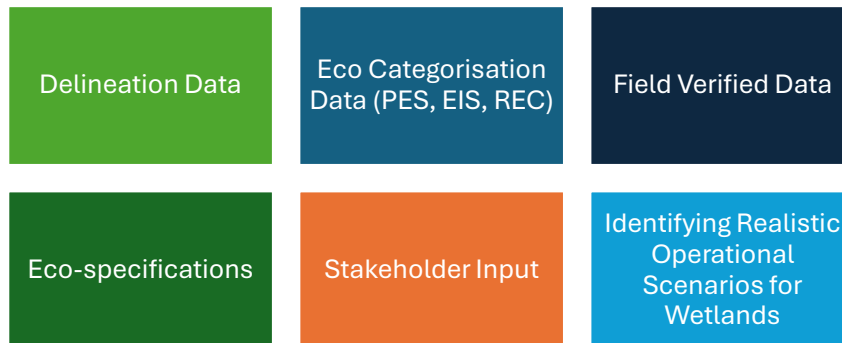


Bredin et al.
2019

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WETLAND RQOs: DATA REQUIREMENTS

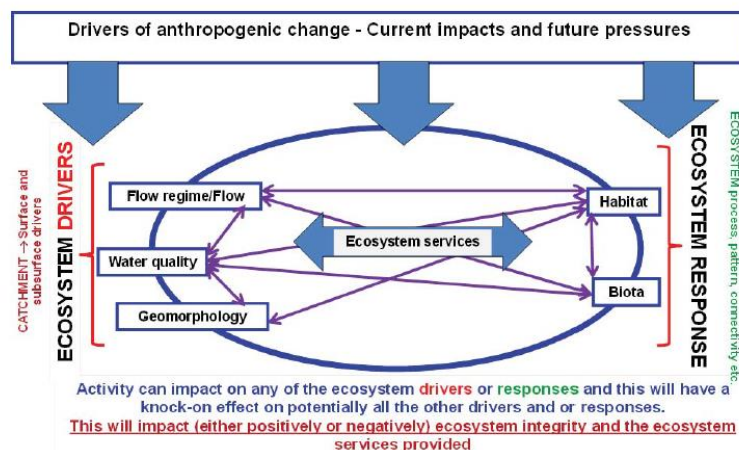
- **Step 4 Determine sub-components and indicators**
 - 14. Build an understanding of impacts, and current and future pressures on priority wetland resources
 - 15. Determine the TEC for priority wetland resources
 - 16. ID relevant sub-components, indicators, and where possible numerical criteria
- These data can include:



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WETLAND RQOs: DEVELOPING RQOs

- **Step 4 Determine sub-components and indicators**
 - 14. Build an understanding of impacts, and current and future pressures on priority wetland resources
 - 15. Determine the TEC for priority wetland resources
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From Roets (2018) in
Bredin et al. 2019

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WETLAND RQOs: DEVELOPING RQOs

- 14. Biological integrity
- Quality
- Habitat
- Biota
- Sub-components

Components	Sub-components
Quantity	Water inputs
	Water distribution and retention patterns
Quality	Nutrients
	Salts
	System variables
	Toxics
	Microbial determinands
Habitat	Present Ecological State (PES)
	Geomorphology
	Wetland Vegetation
Biota	Fish
	Plant species
	Mammals
	Birds
	Amphibians & reptiles
	Periphyton
	Aquatic Invertebrates
	Diatoms

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DWS 2011

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WETLAND RQOs: DEVELOPING RQOs

- Specific indicators are key measurable elements that are linked to the different components and their sub-components. They need to be:
 - Quantifiable
 - Measurable
 - Verifiable
 - Enforceable
 - Sensitive
 - Representative
 - Cost-effective
- RQOs are based off these indicators as they provide specific criteria that the qualitative or quantitative RQOs aim to maintain or achieve

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WETLAND RQOs: DEVELOPING RQOs



- Eco-specifications can be used as the basis for RQOs, as they often inherently have specific components and sub-components that need to be monitored and often have indicators too
- Consider the wetland eco-categorisation
- Links to other water resources
- Two types of RQOs exist – narrative RQOs and numerical RQOs
- Documentation and monitoring

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WETLAND RQOs: DEVELOPING RQOs



- The core purpose of this step is to obtain input from stakeholders on the draft RQOs
- Can occur in the form of stakeholder workshops held within the project area
- Stakeholder comments and inputs, either received at a workshop or via targeted engagement play a crucial role in refining the RQOs
- The wetland specialist needs to consider whether to incorporate these inputs into the RQOs, amend the RQOs to reflect these, or alternatively not to incorporate them (with justification)
- Thereafter the RQOs can be finalised

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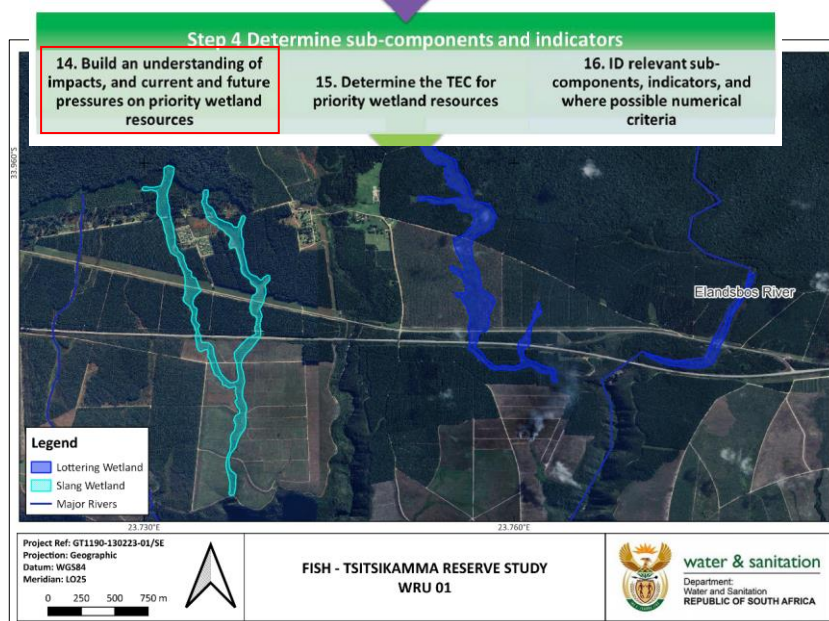
WETLAND RQOs: DEVELOPING RQOs



- An approach to the implementation of the RQOs needs to be developed which includes monitoring and reviewing the RQOs as part of an adaptive management cycle
- Document monitoring requirements
- Base monitoring on selected indicators
- Specify methods and frequencies
- Consider practicality
- Utilise existing methods and align with the NWMP
- Include details in the supporting technical report

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WORKING EXAMPLE: WRU01 – SETTING THE RQOs



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WORKING EXAMPLE: WRU01 – SETTING THE RQOs

Lottering Wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	5.4	1.6	0.6	2.9
PES Score (%)	46%	84%	94%	71%
Ecological Category	D→	B→	A→	C↓
Combined Impact Score	2.9			
Combined PES Score (%)	71%			
Combined Present Ecological Category	C→			

EIS: B

REC: C

Slang Wetland

PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.3	0.9	0.4	1.6
PES Score (%)	67%	91%	96%	84%
Ecological Category	C→	A→	A→	B↓
Combined Impact Score	1.8			
Combined PES Score (%)	82%			
Combined Present Ecological Category	B→			

EIS: A

REC: B

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WORKING EXAMPLE: WRU01 – SETTING THE RQOs

- Other factors to consider:
 - Wetlands are situated in an active forestry area which is an authorised land use activity in this area
 - Wetlands support populations of the near-threatened Garden Route Conebush (*Leucadendrom conicum*) and the vulnerable dragonfly *Syncordulia venator*, the vulnerable Grass Owl (*Tyto capensis*).
 - The wetlands play a vital role in linking the mountains to the coast through the Tsitsikamma plains and are important breeding and/or feeding sites for wetland dependent species
 - Both contain peat deposits
 - Fall within a SWSA
 - High vegetation diversity within the wetlands
 - Downstream floodable property include the R102 and N2 crossings
 - Major threats are invasive alien plants and encroachment of plantations

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WORKING EXAMPLE: WRU01 – SETTING THE RQOs



- The REC was set as the TEC for this wetland
- Given the extent of forestry within the catchment – which is an authorised activity – it is not practical to improve the condition of the wetlands
- Therefore, the objective for the two wetlands were to maintain the current ecological conditions

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WORKING EXAMPLE: WRU01 – SETTING THE RQOs

Step 5 - Set Resource Quality Objectives ,and numerical criteria, and provide implementation information				
Wetland Site	17. Draft RQOs and numerical criteria		18. Stakeholder input	19. Implementation information
Lottering	Valley-bottom/Sleep	Habitat – Ecological Condition	Desktop and field verified PES category based on a Level 1B WET-Health assessment undertaken for the Lottering wetland.	

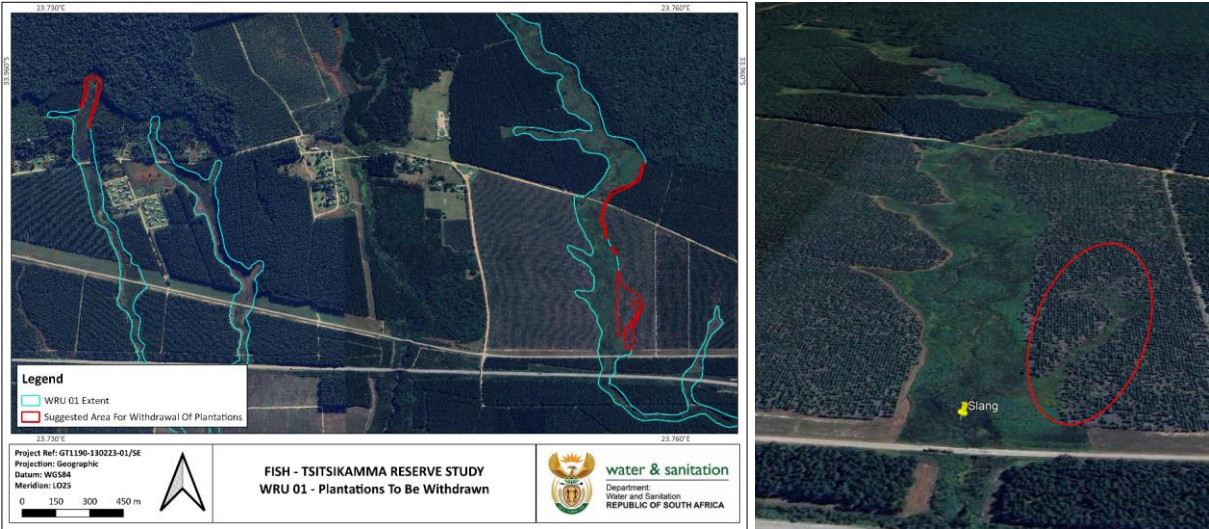
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WORKING EXAMPLE: WRU01 – SETTING THE RQOs

Wetland/ Site	Type	Component prioritised	Indicator	RQO	Numerical Criteria
Lottering	Valley-bottom/Seep	Habitat – Ecological connectivity	Extent of plantations within the valley-bottom wetland	A small portion of the plantation on the eastern margins of the wetland should be excised from the valley-bottom wetland to provide key ecological connectivity, buffer capacity, improved hydrology, and gene flow between them and neighbouring sites	Key plantations on the eastern margin of the Lottering wetland need to be withdrawn.

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WORKING EXAMPLE: WRU01 – SETTING THE RQOs



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WORKING EXAMPLE: WRU01 – SETTING THE RQOs

Wetland/ Site	Type	Component prioritised	Indicator	RQO	Numerical Criteria
Lottering	Valley-bottom/Seep	Habitat – Wetland vegetation	Maintenance of a structurally and compositionally diverse wetland and fynbos habitat	Maintain a burning and grazing regime that is ecologically favourable, both for general wetland and fynbos ecological functioning	A fire record must be established for the wetland to ensure that infrequent fires are maintained for the Lottering wetland. An appropriate fire interval for the wetland is required which meets the dual needs to: (1) accord with the ecological requirements of the native flora, notably that of the re-seeding native species (e.g., <i>Leucadendron conicum</i>); and (2) assist in controlling alien and indigenous invasive species, notably the Keurboom (<i>Virgilia divaricata</i>). The ideal fire regime would be a hot fire every 9-12 years. An agreement needs to be set up with the landowner to carry out this proposed burning regime.

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NEXT STEPS...



- Stakeholder workshops need to be undertaken with the stakeholders in the WRU01 to discuss the RQOs – especially those relating to the removal of plantations and the monitoring of fire
- Thereafter, the RQOs will be refined by the wetland specialist team
- Implementation information and data (reports, assessment spreadsheets, spatial data etc) will be provided to the Department to allow them to undertake the monitoring of these systems.

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Groundwater RQOs



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Prioritisation of RUs

Groundwater

- Objectives are to maintain water quality status quo and provide allocatable groundwater to users
- Important for planning, licensing and monitoring
- Consideration of Groundwater Reserve components
 - Recharge
 - Basic Human Needs
 - Groundwater contribution to EWR/baseflow
- Existing monitoring data used for the assessment

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Prioritisation of RUs

Groundwater

- Groundwater resource unit delineation was based on aquifer type (primary aquifer, secondary aquifer, karst aquifer) and other physical, management and/or functional criteria
- Quaternary catchment boundaries which formed the basic unit for the GW Resource Directed Measures (GRDM) assessment
- The project area comprises 19 No. IUAs, with 345 No. quaternary catchments
- The delineation of 48 Groundwater Resource Units in previous stages
- GWRUs considered various criteria at the quaternary catchment level, and were then prioritised based on average weighting, with sub categories applying
- % Score per quaternary developed and final priority based on a scalable ranking system
- GWRU was assigned the highest quaternary priority score listed

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Prioritisation of RUs

Groundwater

Criteria

- Groundwater use (WARMS, NGA, density)
- Strategic GW Areas (SW, GW, SW-GW)
- Groundwater Dependency
- Stress Index
- Government Control Areas
- Water Quality
- Baseflow Component (new)



Quat	River	GW use (WARMS)	Strat GW Areas	GW Dependency	Stress	Govt Control Areas	GW Quality - (EC)	Eco reliance on GW (Baseflow)	Overall score (total 35)	% score	Priority (1-3)
K80A	Elandsbos & Un-named tributary	1	5	1	1	1	4	5	18	51.4	2
K80B	Storms & Kleinbos	1	2	1	1	1	4	5	15	42.9	2
K80C	Kruis & Elands	4	2	3	1	1	4	5	20	57.1	1
K80D	Groot & Klip	5	2	3	3	1	4	5	23	65.7	1
K80E	Klasies & Tsitsikamma	5	2	3	4	1	4	4	23	65.7	1
K80F	Klipdrift & Un-named tributary	5	2	3	5	1	3	4	23	65.7	1
K90A	Krom	3	2	1	2	1	4	4	17	48.6	2
K90B	-	3	2	1	2	1	1	4	14	40.0	2

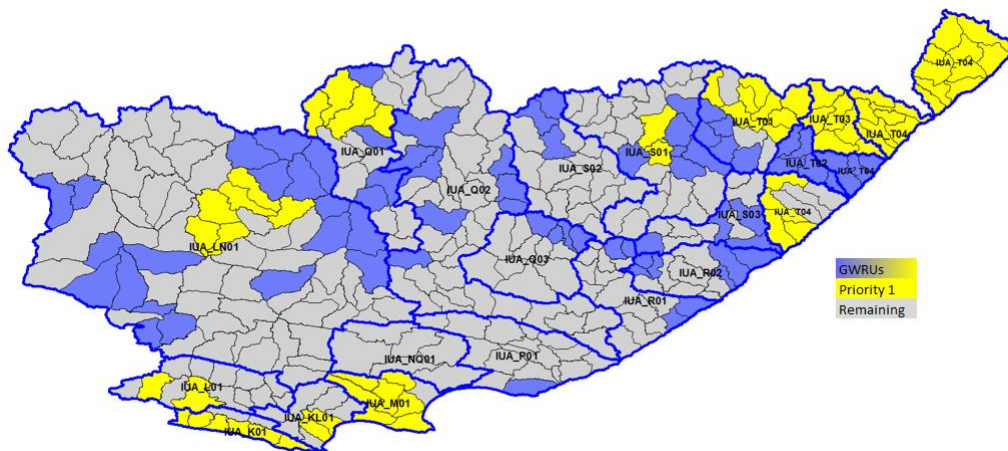
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Prioritisation of RUs

Groundwater

- Of the 48 No. GWRUs identified, 16 No. were set at priority 1 using the current score scaling (65 quaternary catchments)

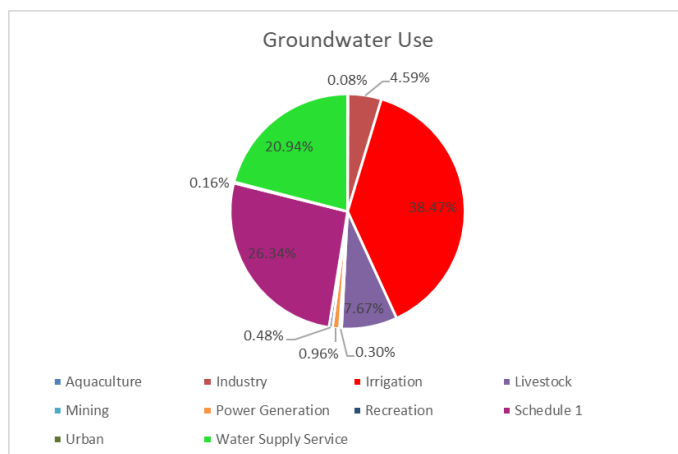


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Data Requirements

Groundwater

- Groundwater Use;
- Predominantly irrigation, schedule 1 and Water Supply Service
- Data Requirements;
 - Time series water levels
 - Time series water quality
 - Abstractions
 - Regional datasets



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Data Requirements

Groundwater

Reserve and Stress Index Calculations

$$\text{Reserve (\%)} = \frac{\text{EWR}_{\text{gw}} + \text{BHN}_{\text{gw}}}{\text{Re}} \times 100$$

Where:

Re = Recharge

BHN_{gw} = Basic human needs derived from groundwater

EWR_{gw} = Groundwater contribution to EWR

$$\text{Stress Index (SI)} = \text{Re} - (\text{GW}_{\text{use}} + \text{EWR}_{\text{gw}} + \text{BHN}_{\text{gw}})$$

Quat	Recharge (Mm ³ /a)	BHN (Mm ³ /a)	Groundwater Baseflow (Mm ³ /a)	Reserve (Mm ³ /a)	GW Use (Mm ³ /annum)	Stress Index Value	Stress Index Category	WQ Reserve	Allocable GW (Mm ³ /a)
K80A	16.538	0.0000	46.56	46.56	0.000	0.0000	A	No	-30.023
K80B	21.966	0.0054	66.27	66.27	0.000	0.0000	A	Yes	-44.306
K80C	24.582	0.0054	63.51	63.51	0.604	0.0246	A	No	-39.535
K80D	21.524	0.0115	35.38	35.39	3.144	0.1461	B	No	-17.011
K80E	26.807	0.0115	31.25	31.26	3.564	0.1330	B	No	-8.022
K80F	18.883	0.0106	23.95	23.96	2.995	0.1586	B	No	-8.076
K90A	19.902	0.0011	9.93	9.93	0.529	0.0266	A	No	9.439
K90B	16.050	0.0011	8.68	8.68	0.331	0.0206	A	Yes	7.038

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Data Requirements

Groundwater

Recharge

- Numerical methods and regional mapping methods (ACRU, Vegter, Harvest Potential)
- Chloride method
- Isotopes
- DWS Data sets (SAGDT, GRAII, NIWIS, etc)

Methods to determine availability for use – Allocatable Use

- Existing data sets (DWS; GRAII, UGEP, NIWIS etc)
- Desktop assessment based on recharge
- Catchment based water balance assessment
- Numerical modelling
- Monitoring (GW levels)
- Baseflow contribution

Groundwater Quality

- Existing data sets (NGA, GRIP, NWS etc)
- Available chemical parameters are:

EC, Alk, NH₄, Ca, Cl, Mg, K, Na, SO₄, NO₂, NO₃, TDS, F

Median concentrations of each chemical parameter were determined to characterise the dominant groundwater quality

Groundwater Quality Reserve was set at median concentrations plus 10% for each chemical parameter

Quaternary Catchment	Recharge Area (km ²)	MAP (m/a)	Available for Recharge (m ³ /d)	Recharge		Demand (m/d)	% of recharge required to meet demand
				%	m ³ /d		
K80A	149.9000	1030.000	423005479	9.64	40777728	1000000	2.45

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Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

Priority groundwater RU: GRU01 (K80A, K80B, K80C, K80D, K80E, K80F)

Overview of the GWRU

The monitoring sites in IUA 1 (K1) include Hydstra and WMS sites

5 (No.) monitoring sites exists for this IUA. Time series data of groundwater levels and groundwater

Groundwater levels vary between 7 - 28mbgl

Groundwater levels have a cyclical trend and indicate strong seasonality

Impacts of prolonged drought are evident

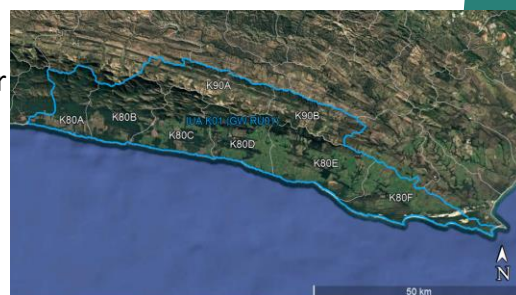
Groundwater quality (EC) within the IUA is very good

Classified as a "Class 1" - Good Water Quality type water

GW use ranges from low to high

GW dependency (K80C – K80F)

Very high stress on GW (K80A – K80D)



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Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

**Priority groundwater RU: GRU01
K80A, K80B, K80C, K80D, K80E, K80F**

- How RQOs were developed for this GWRU
 - Key Risk Based criteria for groundwater management are
 - Quality
 - Quantity
 - Decreased Groundwater Levels
 - Over exploitation Risks
 - Reduced Water Quality
 - Impact on Ecosystems
 - Conflict Over Resources – socio economic
 - Increased Risk of Land Subsidence
 - Positive - reduced surface water demands (and practicality of SW implementation, through smaller scale GW supply projects in rural settings)

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Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

Priority groundwater RU: GRU01 K80A, K80B, K80C, K80D, K80E, K80F

- How RQOs were developed for this GWRU
- Determine RQOs (Narrative and Numerical Limits)

Action	Input	Output
1. Identify critical subcomponents (e.g. stress and use; quality) and select indicators	Water use and recharge.	Threshold.
	Baseflow reduction.	Threshold.
	Water quality time series.	Threshold.
	Water levels time series.	Narrative output.
	Water level time series.	Thresholds for water level trends.
2. Draft a narrative and/or numerical limits for RQOs	Aquifer parameters.	Distance from a river at which to control abstraction.
		Simple and measureable RQOs.

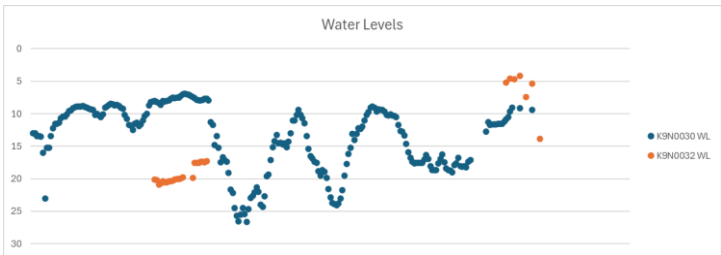
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Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

Priority groundwater RU: GRU01 K80A, K80B, K80C, K80D, K80E, K80F

- Example:
- Water Levels (K9N0030, K9N0032) Kareedouw



	K9N0030 WL	K9N0032 WL
min	6.9	4.2
max	26.6	20.9
average	13.7	16.4
75 th Percentile	17.5	20.3



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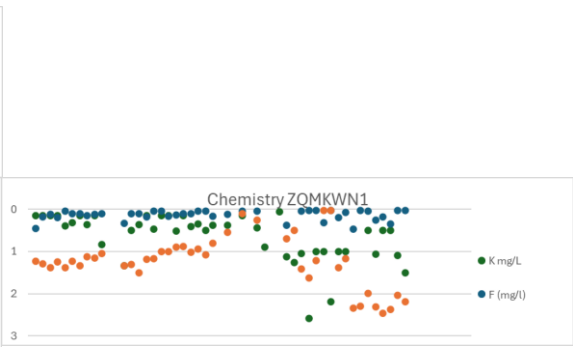
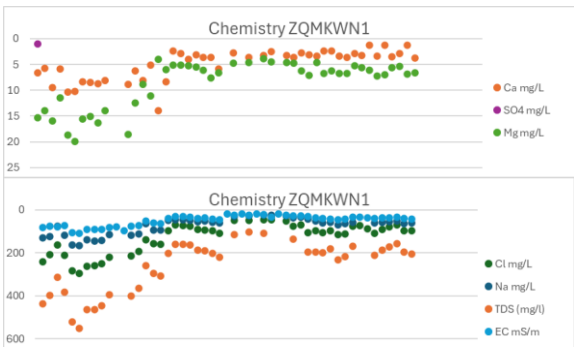
Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

Priority groundwater RU: GRU01 K80A, K80B, K80C, K80D, K80E, K80F

- Example:
- Water Quality (ZQMKWN1)

	EC mS/m	T.Alk mg/L	Ca mg/L	SO4 mg/L	Mg mg/L	K mg/L	F (mg/l)	NO2 + NO3 as N mg/L	TDS (mg/l)	Na mg/L	Cl mg/L
min	18.1	2.5	1.3	5.8	3.9	0.1	0.0	0.0	102.1	25.1	45.9
max	110.0	29.8	14.0	27.0	19.9	2.6	0.5	2.5	550.0	165.8	296.3
average	50.0	10.8	4.9	14.0	8.6	0.6	0.1	1.2	262.0	74.4	128.7
75 th Percentile	74.4	13.9	6.6	16.2	11.5	1.0	0.2	1.4	368.5	104.4	164.9



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Working Example of Groundwater RQOs

IUA_K01 (Tsitsikamma and Kromme)

Priority groundwater RU: GRU01 K80A, K80B, K80C, K80D, K80E, K80F

IUA	GWRU	Quats	Component	RQO	Indicator/Measure	Numeric Limit
IUA_K01	Gw_ru01	K80A K80B K80C K80D K80E K80F K90A K90B	Quantity and Aquifer	Where water use is higher than requirements for Reserve, Schedule 1 and General Authorizations, Groundwater Flow reversal to be prevented near drainage lines	Water Levels Time Series Abstraction Rates	Water Balance; $Q < \text{Average recharge per hectare}$ % of MAR to be set
				Abstraction rates should not exceed the average recharge values of the aquifer based on the licensed area.	Radius of influence (r)*. $r = 1.5 \cdot \sqrt{(T \cdot t / S)}$, T =Transmissivity(m^2/d), t =Time(days), S =Storativity	Radius and cone of depression to be determine through borehole yield test for high yielding abstractions
				The radius of influence should not intersect any other protection zone		Apply Protection Zone
			Quality	Water Level Trends to show recovery over medium to long term	Groundwater Level at active monitoring boreholes using Groundwater Monitoring Guidelines	Require representative monitoring site for application Maximum drawdown around application site < 26.6m Use 75th percentile of 20.3m
				Preserve existing water quality	Water Quality Time Series COCs	Preserve water quality status quo in absence of monitoring data Set limits based on required water use Long term trend 75th percentiles: EC - 75 mg/l Na - 104 mg/l Cl - 165 mg/l SO4 - 17 mg/l NO2/NO3 - 1.4 mg/l
				Protection zone from microbial pollution	Microbial radius (r). $r = 2(0.28 \cdot T) + 53$	Set off set distance / Protection Zone (Pit latrines)
			Ecological	Protection zone along a river/stream is required to protect the ecological reserve	$L = (T \cdot i) / R$, T =Transmissivity(m^2/d), i =Groundwater Gradient, R =Recharge(m/d)	Radius and cone of depression to be determine through borehole yield test for high yielding abstractions L should not overlap with any other radius of influence, cone of depression, protection zone Monitor baseflow component (dry season)

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Groundwater RQOs

Challenges and learnings

Screening Limits

- General Limits
- SAWQG
- SANS241

Groundwater Monitoring

- Lack of current or any data
- Conflicts in datasets
- Water levels (Hydstra)
- Water quality (WMS)
- Abstractions (incl WARMS)
- Baseflow - monitoring river flow

Additional Considerations

- Data problems; baseflow vs recharge
- Expanded monitoring
- Expanded determinant lists
- Climate resilience
- Unauthorised use
- Area based criteria weighting
however there may be a area based concentration on groundwater use (towns etc)



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Prioritisation of RUs

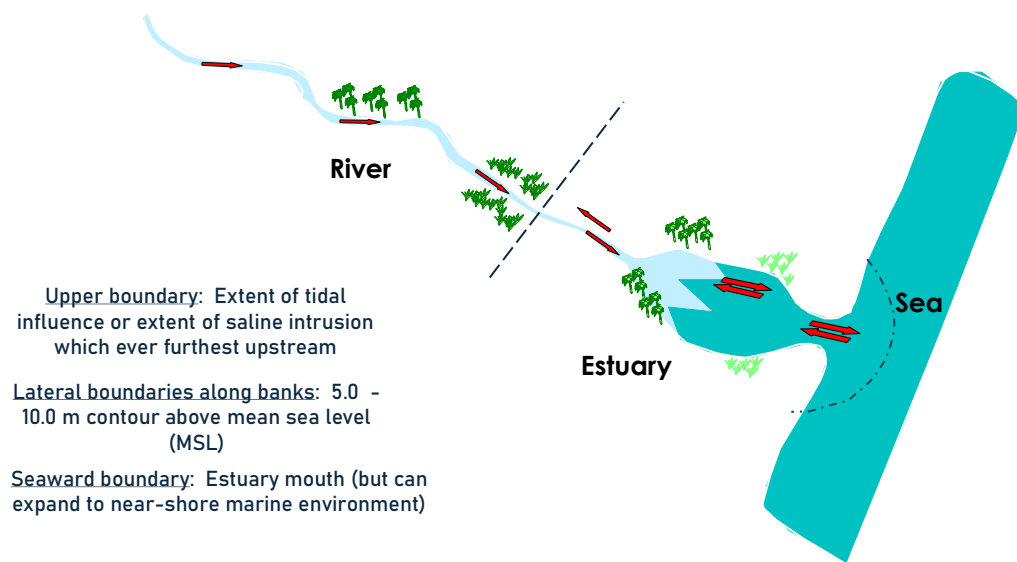
Estuaries

- Estuaries is a single RU based on the Estuarine Functional Zone (EFZ) (previously done national scale by van Niekerk et al. 2019)
- Water resource importance (use/quality)
- High ecological importance (resource is currently/future stressed)
- Previous assessments
- Further considerations/inclusions:
 - High Ecological Category: A, A/B or B (High EC);
 - Critically endangered fish species
 - Carbon sequestration (mangrove, salt marsh & seagrass)
 - Nursery areas
 - Critically endangered species (other)



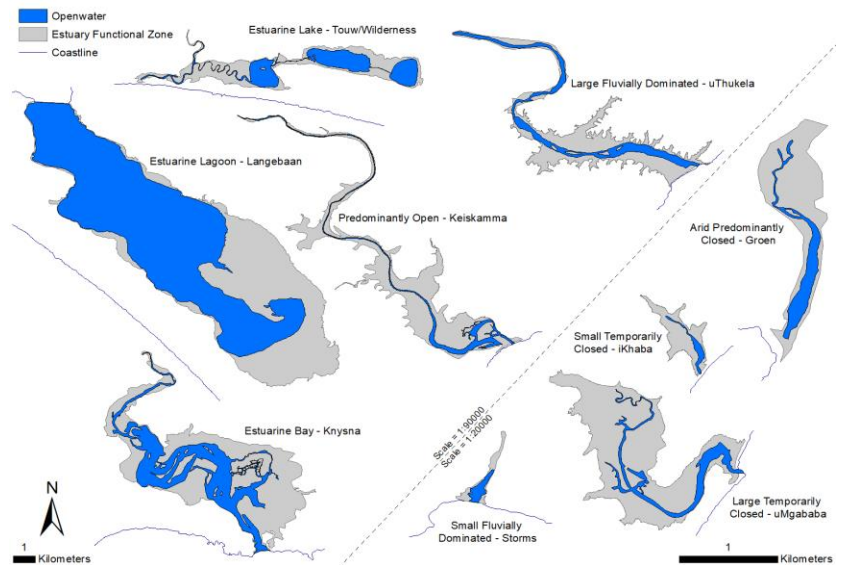
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What is an estuary?



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Important Biophysical Features

- Driven by both river runoff and seawater intrusion
- Longitudinal (and vertical) gradients in salinity & other physical and water quality parameters, influenced by the volume of river inflow and mouth state
- Marked differences between chemistry (or water quality) of river water and seawater, thus volume of river inflow also strongly influence water quality (i.e. not necessarily linked pollution)
- Physical characteristics and water quality usually not result of a single event, but rather that of flow patterns occurring over weeks or months



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Abiotic Drivers

Water Quality

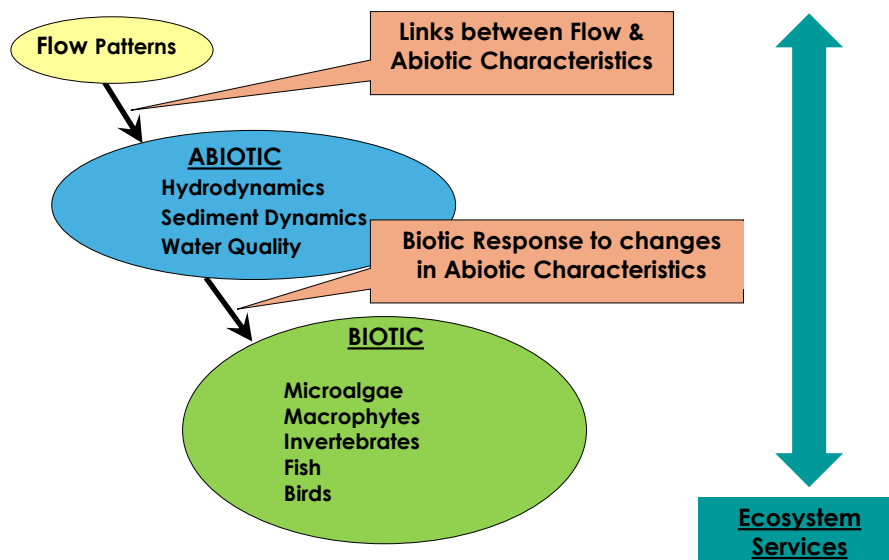
'Water quality' refers to concentrations and distribution patterns of:

- Salinity
- Temperature
- pH
- Dissolved oxygen
- Suspended solids & Turbidity
- Inorganic nutrients (e.g. nitrate & phosphate)
- Organic nutrients (e.g. organic carbon)
- Toxic substances (e.g. trace metals and hydrocarbons)

Continued...

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Ecosystem complexity



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Biological (response) Components

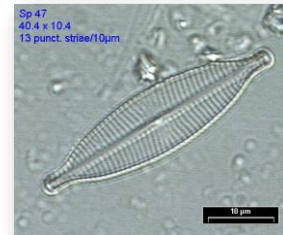
Micro-algae

Micro-algae form a crucial part of food chain in estuaries and include:

- Benthic micro-algae
- Phytoplankton



Cyclotella meneghiniana



Navicula subrhyncocephala

Photos: Gavin Snow

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Biological (response) Components

Macrophytes

Macrophytes provide a safe habitat from predators and a forms a crucial part of food chain in estuaries and include:

- Mangroves
- Saltmarshes
- Submerged macrophytes
- Reeds & sedges
- Macro-algae



Sedge (*Schoenoplectus scirpoides*)

Saltmarsh

Photos: Janine Adams

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Biological (response) Components

Invertebrates

Invertebrates provide an important food source to other estuarine inhabitants such as fish and birds and include:

- Zooplankton
- Crabs
- Sand prawns
- Mud prawns
- Mussels



Sand prawn, *Callinassa kraussi*

Photo: Siyabona Africa

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Biological (response) Components

Fish

Estuaries are important nursery areas for fish - during spring and summer juvenile fish enter estuary to take advantage of sheltered and food rich environment

A variety of fish species is found in estuaries, for example:

- Mullet
- Grunter
- King fish
- Shad
- Moonies



Typical composition of estuarine fish species

Photo: Stephen Lamberth

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Biological (response) Components

Birds

- Herons
- Gulls
- Waders
- Terns
- Cormorants
- Black Oystercatchers (red data species)

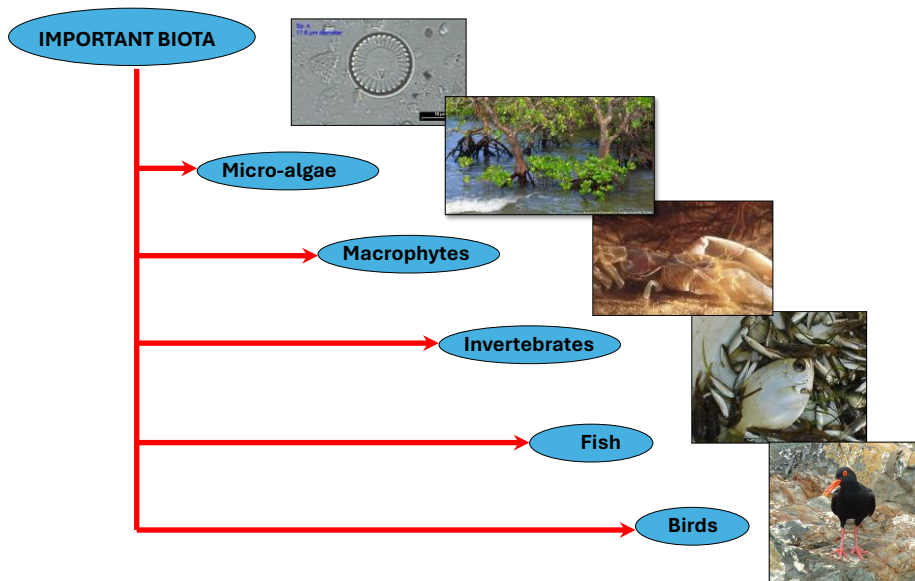


African Black Oyster Catcher

Photo: Avian Demographic Unit, UCT

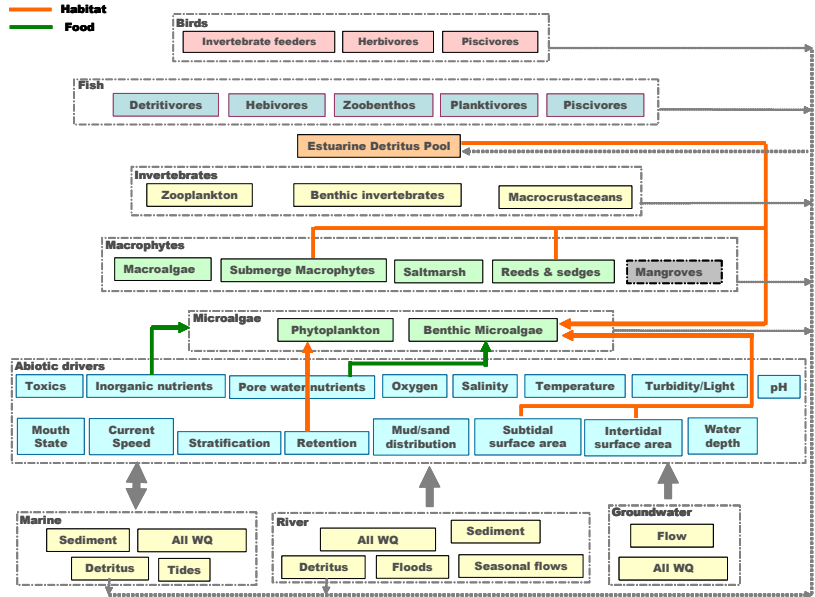
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Key Biotic components...



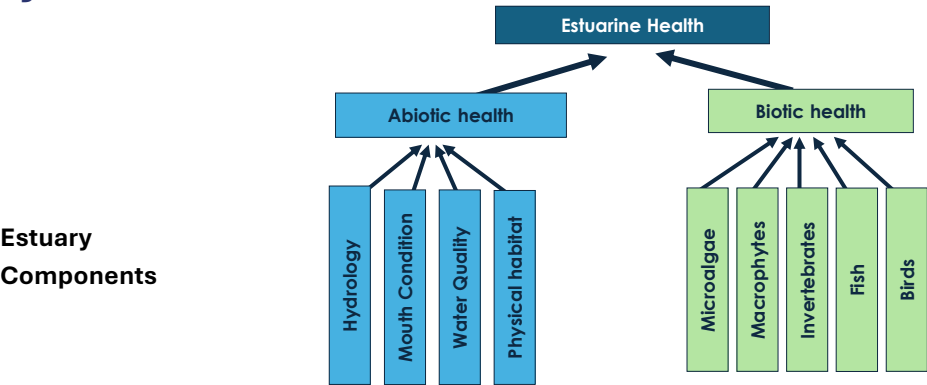
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Ecosystem complexity



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Estuary Health Index



Similarity to Natural
(Reference)

Condition	≥91%	90-75	75 - 61	60 - 41	40-21	≤ 20
Category	A	B	C	D	E	F
	Natural	Largely natural / few changes	Moderately modified	Largely modified	Highly degraded	Extremely degraded
State	Excellent	Good	Fair		Poor	

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Detail captured in RQOs

Study confidence & detail captured in RQOs is influence by :

- Quality of the flow data & simulated hydrology – uncertainty we aggregate
- Historical imagery (aerial photographs and satellite)
- Information on mouth state (if relevant)
- Historical abiotic and biotic measurements and studies
- Do we understand the Reference/Natural conditions?
- Time scales at which an estuary respond to flow (i.e. Keiskamma (weeks to months) vs East Kleinmonde (days))

Limited data available for SA estuaries, especially data matched with salinity data and river inflow data - Specialists often must use expert judgement/option

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Working Example of Estuary RQOs

IUA_R01 (Keiskamma)

Keiskamma Priority estuary

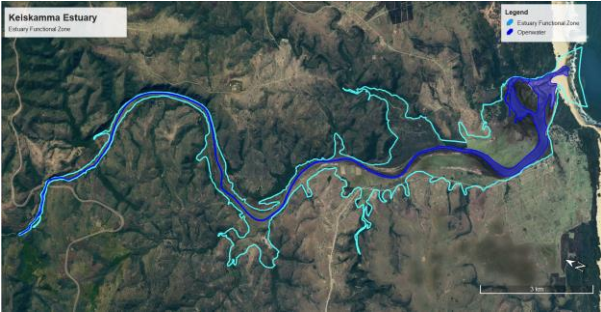
- Overview of estuary complexity & how it is reduced
- Examples of RQOs
- Embedding it in Estuary Management Plans

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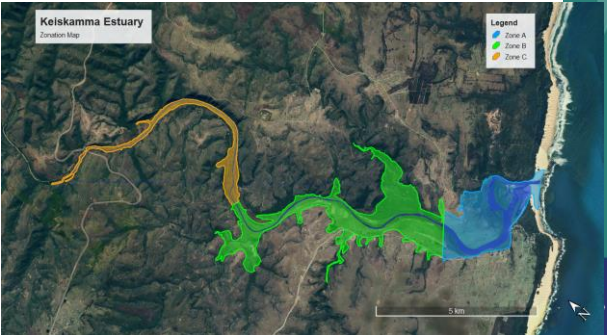
Keiskamma Priority estuary

Estuary Delineation



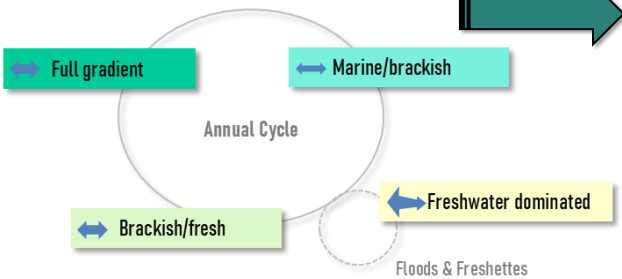
- Predominantly open estuary type
- Very Important Fish Nursery
- Blue Carbon - 9th largest salt marsh in the country!

Zone the estuary in reaches that are similar



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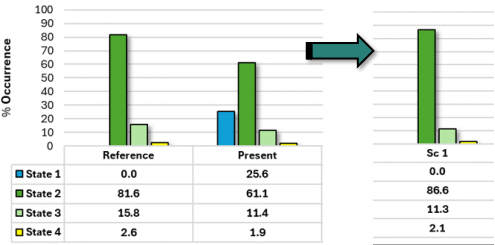
Typical abiotic Conditions/States



Link states to flows

State	Name	Flow range (m3/s)
State 1	Marine/brackish	<0.2
State 2	Full Gradient	0.2-5
State 3	Brackish/Fresh	5-20
State 4	Freshwater dominated	>20

Changes from Reference to Present



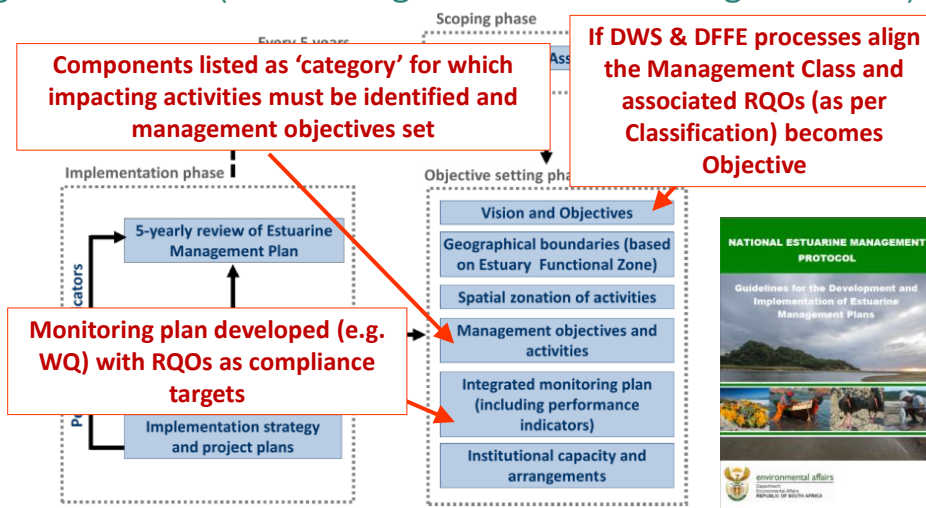
Define typical conditions associated with States

SALINITY (Surface)				SALINITY (Bottom)			
State	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	
State 1	35	20	10	35	25	20	
State 2	30	10	0	35	20	10	
State 3	15	0	0	25	5	0	
State 4	0	0	0	5	0	0	
DIN (ug/l)				DIP (ug/l)			
State	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	
State 1	40	40	40	40	95	95	
State 2	80	65	55	140	130	220	
State 3	65	50	50	115	140	245	
State 4	50	50	50	230	245	245	
DISSOLVED OXYGEN (S) (mg/l)				DISSOLVED OXYGEN (S) (mg/l)			
State	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	
State 1	7.1	7.5	7.9	7.3	7.3	5.0	
State 2	7.5	7.9	8.6	7.8	7.0	5.6	
State 3	8.5	8.9	8.9	7.2	6.8	6.8	
State 4	9.1	9.1	9.1	8.8	8.8	8.8	

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Estuary Management Plans

National Estuarine Management Protocol requires Estuarine Management Plans (under Integrated Coastal Management Act)



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Detail RQOs

Example

PES:	C	REC:	B	TEC:	B
The following non-flow interventions will result in halting the negative trajectory and achieving TEC: - Develop an Estuary Management Plan for the <u>Keiskamma</u> Estuary to prioritise key actions require to address the ongoing decline in condition and coordinate restoration <u>efforts</u>; - Reduce fishing and bait collection pressure by managing access, increase compliance and improve community <u>interactions</u>; - Ensure maintenance of low-flow conditions to prevent prolonged periods of increased water residency that promote the accumulation of microalgal <u>communities</u>; - Manage ever increasing nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring indigenous riparian <u>vegetation</u>; - Restore saltmarsh areas that are fallow at <u>present</u>; - Prevent disturbance of riparian vegetation, including trampling and severe overgrazing by cattle in the <u>EFZ</u>; and - Removal of alien vegetation from <u>EFZ</u> as well.					

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Component/ indicator	Target EC	RQO
Hydrology	C	Maintain Target EC (> 63%). Protect the flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality: - River inflow distribution patterns differ by more than 5% from that of the Scenario 7 (Restoration – EWR, Invasive aliens removed, estuary interventions). - Monthly river inflow < 0.4 m³/s for more than 0% of the time. - Monthly river inflow 0.4-1.0 m³/s for more than 87% of the time. - Monthly river inflow 1.0 - 20.0 m³/s for less than 11% of the time. - Monthly river inflow .20 m³/s for less than 2% of the time.
Hydrodynamics	A	Maintain Target EC (> 93%). Maintain mouth conditions to protect estuarine ecosystems and the associated habitat for birds, fish, macrophytes, microalgae and water quality: - No mouth closure - No change in average water levels. - Changes in tidal amplitude at the tidal amplitude of < 20% from Present State (2024).
Physical habitat (sediments)	B/C	Maintain the Target EC (> 73%). Protect estuarine sediment distributions suitable habitat for estuarine biota: - River inflow distribution patterns (flood components) are < 20% (in terms of magnitude, timing and variability) from that simulated for the present state (refer to DWS, 2024). - Suspended sediment concentration in river inflow not to deviate by more than 20% of sediment load-discharge relationship of the present state (refer to DWS, 2024). - No deviation in sedimentation and erosion patterns in the estuary to occur from the present baseline (refer to DWS 2024). Changes in sediment grain size distribution patterns not to cause exceedance tolerance of benthic invertebrates: - Median bed sediment diameter not to deviate by more than a factor of two from levels of the present baseline (refer to DWS, 2024). - Sand/mud distribution in middle and upper reaches change < 20% from the present baseline (refer to DWS, 2024). - Changes in tidal amplitude at the tidal gauge change < 20% from the present baseline (refer to DWS, 2024) as a result of sediment processes.

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Water quality (general)	C	Maintain the TEC category (> 63%). Water quality to be suitable for maintaining the TEC for dependent biotic components. Water quality of river inflow: 7.5 < pH > 8.5 consistently over 2 months. - DO > 6 mg/l - Turbidity < 50 NTU (low flow < 1 m³/s). - Average DIN < 240 µg/l - Average DIP < 20 µg/l Estuary in situ water quality: - Average turbidity < 50 NTU (low flow) (should decrease with increasing salinity) 6.0 < pH > 8.5 in a sampling survey (to be verified by sampling) - Average DO > 6 mg/l in a sampling survey, but can become hypoxic in bottom waters if water column stratifies, especially deep areas (> 3 m depth) - DIN in freshwater reaches > 240 µg/l (should decrease with increasing salinity) - DIP in freshwater reaches > 20 µg/l (Data could be reviewed depending on the results of the baseline study) Total metal concentrations in water not to exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995 or official future updates thereof). Total metal concentration in estuary sediment not to exceed target values as per West Indian Ocean (WIO) Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2022 or official future updates thereof). For recreational use areas in estuary (see details in DEA, 2012): - Enterococci < 185 counts per 100 ml (90 percentile), and E. coli < 500 counts per 100 ml (90 percentile).
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Detail RQOs

Microalgae	B/C	Maintain the Target EC (>73%) through: Maintain the current composition, richness, and abundance of phytoplankton and benthic microalgal assemblages. No harmful algal bloom (HAB) species, unless constrained to Zone A during open mouth conditions (i.e., marine origin). Phytoplankton: 90th percentile value (i.e., entire estuary) for phytoplankton biomass <10 µg Chl-a l-1. - No bloom conditions (represented by values <20 µg Chl-a l-1); even isolated instances. - Limited presence of potentially HAB-forming taxa. Benthic Microalgae: - Average MPB biomass <50 mg Chl-a m-2. - Average benthic diatom diversity (H') > 2.5. (*Based on average values recorded throughout the estuary, i.e., Zone A-C)
Macrophytes	A/B	Maintain the Target EC (> 88%) through: - Maintain the composition (2024), distribution and abundance of macrophyte habitats, with < 10 % change in the area covered by different macrophyte habitats as these will indicate whether the habitat is increasing or decreasing. - Maintain the endangered seagrass beds <i>Zostera capensis</i> in Zone A. - Maintain the integrity of the riparian zone through the zones, particularly in Zone A where salt marsh is prevalent. - Invasive plants largely absent from the riparian zone. - No unvegetated, cleared areas along the banks.

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Detail RQOs

Example

Fish	B	Maintain the Target EC category (> 78%) through: - Retain fish <u>assemblages</u> (abundance): - Estuarine species (30-40%) - Estuarine associated marine species (60-70%) - Indigenous freshwater species (<1%) < 20% decline in abundance (to be defined as an average with prediction limits). - Marine estuarine-opportunist species should occur throughout Zone A and into the lower reaches at least of Zones B. - All zones of the estuary should function as high value nursery habitat to a diversity of marine estuarine-dependent species with <u>all</u> of the following species occurring in the estuary in two consecutive years. Mullet should occur throughout the system (all zones) every year. - Permanent populations of estuarine resident species should occur throughout the system. - A good trophic basis must exist for predatory (piscivorous) marine estuarine-dependant and opportunist species. Piscivorous fishes (e.g. <i>Agyrosomus japonicus</i>, <i>Caranx</i> spp.) occur in the estuary. - Freshwater fishes should be limited in their distribution through the system. <i>Oreochromis mossambicus</i> is the most abundantly occurring freshwater species and is limited to the Zone C. - The species assemblage should comprise indigenous species only. No non-indigenous fishes should occur.
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Detail RQOs

Example

Birds	B	Maintain the Target EC (> 78%). Maintaining avifaunal community that includes representatives of all original groups as per present baseline (refer to DWS, 2024). ▪ Resident pair of African Fish Eagle present and breed successfully. ▪ Cormorants and/or herons/egrets: No significant reduction in numbers (<20%) ▪ Migratory waders, especially of estuarine-dependent species: No significant reduction in numbers (<10%) ▪ Waterfowl (ducks and geese): No significant reduction in numbers (<10%) ▪ Whole waterbird community: No significant reduction in numbers (<10%) ▪ Tern and gull roost at mouth: No significant reduction in numbers (<10%)
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Detail RQOs

Example

Water quality (salinity)	A	Maintain Target EC (> 93%). Salinity regime to maintain TEC for dependent biotic components. ▪ Average salinity values >25 (surface) and >30 (bottom) in the lower reaches (Zone A) of the estuary. ▪ Average salinity values <10 (surface) and <20 (bottom) in the middle reaches (Zone B) of the estuary. ▪ Average salinity values 0 (surface) and <10 (bottom) in the upper reaches (Zone C) of the estuary.
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Working Example of Estuary RQOs

General RQOs

#	NAME	Present Ecological State	Recommended Ecological Condition	Hydrology	Natural MAR	% Natural	Hydrodynamics	Water Quality: Salinity	Water Quality: General	Estuary: Average Dissolved Oxygen (mg/l)	River: Median Dissolved Inorganic nitrogen (DIN) (mg/l)	River: Median Dissolved Inorganic phosphate (DIP) (mg/l)	Physical habitat	Microalgae	Phytoplankton biomass (µg/l)	Benthic microalgae biomass (mg/m2)	Benthic diatom diversity (H')	Macrophytes	Change < % in composition, distribution & abundance of macrophyte habitats	Zostera capensis present	Invertebrates	Fish	Less than % change in fish biomass	Estuarine pipefish (Syngnathus watermeyer) present	Birds
1	Lottering	A/B	A/B	B	19	91	A	A	A	>6	<0.1	<0.01	A	A	<5	<50	>3	A	20		A	B	20		B
2	Elandsbos	A/B	A/B	B	27	91	A	A	A	>6	<0.1	<0.01	A	A	<5	<50	>3	A	20		A	B	20		B
3	Storms	A/B	A/B	B	54	89	A	A	A	>6	<0.1	<0.01	A	A	<5	<50	>3	A	20		A	B	20		B
4	Elands	A/B	A/B	B	52	90	A	A	B	>6	<0.2	<0.015	A	B	<5	<50	>3	A	20		A	B	20		B
5	Groot (Oos)	A/B	A/B	A	47	94	A	A	B	>6	<0.2	<0.015	A	B	<5	<50	>3	B	20		A	B	20		B
6	Tsitsikamma	B/C	B	C	20	72	C	C	C	>4	<0.3	<0.025	A	C	<20	<100	2-3	B	20		B	C	20		B
7	Klipdrif (Oos)	C	C	B	33	56	C	B	E	>4*	<0.5	<0.125	B	D	<60	<150	1-2	C	20		D	D	20		B
8	Slang	C/D	C/D	B	5	90	C	B	E	>4*	<0.5	<0.125	D	D	<60	<150	1-2	D	20		D	D	20		C
9	Kromme	C/D	C	E	72	51	A	E	E	>4*	<0.5	<0.125	C	F	≥60	≥150	<1	D	10	●	F	D	10		C
10	Seekoei	D/E	C	D	20	56	E	E	D	>4*	<0.5	<0.125	C	E	≥60	≥150	<1	E	10		E	E	20		E
11	Kabeljous	B	B	C	5	89	C	B	C	>4	<0.3	<0.025	C	C	<20	<100	2-3	C	10		C	C	10		B
13	Van Stadens	B	A/B	C	17	91	B	B	C	>4	<0.3	<0.025	B	C	<20	<100	2-3	B	20		B	B	20		B
14	Maitland	B/C	B	C	13	91	B	B	C	>4	<0.3	<0.025	B	C	<20	<100	2-3	B	20		C	C	20		B
15	Baakens	E/F	E	D	4	88	E	E	F	>4*	<0.5	<0.125	F	E	≥60	≥150	<1	F	20		F	F	20		F

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Monitoring

Example

Component	Action	Frequency	Location
...			
Salinity	Record longitudinal salinity and temperature profiles	Seasonally every year	Entire estuary at 6 stations
Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey every 3 years	Entire estuary at 3 stations
...			

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Estuary RQOs

Challenges and learnings

- Limited / no datasets on most systems – expert judgement
- Water Quality monitoring expensive and needs to go to marine lab
- Habitat data are relative up to date (NMU botanical database)
- Some CWAC bird data
- Higher ecology datasets are in most cases >30 years old
- Important & pristine ecological infrastructure in the WMA – thus being innovative to add relevant RQOs even for smaller estuaries
- Will need to collaborate with other authorities & agencies to achieve the RQOs



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Relevant Literature

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Thank you



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