Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz WMA:

Estuary Component

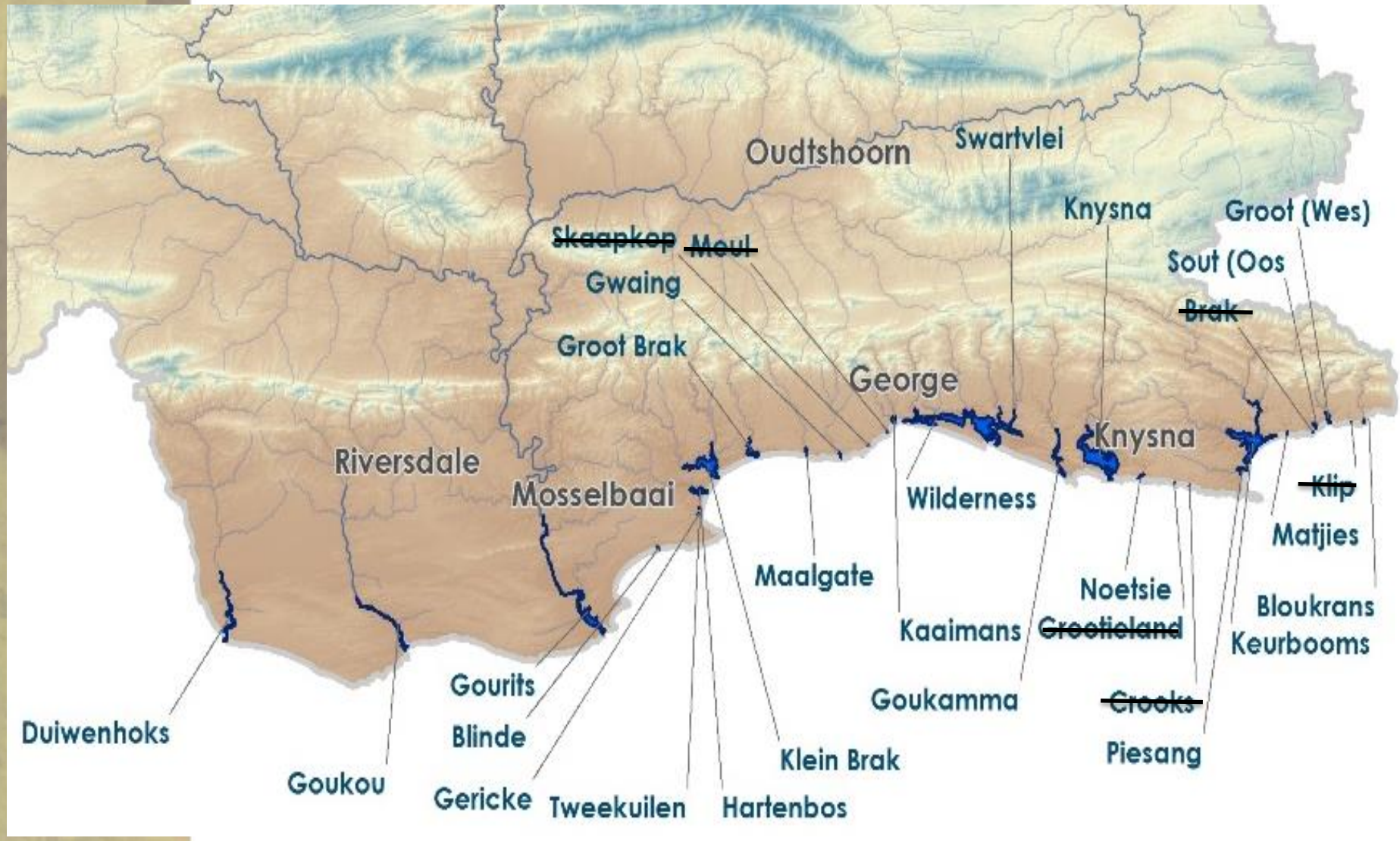
Barry Clark

Outline

1. Estuaries in the Breede Gouritz WMA (Breede-Overberg and Gouritz regions)
2. Integrated Units of Analysis (IUAs) in the Breede Gouritz WMA
3. Linking estuary health and flow
4. Flow scenarios considered in this study
5. Impacts of flow scenarios on estuary health
6. Socio-economic consequences of flow scenarios
7. Ecological consequences of the Spatial targeted scenario
8. Resource Quality Objectives (RQO) for estuaries
9. Monitoring recommendations

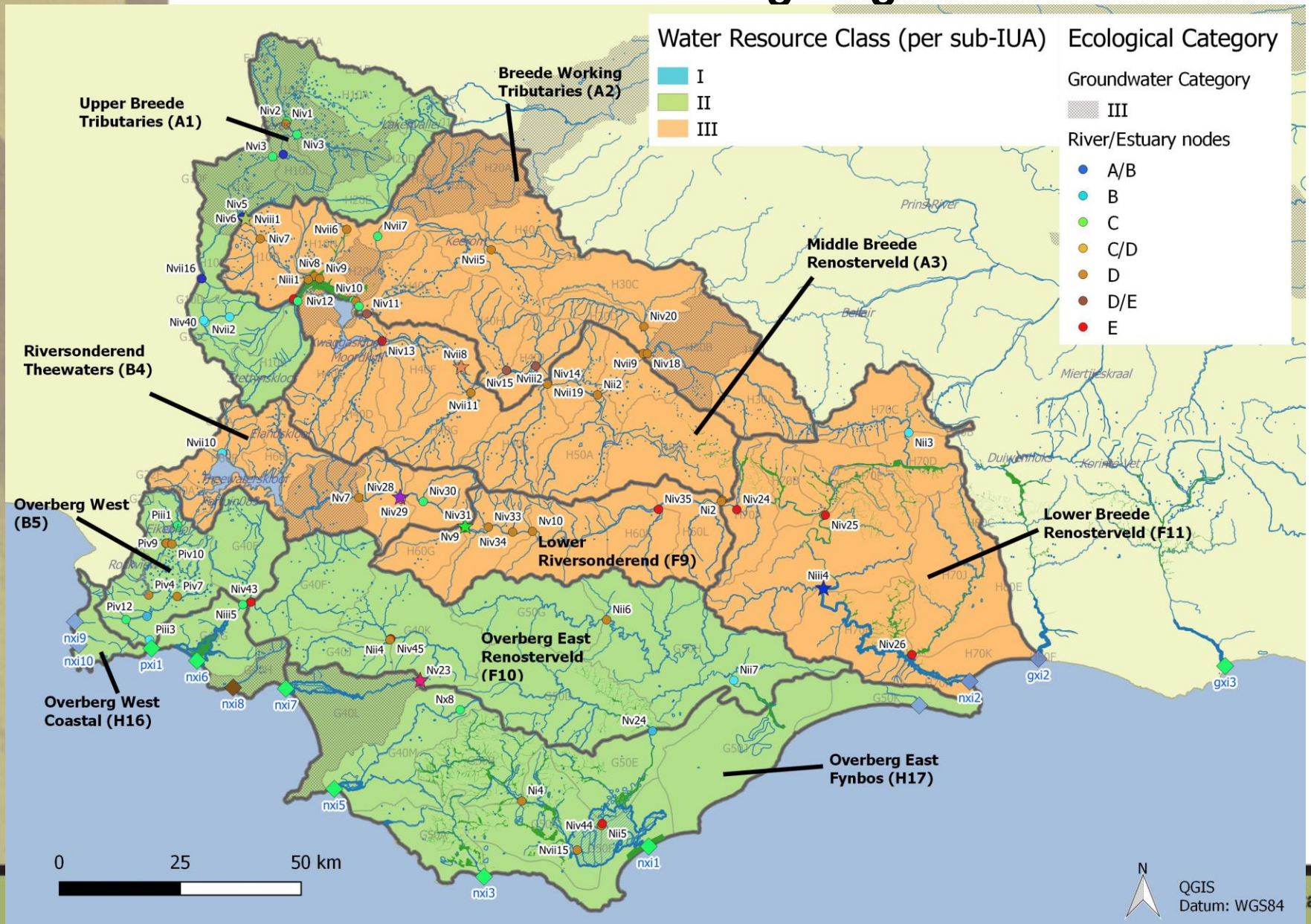
Estuaries in the Breede Overberg Region

Estuaries in the Gouritz region



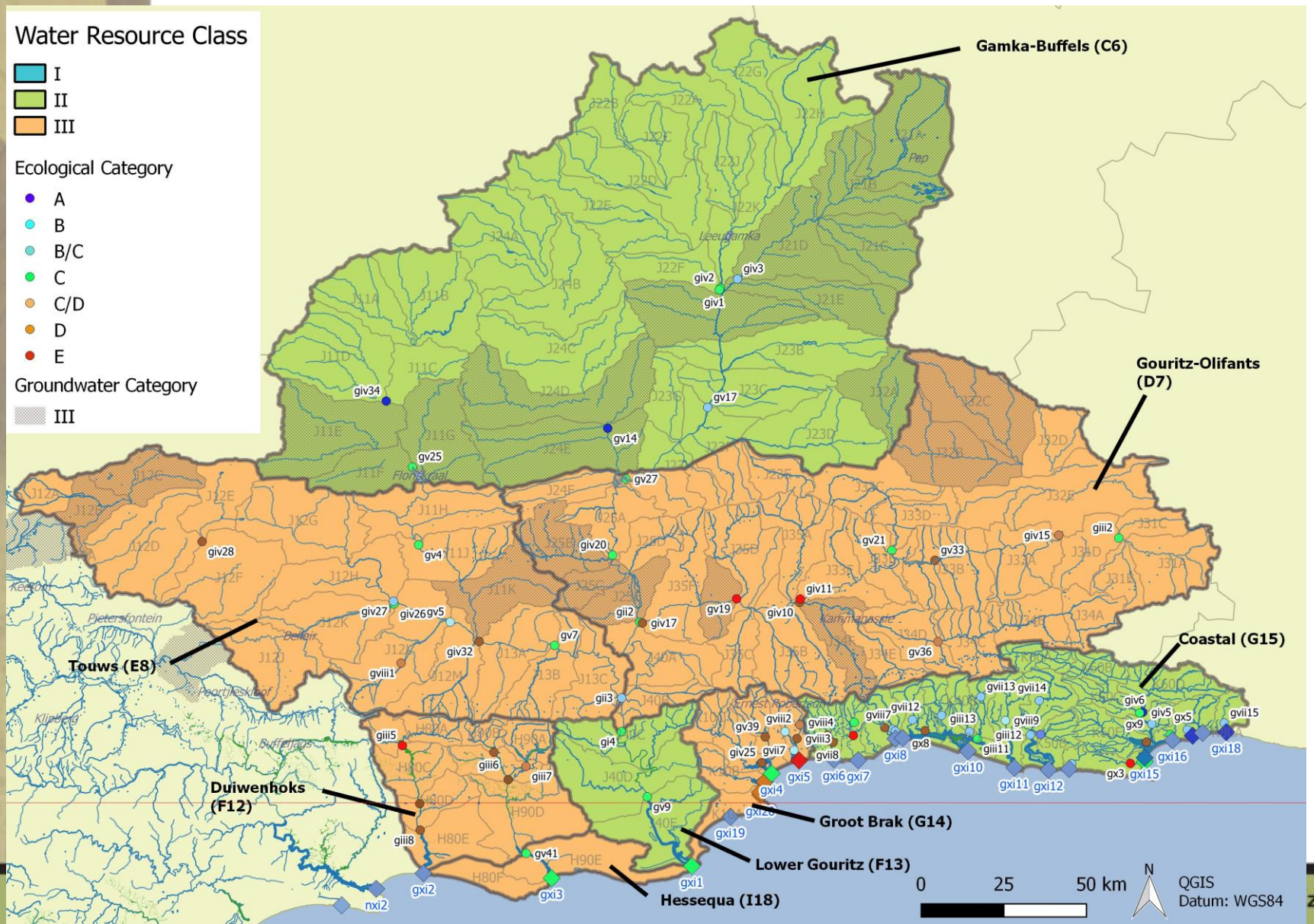
Integrated Units of Analysis and Nodes

Breede-Overberg Region

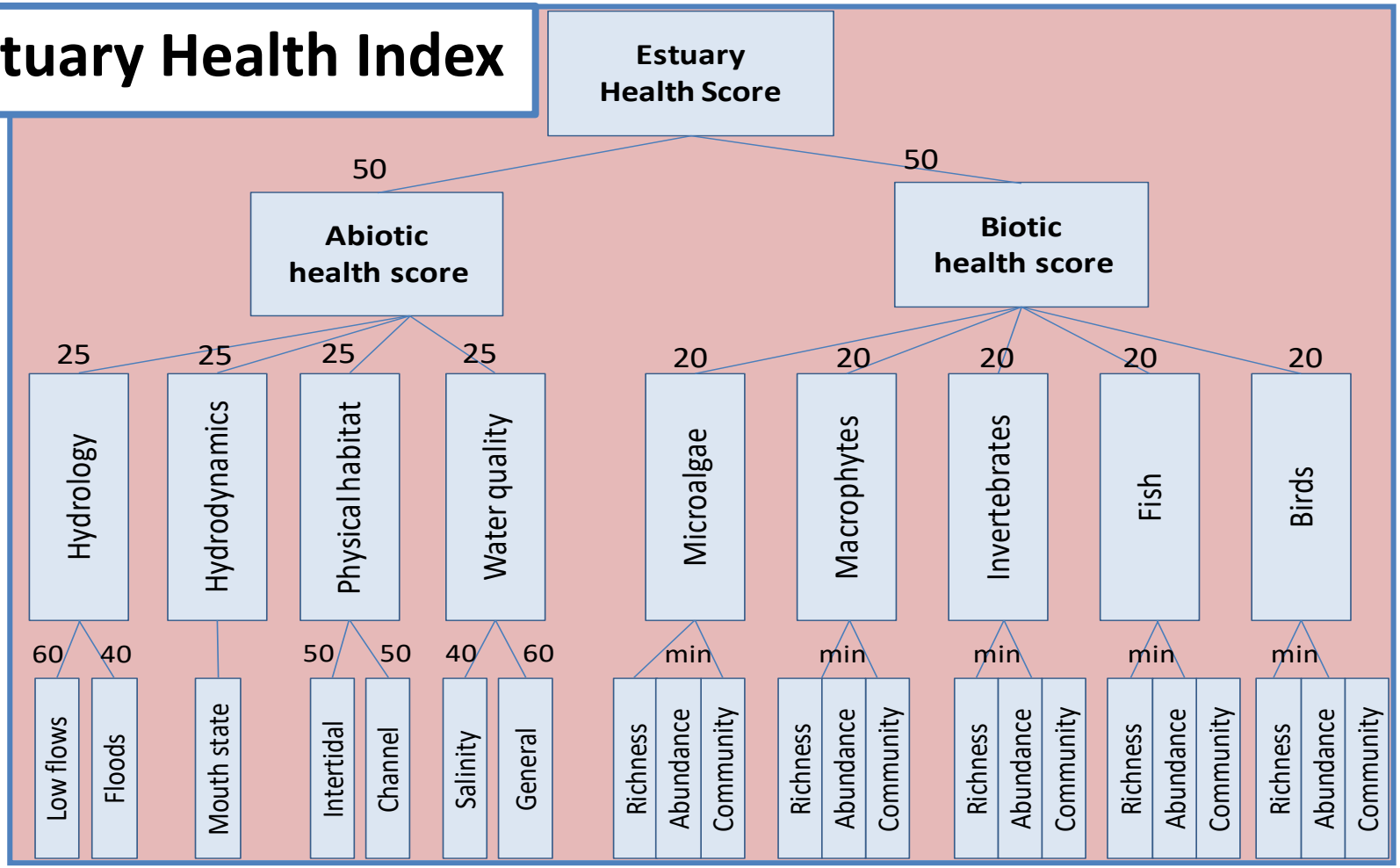


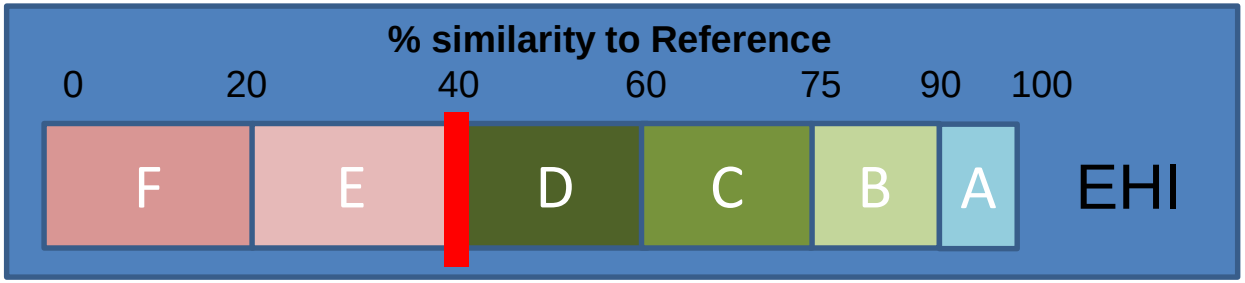
Integrated Units of Analysis and Nodes

Gouritz-Coastal Region

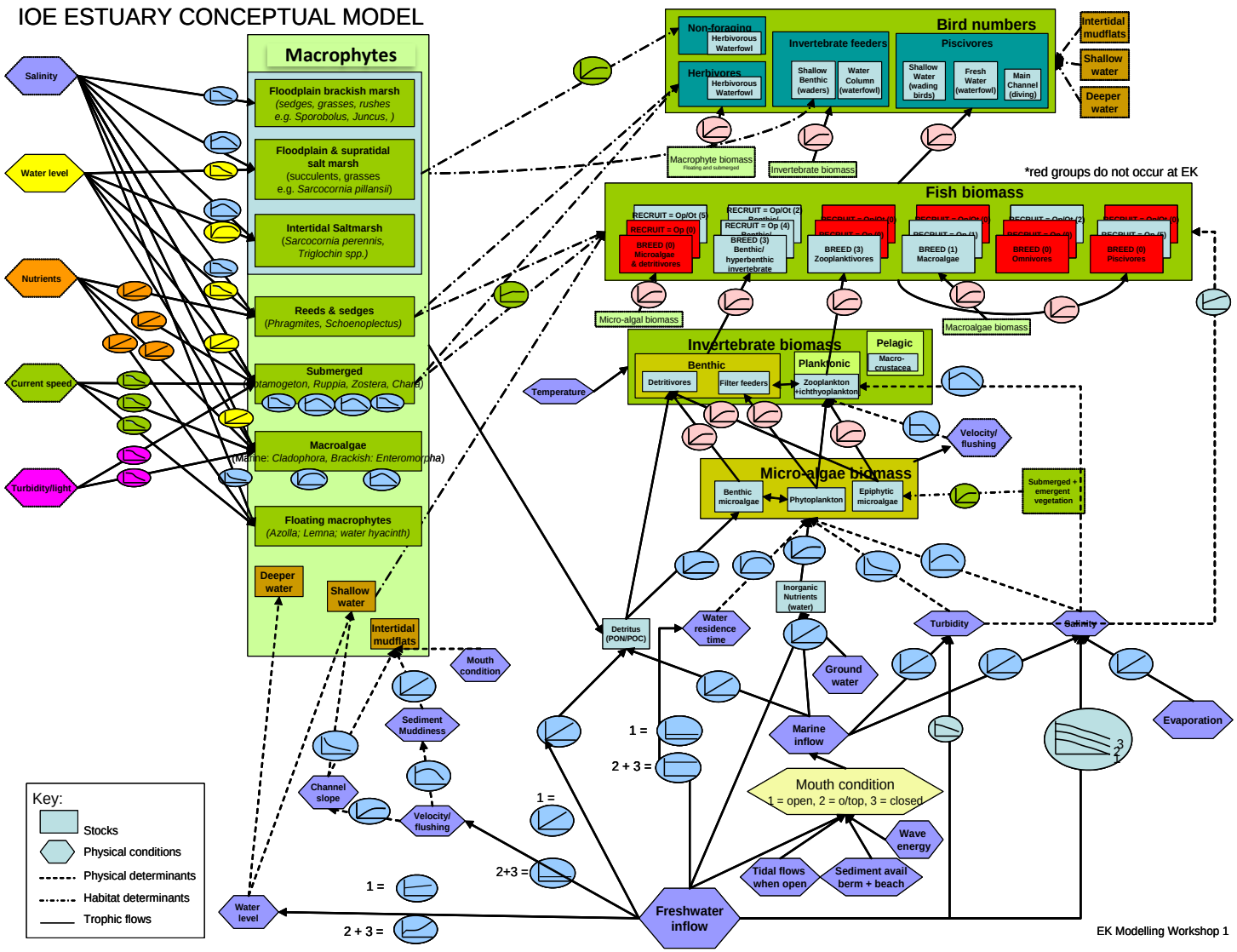


Estuary Health Index





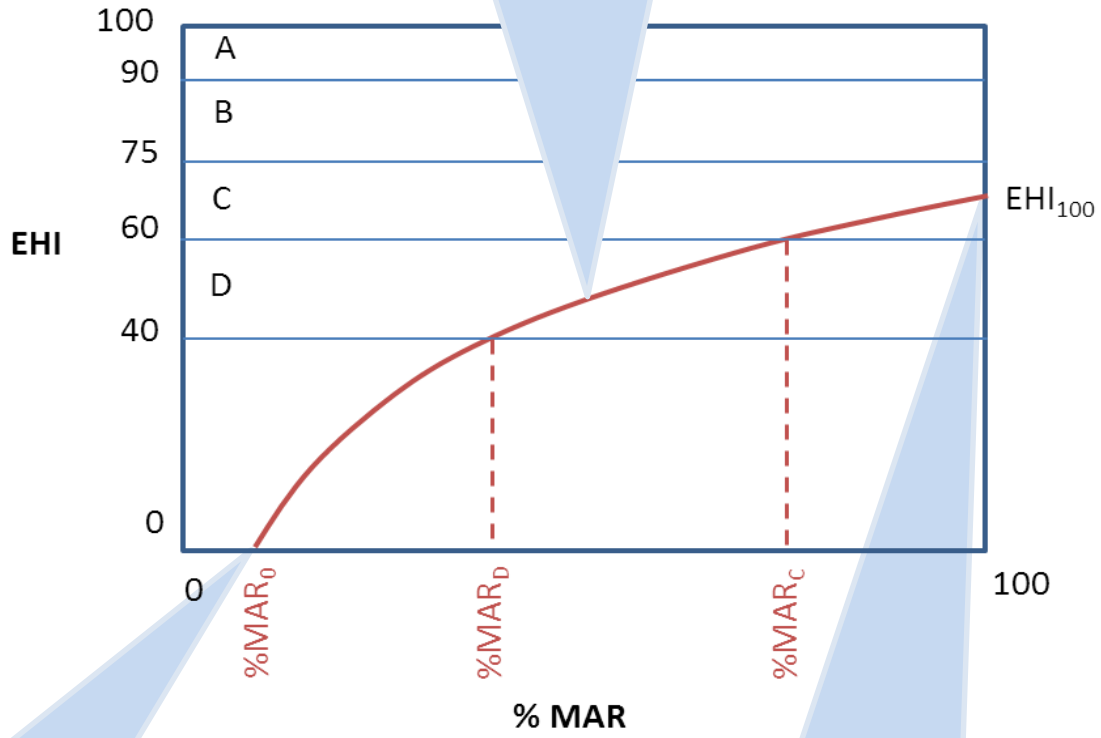
Conceptual model of estuarine functioning



LINKING ESTUARY HEALTH AND FLOW

1. Relationship between health and flow is logarithmic – health declines increasingly rapidly as %MAR declines

A. Models were developed which allowed us to project likely changes in estuary health from A to E category as flows decline based on data from Reserve determination studies for individual estuaries

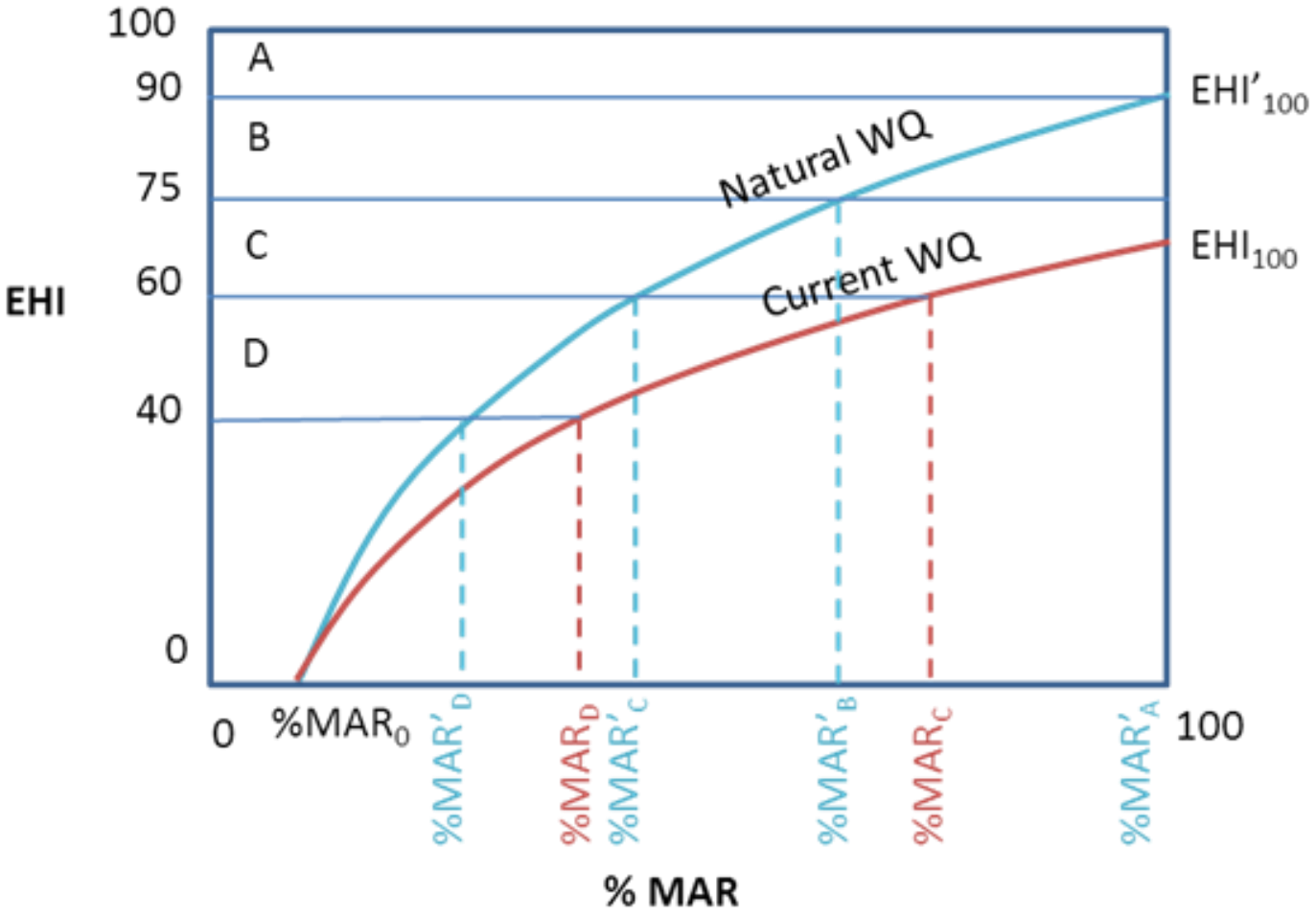


2. The ability of an estuary to support biodiversity drops to zero before MAR drop to zero

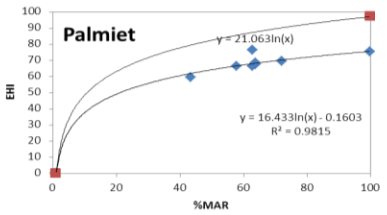
3. It is often not possible to restore health to 100% of natural through restoration of flow alone due to other non-flow related impacts

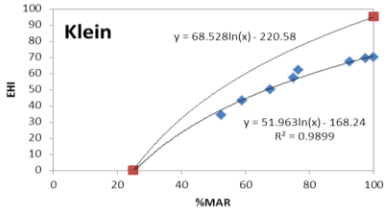
LINKING ESTUARY HEALTH AND FLOW

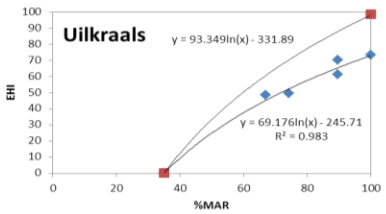
Model relationship between Estuary Heath Index (EHI) and changes in Mean Annual Runoff (MAR) and Water Quality

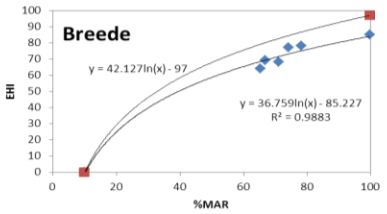


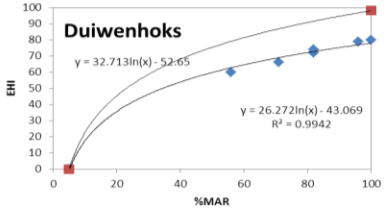
Change in Estuarine Health with Flow

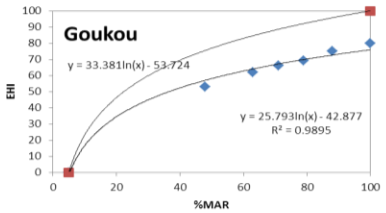


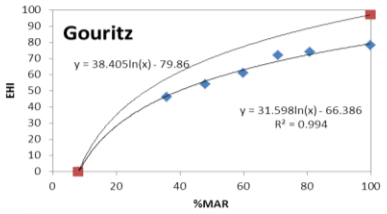


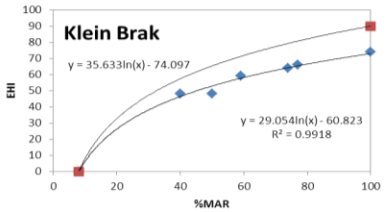


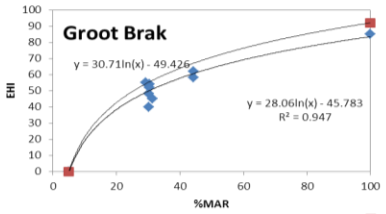


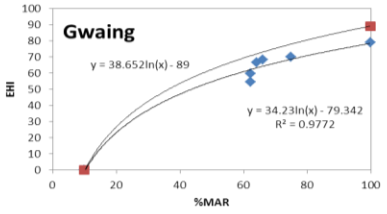


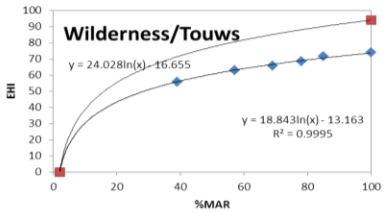


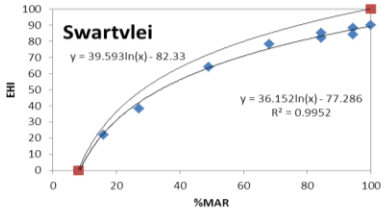


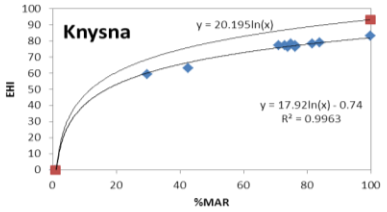


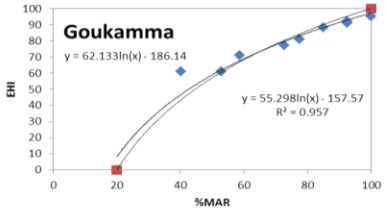


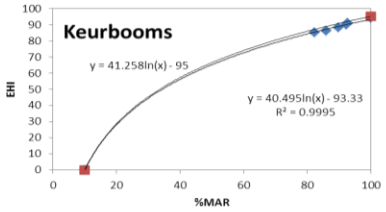


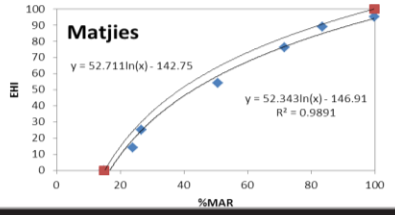


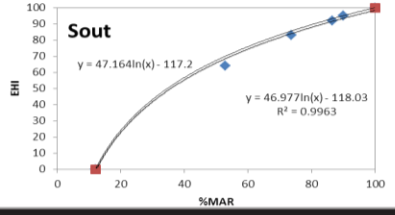












Flow scenarios considered for the Breede-Gouritz WMA

HOW TO DETERMINE REC FOR AN ESTUARY?

		PRESENT ECOLOGICAL STATUS			
		A	B	C	D, E or F
Estuary importance	Protected or desired protected status	A or BAS	A or BAS	A or BAS	A or BAS
	Highly important (80 – 100)	A	A	B	C
	Important (60 – 80)	A	A	B	C
	Of low to average importance (0 – 60)	A	B	C	D

EHI scores under different scenarios: Breede-Overberg

Estuary	Rec	1. PES - Baseline	% nMAR	2. ESBC - Bottom line	% nMAR	3. REC	% nMAR	4. Future Growth-NoEC	% nMAR	5. Climate change (10%)	% nMAR
Rooiels	B	B	98.6	D	71.7	B	98.6	B	98.6	C	84.5
Buffels	B	B	81.9	B	81.9	B	81.9	B	81.9	B	69.9
Palmiet	B	C	70.1	C	45.2	C	70.1	C	68.4	C	59.7
Bot	B	C	81.8	D	57.9	C	81.8	C	81.8	D	56.2
Onrus	D	D	51.8	D	51.8	D	51.8	E/F	27.2	E	36.7
Klein	B	C	80.3	D	55.7	B	98.1	C	80.3	D	54.3
Uilkraal	C	E	43.9	E	43.9	C	63.7	E/F	40.4	E/F	27.3
Ratel	C	C	90.0	D	58.5	C	90.0	C	90.0	C/D	66.0
Klipdrifsfontein	A	A	64.8	A	64.8	A	64.8	A	64.8	C	48.0
Heuningnes	A	C	68.8	D	58.8	A/B	78.0	C	71.2	D	49.0
Bree	B	B	49.5	B	46.9	B	50.2	B	44.5	C	39.4

EHI scores under different scenarios - Gouritz region

Estuary	Nat MAR	REC	1. PES		2. ESBC scenario		3. REC scenario		4. Future growth - NoEC		5. Climate change	
			EC	%nMAR	EC	%nMAR	EC	%nMAR	EC	%nMAR	EC	%nMAR
Gouritz	612.4	B	C	61.9	D	39.1	C	66.0	C	59.4	D	43.8
Duiwenhoks	88.8	A	B	91.9	C	51.7	B	91.9	B	90.7	B/C	65.7
Goukou	110.5	B	C	81.4	D	48.3	C	81.4	C	79.1	C/D	56.9
Klein-Brak	50.7	C	C	77.0	D	44.0	C	77.0	C	77.0	D	53.4
Groot-Brak	29.8	C	E	56.2	E	48.6	E	56.2	F	31.1	F	40.2
Blinde	1.3	B	B	69.2	C/D	40.8	B	69.2	B	69.2	C	46.3
Tweekuilen	1.3	D	D	96.7	D	72.3	D	72.3	D	96.7	D/E	64.7
Gericke	0.4	D	D	96.8	D	72.3	D	72.3	D	96.8	D/E	64.7
Hartenbos	5.1	C	D	65.0	D	72.0	C	80.7	D	65.0	E	44.4
Maalgate	37.4	B	B	79.3	C	51.6	B	79.3	B	79.3	C	62.8
Gwaing	26.6	B	B	85.0	C/D	55.1	B	85.0	C	72.5	C	67.5
Kaaimans	48.7	B	B	72.5	D/E	27.5	B	72.5	C	52.2	C	58.3
Wilderness	32.7	A	B	88.6	C/D	34.1	B	88.6	B	88.6	B/C	69.0
Swartvlei	88.0	B	B	86.6	D	31.1	B	86.6	B	86.6	B	85.5
Goukamma	52.9	A	B	87.5	D	44.3	B	87.5	B	87.5	B/C	71.0
Knysna	90.5	B	B	90.6	C/D	25.6	B	90.6	B/C	80.9	B/C	73.2
Noetsie	5.5	A	B	92.5	D	42.5	B	92.5	B	92.5	B/C	73.5
Piesang	6.9	B	C	73.0	D	53.8	B/C	82.8	C	73.0	C	58.1
Keurbooms	169.0	A	A	91.2	D	34.8	A	91.2	A/B	83.5	A/B	73.5
Matjies	5.1	B	B	83.7	D	44.1	B	83.7	B	83.7	B/C	70.7
Sout(Oos)	7.0	A	A	85.6	D	30.0	A	85.6	A	85.6	A/B	72.3
Groot(Wes)	12.8	B	B	86.7	C	51.2	B	86.7	B	86.7	B/C	73.3
Bloukrans	40.1	A	A	98.0	D	30.0	A	98.0	A	98.0	A	85.2

EHI scores under different scenarios: Breede-Overberg

Estuary	Rec	PES - Baseline	% nMAR	ESBC - Bottom line	% nMAR	REC	% nMAR	Future Growth-NoEC	% nMAR	Climate change (10%)	% nMAR	Spatially Targeted Scenario	% nMAR
Rooiels	B	B	98.6	D	71.7	B	98.6	B	98.6	C	84.5	B	98.6
Buffels	B	B	81.9	B	81.9	B	81.9	B	81.9	B	69.9	B	81.9
Palmiet	B	C	70.1	C	45.2	C	70.1	C	68.4	C	59.7	C	70.1
Bot	B	C	81.8	D	57.9	C	81.8	C	81.8	D	56.2	C	81.8
Onrus	D	D	51.8	D	51.8	D	51.8	E/F	27.2	E	36.7	D	51.8
Klein	B	C	80.3	D	55.7	B	98.1	C	80.3	D	54.3	C	85.6
Uilkraal	C	E	43.9	E	43.9	C	63.7	E/F	40.4	E/F	27.3	C/D	58.8
Ratel	C	C	90.0	D	58.5	C	90.0	C	90.0	C/D	66.0	C	90.0
Klipdrifsfontein	A	A	64.8	A	64.8	A	64.8	A	64.8	C	48.0	A	64.8
Heuningnes	A	C	68.8	D	58.8	A/B	78.0	C	71.2	D	49.0	A/B	78.2
Bree	B	B	49.5	B	46.9	B	50.2	B	44.5	C	39.4	B	47.2

EHI scores under different scenarios: Breede-Overberg

Importance score	Estuary	Rec	PES - Baseline	% nMAR			REC	% nMAR				Spatially Targeted Scenario	% nMAR
43.3	Rooiels	B	B	98.6			B	**98.6**				B	98.6
46.9	Buffels	B	B	81.9			B	**81.9**				B	81.9
62.8	Palmiet	B	C	70.1			C	**70.1**				C	70.1
96.6	Bot	B	C	81.8			C	**81.8**				C	81.8
58.9	Onrus	D	D	51.8			D	**51.8**				D	51.8
97.0	Klein	B	C	80.3			B	**98.1**				C	85.6
76.0	Uilkraal	C	E	43.9			C	**63.7**				C/D	58.8
32.5	Ratel	C	C	90.0			C	**90.0**				C	90.0
83.1	Klipdrifsfontein	A	A	64.8			A	**64.8**				A	64.8
18.4	Heuningnes	A	C	68.8			A/B	**78.0**				A/B	78.2
86.8	Breede	B	B	49.5			B	**50.2**				B	47.2

EHI scores under different scenarios - Gouritz region

Estuary	Nat MAR	REC	PES scenario		ESBC scenario		REC scenario		Future growth - NoEC		Climate change		Spatially targeted	
			EC	%nMAR	EC	%nMAR	EC	%nMAR	EC	%nMAR	EC	%nMAR	EC	%nMAR
Gouritz	612.4	B	C	61.9	D	39.1	C	66.0	C	59.4	D	43.8	C	59.7
Duiwenhoks	88.8	A	B	91.9	C	51.7	B	91.9	B	90.7	B/C	65.7	B	91.9
Goukou	110.5	B	C	81.4	D	48.3	C	81.4	C	79.1	C/D	56.9	C	81.4
Klein-Brak	50.7	C	C	77.0	D	44.0	C	77.0	C	77.0	D	53.4	C	77.0
Groot-Brak	29.8	C	E	56.2	E	48.6	E	56.2	F	31.1	F	40.2	E	56.2
Blinde	1.3	B	B	69.2	C/D	40.8	B	69.2	B	69.2	C	46.3	B	69.2
Tweekuilen	1.3	D	D	96.7	D	72.3	D	72.3	D	96.7	D/E	64.7	D	72.3
Gericke	0.4	D	D	96.8	D	72.3	D	72.3	D	96.8	D/E	64.7	D	72.3
Hartenbos	5.1	C	D	65.0	D	72.0	C	80.7	D	65.0	E	44.4	D	65.0
Maalgate	37.4	B	B	79.3	C	51.6	B	79.3	B	79.3	C	62.8	B	79.3
Gwaing	26.6	B	B	85.0	C/D	55.1	B	85.0	C	72.5	C	67.5	B	85.0
Kaaimans	48.7	B	B	72.5	D/E	27.5	B	72.5	C	52.2	C	58.3	B	72.5
Wilderness	32.7	A	B	88.6	C/D	34.1	B	88.6	B	88.6	B/C	69.0	B	88.6
Swartvlei	88.0	B	B	86.6	D	31.1	B	86.6	B	86.6	B	85.5	B	86.6
Goukamma	52.9	A	B	87.5	D	44.3	B	87.5	B	87.5	B/C	71.0	B	87.5
Knysna	90.5	B	B	90.6	C/D	25.6	B	90.6	B/C	80.9	B/C	73.2	B	86.8
Noetsie	5.5	A	B	92.5	D	42.5	B	92.5	B	92.5	B/C	73.5	B	92.5
Piesang	6.9	B	C	73.0	D	53.8	B/C	82.8	C	73.0	C	58.1	C	73.8
Keurbooms	169.0	A	A	91.2	D	34.8	A	91.2	A/B	83.5	A/B	73.5	A	90.0
Matjies	5.1	B	B	83.7	D	44.1	B	83.7	B	83.7	B/C	70.7	C	70.5
Sout(Oos)	7.0	A	A	85.6	D	30.0	A	85.6	A	85.6	A/B	72.3	A	85.6
Groot(Wes)	12.8	B	B	86.7	C	51.2	B	86.7	B	86.7	B/C	73.3	B	86.7
Bloukrans	40.1	A	A	98.0	D	30.0	A	98.0	A	98.0	A	85.2	A	98.0

EHI scores under different scenarios - Gouritz region

Imp. Score	Estuary	Nat MAR	REC	PES scenario				REC scenario				Spatially targeted	
				EC	%nMAR			EC	%nMAR			EC	%nMAR
75.0	Gouritz	612.4	B	C	61.9			C	66.0			C	59.7
83.6	Duiwenhoks	88.8	A	B	91.9			B	91.9			B	91.9
80.3	Goukou	110.5	B	C	81.4			C	81.4			C	81.4
52.8	Klein-Brak	50.7	C	C	77.0			C	77.0			C	77.0
76.9	Groot-Brak	29.8	C	E	56.2			E	56.2			E	56.2
26.9	Blinde	1.3	B	B	69.2			B	69.2			B	69.2
-	Tweekuilen	1.3	D	D	96.7			D	72.3			D	72.3
-	Gericke	0.4	D	D	96.8			D	72.3			D	72.3
65.6	Hartenbos	5.1	C	D	65.0			C	80.7			D	65.0
37.9	Maalgate	37.4	B	B	79.3			B	79.3			B	79.3
10.4	Gwaing	26.6	B	B	85.0			B	85.0			B	85.0
27.9	Kaaimans	48.7	B	B	72.5			B	72.5			B	72.5
82.5	Wilderness	32.7	A	B	88.6			B	88.6			B	88.6
96.9	Swartvlei	88.0	B	B	86.6			B	86.6			B	86.6
59.8	Goukamma	52.9	A	B	87.5			B	87.5			B	87.5
100.0	Knysna	90.5	B	B	90.6			B	90.6			B	86.8
28.3	Noetsie	5.5	A	B	92.5			B	92.5			B	92.5
71.1	Piesang	6.9	B	C	73.0			B/C	82.8			C	73.8
88.3	Keurbooms	169.0	A	A	91.2			A	91.2			A	90.0
25.0	Matjies	5.1	B	B	83.7			B	83.7			C	70.5
59.4	Sout(Oos)	7.0	A	A	85.6			A	85.6			A	85.6
62.4	Groot(Wes)	12.8	B	B	86.7			B	86.7			B	86.7
51.4	Bloukrans	40.1	A	A	98.0			A	98.0			A	98.0

Estuary RQO Template - Hartenbos

IUA	Node	Quat	REC		Current		Target	
			EC	%nMAR	PES	%nMAR	EC	%nMAR
G14-Groot Brak	Gxi22	K10B	C	80.7	D	65.0	C	65.0

MOTIVATION FOR ACHIEVING REC/TEC

The Hartenbos estuary is considered to be of "average importance" from a biodiversity conservation perspective (ranked 75 out of 273 estuaries in South Africa) and has not been included on the list of existing or desired protected areas (Turpie et al. 2012). The system is nonetheless important from a socio-economic perspective – it is an important node for recreation, tourism and contributes significantly to property value. It is also important to maintain the system in a state of health that is safe for contact recreation. The REC for the estuary is thus a C, one category higher than present. However, it has been determined that water abstraction from this system cannot be reduced in future without compromising requirements for other users in this region. The MAR for the Target Ecological Condition thus remains as for present (65.0%). The most important threats to the Hartenbos estuary include freshwater deprivation (due to abstractions from the Hartbeeskuil Dam, for agricultural and domestic use), sedimentation (due to reduced flow and concomitant changes in mouth dynamics) and impaired water quality (due to agricultural return flows and poor quality of stormwater from informal settlements). Given that it is not possible to restore flows required to achieve the REC, concerted effort on the part of DWS and other stakeholders (local, provincial and other national government agencies) is thus required to address other threats to the estuary in accordance with the Ecological Specifications included below, thereby facilitating its restoration to the REC.

Component	SPECIFICATIONS
Flow	• %nMAR: 65.0, dry season flow >0.05 Mm^3/month
Mouth condition	• % time mouth closed should not increase/decrease by >10% from present; no period of closure >3 months
Water quality	• DIN not to exceed 200 µg/ℓ (average); DIP not to exceed 50 µg/ℓ (average)
Microalgae	• Phytoplankton not to exceed 8 µg/ℓ (median), and/or 20 µg/ℓ (once-off) and/or cell density not to exceed 10 000 cells/ml (once-off) • Benthic microalgae not to exceed 42 mg/m^2 (median)
Macrophytes (plants)	• Maintain distribution of macrophyte habitats within 20% of present (Supratidal salt marsh: 29%, Reeds & sedges: 10%, sand/mud banks: 10%)
Invertebrates	• Populations of key invertebrate species should not deviate from average baselines (as determined in first three visits) by more 30%
Fish	• Relative contribution for key groups of fish (estuarine resident, marine migrant, freshwater, etc.) should not deviate from average baselines (as determined in first three visits) by more 30%
Birds	• Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, should not deviate by more than 30% from baseline median (determined by past data and/or initial surveys)

IUA	Node	Quat	REC		Current		Target	
			EC	%nMAR	PES	%nMAR	EC	%nMAR
G14-Groot Brak	Gxi22	K10B	C	80.7	D	65.0	C	65.0

Additional (non-flow related) interventions to achieve the REC:

- Dam construction has resulted in a reduction in base flow and floods to the system, with a shift in the onset of the high flow period and an increase in the duration of the low flow period;
- Artificial breaching;
- Loss of tidal flows and habitat as result of bridge construction (e.g. old N2, railway bridge);
- Infilling of estuary channel and mouth area as a result of loss of floods and artificial breaching;
- A significant reduction in water quality as a result of the Mossel Bay WWTW discharge and urban runoff;
- Development in the EFZ;
- Alien vegetation;
- Limited bait collection and fishing effort; and
- Human disturbance (which influences bird abundance).

Source of information DWS (2015) Desktop Assessment of Estuaries in the Gouritz WMA

Estuary monitoring programme

1. Additional baseline surveys to improve confidence of EWR study on the Klein Brak Estuary (priority components are highlighted).

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Once-off.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably for 2 years	Entire estuary (10 - 13 stations).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably over two years	Along length of estuary minimum five stations (include stations in upper reaches of Brandwag and Moordkuil arms).

Estuary monitoring programme

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Macrophytes		
In the field map the area covered by the different macrophyte habitats. Record boundaries and the total number of macrophytes species. 2013 was a rapid field survey and did not include detailed vegetation mapping and ground-truthing. Assess extent of invasive species within the 5 m contour line. Locate the position of reed and sedge areas as indicators of future salinity changes. Identify supratidal salt marsh areas and their condition in terms of area of bareground. Map sensitive submerged macrophyte habitats such as *Ruppia cirrhosa* and *Z. capensis* beds. Identify macroalgae present, their distribution and potential for future expansion (bloom formation) particularly under low flow conditions. Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Once-off.	Entire estuary.
Invertebrates		
Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). Intertidal invertebrate hole counts using 0.25 m2 grid (five replicates per site). Establish the species concerned using a prawn pump. Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Quarterly, preferably over two years.	Minimum of three sites along length of entire estuary. For hole counts – three sites in muddy substrata on eastern shore below N2 bridge.

Estuary monitoring programme

1. Recommended long-term monitoring programme for the Klein Brak Estuary (priority components are highlighted).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	At bridge near mouth.
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Aerial photographs of estuary (spring low tide).	Every three years.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.
Water quality		
Collect data on conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly, continuous.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Every three - six years, or when contamination is expected.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect *in situ* continuous salinity data with mini CTD probe at a depth of about 1 m.	Continuous.	Four - six sites. Head of the estuary in the Brandwag and Moordkuils arms, Brandwag and Moordkuil weirs/causeways, the confluence of the two arms, the lower bridge.
Record longitudinal *in situ* salinity and temperature pH, DO, turbidity profiles.	Seasonally, every year.	Entire estuary (10 - 13 stations).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (10 - 13 stations).
Measure pesticides/herbicides and metal accumulation in sediments.	Every three - six years, or when contamination is expected.	Entire estuary, including depositional areas (i.e. muddy areas).

Estuary monitoring programme

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Microalgae		
Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly for first two years and then low flow surveys. Every three years.	Along length of estuary minimum five stations (include stations in upper reaches of Brandwag and Moordkuil arms).
Macrophytes		
In the field map the area covered by the different macrophyte habitats. Record boundaries and the total number of macrophytes species. 2013 was a rapid field survey and did not include detailed vegetation mapping and ground truthing. Assess extent of invasive species within the 5 m contour line. Locate the position of reed and sedge areas as indicators of future salinity changes. Identify supratidal salt marsh areas and their condition in terms of area of bareground. Map sensitive submerged macrophyte habitats such as *R. cirrhosa* and *Z. capensis* beds. Identify macroalgae present, their distribution and potential for future expansion (bloom formation) particularly under low flow conditions. Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Every three years during summer.	Entire estuary.

Estuary monitoring programme

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). Intertidal invertebrate hole counts using 0.25 m2 grid (five replicates per site). Establish the species concerned using a prawn pump. Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Every two years in mid-summer.	Minimum of three sites along length of entire estuary. For hole counts – three sites in muddy substrata on eastern shore below N2 bridge.
Fish		
Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually. Spring/Summer and autumn/winter.	Entire estuary (10 stations).
Birds		
Undertake counts of all non-passerine water birds, identified to species level	Annual winter and summer surveys.	Entire estuary including floodplain. Divide into sections: lower to N2; lower estuary adjacent marshes; middle to confluence including marshes; Moordkuils to top, Brandwag to top; upper floodplain wetlands (sections must be standardised).


THANK YOU!