The Determination Of Water Resource Classes, Reserve And Resource Quality Objectives For Secondary Catchments (A5-A9) Within The Limpopo WMA And Secondary Catchment B9 in the Olifants WMA

Project Steering Committee Meeting #3

Scenario Evaluation and draft Water Resource Classes

Presented by: Jane Turpie, Gwyn Letley, Toriso Tlou, Alison Joubert, Karl Reinecke, Martin Holland, James MacKenzie, Nico Rossouw
Company: Myra Consulting with Southern Waters, Anchor Research and Monitoring and Delta-H as sub-consultants

Date: 22 October 2024

WATER IS LIFE - SANITATION IS DIGNITY

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

2030 NDP

OUTLINE

- Introduction and overview (J Turpie)
- Descriptions of scenarios (G Letley)
- Surface and groundwater resources (T Tlou)
- Groundwater condition (M Holland)
- Water quality (N Rossouw)
- River and wetland health (K Reinecke, J MacKenzie)
- Ecosystem services, society and economy (G Letley)
- Overall comparison of scenarios (G Letley)
- Conclusions (J Turpie)

INTRODUCTION & OVERVIEW OF SCENARIO ANALYSIS APPROACH

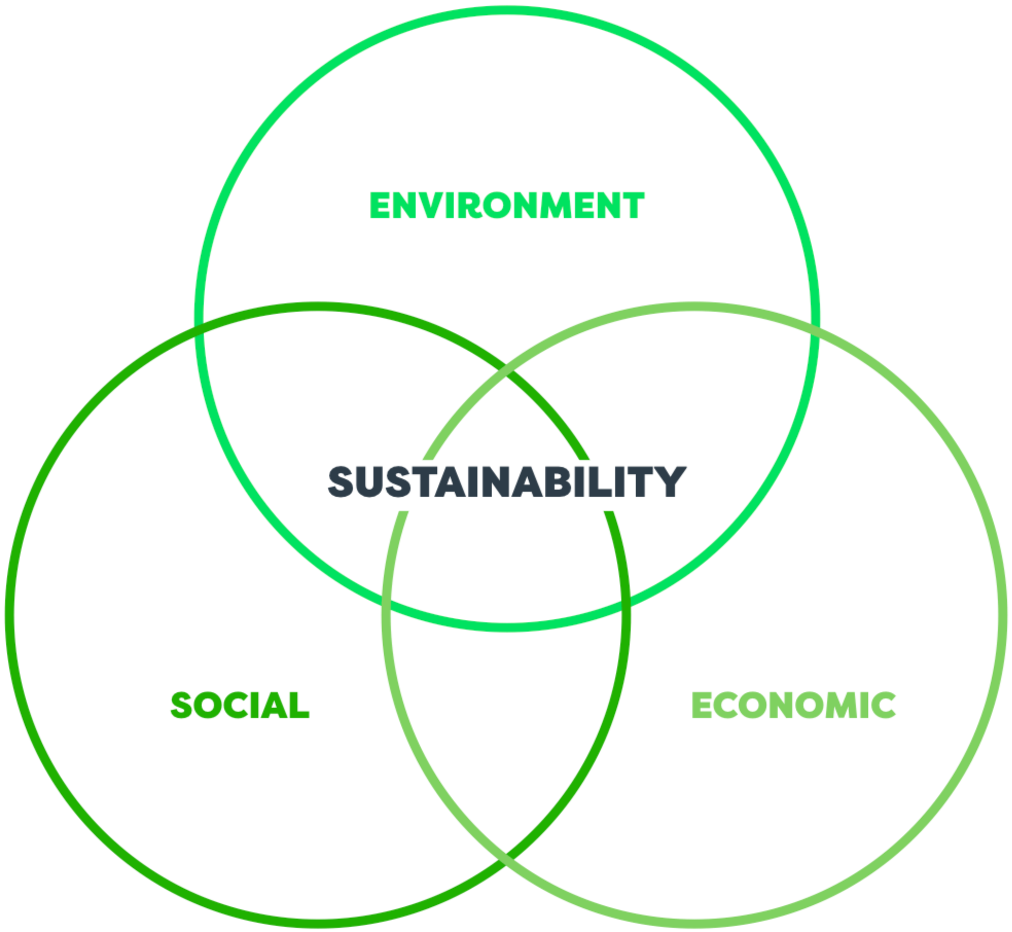
PLANNING UNDER CONDITIONS OF SCARCITY

- Water availability limits economic development and growth
- Nearly all catchments stressed
  - demand>supply
- Planning focused on infrastructure
  - extract more runoff and groundwater
- Impacts on aquatic ecosystems and biodiversity
- Impacts ecosystem services and society

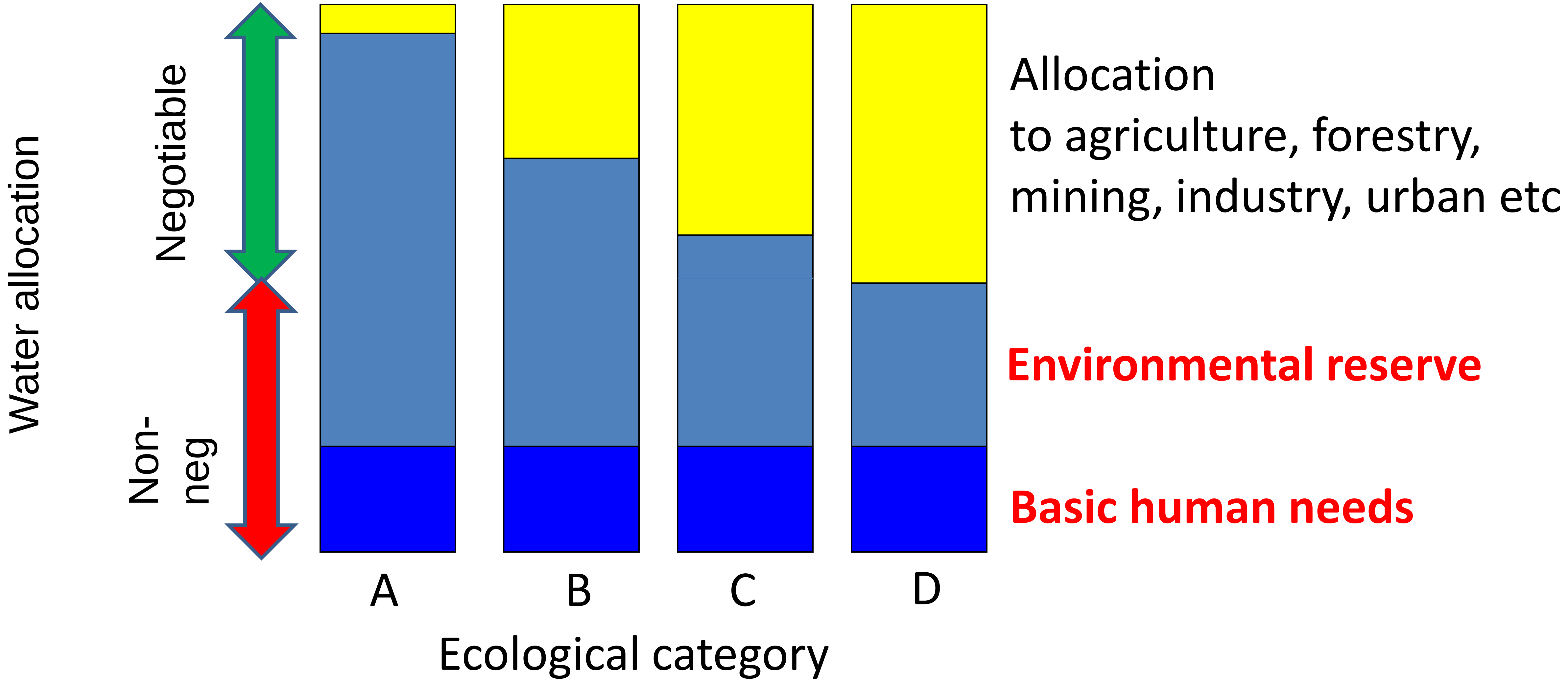
Nandoni Dam

CLASSIFICATION

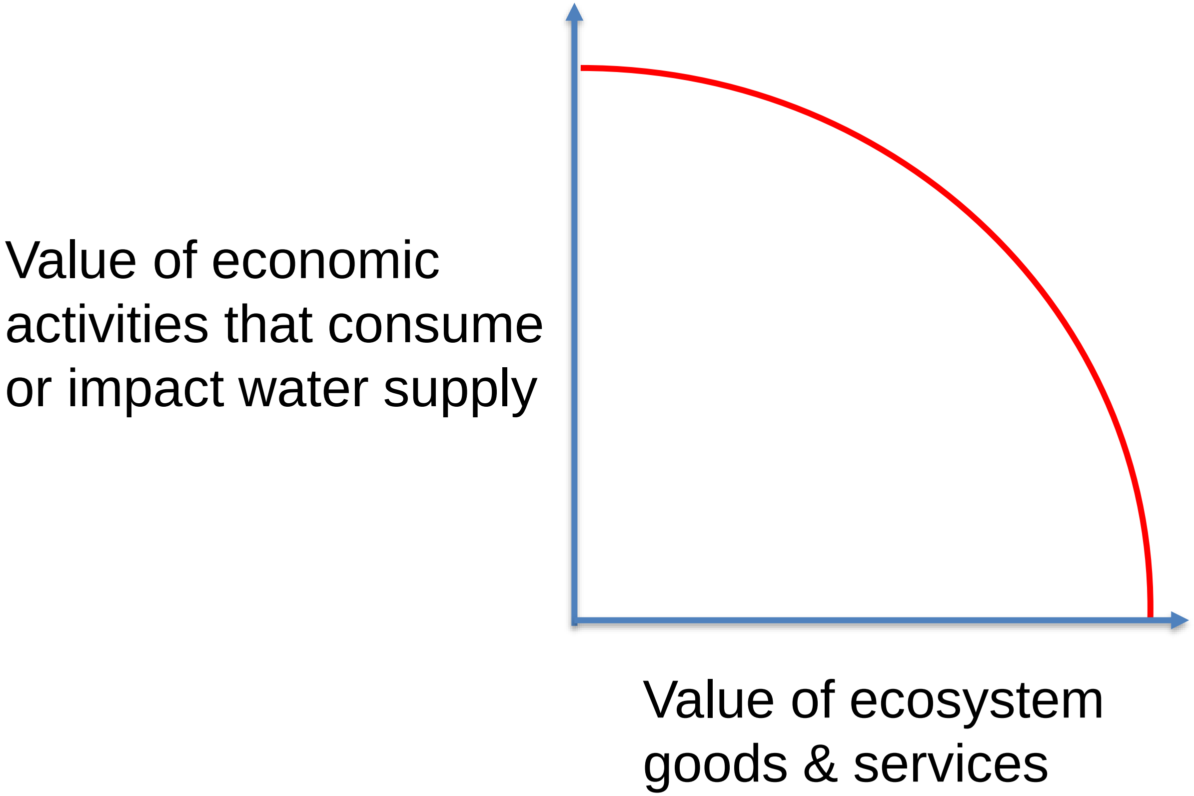
- Determines the ‘ecological Reserve’
  - aquatic and groundwater-dependent ecosystems.
- Involves choices which have economic and social implications
- Classification Process is to evaluate the trade-offs involved
- Decisions based on Economic, Social and Biodiversity criteria
  - not just biodiversity considerations.

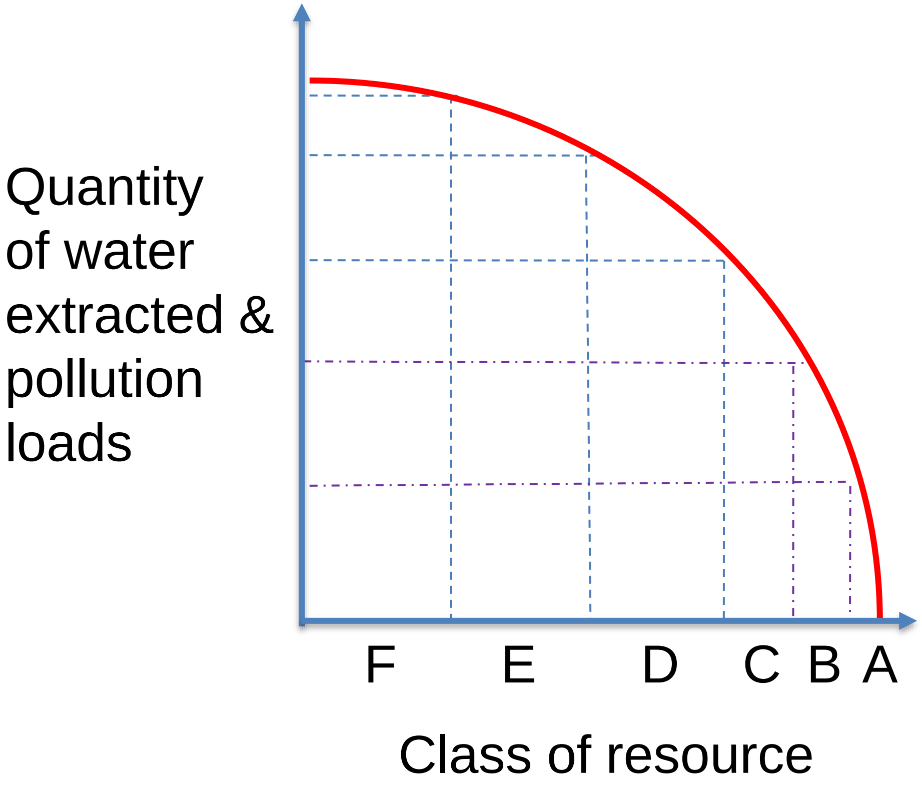


WHAT IS NEGOTIABLE

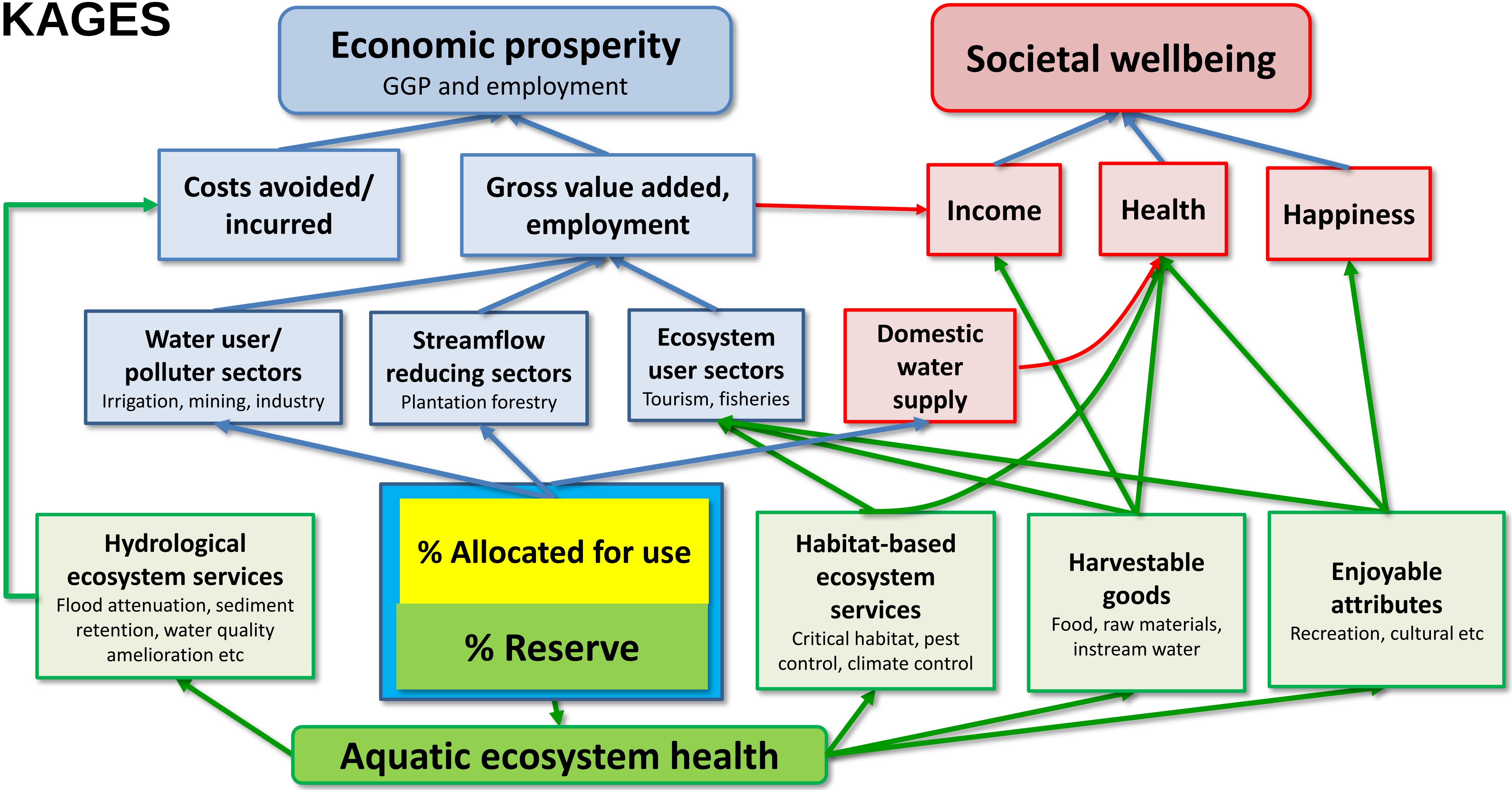


TRADE-OFFS INHERENT IN CLASSIFICATION





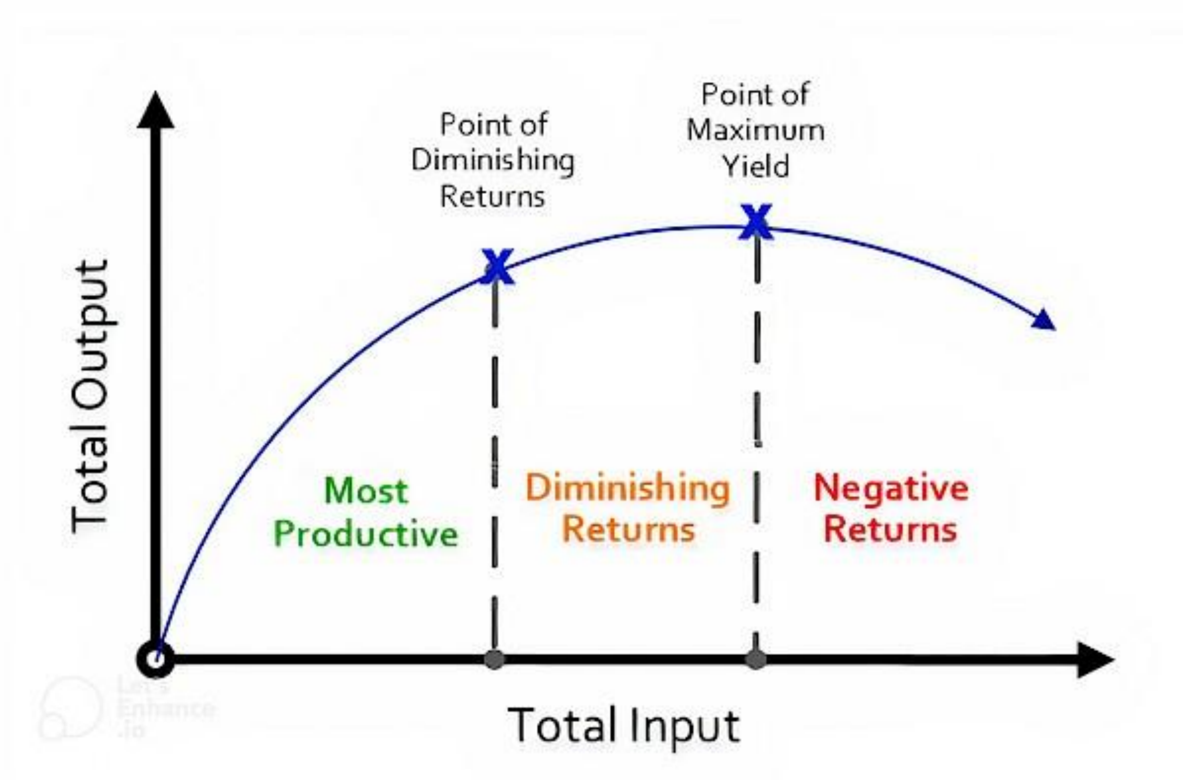
LINKAGES



Economic prosperity
GGP and employment
Societal wellbeing
Costs avoided/ incurred
Gross value added, employment
Income
Health
Happiness
Water user/ polluter sectors
Irrigation, mining, industry
Streamflow reducing sectors
Plantation forestry
Ecosystem user sectors
Tourism, fisheries
Domestic water supply
Hydrological ecosystem services
Flood attenuation, sediment retention, water quality amelioration etc
% Allocated for use
% Reserve
Habitat-based ecosystem services
Critical habitat, pest control, climate control
Harvestable goods
Food, raw materials, instream water
Enjoyable attributes
Recreation, cultural etc
Aquatic ecosystem health

A MAXIMISATION CHALLENGE

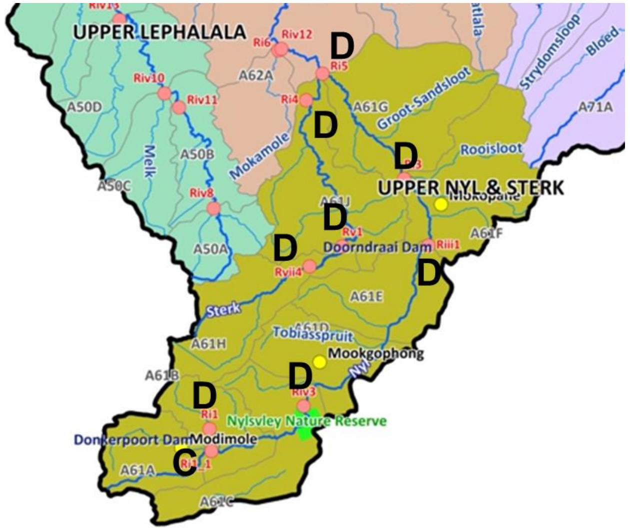
- Aim: maximise societal wellbeing by utilising resources in most efficient way
- Relationships between water use and value are not linear
  - marginal value of water changes
- Best when marginal value of water is equal across all its uses
  - Including environment
- Complex analysis

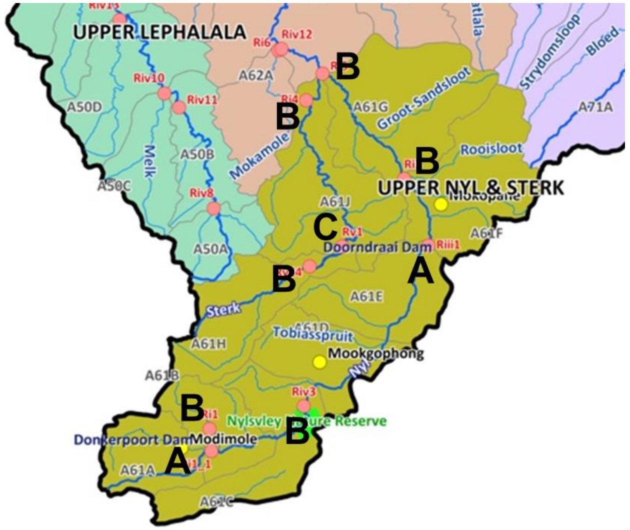


LAW OF DIMINISHING RETURNS

SCENARIO ANALYSIS

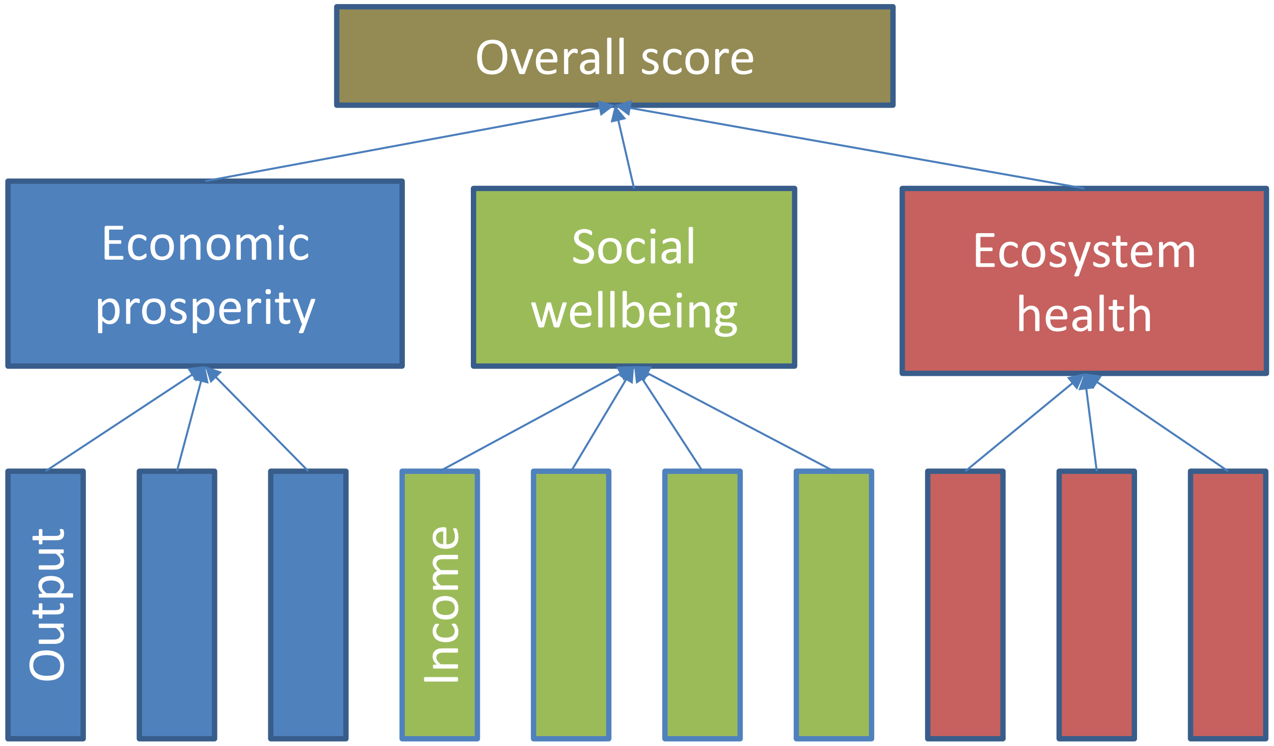
- Pragmatic way to reach a decision on allocation
- Less computationally complex than mathematical maximisation / optimization
- But still a multiscale, multidimensional, dynamic (time-dependent) problem
- Can be compared using
  - Cost-benefit Analysis or
  - Multi-Criteria Analysis



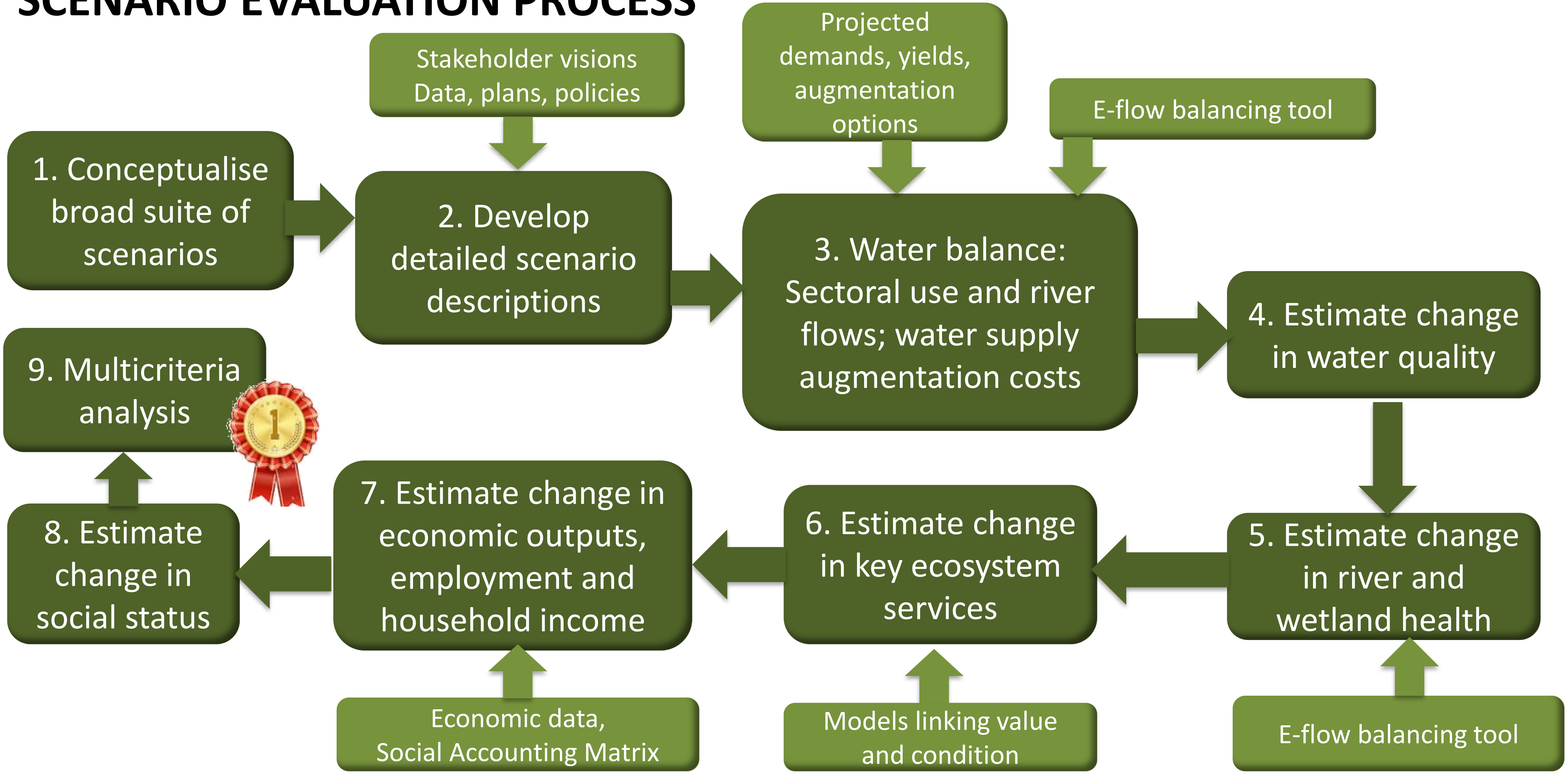


MULTI-CRITERIA ANALYSIS (MCA)

- Used when some values difficult to monetise
- Scenarios compared and ranked based on a scoring process
- To score scenarios,
  – Score sub-criteria
  – Then aggregate scores for main criteria
  – Then calculate overall score



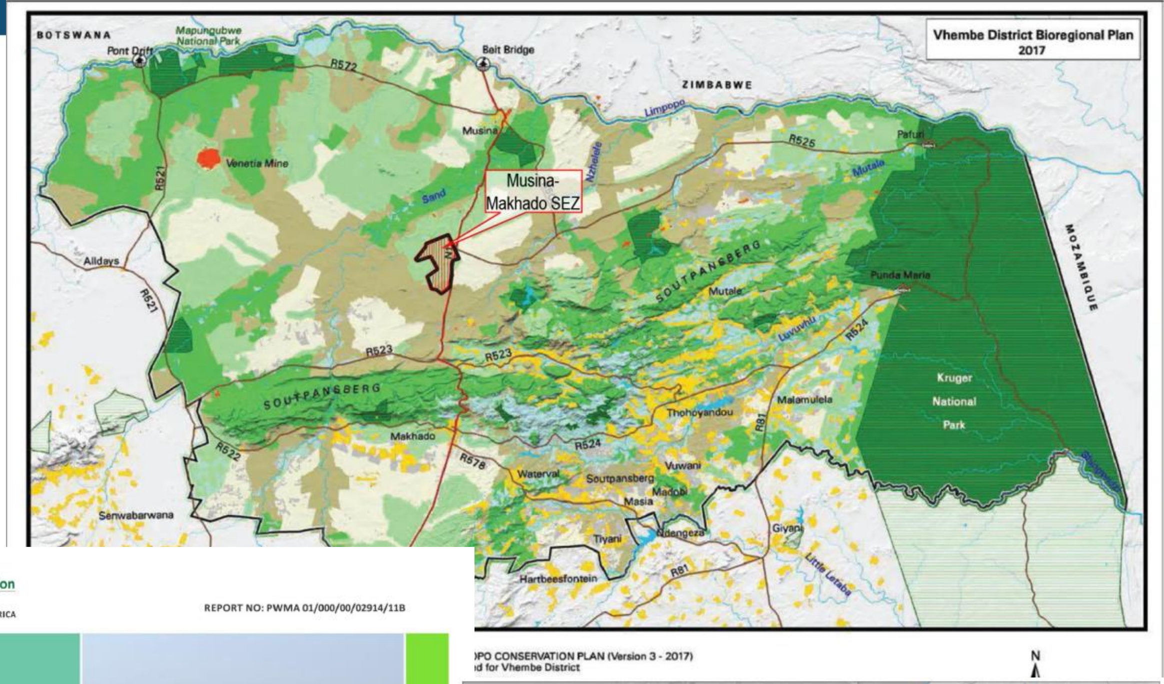
SCENARIO EVALUATION PROCESS

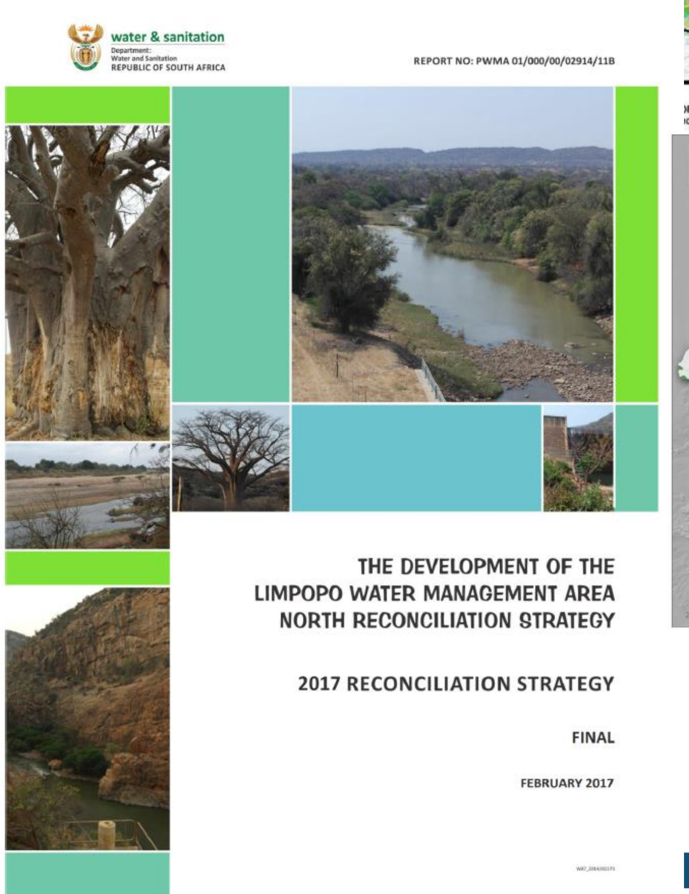


SELECTING AND DESCRIBING THE SCENARIOS

SET UP MULTIPLE SCENARIOS

- National, provincial and municipal spatial plans, CBAs, PA plans etc.
- Municipal IDPs
- Reconciliation strategies
- National strategies relating to biodiversity, conservation and water
- Census data
- Stakeholder visions

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REPUBLIC OF SOUTH AFRICA

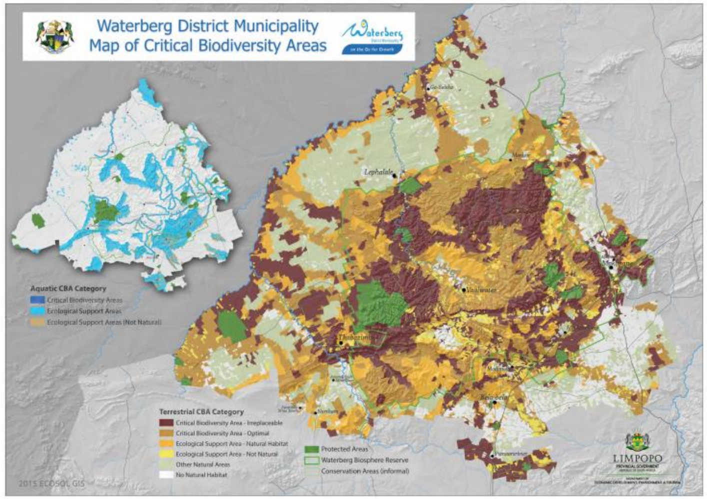
REPORT NO: PWMA 01/000/00/02914/11B

THE DEVELOPMENT OF THE LIMPOPO WATER MANAGEMENT AREA NORTH RECONCILIATION STRATEGY

2017 RECONCILIATION STRATEGY

FINAL

FEBRUARY 2017

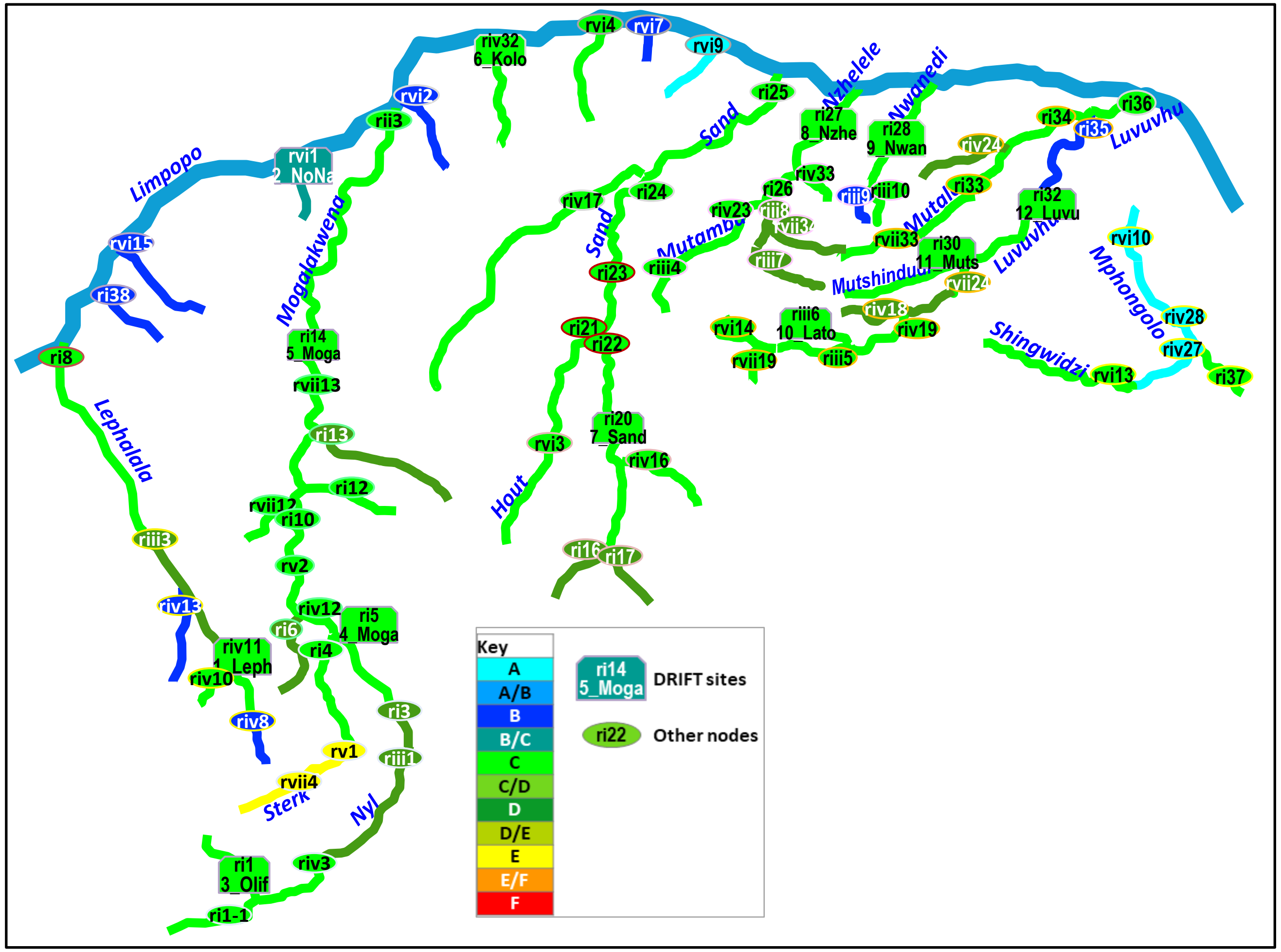


SCENARIOS

#	Scenario	Abbreviation	Description
1	**Maintain Present Ecological Status**	PES	Rivers and wetlands maintained in most recently assessed condition.
2	**Ecological Bottom Line**	ESBC	All water resources maintained in D class (i.e. the "ecological bottom line"), maximising volume available for economic activities. i.e. a "constrained" development scenario.
3	**Biodiversity Economy**	BE	Rivers maintained in best attainable state (BAS) to facilitate sustainable biodiversity economy founded on a strong conservation outcome.
4	**Unconstrained Development**	DEV	Water demands for all future planned or potential developments are met as far as possible without any limit on ecological condition (i.e. can have worse than a D category)
5	**Spatially-targeted Conservation and Development**	STCD	Areas of high conservation value are protected by meeting RECs (including at LIMCOM sites), while other areas allow up to maximum sustainable use of water, within the constraint of min D category.

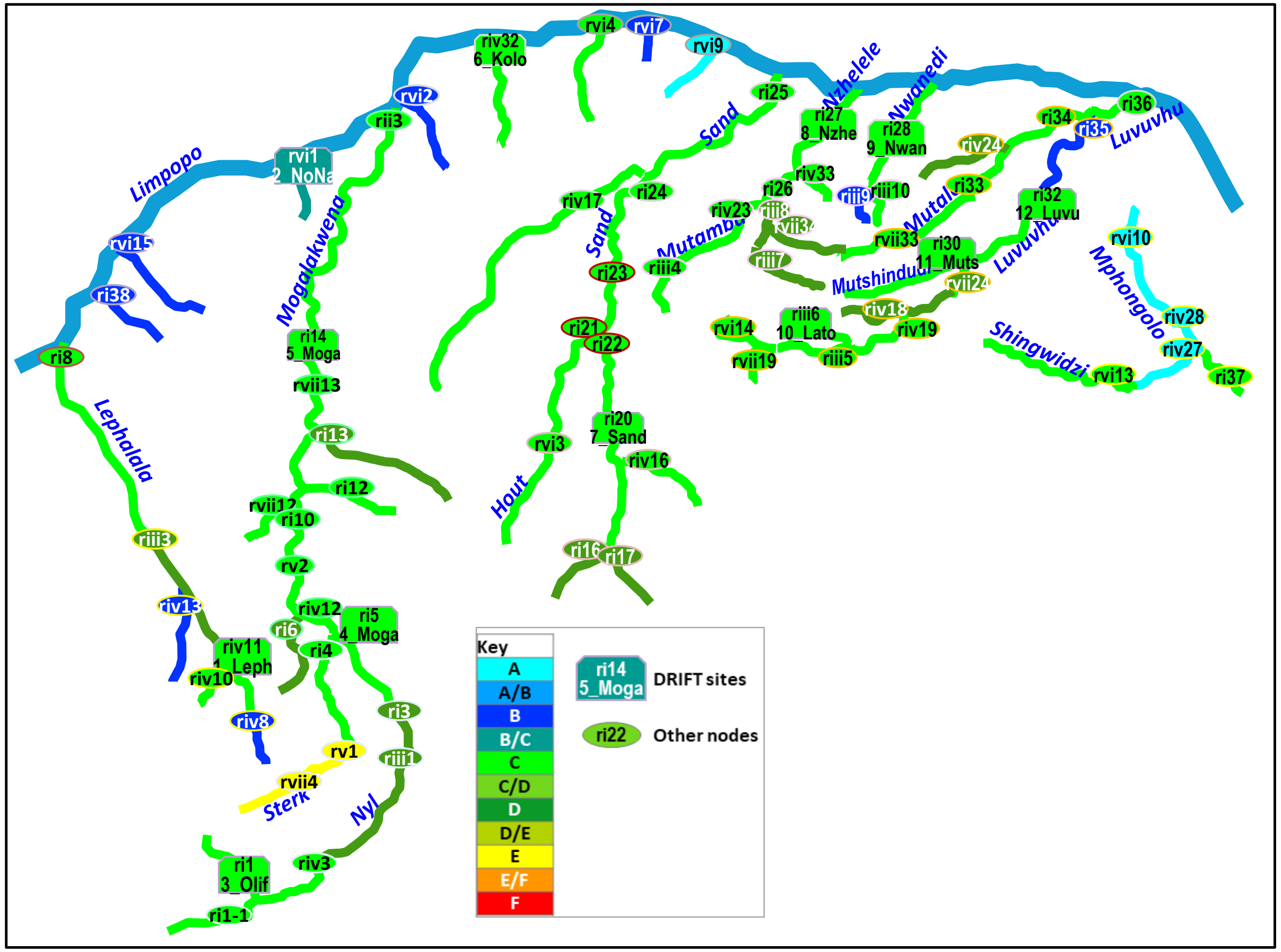
SCENARIO 1:
MAINTAIN PRESENT ECOLOGICAL STATUS (PES)

- Maintains present ecological status (PES) as at the most recent assessment of river and wetland health.
- Assumes efforts are made to maintain river and wetland systems in their present condition in spite of economic and population growth.



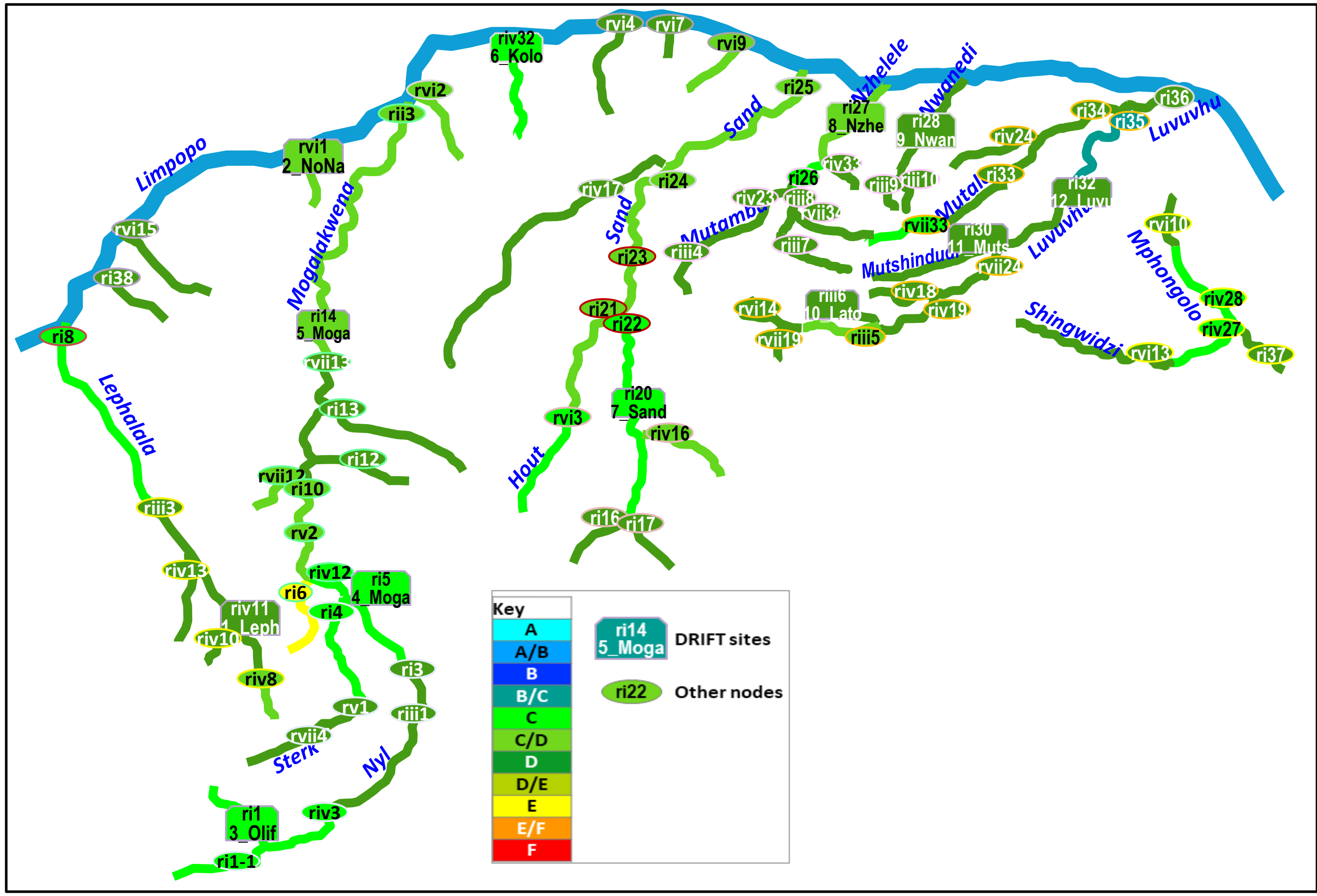
SCENARIO 1:
MAINTAIN PRESENT ECOLOGICAL STATUS (PES)

- Maintains present ecological status (PES) as at the most recent assessment.
- For rivers/wetlands currently in an E or F, these would be improved to a D as far as possible.
- Assumes efforts are made to maintain river and wetland systems in their present condition in spite of economic and population growth.



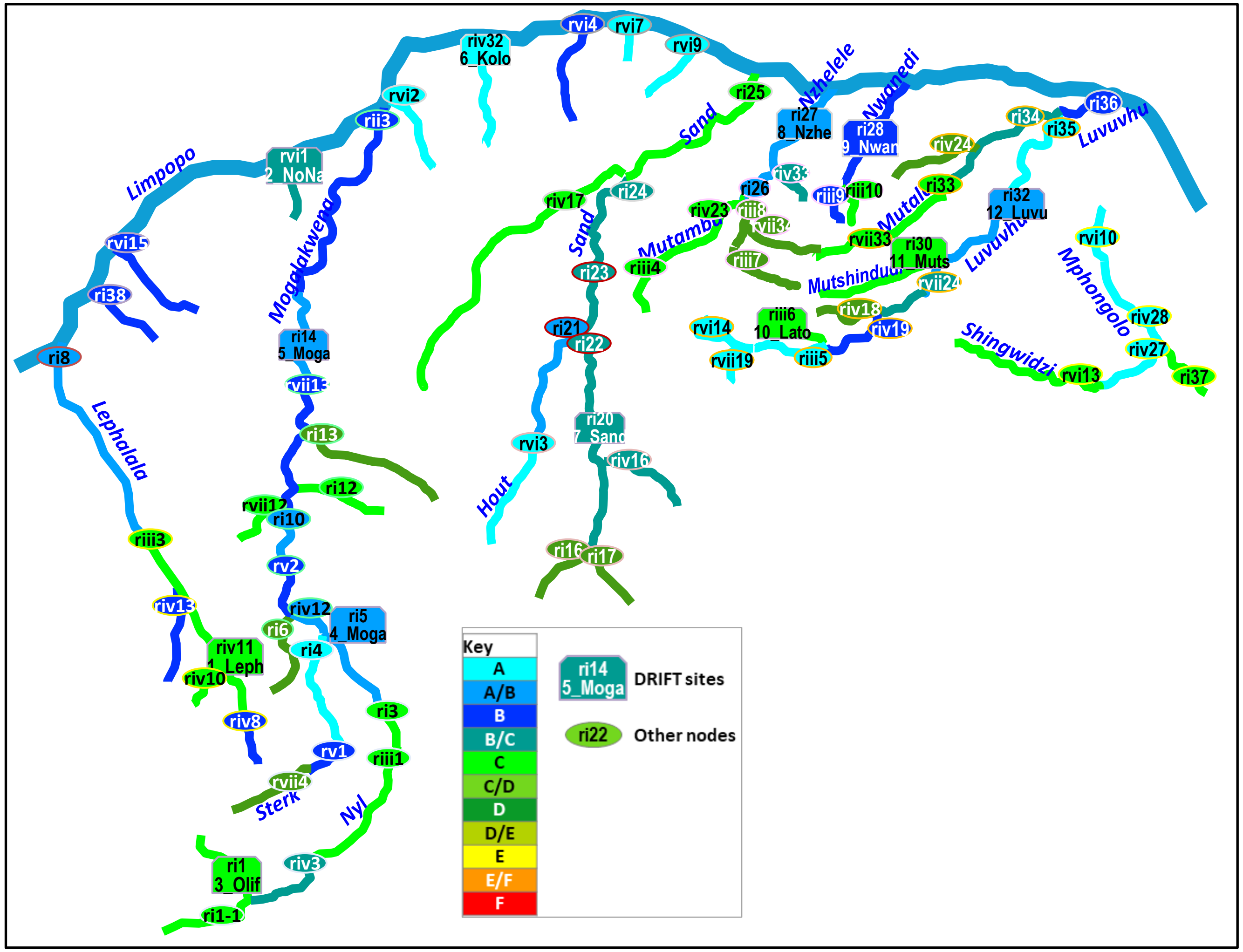
SCENARIO 2:
ECOLOGICAL BOTTOM LINE (ESBC)

- Maximum sustainable volume of water is made available for abstraction for economic activities
- Constrained – no water resources below D category.
- This can also be seen as a "constrained" development scenario.



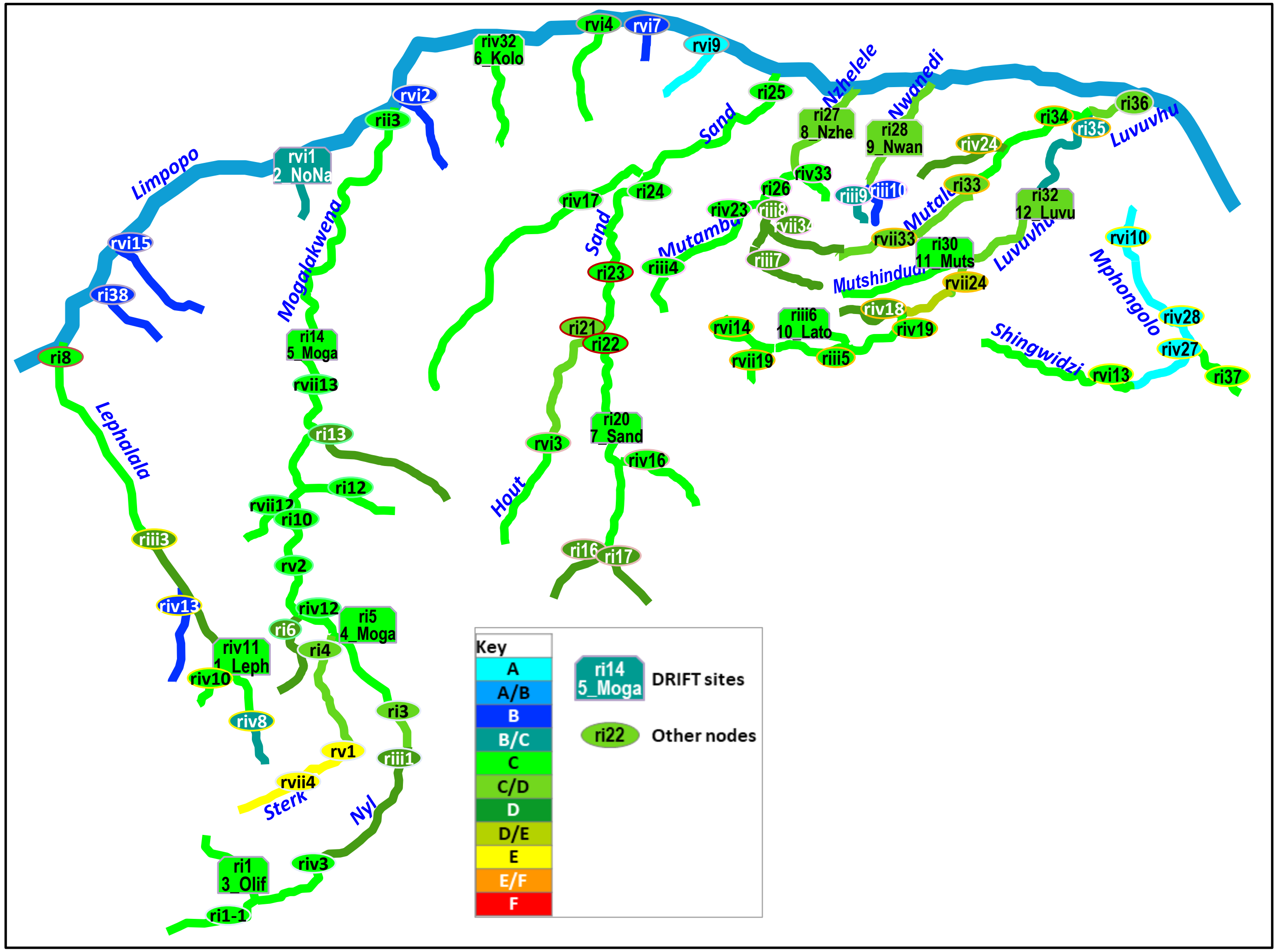
SCENARIO 3: BIODIVERSITY ECONOMY (BE)

- Conservation-focused scenario
- Best attainable state (BAS) for rivers and wetlands
- Growth in sectors that involve extraction and pollution of water is strongly curtailed.
- Area prioritised for ecological restoration and protection, biodiversity economy activities and development of biodiversity products.
- In developed areas, activities such as climate smart agriculture, increased water use efficiency and improved environmental management reduce negative impacts on ecosystems.
- Contributes to existing international commitments and national plans



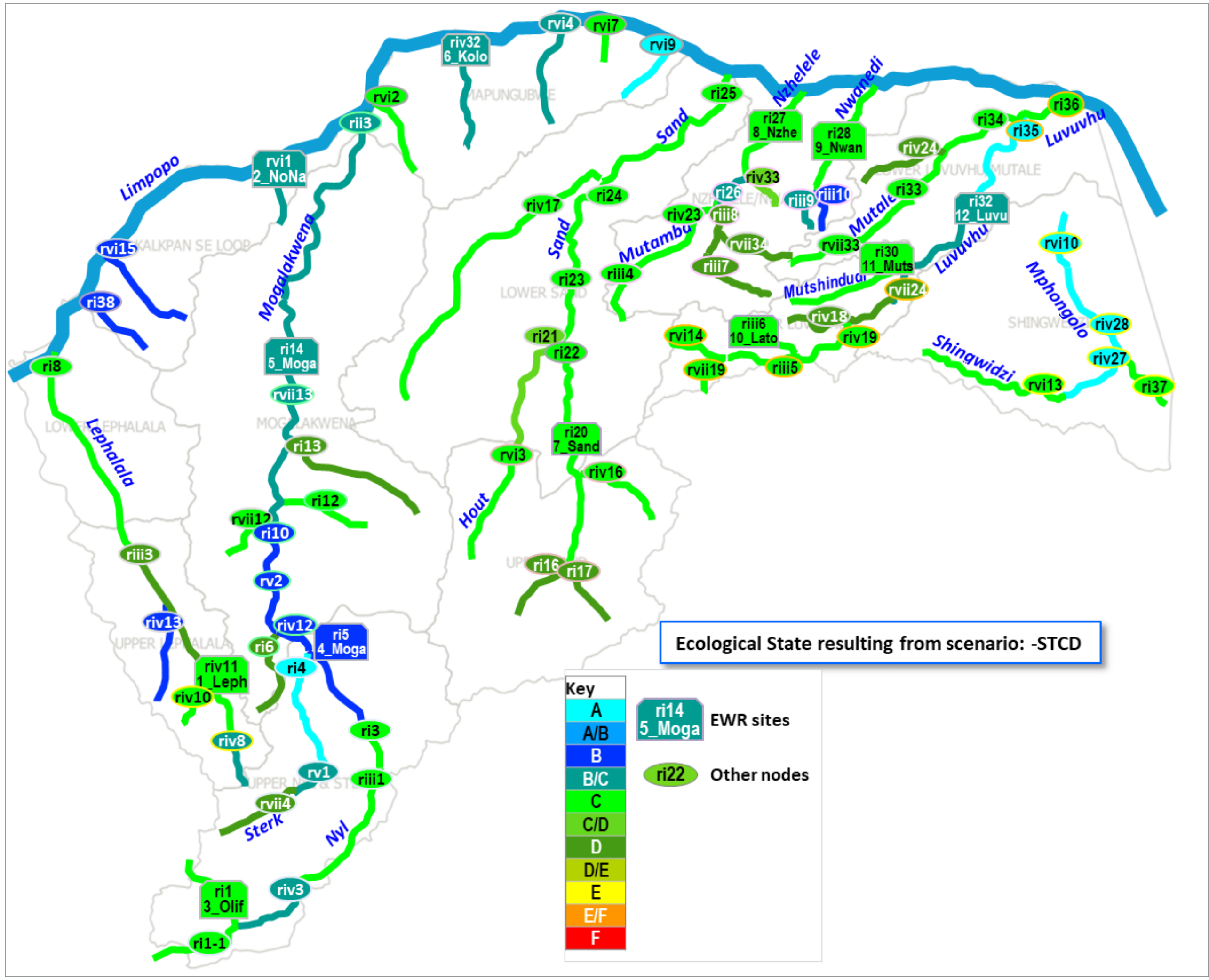
SCENARIO 4:
UNCONSTRAINED DEVELOPMENT (DEV)

- Considers impact of future development with no constraints applied in terms of making water available for environmental flows
- Growth in domestic/urban, irrigation agriculture, mining and industry



SCENARIO 5:
SPATIALLY-TARGETED CONSERVATION & DEVELOPMENT (STCD)

- Priority conservation areas are assigned BAS, while other areas can be developed (min D).
- Designed to spread opportunities among biodiversity and conventional water using sectors
- All within sustainable limits



DETERMINATION OF THE CONSERVATION PRIORITY AREAS

- Each quat was scored in terms of a range of criteria
- Scores were normalised and then a weighted average calculated
- High scoring areas consolidated into conservation areas

Category	Weight	Relative weights
Protected areas	2.6	0.19
Critical Biodiversity Areas 1	1.0	0.07
Critical Biodiversity Areas 2	0.5	0.04
Ecological Support Areas 1	0.3	0.02
Ecological Support Areas 2	0.3	0.02
High priority wetlands	1.25	0.09
Surface Water Source Areas – groundwater	0.5	0.04
Surface Water Source Areas – surface water	0.5	0.04
Fish sanctuaries 1 (vulnerable/ near threatened)	0.4	0.03
Fish sanctuaries 2 (critically endangered)	1.0	0.07
Present Ecological Status A	0.8	0.06
Present Ecological Status B	0.5	0.04
Ecological Importance High	1.0	0.14
Ecological Importance Very High	0.7	0.05
Freshwater Ecosystem Priority Area	0.7	0.05
Fish Support Area	0.5	0.04
Phase 2 FEPA	0.3	0.02
Upstream Management Area	0.2	0.01
Sum	14.1	1

E.G. SCORING

1. The % of quat catchment in a:
   - Protected area
   - CBA 1, CBA 2, ESA 1, ESA 2
   - Strategic water source area
2. The number of high priority wetlands in a quaternary catchment
3. Number of rivers with a PES in an A category

Etc.

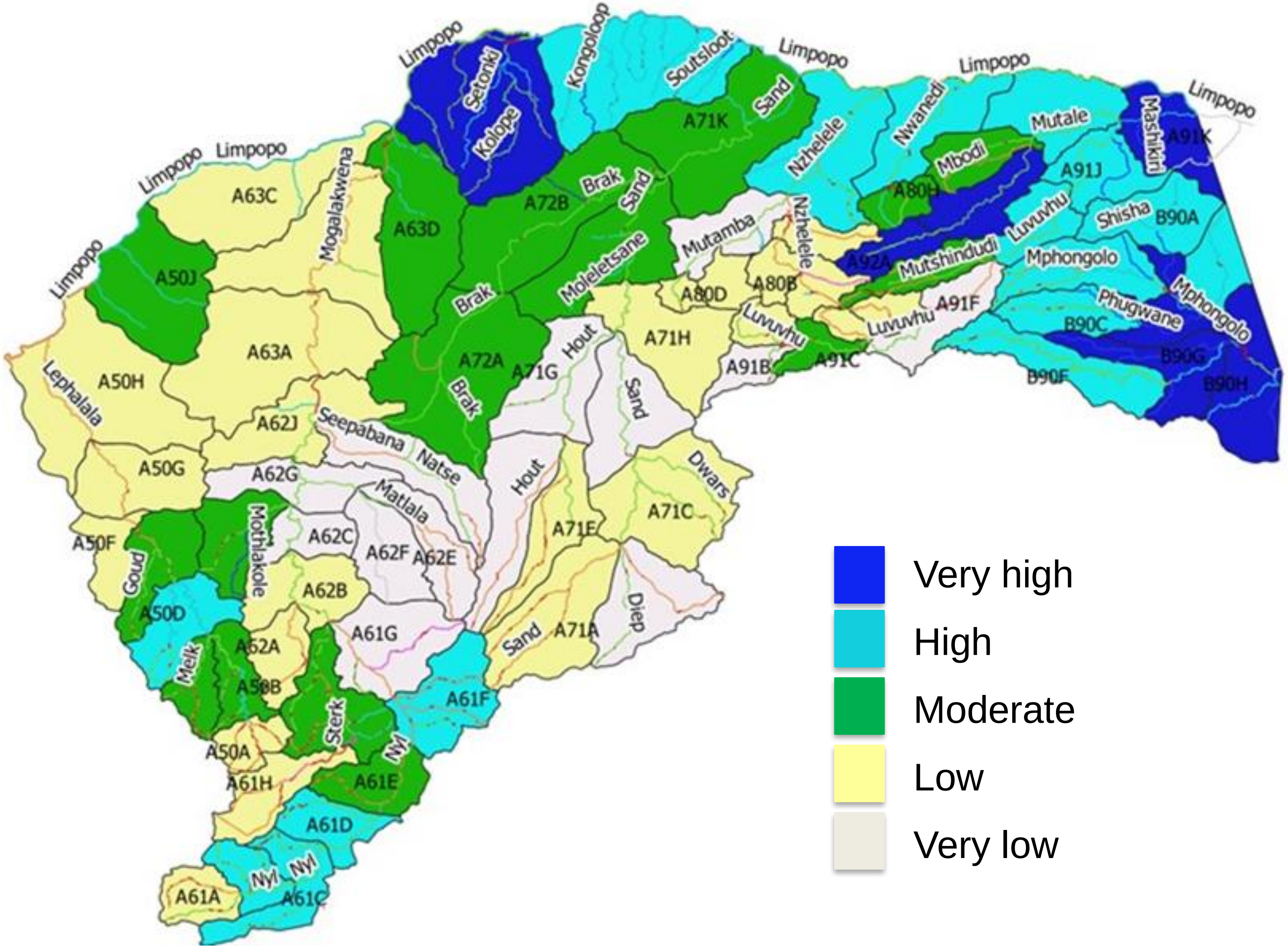
%	Score
< 20	1
21 – 40	2
41 – 60	3
61-80	4
>81	5

Number	Score
0	0
1	4
>1	5

Number	Score
0	0
1	3
2	4
> 3	5

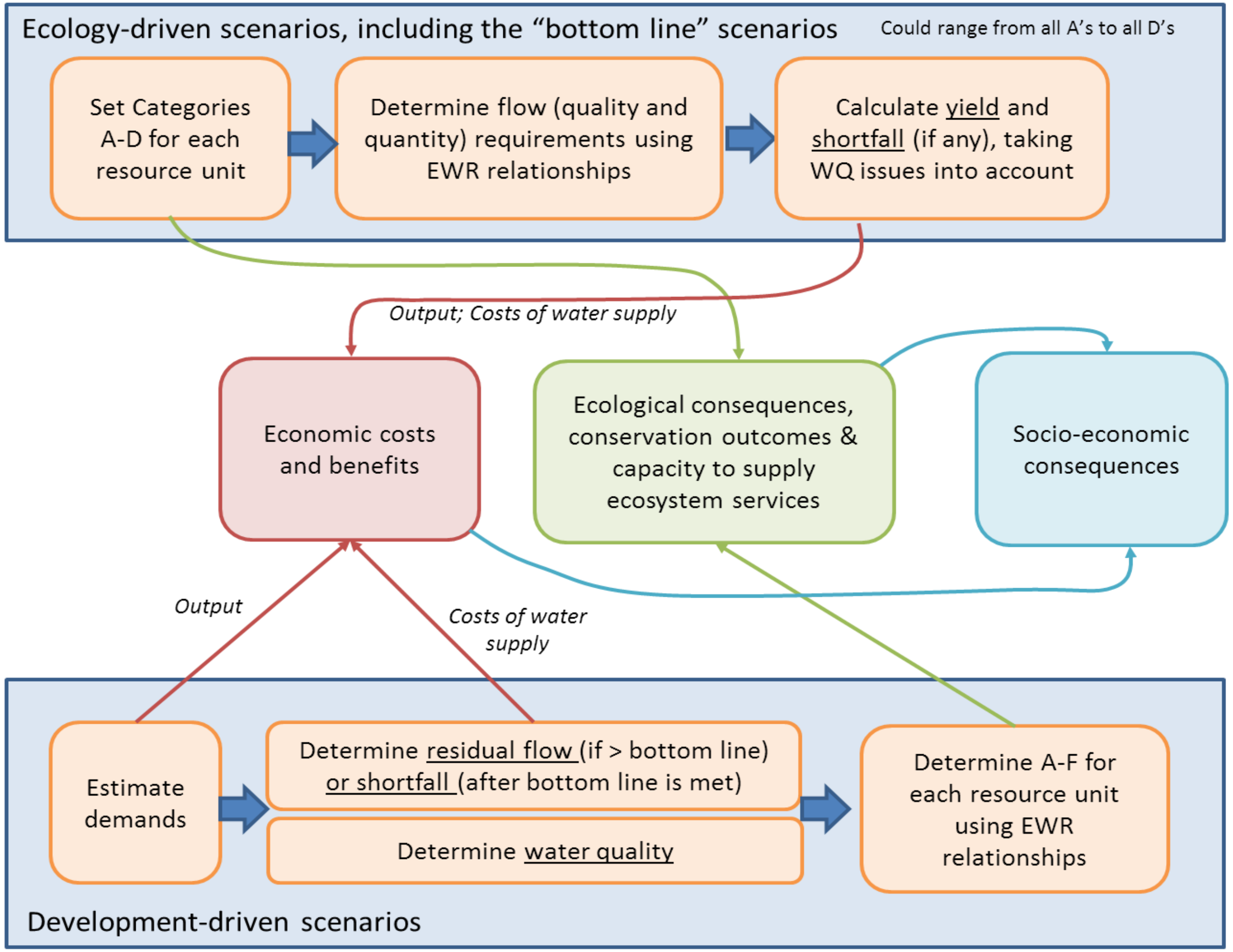
CONSERVATION PRIORITIES

- Areas of high and very high conservation importance prioritised in the spatially targeted scenario



ECOLOGICAL VS DEVELOPMENT DRIVEN SCENARIOS

	Scenario	Ecological categories
1	Maintain Present Ecological Status	PES
2	Ecological bottom line	All D’s
3	Biodiversity Economy	All best attainable state
4	Unconstrained Development	Determined residually
5	Spatially-targeted Conservation and Development	Some areas BAS, other areas D’s,



IMPLICATIONS FOR SURFACE AND GROUNDWATER RESOURCES

IMPACT OF THE SCENARIOS ON THE CURRENT & FUTURE WATER REQUIREMENTS - METHOD STATEMENT

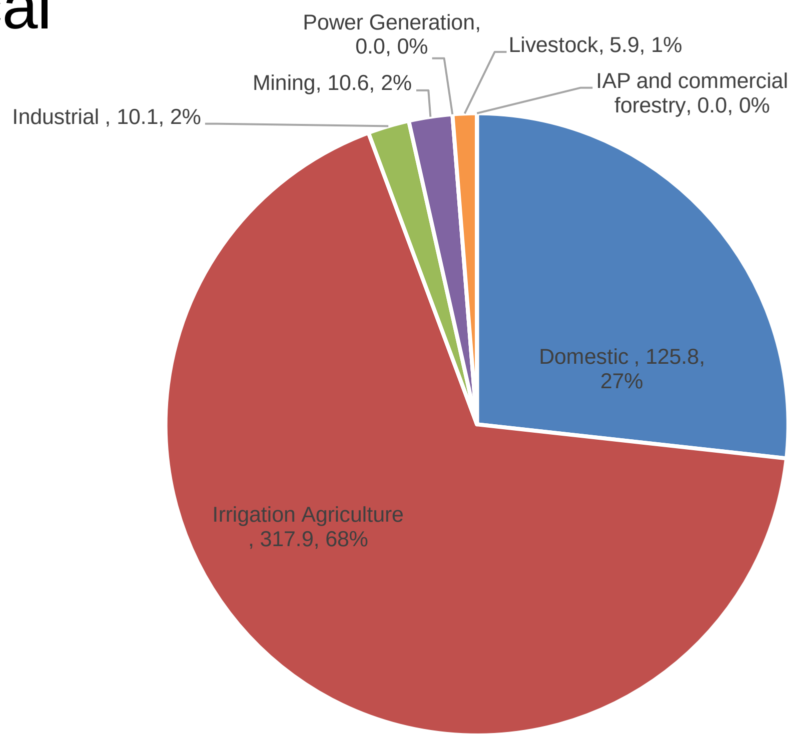
- Current Water Use/ Requirements per IUA
  - Determined water being taken either out of the rivers or being transferred into the IUAs from various studies
  - Existing water allocations used in the case of irrigation agriculture
  - Determined the return flows – water being either returned back to the river downstream or reused by other water users
- Water Requirements Projections to 2050
  - Assumptions made – Irrigation agriculture will only grow to its water allocation
  - Used the DWS reconciliation strategy for the domestic, industries &
  - Projected based on 2022 population projections where information was not available
- Water Resources Availability per IUA
  - Determined based on the yield analysis conducted for the Limpopo WMA

Present & Development – Water Requirements

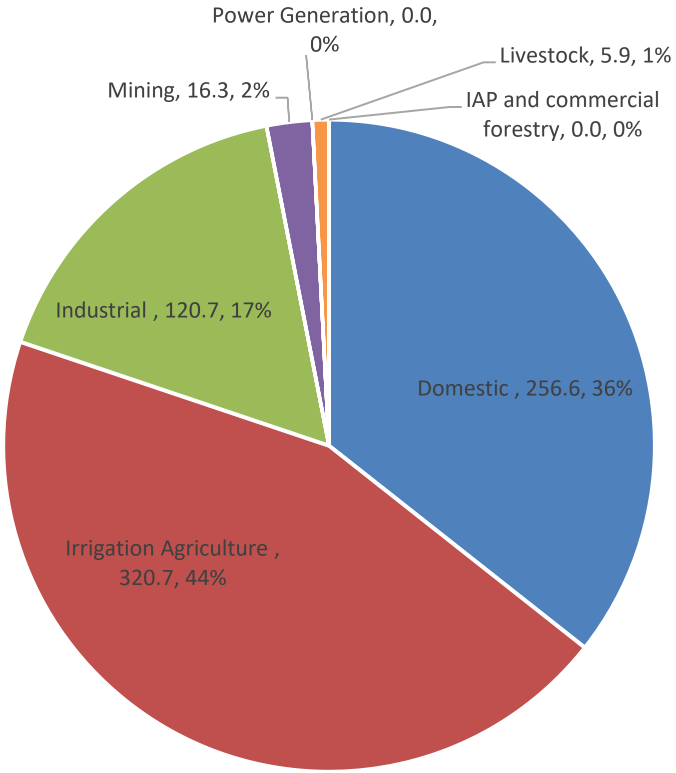
IUA	Total		Domestic		Mining and industry		Irrigation agriculture		Livestock	
	Present (2020)	Development (2050)	Present (2020)	Development (2050)	Present (2020)	Development (2050)	Present (2020)	Development (2050)	Present (2020)	Development (2050)
Upper Lephalala	33.82	36.12	2.82	4.34			28.61	29.33	2.39	2.45
Lower Lephalala	17.40	21.46	3.10	6.79			14.30	14.66		
Upper Nyl & Sterk	25.87	43.79	10.26	22.41	10.64	16.28	4.97	5.09		
Mogalakwena	62.82	66.20	3.34	5.22			55.98	57.39	3.50	3.59
Upper Sand	58.98	129.09	40.99	89.35	5.10	23.65	12.89	16.09		
Lower Sand	125.92	230.24	7.51	18.45	4.50	95.00	113.91	116.79		
Nzhelele/Ṅwanedi	42.93	54.53	8.02	14.44	0.50	2.04	34.41	38.06		
Upper Luvuvhu	83.39	129.76	41.63	83.57			41.76	46.19		
Lower Luvuvhu/Mutale	7.45	8.48	0.62	0.93			6.83	7.55		
Shingwedzi	11.70	19.70	7.50	15.06			4.20	4.65		
Total	**470.27**	**739.37**	**125.79**	**260.56**	**20.74**	**136.97**	**317.85**	**335.80**	**5.89**	**6.04**
		1.52%		2.46%		6.49%		0.2%		

Present & Development – Water Requirements

Historical



Projected 2050

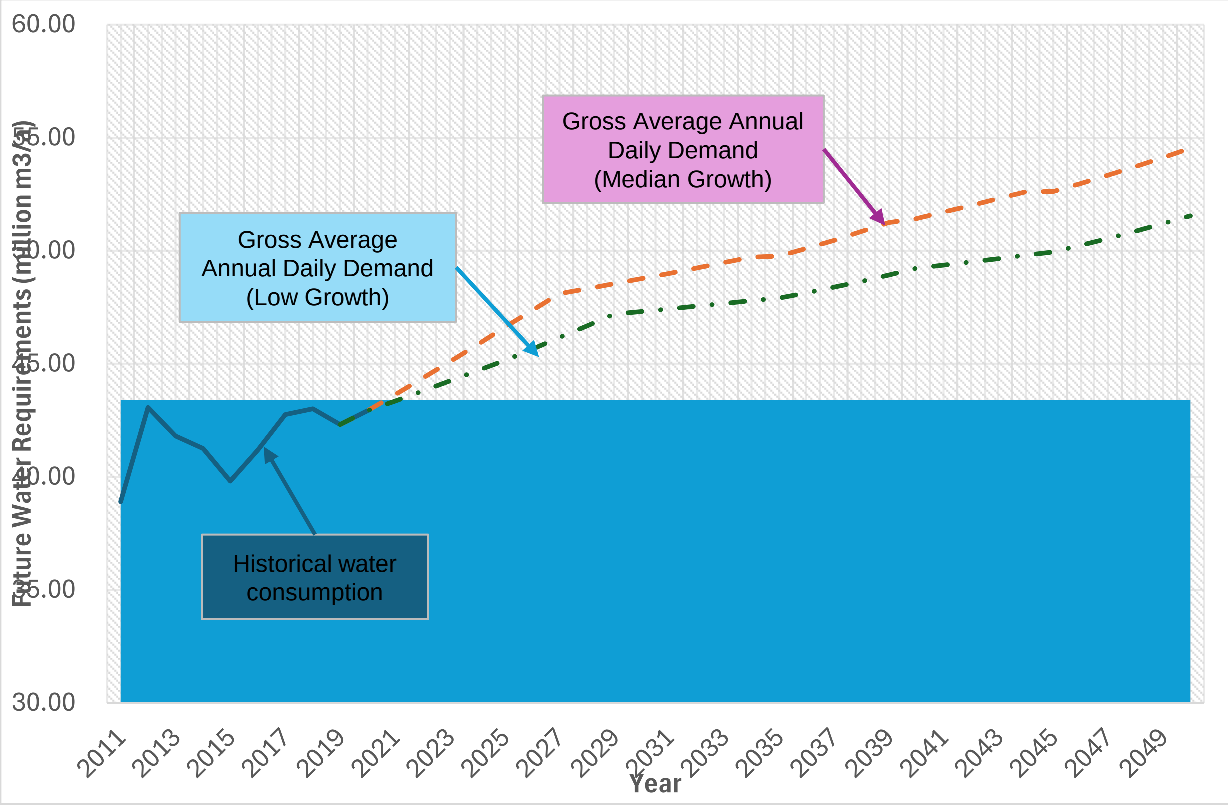


Increase in Domestic, Mining & Industrial Water Requirements Projections

IMPACT OF THE SCENARIOS ON THE CURRENT & FUTURE WATER REQUIREMENTS – METHOD STATEMENT

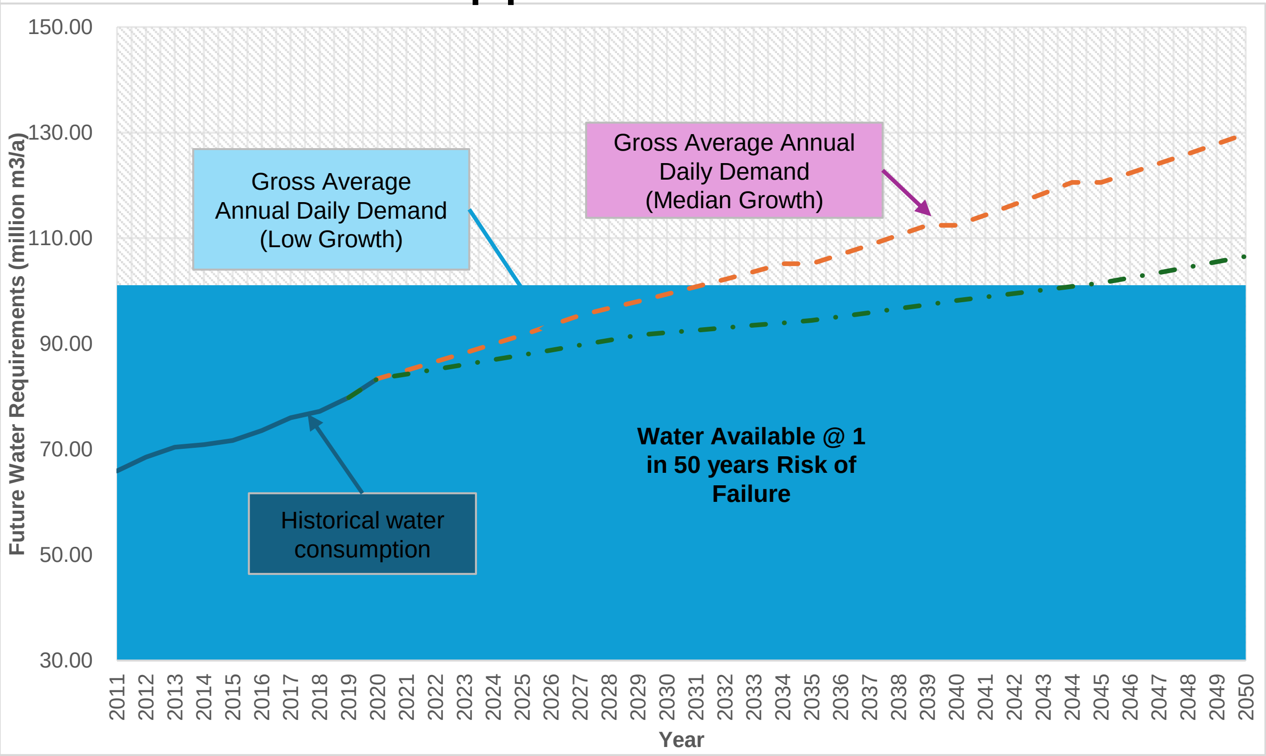
- Water Balance Perspective
  - Comparison of the water requirements projects and the available yield from existing dams
  - Mixed assurance of supply for the different water use sectors in each IUA
  - Determined the timing, extent of additional water required to meet the growing without constraints
- Water Resource Development Options
  - Identified the development options required to meet the water requirement projects based on the water balance analysis
  - Main source of the development option – Reconciliation Strategies of Limpopo
  - Developed a costing model to update CAPEX and determine the URV of each development option

Water Balance Perspective

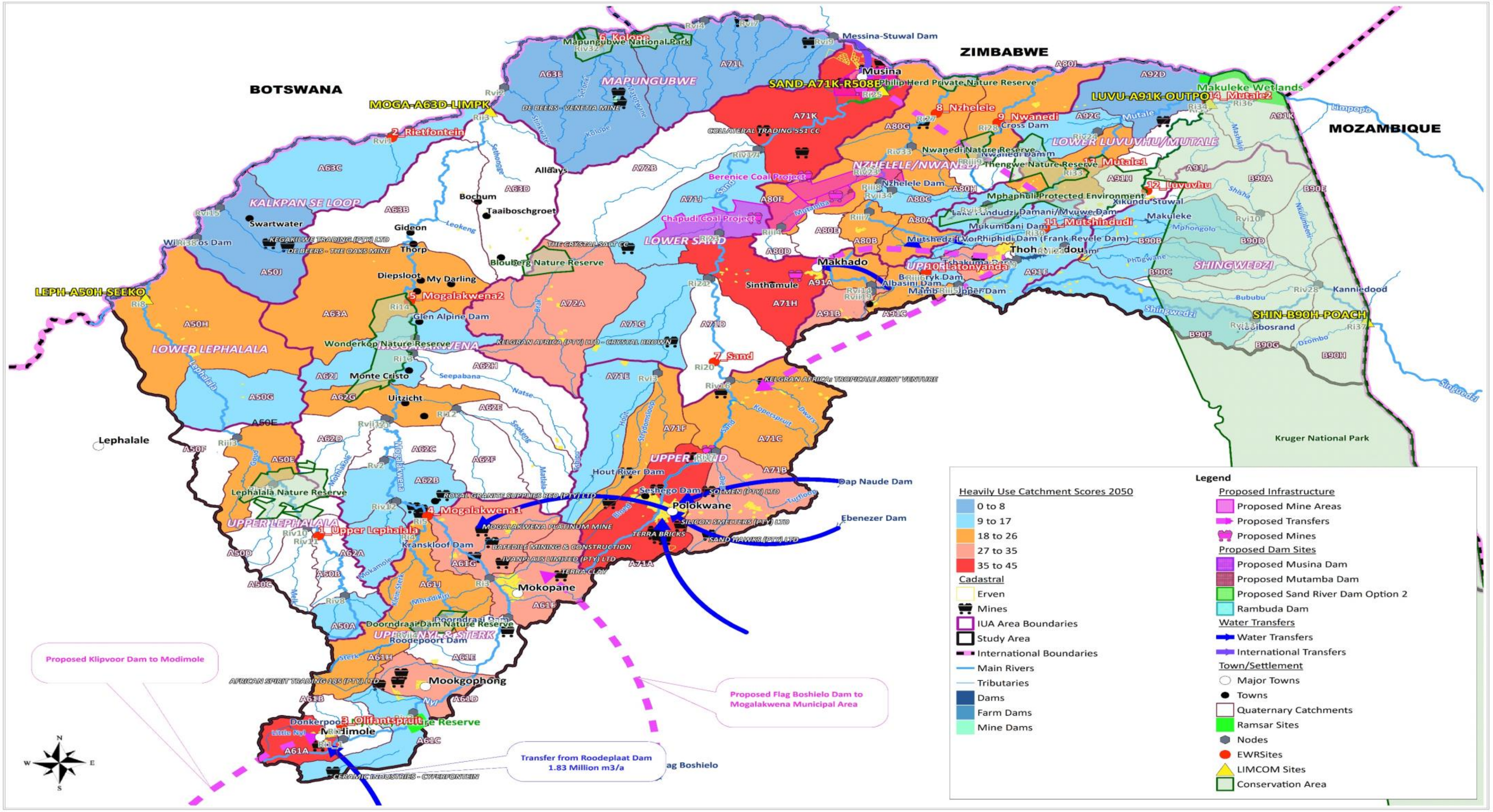


Water Balance Perspective – Nzhelele /Nwanedi IUA

Water Balance Perspective – Upper Luvuvhu IUA



Extent of Utilization per Quaternary Catchment - 2050



POTENTIAL DEVELOPMENT OPTIONS TO MEET 2050 WATER REQUIREMENTS

IUA	Development Option	Name	Additional Water Required	Additional water supplied (Mm^3/a)	Total Cost R million	URV @8% (R/m3)
Upper Nyl & Sterk	Water transfer	Klipvoor Dam - Upper Nyl	10.28	6.85	2 237.97	R12.16
	Water transfer	Flag Boshielo to Mogalakwena Municipality		3.4	527.5	R5.73
Mogalakwena	Groundwater		3.51	3.5	87.1	R0.82
Upper Sand	Water transfer	Nandoni Dam to Polokwane	64.35	64.4	9,795.4	R5.67
Lower Sand	Dam	Musina Dam (no pumped scheme)	88.88	13	2,600.0	R7.45
	Dam	Musina Dam off channel storage		44	11,440.0	R9.68
	Dam	Sand River Dam		223	44,154.0	R11.80
	Water transfer	From Beit Bridge Zim		15	2,970.0	R11.80
Nzhelele / Nwanedi IUA	Dam	Mutamba River	11.13	2.1	556.5	R9.87
	Water conservation + demand management	Refurbishment of irrigation canals		6.2	1,050.5	R6.29
Lower Luvuvhu & Mutale IUA	Dam	Rambuda Dam	0.48	16.7	3,907.8	R13.94
	Dam	Tswera Dam		53	5,512.0	R3.44
	Dam	Paswane Dam		43	4,515.0	R2.96
	Dam	Thengwe Dam		51	5,559.0	R4.06

Scenario Impact on Development

- Two Scenarios (ESBC & STCD)
- Evaluated to determine the impact on the development & extent of curtailment on 2050 water requirements
- Priority Classification
  - Done to equitably reduce water use in the event of water restrictions
  - Based on the assurance levels required to determine curtailments required when there is limited water available
  - Done for each category of water users

Category /Water User	Priority Classification				
	Low **90% Assurance** **(1 in 10 years)**	**Medium Low** **95% Assurance** **(1 in 20 years)**	**Medium** **98% Assurance** **(1 in 50 years)**	**High** **99% Assurance** **(1 in 100 years)**	**Very High** **(99.5% Assurance)** **(1 in 200 years)**
Domestic & Urban	5%	15%	20%	40%	20%
Mining, Industries & Power Generation	5%	20%	20%	35%	20%
Irrigation	30%	35%	20%	15%	0%
Return Flows	25%	25%	20%	20%	10%

Curtailment Level	**0**	**1**	**2**	**3**	**4**	**5**

Scenario Impact on Development

- For ESBC scenario
  - Upper Nyl & Sterk IUA will need to be curtailed by approximately 0.94 million m3/a,
    - 0.48 million m3/a curtailed from domestic/urban use,
    - 0.35 million m3/a from mining &
    - 0.11 million m3/a from irrigation
- For the STCD scenario
  - Curtailment significant on irrigation agriculture because of its low assurance of supply
  - Mogalakwena & Lower Luvuvhu/Mutale are significantly curtailed

IUA	Total	Irrigation	Domestic/ urban	Livestock	Mining and Industry
Lephalala	1.85	1.26	0.59		
Upper Nyl & Sterk	9.34	1.09	4.78		3.47
Mogalakwena	14.62	12.68	1.15	0.79	
Nzhelele/Ṅwanedi	1.43	1.00	0.38		0.05
Upper Luvuvhu	7.50	2.67	4.83		
Lower Luvuvhu/Mutale	34.09	30.36	3.73		

GROUNDWATER CONDITION

APPROACH FOR ASSESSING GROUNDWATER CONDITION

- Groundwater condition (stress levels) was largely based on the variation of groundwater abstraction under the different scenarios.
- The stress index (SI) provides a measure of the groundwater balance in a groundwater unit indicating:
  - Recharge, BHN, GW supporting the base flow and (iii) the actual groundwater use /abstraction
- Outcome of the scenarios → the potential volume of groundwater for development and qualitative statements based on expert opinion in terms of impacts from groundwater usage on baseflow as well as the potential (volumes) for further groundwater development.

Index	Description
< 0.20 (20 %)	Low
0.20 (20 %) - 0.40 (40 %)	Moderate
0.40 (40 %) - 0.65 (65%)	Moderate to High
0.65 (65 %) - 0.95 (95%) High	High
> 0.95 (95 %)	Critical

APPROACH FOR ASSESSING GROUNDWATER CONDITION

#	Scenario	Abbreviation	Description
1	Maintain Present Ecological Status	PES	Current groundwater index (i.e., groundwater contribution to baseflow, BHN and current groundwater abstraction)
2	Ecological Bottom Line	ESBC	Current groundwater uses plus allocable groundwater abstraction (i.e., groundwater contribution to baseflow, BHN and current groundwater abstraction + allocable groundwater) SI of 65 to 85%
3	Biodiversity Economy	BE or BAS	Current groundwater uses while over-exploited catchments were reduced to a SI of below 95%.
4	Unconstrained Development	DEV	Current groundwater uses plus additional exploitation of groundwater (i.e., groundwater contribution to baseflow, BHN and current groundwater abstraction + additional groundwater potential) SI of 75% for areas with low to moderate to groundwater potential. SI of 85% with moderate groundwater potential.
5	Spatially-targeted Conservation and Development	STCD	Like the DEV scenario but consideration is given to high ecological priority areas. As such groundwater development in these IUAs are limited to a SI of 50% or up to 60% with limited priority catchments.

IMPLICATIONS FOR GROUNDWATER CONDITION

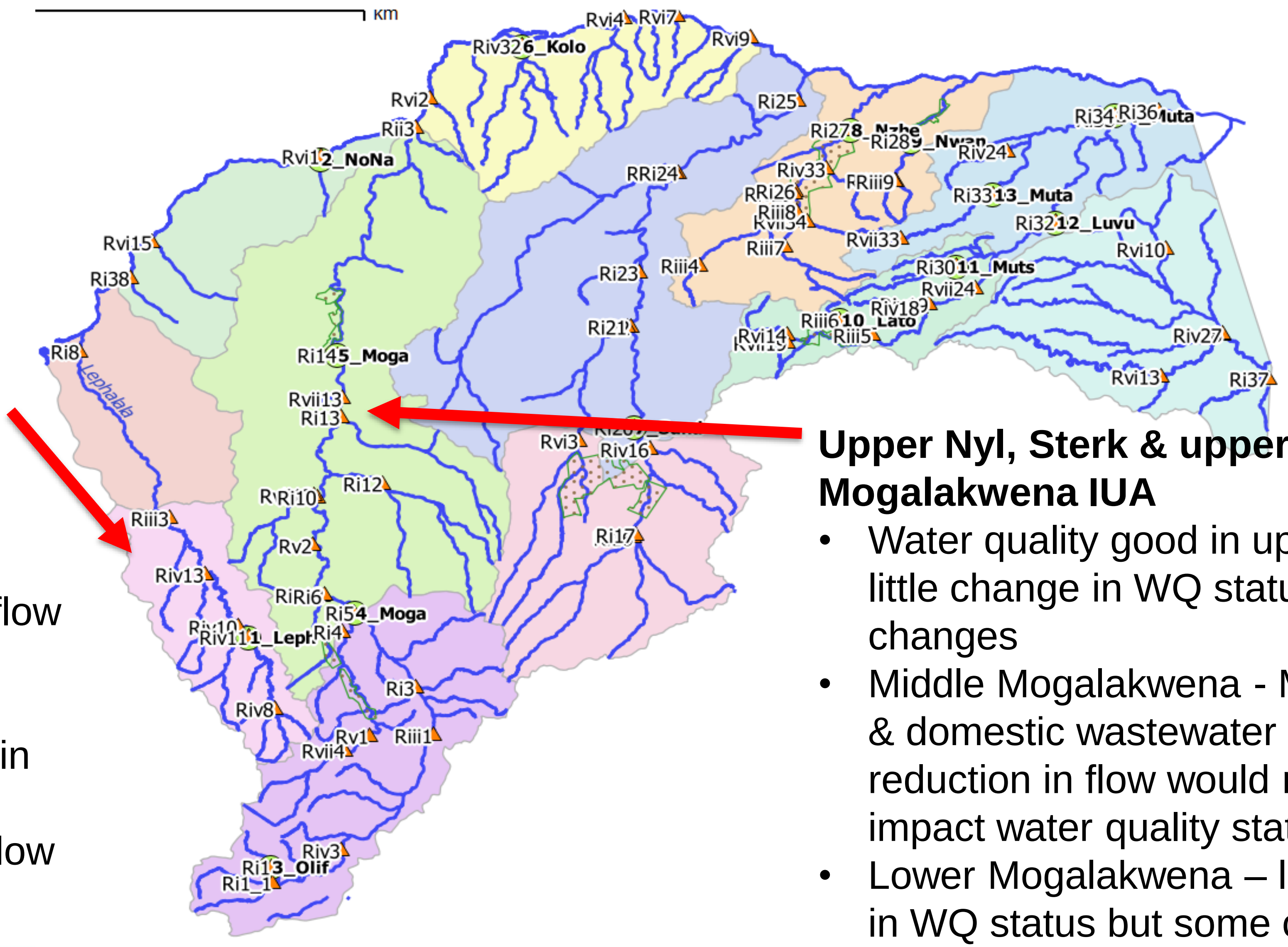
IUA	ESBC	BE	DEV	STCD	Comment
	% Change in SI Classification from PES				
Upper and Lower Lephalala	36.17%	0.00%	40.61%	15.70%	Potential for additional abstraction/Low GW potential
Kalkpan se Loop	24.71%	0.00%	0.00%	0.00%	Potential for additional abstraction/No Development
Upper Nyl and Sterk	24.13%	0.00%	33.08%	8.27%	Moderate current GW use/High priority areas limit large groundwater development for STCD scenario
Mogalakwena	24.80%	-0.96%	40.59%	34.59%	Potential for additional abstraction with limited impact on the groundwater system
Mapungubwe	0.00%	-9.74%	0.00%	0.00%	High existing GW use; High priority area/Reduction from critical to high groundwater index may result in positive impact to GDEs along the Limpopo River
Upper and Lower Sand	2.60%	-23.08%	0.00%	0.00%	Reduction to high groundwater class (from critical) may result in positive impact on groundwater levels during drought cycles
Nzhelele/Nwanedi	26.29%	0.00%	30.98%	7.23%	High priority areas limit groundwater development for STCD scenario
Upper Luvuvhu	28.65%	-4.37%	33.45%	30.57%	Potential for additional abstraction with limited impact on the groundwater system (in low probability of baseflow catchments)/within the upper catchment, potential impact on baseflow via sub surface seepages and springs
Lower Luvuvhu/Mutale	53.69%	0.00%	62.26%	38.05%	High priority areas limit large groundwater development for STCD scenario/Low GW potential
Shingwedzi	59.15%	0.00%	71.03%	45.92%	High priority areas limit large groundwater development for STCD scenario/Low GW potential

WATER QUALITY

APPROACH TO ASSESSING THE WATER QUALITY IMPLICATIONS

- No modelling of water quality as for flow scenarios
- Assessment based on knowledge of water quality responses to decrease in flows, or restoring flows
- Decrease in flow means less dilution of point and nonpoint source pollution
- Maintenance of flow regime would probably maintain WQ status but over time it could deteriorate if trends continue
- Slight improvement in flow regime would probably maintain WQ status

LIKELY WATER QUALITY IMPACTS



Lephalala upper & lower IUA

- Largely natural upper catchment – no major changes in overall WQ status with changes in flow
- Minor point sources in lower IUA – WQ status would probably remain in the same category with envisaged changes in flow

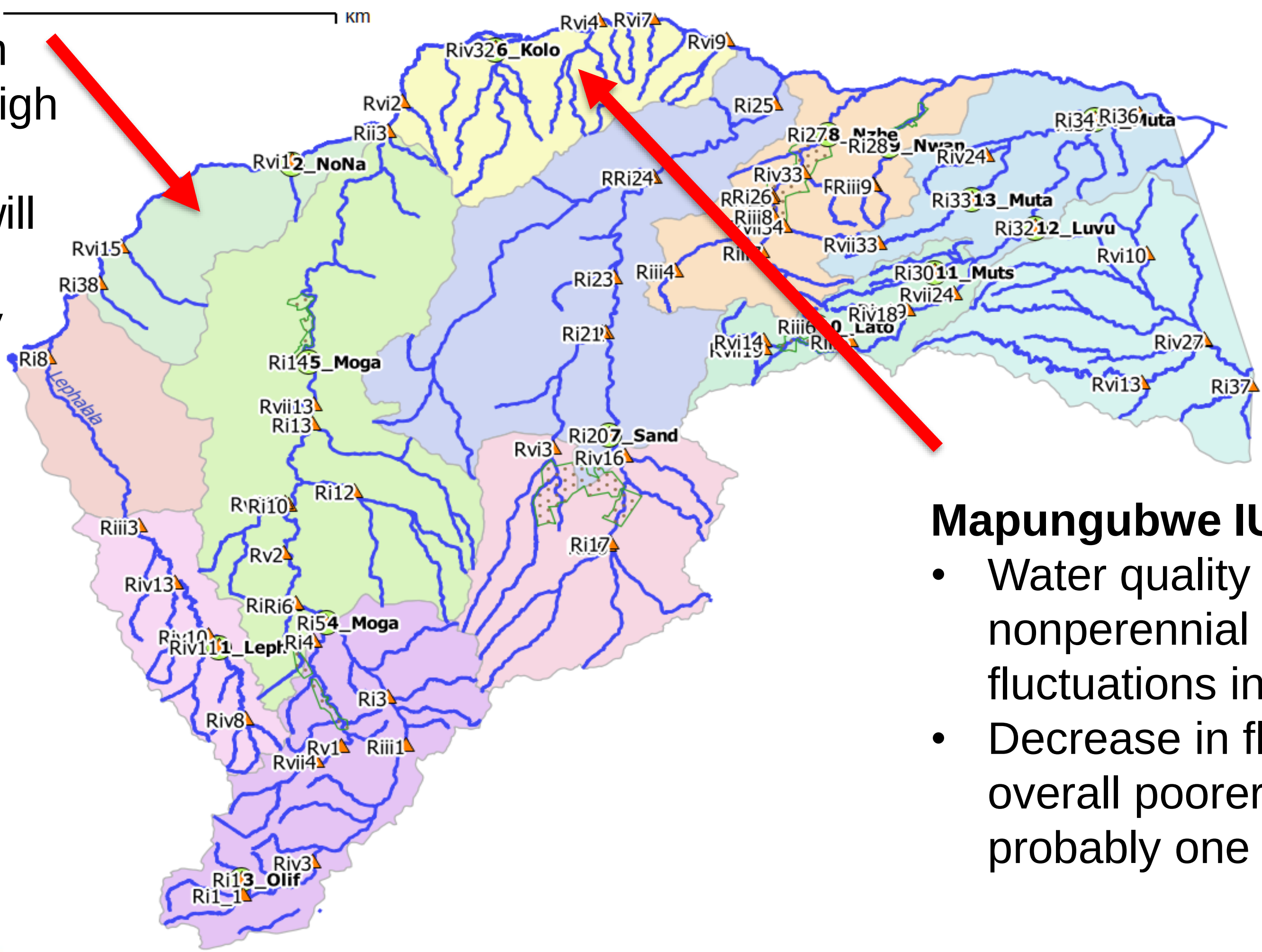
Upper Nyl, Sterk & upper & lower Mogalakwena IUA

- Water quality good in upper reaches, little change in WQ status with flow changes
- Middle Mogalakwena - Many mining & domestic wastewater sources – reduction in flow would negatively impact water quality status
- Lower Mogalakwena – little change in WQ status but some carry-over from upstream IUAs

LIKELY WATER QUALITY IMPACTS

Kalkpan se loop IUA

- Only perennial stream fed from spring with high salinity water
- Water quality status will probably remain unchanged due to dry nature of the IUA



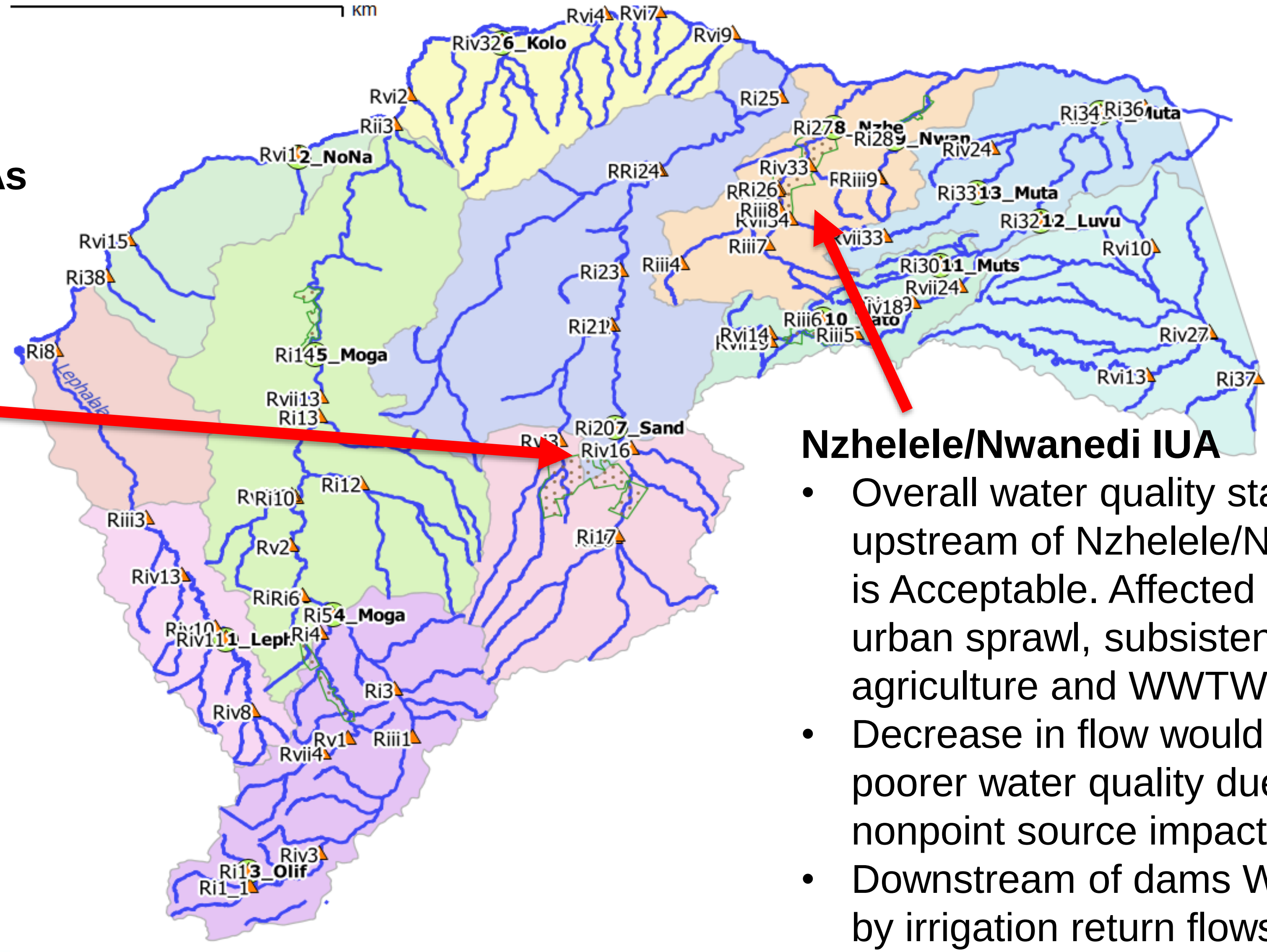
Mapungubwe IUA

- Water quality characteristic of nonperennial stream – wide fluctuations in water quality
- Decrease in flow would lead to overall poorer water quality – probably one WQ category poorer

LIKELY WATER QUALITY IMPACTS

Upper and lower Sand IUAs

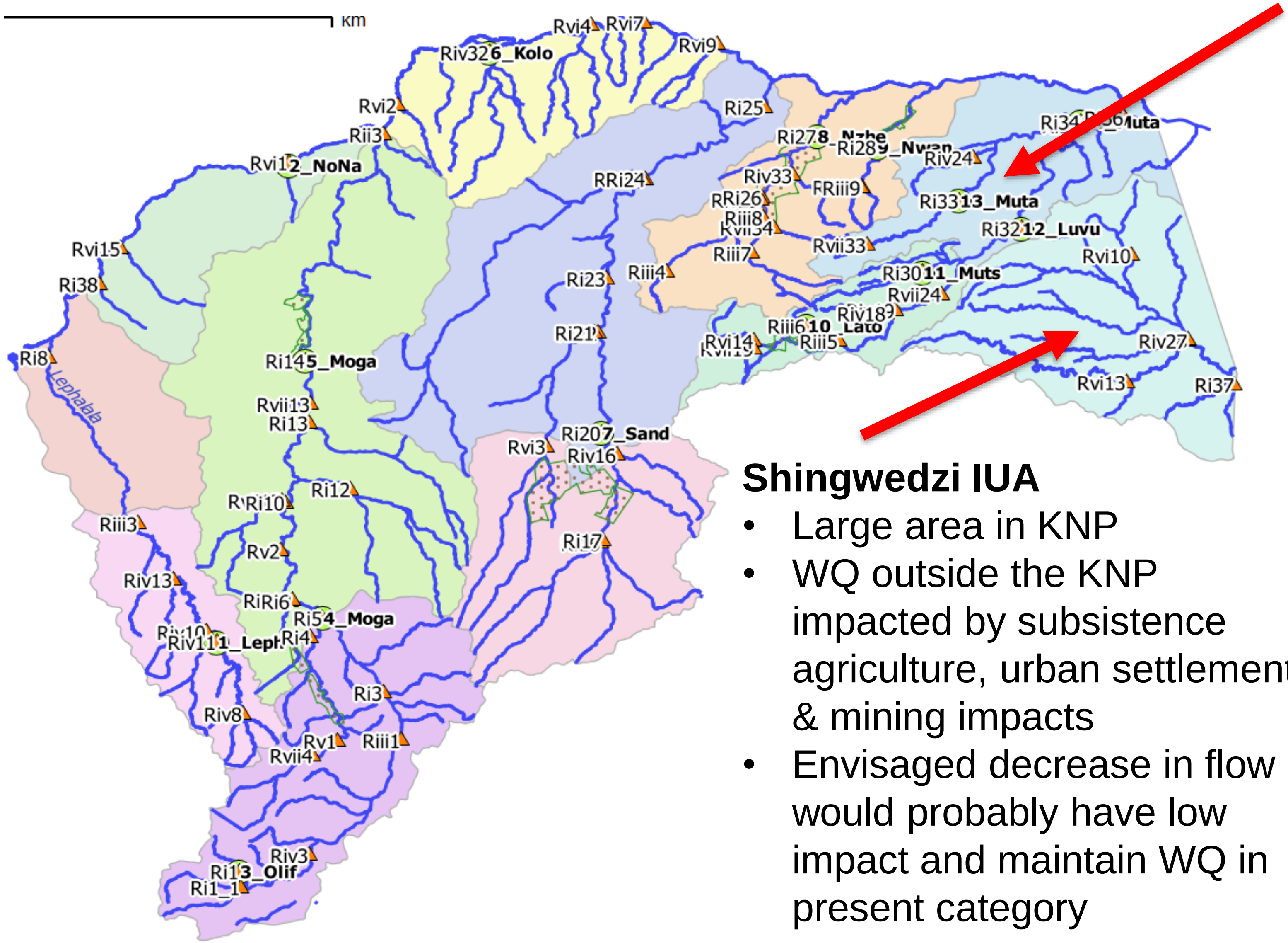
- Upper Sand highly impacted by poorly performing WWTW
- Decrease in flow would aggravate impacts resulting in poorer WQ status
- Lower Sand almost nonperennial, water quality status poor – changes in flow would probably maintain poor status



Nzhelele/Nwanedi IUA

- Overall water quality status upstream of Nzhelele/Nwanedi dams is Acceptable. Affected by dense urban sprawl, subsistence agriculture and WWTWs
- Decrease in flow would result in poorer water quality due to point & nonpoint source impacts
- Downstream of dams WQ impactsed by irrigation return flows. Decrease in flow would result in poorer WQ

LIKELY WATER QUALITY IMPACTS



Upper and lower Luvuvhu IUA

- Upper catchment WQ affected by intensive agriculture
- Middle reaches by urban sprawl and WWTWs
- WQ in Mutale and lower Luvuvhu is in Ideal to Acceptable categories
- Decrease in flow in the upper Luvuvhu would result in poorer WQ category
- Water quality status in Lower Luvuvhu and Mutale would probably remain unchanged due to allocations remaining unchanged

Shingwedzi IUA

- Large area in KNP
- WQ outside the KNP impacted by subsistence agriculture, urban settlements & mining impacts
- Envisaged decrease in flow would probably have low impact and maintain WQ in present category

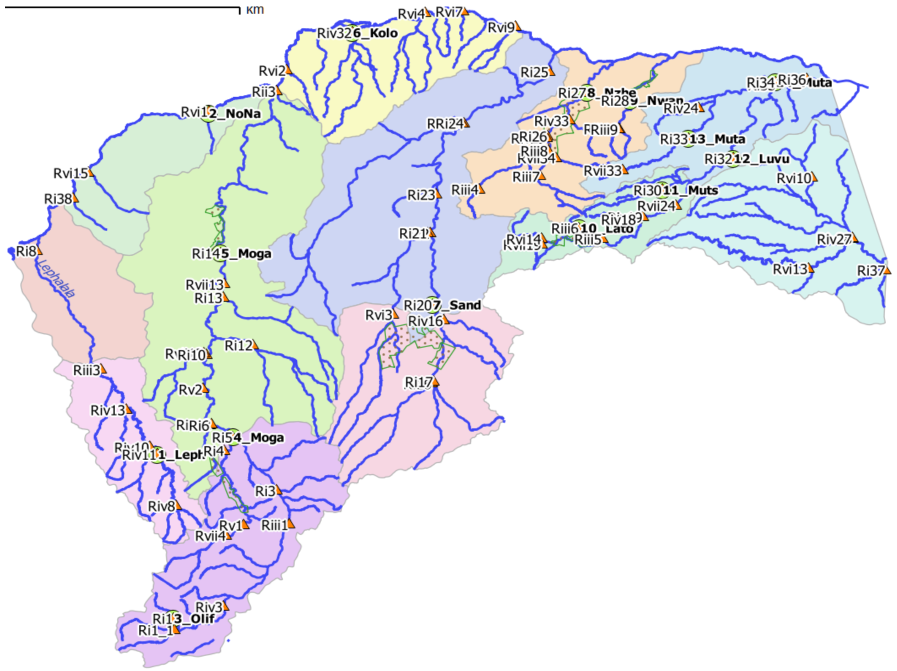
IMPLICATIONS FOR RIVER AND WETLAND HEALTH

APPROACH TO MODELLING RIVER FLOW AND HEALTH

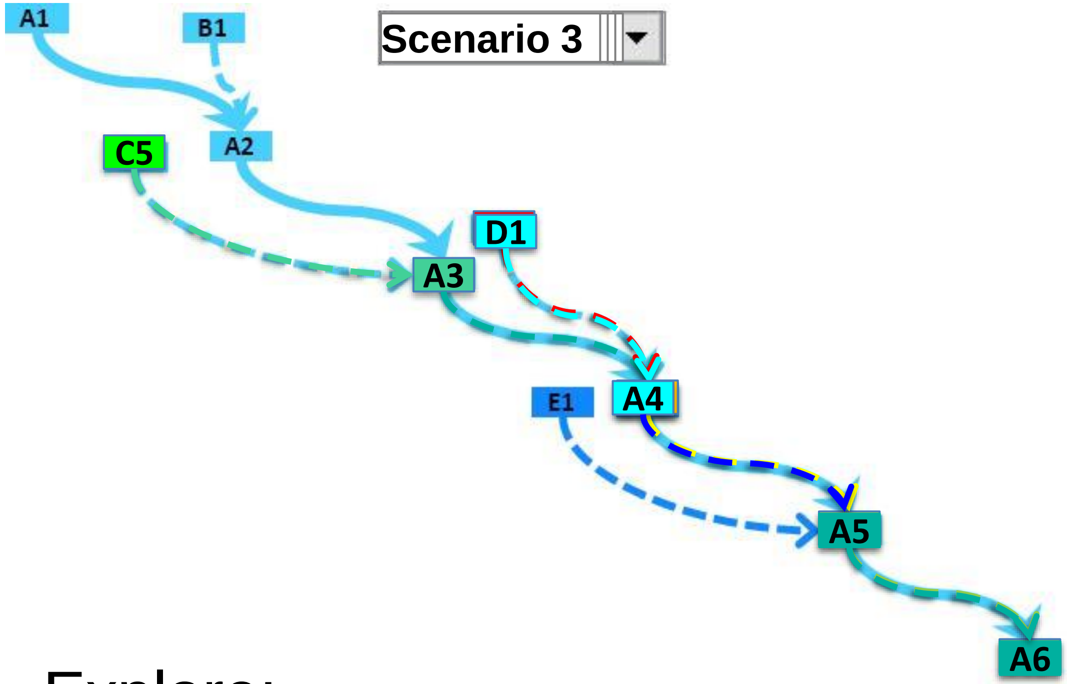
- Created a model in MSExcel with macros to run and view scenarios
- Is a simple water balance model using volumes
- Is interactive…by changing flow at any site, one can view how the flows and condition of that and downstream sites change
- Is called the Balancing Tool

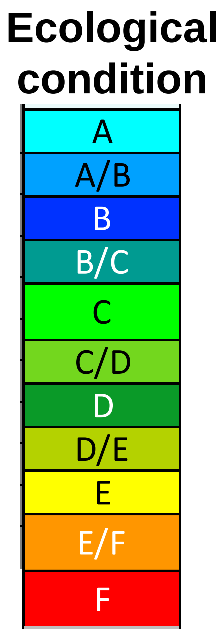
THE BALANCING TOOL

- The BT lays out the flow of water through a number of **nodes** (75) from upstream to downstream, west to east
  - **14 EWR sites** used in the detailed EFlows assessment in DRIFT
  - **61 additional nodes** for broader spatial representation (incl. LIMCOM)
  - 8 of the 75 nodes are stand-alone (no upstream or downstream nodes (including the DRIFT site 2_Rietfontein)
- Changes are based on flow alone



EXPLORING SCENARIOS





Explore:

Ecological states

Changes in flow (annually, seasonally)

Contributions of particular reaches

BACKGROUND DATA / INPUTS (1)

1. List of sites and nodes
2. For all sites for Natural and Present Day (2023):
   a. Average monthly **volumes**
   b. Present **Ecological Status** (PESs), A to F
   c. Associated with the Present volumes are **Flow States** (BFSs), based on seasonal %s of Natural flows, also A to F

So, may have FS of B, but PES of D if there are other e.g. water quality issues.

(a) Linked Average monthly volumes (Natural, Present), (b) PES, (c) PFS

	A	HH	HI	HJ	HK	HL	HM	HN	HO	HP	HQ	HR	HS	HT	HU	HV	HW	HX	HY	HZ	IA	IB	IC	ID	IE	IF	IG	IY	JB
1		NATURAL													CURRENT DAY														
2	Nodes	CUMULATIVE Natural													CUMULATIVE Current														% of Nat
3	66	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL	PES	PFS
4		0.3	0.6	1.5	2.8	4	3.79	2.4	1.4	1.1	0.8	0.47	0.3		10	11	12	1	2	3	4	5	6	7	8	9			
5	Riv8	0.58	1.08	2.45	4.32	6.26	6.01	4.29	2.86	2.06	1.36	0.79	0.49	32.56	0.13	0.31	1.01	2.46	4.91	5.22	3.82	2.51	1.51	0.76	0.20	0.08	22.93	B	D/E
6	Riv11	1.25	2.21	4.94	8.76	12.88	12.51	9.00	6.08	4.37	2.88	1.67	1.07	67.63	0.68	1.32	3.32	6.62	11.30	11.51	8.44	5.63	3.71	2.14	0.95	0.54	56.16	C	C
7	Riv10	0.36	0.44	0.76	1.65	3.46	2.66	2.12	1.44	0.75	0.46	0.42	0.33	14.86	0.19	0.28	0.48	1.25	3.10	2.45	1.97	1.32	0.64	0.34	0.25	0.15	12.43	C	C
8	Riv13	0.31	0.60	0.76	1.87	3.33	2.42	1.27	0.84	0.64	0.53	0.41	0.29	13.27	0.25	0.56	0.72	1.83	3.29	2.38	1.24	0.81	0.62	0.50	0.37	0.25	12.83	B	A/B
9	Riii3	2.59	4.75	8.60	16.24	26.00	22.19	14.90	10.05	7.06	4.93	3.31	2.29	122.93	0.77	2.32	4.56	11.36	22.92	20.47	13.60	8.73	5.51	3.36	1.90	0.88	96.37	D	C/D
10	Ri8	3.00	5.71	10.10	19.31	30.72	24.94	15.94	10.61	7.51	5.36	3.68	2.58	139.46	0.59	2.19	3.87	12.04	25.99	21.61	13.18	7.70	4.48	2.43	1.19	0.43	95.70	C	D/E
11																													
12	Ri38	0.02	0.15	0.28	0.54	0.65	0.30	0.07	0.02	0.01	0.01	0.01	0.01	2.08	0.01	0.09	0.16	0.37	0.51	0.22	0.03	0.00	0.00	0.00	0.00	0.00	1.38	B	D
13	Rvi15	0.02	0.12	0.22	0.43	0.51	0.24	0.05	0.01	0.01	0.01	0.01	0.00	1.64	0.01	0.07	0.13	0.29	0.40	0.17	0.02	0.00	0.00	0.00	0.00	0.00	1.09	B	D
14	Rvi1	0.00	0.00	0.01	0.05	0.07	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.01	0.03	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.14	B/C	C/D
15																													
16	Rvii4	1.16	4.06	5.40	7.53	7.09	3.18	1.97	1.27	1.00	0.98	0.97	0.94	35.56	0.35	2.53	3.24	4.84	5.58	2.27	1.40	0.70	0.33	0.29	0.29	0.26	22.09	E	D
17	Rv1	1.30	4.53	6.02	8.39	7.89	3.54	2.19	1.41	1.11	1.09	1.09	1.05	39.60	0.04	1.00	2.02	2.43	4.02	1.34	0.80	0.24	0.06	0.06	0.06	0.05	12.13	E	E/F
18	Ri4	1.98	5.44	7.18	10.72	12.83	5.89	3.57	2.61	2.15	2.04	1.95	1.81	58.17	0.27	1.45	2.72	3.90	7.95	2.83	1.37	0.70	0.48	0.47	0.39	0.33	22.87	C	E
19	Ri1	0.19	0.62	1.16	1.42	1.66	1.43	0.78	0.32	0.16	0.13	0.12	0.11	8.11	0.14	0.58	1.10	1.36	1.60	1.38	0.74	0.29	0.14	0.11	0.09	0.08	7.61	C	B
20	Ri1-1	0.77	1.68	2.48	3.19	4.01	3.36	2.44	1.79	1.37	1.12	0.89	0.70	23.80	0.50	1.38	2.09	2.80	3.80	3.22	2.37	1.72	1.29	1.01	0.72	0.51	21.41	C	B
21	Riv3	0.50	1.69	3.24	4.06	5.17	4.32	2.23	0.84	0.42	0.34	0.32	0.30	23.44	0.38	1.54	3.00	3.72	4.91	4.04	2.09	0.76	0.36	0.28	0.24	0.21	21.55	C	B
22	Riii1	0.08	1.95	4.18	7.48	9.75	5.34	2.54	0.75	0.32	0.21	0.076	0.019	32.69	0.02	1.20	2.92	5.61	8.29	4.11	1.66	0.33	0.03	0.01	0.00	0.00	24.18	D	D
23	Ri3	0.52	3.01	5.90	11.73	15.81	7.73	3.67	1.55	0.96	0.80	0.61	0.48	52.78	0.04	1.79	3.86	8.60	13.25	5.81	2.27	0.69	0.28	0.21	0.12	0.07	36.99	D	D/E
24	Ri5	2.96	9.70	15.03	27.12	35.42	16.28	8.48	5.06	3.82	3.49	3.13	2.79	133.27	0.45	4.09	8.04	16.47	27.38	10.83	4.55	1.97	1.20	1.07	0.81	0.62	77.49	C	D/E
25	Riv12	2.99	9.85	15.16	27.50	36.28	16.74	8.74	5.26	3.95	3.58	3.18	2.82	136.05	0.45	4.20	8.13	16.81	28.20	11.26	4.79	2.15	1.31	1.14	0.84	0.63	79.92	C	D/E
26	Ri6	0.05	0.62	0.85	2.46	4.41	2.85	1.84	1.10	0.48	0.19	0.10	0.06	15.01	0.00	0.50	0.52	1.89	4.04	2.51	1.66	0.97	0.34	0.09	0.02	0.00	12.55	D	D/E

BACKGROUND DATA / INPUTS (2)

For all sites:

3. Average monthly volumes for EWRs for Ecological Categories A to D from the Revised Desktop Model
   - Generally have PES, one up and one down from the Revised Desktop Model
   - Other Ecological Categories use averages of Desktop results and referring to River Type (Hydrological Index and flow pattern)
4. Average monthly volumes for modelled scenarios

AVERAGE MONTHLY VOLUMES FOR EWRS

	A	DH	DI	DJ	DK	DL	DM	DN	DO	DP	DQ	DR	DS	DT
1														
2	Nodes	D												
3	66	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOT/
4		15	16	17	18	19	20	21	22	23	24	25	26	
5	Riv8	0.06	0.15	0.59	1.34	1.94	1.863	0.73	0.4	0.23	0.15	0.09	0.0637	7.605
6	Riv11	0.49	0.91	1.85	3.51	6.24	6.031	3.85	2.45	1.83	1.3	0.83	0.50478	29.78
7	Riv10	0.08	0.15	0.28	0.81	2.3	1.494	1.08	0.61	0.23	0.09	0.07	0.04067	7.238
8	Riv13	0.03	0.08	0.18	0.58	1.03	0.751	0.22	0.12	0.07	0.06	0.04	0.03807	3.208
9	Riii3	0.29	1.62	2.66	6.09	13.2	9.882	5.61	3.43	2.38	1.53	0.98	0.56725	48.29
10	Ri8	0.14	1.72	3.54	8.34	17.4	11.93	6.87	4.18	2.88	1.97	1.16	0.37203	60.53
11														
12	Ri38	0	0.04	0.07	0.16	0.19	0.091	0.02	0	0	0	0	0.00126	0.594
13	Rvi15	0	0.03	0.06	0.13	0.15	0.072	0.01	0	0	0	0	0.00096	0.47
14	Rvi1	0	0	0	0.01	0.02	0.012	0	0	0	0	0	1.4E-05	0.055
15														
16	Rvii4	0.38	1.79	2.33	3.49	3.11	1.405	1.03	0.65	0.33	0.29	0.29	0.26434	15.35
17	Rv1	0.1	1.51	2.16	3.46	3.13	1.192	0.63	0.24	0.07	0.06	0.07	0.05176	12.67
18	Ri4	0.33	2.4	3.27	5.56	7.34	2.487	1.14	0.66	0.49	0.47	0.39	0.33035	24.88
19	Ri1	0.09	0.22	0.42	0.54	0.76	0.662	0.31	0.12	0.06	0.05	0.04	0.04121	3.301
20	Ri1-1	0.42	0.68	0.96	1.34	1.95	1.406	0.96	0.79	0.66	0.61	0.53	0.44222	10.74
21	Riv3	0.45	0.83	1.23	1.52	2.01	2.051	1.17	0.55	0.37	0.27	0.17	0.1	10.72
22	Riii1	0.01	1.02	1.87	3.92	5.61	2.684	1.01	0.25	0.05	0.01	0	0.00066	16.44
23	Ri3	0.05	1.64	2.75	6.76	9.78	4.058	1.51	0.57	0.29	0.21	0.12	0.07581	27.82
24	Ri5	0.52	4.92	7.73	15.9	22	9.094	3.82	1.99	1.29	1.11	0.83	0.62508	69.78
25	Riv12	0.52	4.54	6.58	14.3	20.4	8.181	3.48	2.01	1.37	1.16	0.86	0.63128	64.05
26	Ri6	0	0.26	0.3	1.2	2.63	1.371	0.81	0.48	0.18	0.03	0.01	0.00262	7.274
27	Rv2	0.46	4.39	6.36	15.9	24.6	9.91	4.04	2.2	1.37	1.1	0.83	0.58779	71.69
28	Rvii12	0.02	0.24	0.12	0.43	1.42	0.555	0.13	0.12	0.09	0.08	0.06	0.03831	3.313

	A	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED	EE	EF	EG
1		CUMULATIVE												
2	Nodes	C/D												
3	66	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOT.
4		28	29	30	31	32	33	34	35	36	37	38	39	
5	Riv8	0.07	0.26	0.73	1.56	2.5	2.42	1.3	0.83	0.56	0.4	0.17	0.08	10.88
6	Riv11	0.5	0.97	1.97	3.72	6.51	6.32	4.08	2.67	1.98	1.4	0.87	0.51	31.49
7	Riv10	0.09	0.18	0.31	0.86	2.38	1.56	1.13	0.66	0.25	0.11	0.09	0.05	7.67
8	Riv13	0.06	0.17	0.23	0.78	1.63	1.07	0.39	0.21	0.14	0.11	0.08	0.06	4.908
9	Riii3	0.63	2.05	3.14	6.74	13.9	10.5	6.14	3.85	2.73	1.81	1.22	0.81	53.55
10	Ri8	0.76	2.24	4.06	8.85	18.1	12.4	7.24	4.56	3.19	2.31	1.56	0.92	66.15
11														
12	Ri38	0.01	0.05	0.1	0.25	0.33	0.13	0.02	0	0	0	0	0	0.9
13	Rvi15	0	0.04	0.08	0.19	0.26	0.1	0.01	0	0	0	0	0	0.704
14	Rvi1	0	0	0	0.02	0.04	0.02	0	0	0	0	0	0	0.092
15														
16	Rvii4	0.61	1.97	2.53	3.68	3.24	1.56	1.14	0.78	0.53	0.5	0.49	0.44	17.47
17	Rv1	0.52	1.9	2.55	3.86	3.5	1.55	1.04	0.62	0.44	0.42	0.42	0.39	17.21
18	Ri4	0.33	2.44	3.34	5.69	7.47	2.62	1.17	0.68	0.49	0.47	0.39	0.33	25.43
19	Ri1	0.1	0.24	0.45	0.58	0.8	0.7	0.34	0.14	0.07	0.06	0.05	0.05	3.584
20	Ri1-1	0.43	0.71	1.01	1.4	2.01	1.47	1.02	0.83	0.69	0.64	0.56	0.45	11.22
21	Riv3	0.48	0.88	1.29	1.6	2.08	2.14	1.23	0.63	0.43	0.31	0.21	0.11	11.38
22	Riii1	0.01	0.96	1.78	3.95	5.77	2.64	0.93	0.2	0.04	0.01	0	0	16.3
23	Ri3	0.19	1.78	2.91	7.02	10.1	4.25	1.7	0.71	0.41	0.35	0.27	0.21	29.87
24	Ri5	0.52	4.97	7.99	16.1	22.2	9.29	3.95	2.03	1.29	1.12	0.83	0.63	70.91
25	Riv12	0.52	4.59	6.84	14.6	20.7	8.45	3.68	2.06	1.38	1.17	0.86	0.63	65.5
26	Ri6	0.01	0.27	0.33	1.26	2.71	1.45	0.86	0.52	0.21	0.06	0.03	0.01	7.712
27	Rv2	0.47	4.49	6.54	16.2	25	10.3	4.28	2.4	1.53	1.23	0.9	0.61	73.92
28	Rvii12	0.02	0.24	0.13	0.44	1.43	0.56	0.14	0.13	0.1	0.09	0.06	0.04	3.37

	A	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET
1					This page contains actual EWRs requested (for REC and sometimes others). The r									
2	Nodes	C												
3	66	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTA
4		41	42	43	44	45	46	47	48	49	50	51	52	
5	Riv8	0.08	0.376	0.877	1.779	3.0496	2.9852	1.872	1.259	0.899	0.644	0.245	0.09	14.16
6	Riv11	0.511	1.024	2.096	3.94	6.7727	6.5995	4.305	2.891	2.135	1.507	0.904	0.52	33.2
7	Riv10	0.097	0.197	0.339	0.921	2.4621	1.6266	1.187	0.704	0.268	0.125	0.108	0.067	8.101
8	Riv13	0.079	0.248	0.282	0.977	2.2252	1.381	0.557	0.308	0.213	0.156	0.107	0.073	6.608
9	Riii3	0.974	2.482	3.622	7.384	14.504	11.201	6.667	4.266	3.086	2.091	1.474	1.058	58.81
10	Ri8	1.386	2.762	4.582	9.356	18.685	12.88	7.608	4.929	3.494	2.644	1.968	1.475	71.77
11														
12	Ri38	0.007	0.061	0.132	0.337	0.4589	0.1784	0.025	0.003	0.001	0.001	5E-04	1E-04	1.205
13	Rvi15	0.004	0.053	0.103	0.261	0.3585	0.1372	0.017	0.003	9E-04	0.001	4E-04	1E-04	0.939
14	Rvi1	0	4E-05	0.007	0.031	0.0571	0.0294	0.006	6E-04	1E-05	6E-06	6E-06	0	0.13
15														
16	Rvii4	0.835	2.151	2.729	3.862	3.3679	1.7223	1.243	0.906	0.732	0.719	0.704	0.619	19.59
17	Rv1	0.948	2.294	2.945	4.259	3.8609	1.9083	1.442	1	0.807	0.781	0.773	0.724	21.74
18	Ri4	0.339	2.468	3.404	5.826	7.5935	2.7607	1.201	0.696	0.493	0.47	0.393	0.33	25.98
19	Ri1	0.115	0.266	0.48	0.613	0.8338	0.748	0.368	0.162	0.083	0.071	0.065	0.061	3.867
20	Ri1-1	0.441	0.746	1.068	1.455	2.063	1.5292	1.069	0.867	0.727	0.673	0.586	0.462	11.69
21	Riv3	0.5	0.923	1.36	1.674	2.1477	2.2196	1.299	0.72	0.49	0.35	0.25	0.11	12.04
22	Riii1	0.012	0.911	1.689	3.984	5.93	2.5905	0.859	0.143	0.026	0.015	0.002	0.002	16.16
23	Ri3	0.334	1.926	3.072	7.27	10.363	4.4406	1.88	0.858	0.54	0.495	0.413	0.338	31.93
24	Ri5	0.52	5.021	8.245	16.39	22.387	9.4782	4.075	2.057	1.299	1.117	0.833	0.627	72.05
25	Riv12	0.524	4.644	7.092	14.85	21.065	8.7252	3.886	2.107	1.393	1.169	0.865	0.637	66.96
26	Ri6	0.02	0.286	0.352	1.307	2.7901	1.5223	0.909	0.554	0.245	0.089	0.048	0.027	8.149
27	Rv2	0.484	4.584	6.724	16.54	25.33	10.677	4.516	2.608	1.698	1.369	0.972	0.639	76.14
28	Rvii12	0.028	0.249	0.129	0.442	1.4381	0.5666	0.143	0.129	0.1	0.091	0.065	0.046	3.427

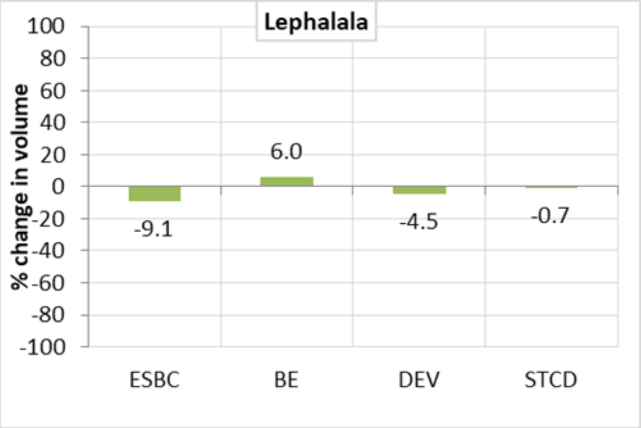
	A	EU	EV	EW	EX	EY	EZ	FA	FB	FC
1										
2	Nodes	B/C								
3	66	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
4		54	55	56	57	58	59	60	61	62
5	Riv8	0.1	0.4	0.9	1.8	3.2	3.1	2	1.3	0.9
6	Riv11	0.6	1.1	2.2	4.1	7	6.8	4.5	3.1	2.2
7	Riv10	0.1	0.2	0.4	1	2.5	1.7	1.2	0.7	0.3
8	Riv13	0.1	0.3	0.3	1	2.3	1.4	0.6	0.4	0.3
9	Riii3	1.5	3	5.3	11	18	15	9.1	5.9	4.2
10	Ri8	1.9	3.5	6.3	13	22	17	9.9	6.4	4.6
11										
12	Ri38	0	0.1	0.1	0.3	0.5	0.2	0	0	0
13	Rvi15	0	0.1	0.1	0.3	0.4	0.1	0	0	0
14	Rvi1	0	0	0	0	0.1	0	0	0	0
15										
16	Rvii4	0.9	2.6	3.5	5.1	4.7	2.2	1.4	0.9	0.7
17	Rv1	1	2.8	3.9	5.7	5.3	2.4	1.6	1	0.8
18	Ri4	0.9	3	3.9	6.5	8.1	3.3	1.7	1.3	1
19	Ri1	0.1	0.3	0.5	0.6	0.9	0.8	0.4	0.2	0.1
20	Ri1-1	0.5	0.8	1.1	1.5	2.1	1.6	1.1	0.9	0.8
21	Riv3	0.5	1	1.4	1.7	2.2	2.3	1.3	0.7	0.5
22	Riii1	0	0.8	1.8	3.9	5.4	2.6	1	0.2	0.1
23	Ri3	0.3	1.8	3.1	7.2	10	4.5	1.9	0.9	0.6
24	Ri5	1.5	5.9	9	17	23	10	4.7	2.8	2.1
25	Riv12	1.4	5.4	7.8	16	22	9.4	4.4	2.8	2.1
26	Ri6	0	0.3	0.4	1.4	2.8	1.6	0.9	0.6	0.3
27	Rv2	1.1	5.2	7.4	17	26	11	5.1	3.1	2.1
28	Rvii12	0	0.3	0.2	0.5	1.5	0.6	0.2	0.1	0.1

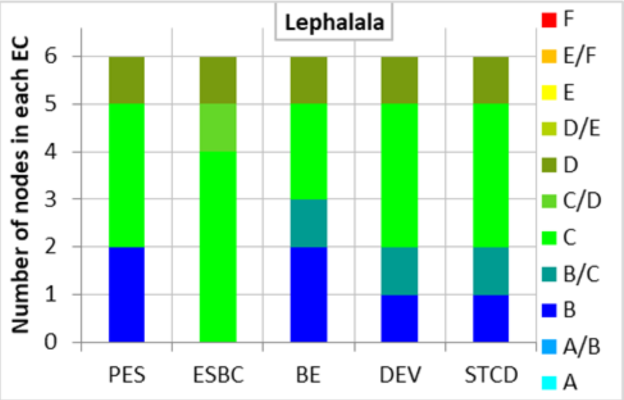
OUTPUTS

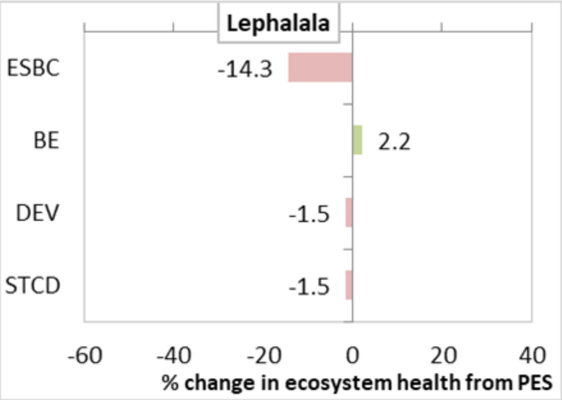
- Outputs are:
  - Tables, map and schematic of resulting Ecological Categories
  - Annual and monthly volumes at each node
  - Annual and seasonal distribution of volume as %s of Natural
  - Deficits and surpluses of volume in delivering the flows required to meet the ECs
  - etc., etc.
- Information from here (volumes, EC) is provided to further model e.g. Yield etc. for the socio-economic assessment

UPPER AND LOWER LEPHALALA IUAs

		Natural	PES		ESBC		BE		DEV		STCD	
Node	River	Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Upper Lephalala IUA												
Riv8	Lephalala	32.56	22.93	B	16.97	C	22.93	B	20.02	B/C	20.02	B/C
Riv11	Lephalala	67.63	56.16	C	45.70	C	51.65	C	53.15	C	53.15	C
Riv10	Melk	14.86	12.42	C	9.77	C	9.77	C	12.22	C	12.22	C
Riv13	Boklandspruit	13.27	12.83	B	7.80	C/D	12.83	B	12.83	B	12.83	B
Riii3	Lephalala	122.93	96.37	D	90.39	D	101.38	D	93.08	D	93.08	D
Lower Lephalala IUA												
Ri8	Lephalala	139.46	95.70	C	98.72	C	115.70	B/C	91.89	C	102.99	C







Riv11 (EWR site 1_Lephalala) REC B/C

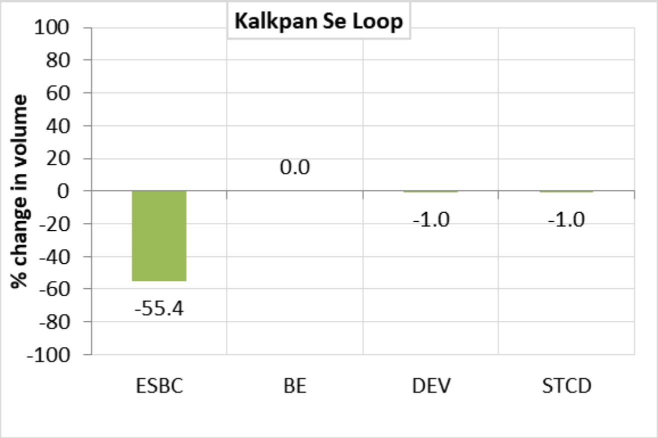
- STCD = C
- Management recommendations
- Remove exotic plants, stock indigenous fish

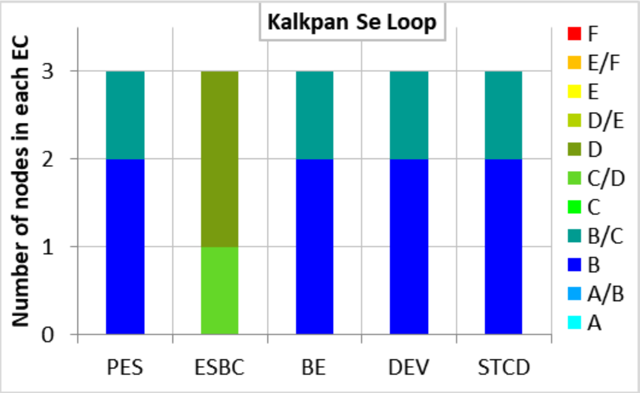
Ri8 (EWR site LEPH-A50H-SEEKO) REC C

- STCD = C

KALKPAN SE LOOP IUA

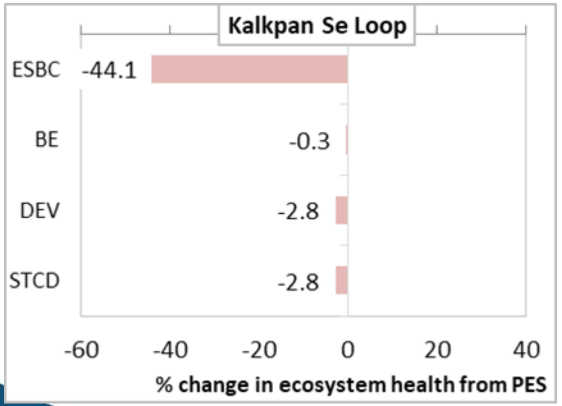
Node	River	Natural	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Ri38	A63C Trib 1	2.08	1.38	B	0.60	D	1.38	B	1.37	B	1.37	B
Rvi15	A63C Trib 2	1.64	1.09	B	0.47	D	1.09	B	1.08	B	1.08	B
Rvi1	Rietfontein	0.19	0.14	B/C	0.09	C/D	0.14	B/C	0.13	B/C	0.13	B/C





Rvi1 (EWR site 2_Rietfontein) REC B/C

- STCD = B/C



UPPER NYL, STERK, MOGALAKWENA IUAs

		Natural	PES		ESBC		BE		DEV		STCD	
Node	River	Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Upper Nyl and Sterk IUA												
Rvii4	Sterk	35.56	22.09	E	28.78	D	29.89	D	22.08	E	28.77	D
Rv1	Sterk	39.60	12.13	E	18.83	D	34.41	B	7.69	E	29.80	B/C
Ri4	Sterk	58.17	22.87	C	23.07	C	49.99	A	18.59	C/D	40.70	A
Ri1	Olifantspruit	8.11	7.61	C	7.51	C	7.61	C	7.61	C	7.61	C
Ri1-1	Nyl	23.80	21.41	C	19.81	C	21.41	C	19.03	C	19.80	C
Riv3	Nyl	23.44	21.55	C	19.85	C	24.52	B/C	21.42	C	22.91	B/C
Riii1	Nyl	32.70	24.18	D	22.48	D	29.72	C	23.88	D	28.10	C
Ri3	Mogalakwena	52.78	36.99	D	35.30	D	47.68	C	43.66	C/D	45.93	C
Ri5	Mogalakwena	133.27	77.49	C	76.00	C	115.30	A/B	79.63	C	104.01	B
Mogalakwena IUA												
Riv12	Mogalakwena	136.05	79.92	C	78.43	C	117.73	A/B	82.00	C	106.38	B
Ri6	Mokamole	15.01	12.55	D	7.27	E	12.55	D	12.53	D	12.53	D
Rv2	Mogalakwena	161.14	100.98	C	85.96	C/D	130.04	B	102.72	C	127.10	B
Rvii12	Klein Mogolak	5.04	3.94	C	2.82	C/D	3.94	C	3.93	C	3.93	C
Ri10	Mogalakwena	165.59	103.86	C	88.33	C/D	147.76	A/B	105.47	C	129.85	B
Ri12	Matlalane	9.65	8.19	C	5.04	D	8.19	C	8.14	C	8.14	C
Ri13	Seepabana	4.71	4.14	D	4.14	D	4.14	D	4.09	D	4.09	D
Rvii13	Mogalakwena	190.98	125.31	C	103.86	D	173.43	B	126.78	C	151.16	B/C
Ri14	Mogalakwena	193.27	114.30	C	92.85	C/D	175.54	A/B	112.72	C	137.10	B/C
Rii3	Mogalakwena	205.52	120.45	C	93.34	C/D	168.50	B	118.46	C	142.84	B/C

Ri1 (EWR site Olifantspruit) REC B/C

- STD = C (clear exotics, limit water use for Nylsvlei)

Ri5 (EWR site 4_Mogalakwena1) REC C

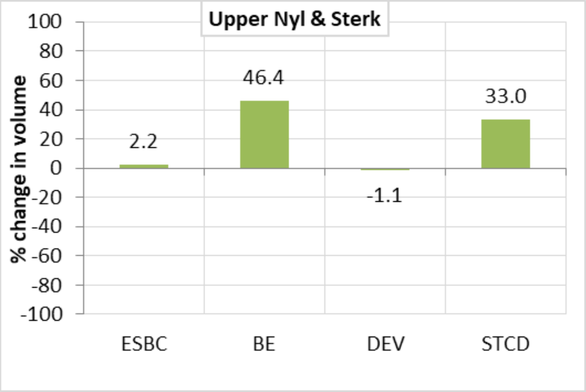
- STCD = B

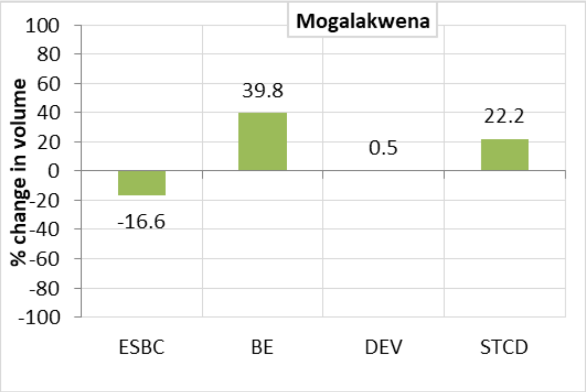
Ri14 (EWR site 5_Mogalakwena2) REC C

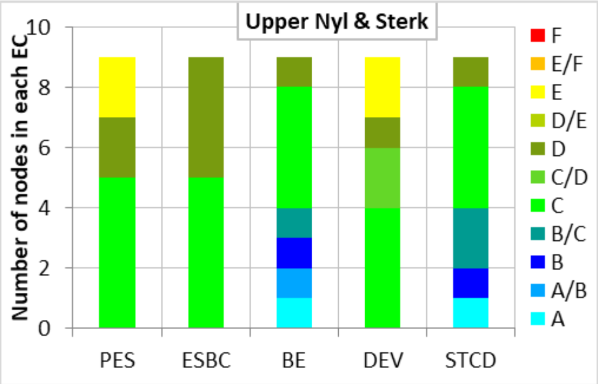
- STCD = B/C

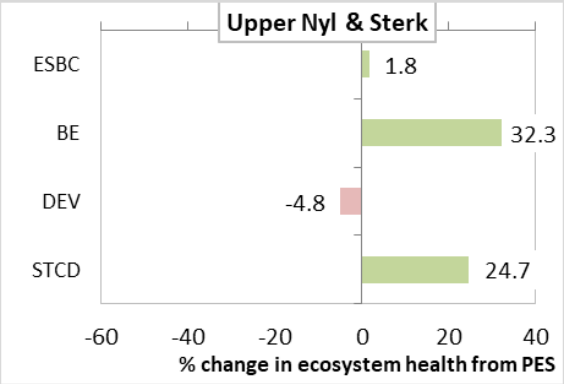
Rii3 (EWR site MOGA-A63D-LIMPK) REC C

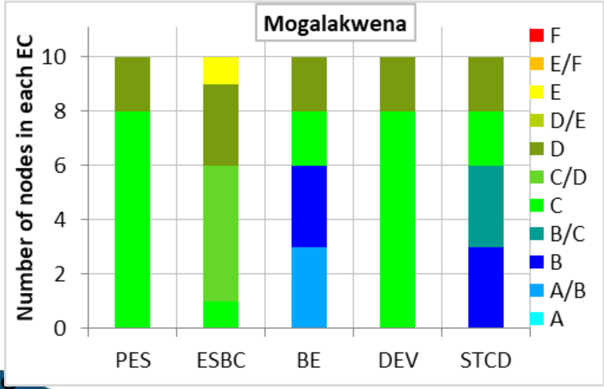
- STCD = B/C

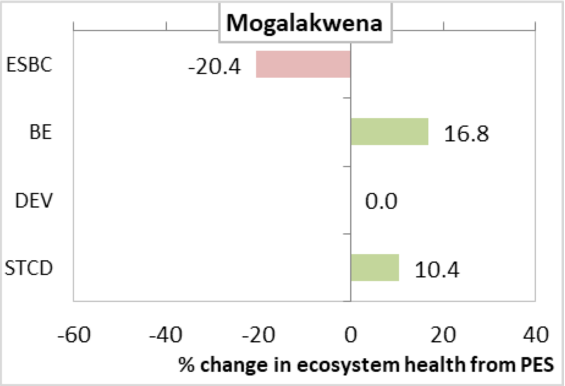






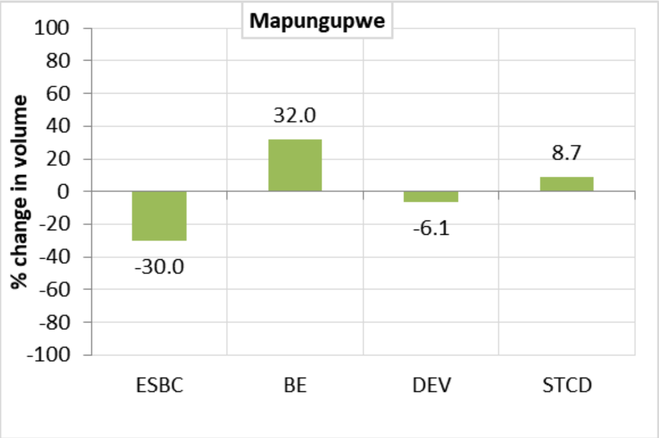


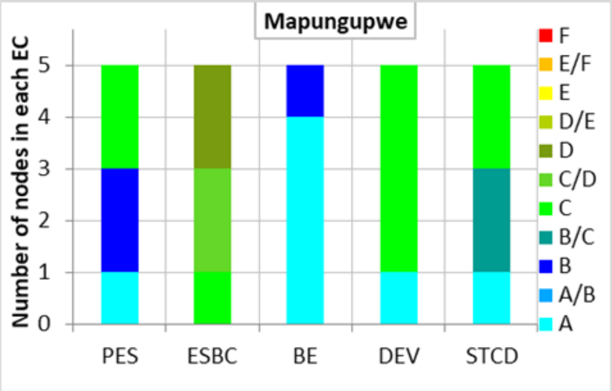


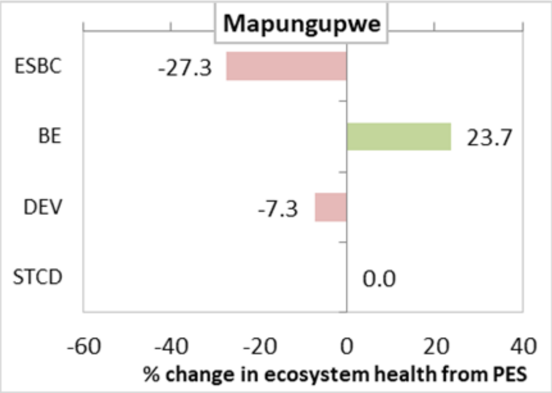


MAPUNGUBWE IUA

Node	River	Natural	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Rvi2	Stinkwater	0.24	0.12	B	0.05	C/D	0.17	A	0.07	C	0.07	C
Riv32	Kolope	2.06	1.05	C	1.03	C	1.56	A	1.00	C	1.24	B/C
Rvi4	Kongoloop	3.14	1.92	C	1.39	D	2.44	B	1.87	C	2.22	B/C
Rvi7	A71L Trib 4	0.20	0.12	B	0.04	D	0.15	A	0.07	C	0.07	C
Rvi9	Soutsloot	1.10	0.67	A	0.22	C/D	0.81	A	0.62	A	0.62	A





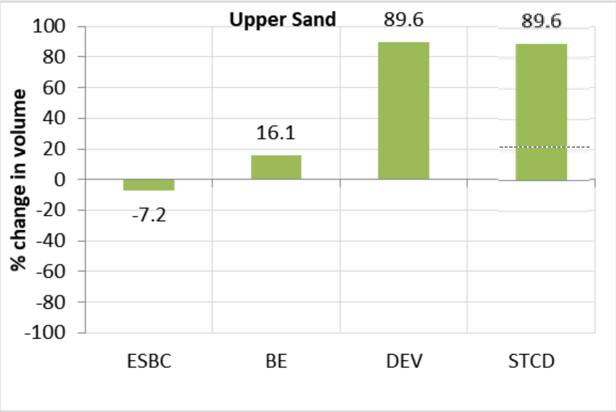


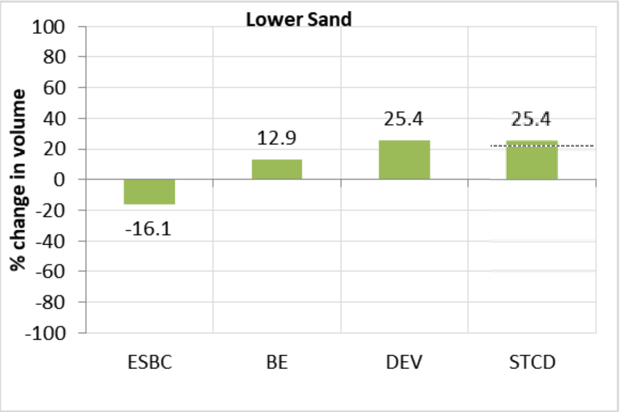
Riv32 (EWR site 6_Kolope) REC B/C

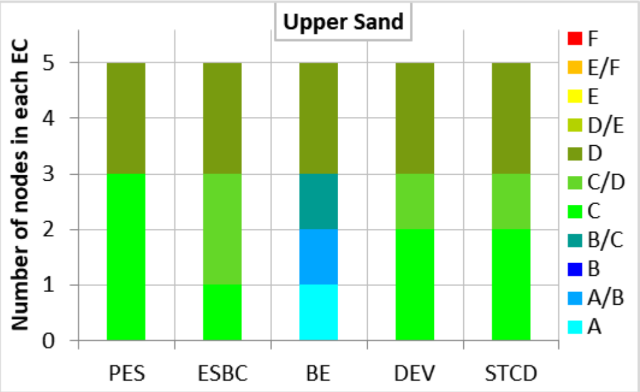
- STCD = B/C
- Curb bank instability (at gabions)
- Monitor recovery of riparian vegetation

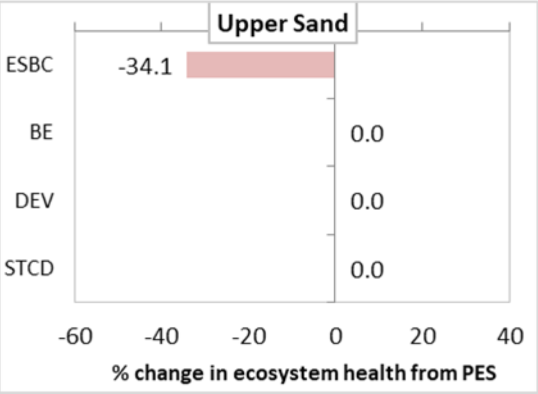
UPPER AND LOWER SAND IUAs

Node	River	Natural	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Upper Sand IUA												
Rvi3	Hout	6.92	3.07	C	2.97	C	5.00	A	2.88	C	2.88	C
Ri21	Hout	11.70	5.88	C	5.16	C/D	8.53	A/B	4.85	C/D	4.85	C/D
Ri16	Sand	11.05	13.11	D	13.11	D	13.11	D	41.17	D	41.17	D
Ri17	Diep	7.83	6.10	D	5.16	D	6.10	D	5.96	D	5.96	D
Riv16	Dwars	2.43	1.51	C	1.13	C/D	1.71	B/C	1.38	C	1.38	C
Lower Sand IUA												
Ri20	Sand	27.45	23.48	C	22.34	C	26.41	B/C	51.25	C	51.25	C
Ri22	Sand	31.59	24.12	C	23.74	C	28.90	B/C	51.78	C	51.78	C
Ri23	Sand	52.35	36.90	C	33.32	C/D	44.01	B/C	35.99	C	35.99	C
Ri24	Sand	62.54	45.82	C	37.64	C/D	50.73	B/C	44.88	C	44.88	C
Riv17	Brak	13.55	12.16	C	8.26	D	12.16	C	12.13	C	12.13	C
Ri25	Sand	85.32	64.16	C	48.18	C/D	71.06	C	63.15	C	63.15	C







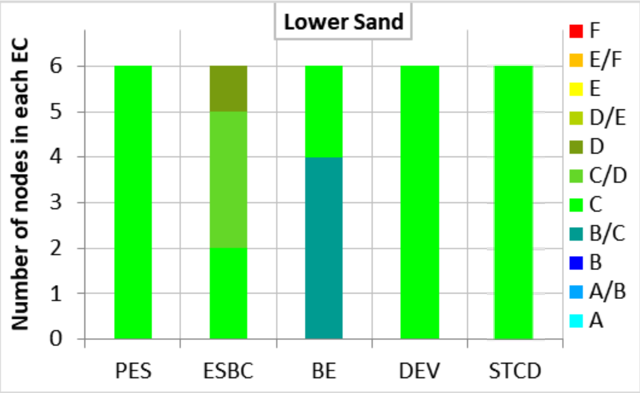


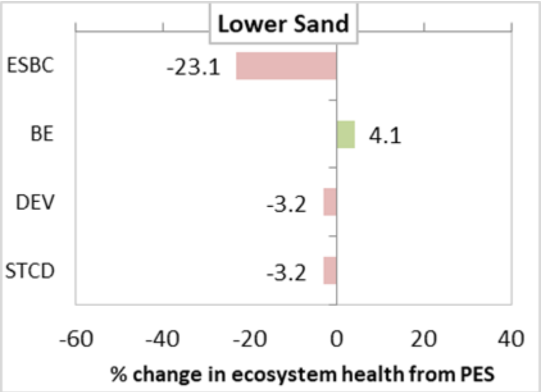
Ri20 (EWR site 7_Sand) REC C

- STCD = C

Ri25 (EWR site SAND-A71K-R508B) REC C

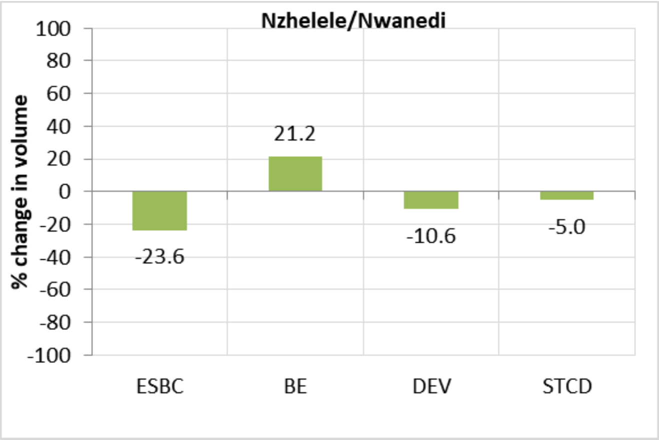
- STCD = C

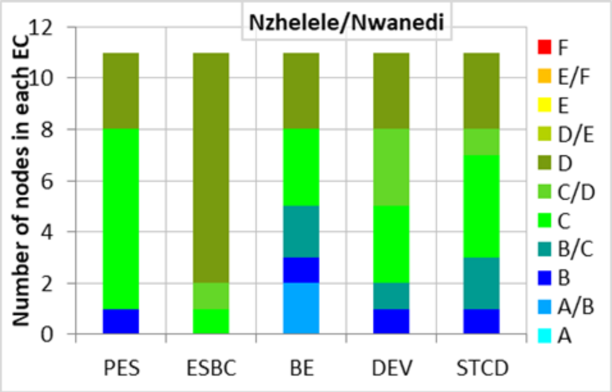


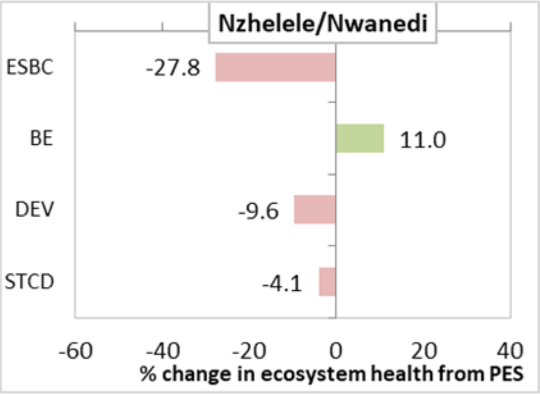


NZHELELE / ṄWANEḒI IUAs

Node	River	Natural	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Riii4	Mutamba	7.14	6.96	C	4.01	D	6.96	C	6.96	C	6.96	C
Riv23	Mutamba	18.61	20.99	C	11.35	D	20.99	C	14.26	C	14.26	C
Riii7	Nzhelele	14.81	13.69	D	11.91	D	13.69	D	13.63	D	13.63	D
Rvii34	Mufungudi	6.68	6.00	D	5.38	D	6.00	D	5.95	D	5.95	D
Riii8	Nzhelele	76.26	56.61	D	43.63	D	56.61	D	53.68	D	49.72	D
Ri26	Nzhelele	94.92	61.08	C	55.53	C	84.48	A/B	54.44	C	64.52	B/C
Riv33	Tshishiru	1.27	0.72	C	0.51	D	0.83	B/C	0.68	C/D	0.68	C/D
Ri27	Nzhelele	99.73	59.60	C	50.02	C/D	87.25	A/B	53.27	C/D	59.12	C
Riii9	Ṅwaneḓi	21.85	17.91	B	8.51	D	17.91	B	14.31	B/C	14.31	B/C
Riii10	Luphephe	10.17	8.08	C	4.74	D	8.57	C	10.47	B	10.47	B
Ri28	Ṅwaneḓi	33.47	26.63	C	15.49	D	31.23	B/C	21.07	C/D	24.84	C







Riv27 (EWR site 8_Nzhelele) REC C

- STCD = C

Riv28 (EWR site 9_Ṅwaneḓi) REC C

- STCD = C

Maintain perennial flow downstream of dams
Flows to be met at the Limpopo River

UPPER AND LOWER LUVUVHU/MUTALE IUAs

Node	River	Natural	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Upper Luvuvhu IUA												
Rvi14	Luvuvhu	22.60	8.18	C	4.62	D	18.95	A	8.17	C	8.17	C
Rvii19	Doringspruit	11.58	6.09	C	2.97	D	9.73	A	6.05	C	6.05	C
Riii5	Luvuvhu	75.34	21.34	C	14.70	C/D	62.86	A	21.24	C	21.24	C
Riii6	Latonyanda	23.55	18.25	C	10.63	D	19.78	C	18.20	C	18.20	C
Riv18	Dzindi	69.63	66.32	D	66.32	D	66.32	D	66.18	D	66.18	D
Riv19	Luvuvhu	172.98	97.62	C	62.43	D	145.21	B	97.36	C	97.36	C
Rvii24	Luvuvhu	247.68	138.06	D	133.63	D	234.44	B/C	104.67	D/E	154.44	D
Ri30	Mutshindudi	55.81	46.03	C	25.94	D	47.17	C	36.69	C	46.94	C
Lower Luvuvhu/Mutale IUA												
Ri32	Luvuvhu	398.53	247.76	C	178.43	D	339.97	A/B	193.21	C/D	259.66	B/C
Rvii33	Mutale	73.89	66.29	C	66.29	C	66.29	C	49.24	C/D	59.05	C
Ri33	Mutale	124.65	114.10	C	78.07	D	114.10	C	90.82	C/D	100.64	C
Riv24	Mbodi	4.49	4.33	D	4.33	D	4.33	D	4.31	D	4.31	D
Ri34	Mutale	154.95	143.64	C	90.21	D	151.04	B/C	119.28	C	129.10	C
Ri35	Luvuvhu	416.74	265.95	B	193.05	B/C	376.34	A	211.40	B/C	277.85	A
Ri36	Luvuvhu	573.18	411.08	C	298.99	D	524.34	B	332.17	C/D	408.43	C

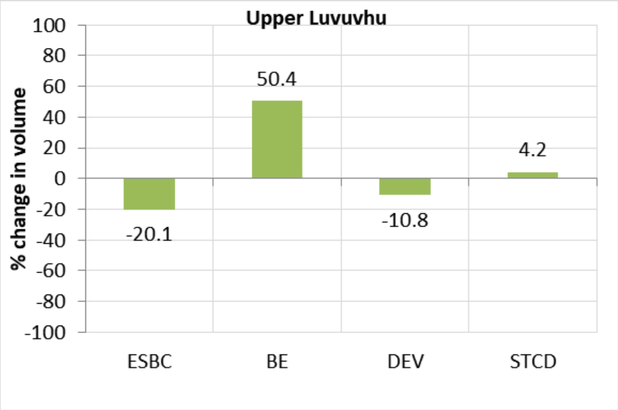
Riii6 (EWR site 10_Latonyanda) REC C
- STCD = C

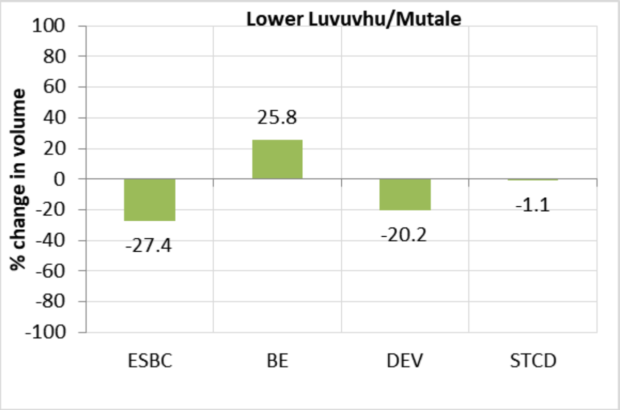
Ri30 (EWR site 11_Mutshindudi) REC C
- STCD = C (remove exotic plant *Mimosa pigra)*

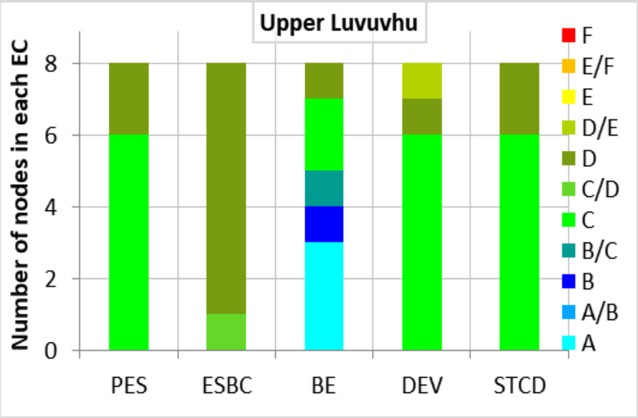
Ri32 (EWR site 12_Luvuvhu) REC B/C
- STCD = B/C (manage WWTW, sand mining, exotic plants)

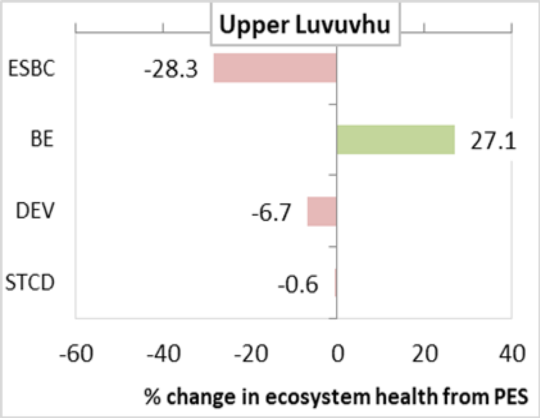
Ri33 / Ri34 (EWR site 13/14_Mutale1&2) REC C
- STCD = C

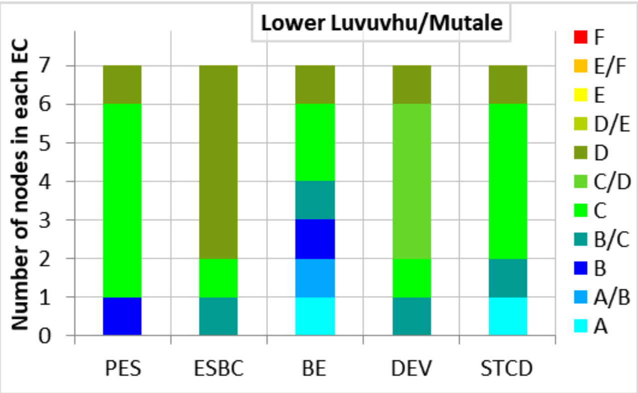
Ri36 (EWR site LUVU-A91K-OUTPO REC C
- STCD = C

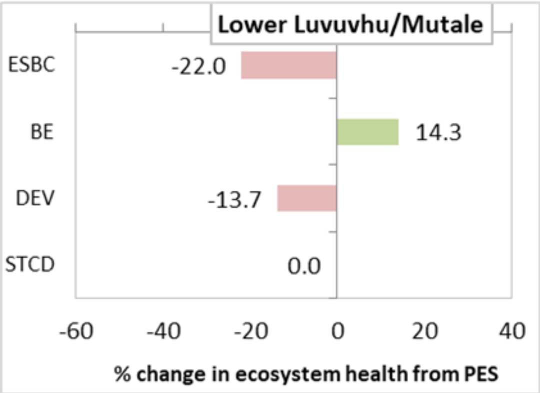






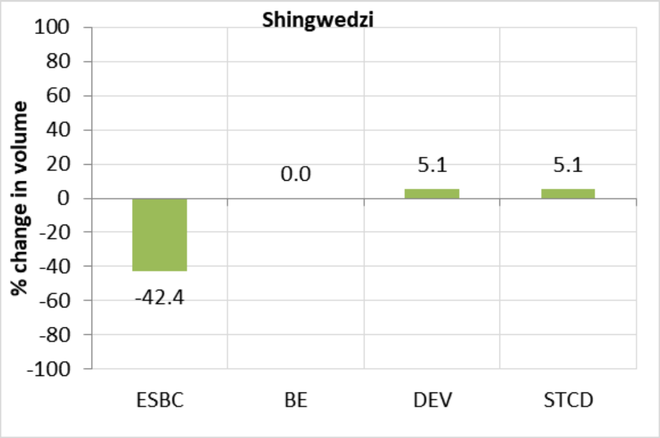


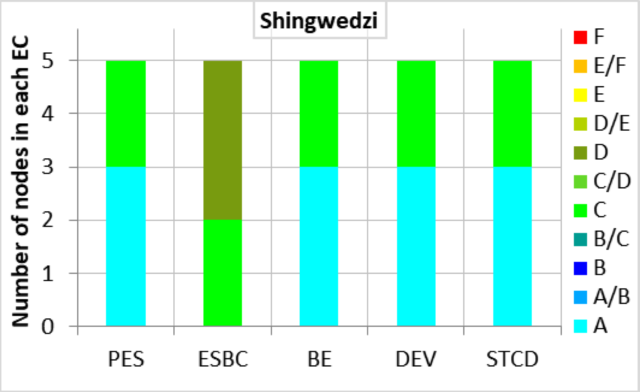


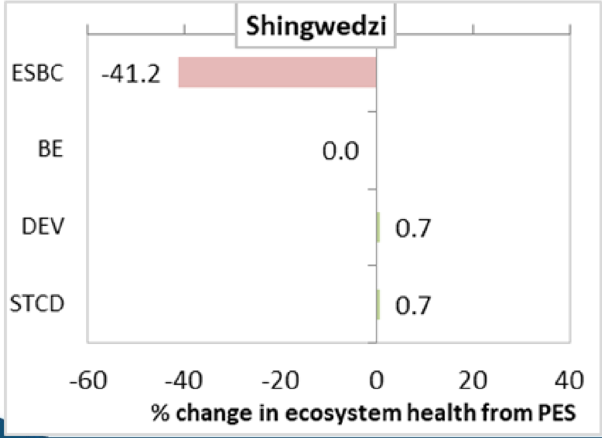


SHINGWEDZI IUA

Node	River	Natural	Current		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Rvi10	Shisha	7.10	7.10	A	2.81	D	7.10	A	7.10	A	7.10	A
Riv28	Mphongolo	39.31	36.43	A	19.48	C	36.43	A	41.10	A	41.10	A
Rvi13	Shingwidzi	18.67	18.14	C	11.86	D	18.14	C	18.06	C	18.06	C
Riv27	Shingwidzi	33.80	33.13	A	19.18	C	33.13	A	33.05	A	33.05	A
Ri37	Shingwidzi	89.63	85.82	C	50.64	D	85.82	C	90.42	C	90.42	C





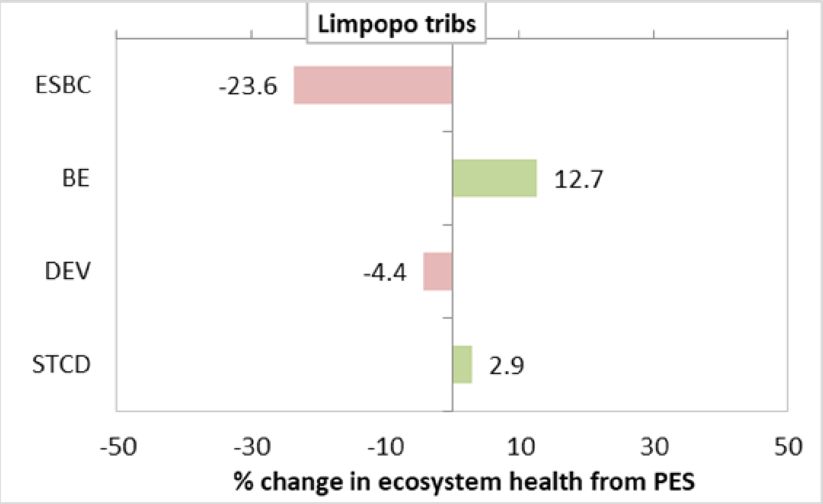


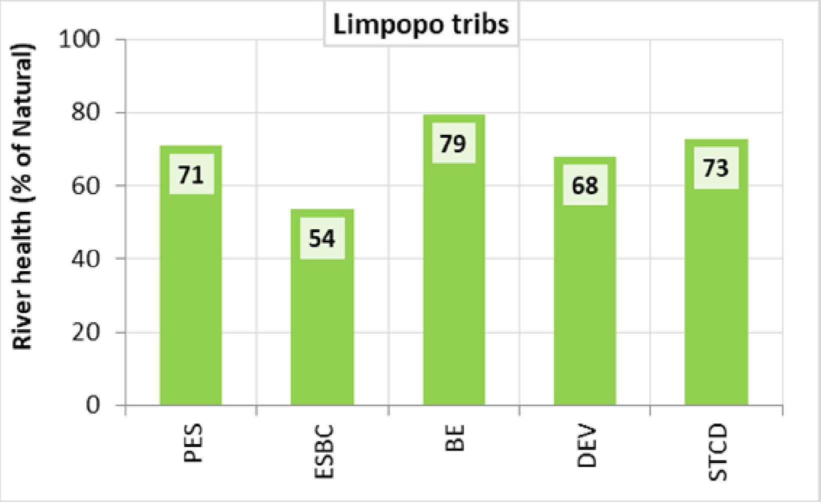
Ri37 (EWR site SHIN-B90H-POACH) REC B/C

- STCD = C

SUMMARY OF RIVER HEALTH OVERALL

- A large decrease for ESBC
- A relatively small decrease for DEV
- A large improvement in BE
- A small improvement in STCD
- PES ~71% of natural





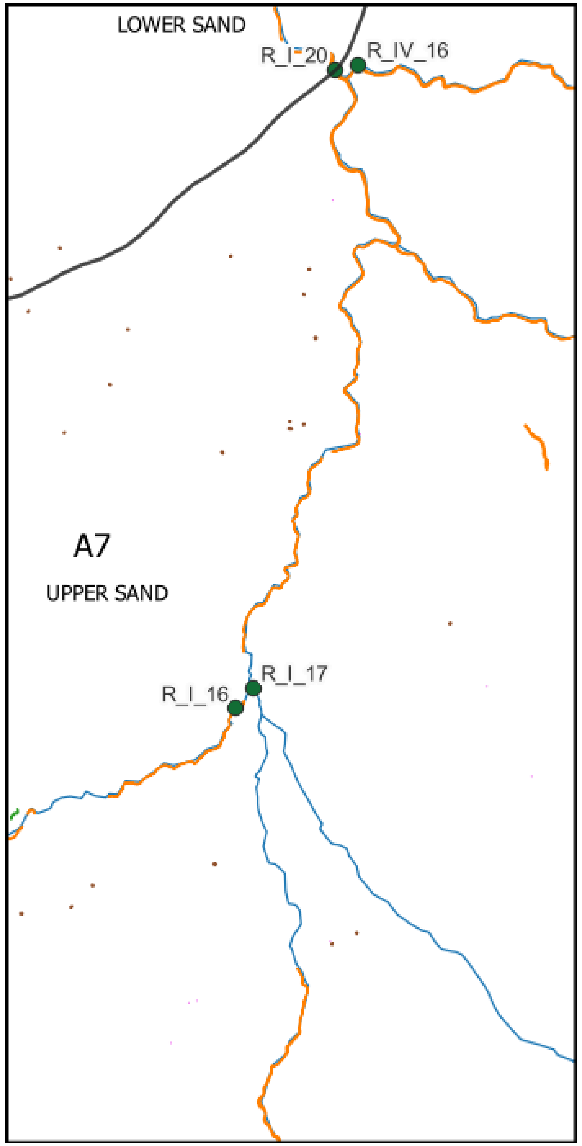
WETLANDS: APPROACH

- Changes in wetland health undertaken at different levels and with differing degrees of confidence / precision.
- At broadest (IUA) scale, qualitative assessments based on expert opinion:
  - Distinction made between different HGM wetland types - respond differently or are affected differently under the scenarios.
  - Depressional, seepage and unchanneled valley bottom wetlands usually more robust to flow scenarios.
  - Riverine wetlands respond similarly to the rivers with which they are associated - these were aligned to applicable river nodes and associated changes in volume (from present day – PES) used to make interpretations

WETLANDS: APPROACH

- Floodplains are affected in complex ways and the two main floodplains (Nyl & Luvuvhu) were modelled in detail resulting in high confidence assessments of ecological response and altered condition to flow regimes, based on:
  - hydrodynamic models underpinning assessments for each floodplain.
  - vegetation mapping with ground-truthing / field verification.
  - extensive information on flow/flood relationships for river and floodplain organisms (plant & animal) used to populate a DRIFT model for each.

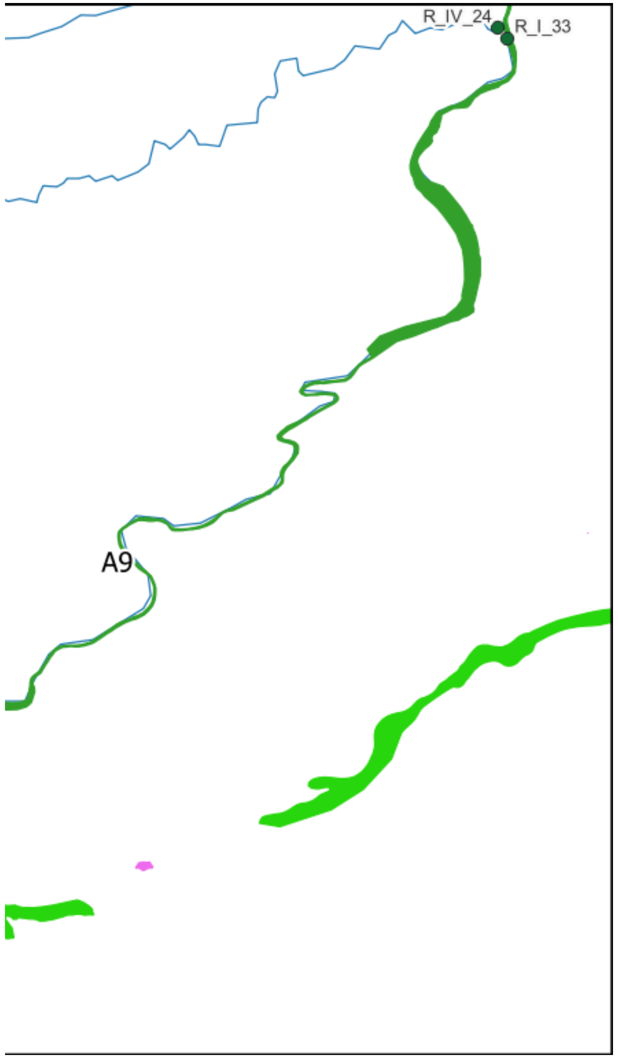
ASSESSMENT OF RIVERINE WETLANDS



- In this example riverine wetlands (orange) are aligned to modelled river nodes Ri16, Ri17 and Riv16 in the Upper Sand IUA for assessment using volume (MCM)

Ref node	River/Wetland HGM	Nat	PES		ESBC		BE		DEV		STCD	
		Vol	Vol	EC	Vol	EC	Vol	EC	Vol	EC	Vol	EC
Upper Sand IUA												
Ri16	Sand	11.05	13.1	D	13.1	D	13.1	D	41.2	D	41.2	D
Ri17	Diep	7.83	6.10	D	5.16	D	6.10	D	5.96	D	5.96	D
Riv16	Dwars	2.43	1.51	C	1.13	C/D	1.71	B/C	1.38	C	1.38	C
	Riverine wetlands			D		D		C		C		C

ASSESSMENT OF CHANNELLED VALLEY BOTTOM WETLANDS



- In this example CVB (green) are aligned to modelled river nodes Ri33 in the Mutale IUA for assessment using volume (MCM)

		Nat	PES		ESBC		BE		DEV		STCD	
Lower Luvuvhu/Mutale IUA												
Node	**River / wetland**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
	Lake Fundudzi			B/C		B/C		B/C		C		B/C
Ri33	Mutale	124.65	114.10	C	78.07	D	114.10	C	90.82	C/D	100.64	C
	Mutale wetlands			C/D		D		C/D		D		C/D

SUMMARY OF PRIORITY WETLANDS

		Nat	PES		ESBC		BE		DEV		STCD	
Upper Nyl and Sterk IUA												
Node	**River / Wetland**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
Riv3	Nyl	23.44	21.55	C	19.85	C	24.42	B/C	21.42	C	22.91	B/C
	Nyl Floodplain			C		C/D		B/C		C		B/C
	Woderkrater			B/C		B/C		B/C		B/C		B/C
Ri3	Mogalakwena	52.78	36.99	D	35.30	D	47.58	C	43.66	C/D	45.93	C
	Nyl Pans			D		D		C		C/D		C
Mogalakwena IUA												
Node	**River / Wetland**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
Ri6	Mokamole	15.01	12.55	D	7.27	E	12.55	D	12.53	D	12.53	D
	Makamole wetlands			B/C		C/D		B/C		B/C		B/C

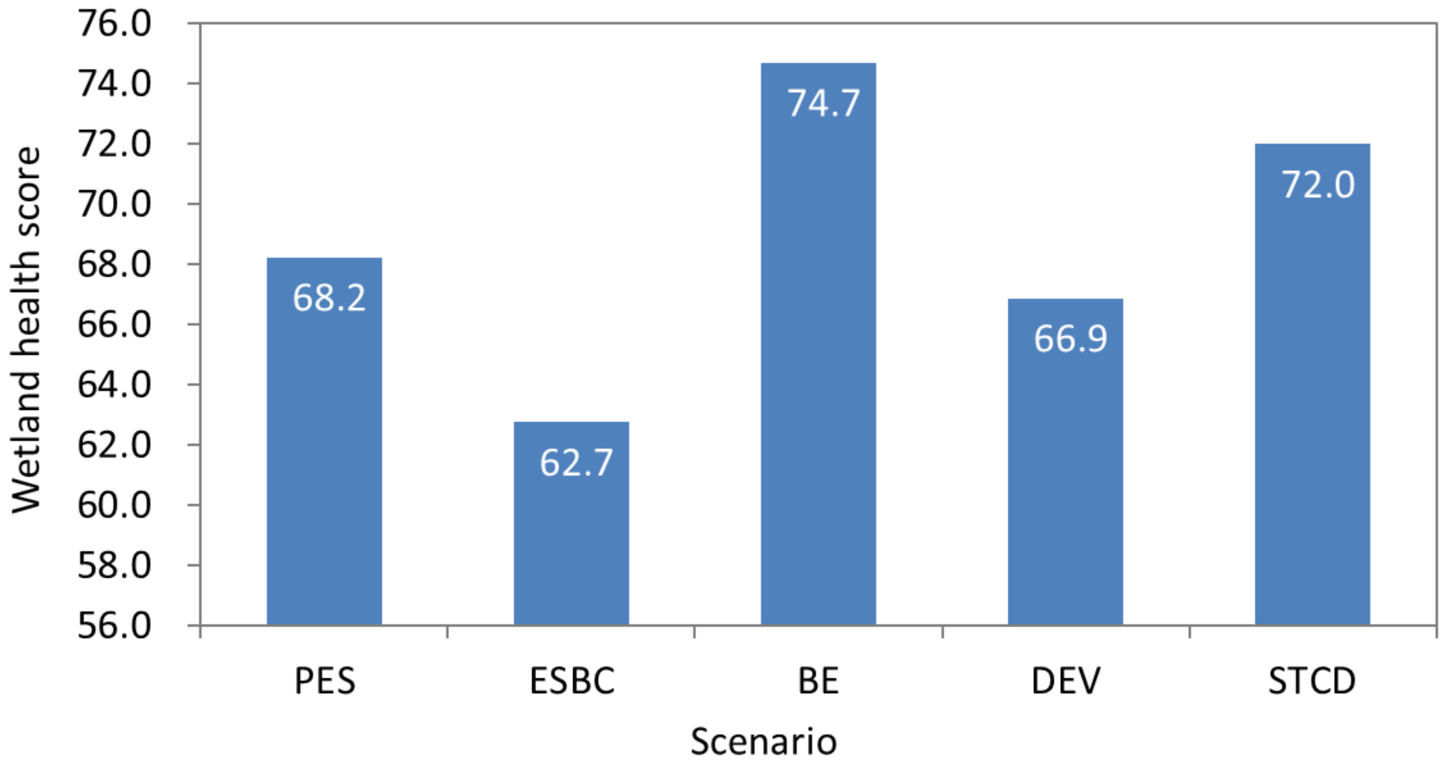
SUMMARY OF PRIORITY WETLANDS (CONT)

		Nat	PES		ESBC		BE		DEV		STCD	
Mapungubwe IUA												
Node	**River / Wetland**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
Riv32	Kolope	2.06	1.05	C	1.03	C	1.56	A	1.00	C	1.24	B/C
	Kolope riverine wetlands			A/B		A/B		A/B		A/B		A/B
	Maloutswa floodplain			C		C		B		C		B/C
	Mapungubwe wetlands			C		C		B/C		C		B/C
Lower Luvuvhu/Mutale IUA												
Node	**River / Wetland**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
	Lake Fundudzi			B/C		B/C		B/C		C		B/C
Ri33	Mutale	124.65	114.10	C	78.07	D	114.10	C	90.82	C/D	100.64	C
	Mutale wetlands			C/D		D		C/D		D		C/D
Ri34	Mutale	154.95	143.64	C	90.21	D	151.04	B/C	119.28	C	129.10	C
Ri35	Luvuvhu	416.74	265.95	B	193.05	B/C	376.34	A	211.40	B/C	277.85	A
Ri36	Luvuvhu	573.18	411.08	C	298.99	D	524.34	B	332.17	C/D	408.43	C
	Luvuvhu floodplain			B/C		D		B		C		B/C

SUMMARY OF PRIORITY WETLANDS (CONT.)

		Nat	PES		ESBC		BE		DEV		STCD	
Shingwedzi IUA												
Node	**River**	**Vol**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**	**Vol**	**EC**
Rvi13	Shingwidzi	18.67	18.14	C	11.86	D	18.14	C	18.06	C	18.06	C
Riv27	Shingwidzi	33.80	33.13	A	19.18	C	33.13	A	33.05	A	33.05	A
	Bububu wetlands			A		B/C		A		A		A
	Peat domes (Malahlapanga)			B/C		B/C		B/C		B/C		B

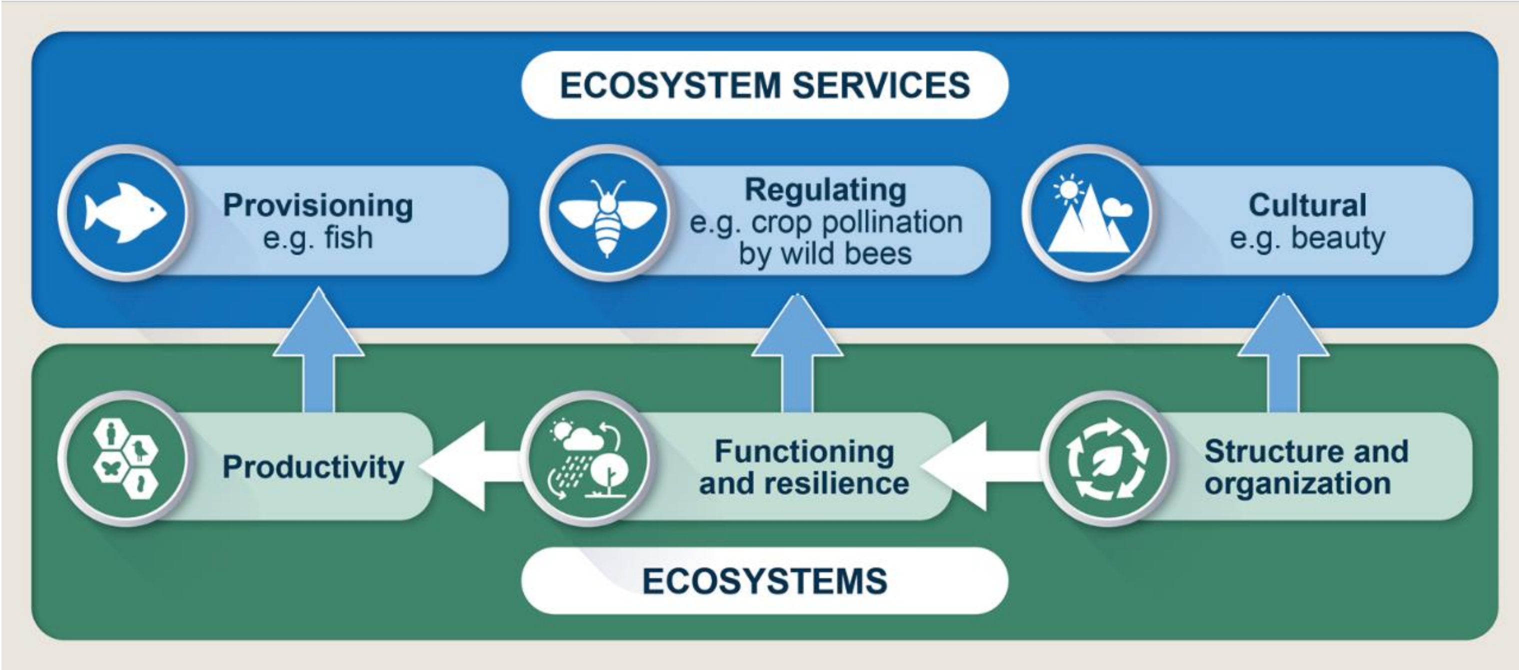
OVERALL COMBINED WETLAND HEALTH SCORE FOR PRIORITY WETLANDS



ECOSYSTEM SERVICES, SOCIETY AND ECONOMY

ECOSYSTEM SERVICES

- These are benefits obtained by people from ecosystems
- Ecosystem services are fundamentally linked to biodiversity
- Biological diversity found in an ecosystem is critically important to its functioning and value

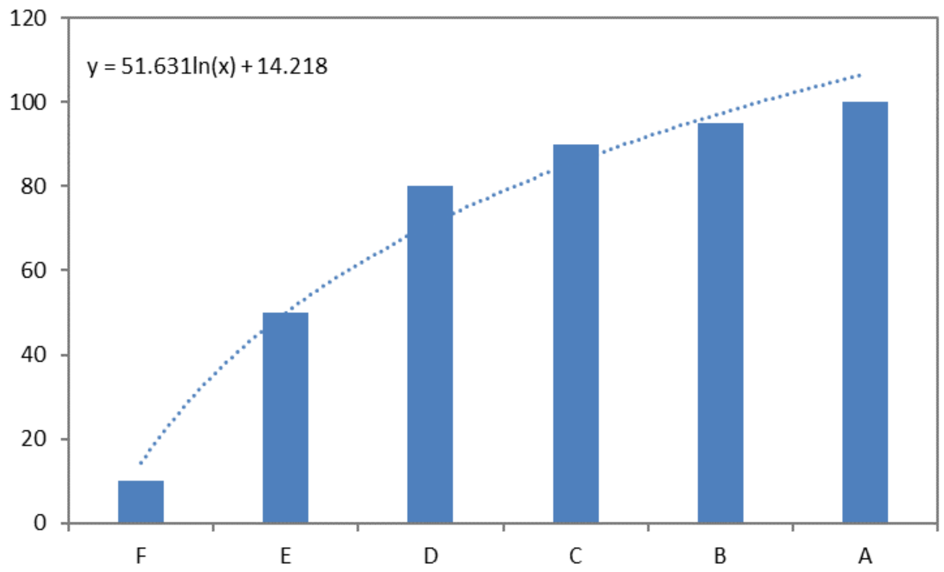


ECOSYSTEM SERVICES

Category of service	Types of values	Description of EGSA	Independent variables related to river and wetland condition
Goods (Provisioning services)	Harvesting of wild plant and animal resources	Wild plants and fish collected on a subsistence basis for consumption	Overall health Freshwater fish abundance Wetland plant abundance
	Instream water use	Instream water used by households for basic human needs and for irrigation of small home gardens.	Water quantity and quality
Services (Regulating services)	Carbon storage and sequestration	Contribution to the amelioration of climate change damages through sequestration of carbon by riverine and wetland habitats	Overall health Extent of riparian vegetation Water quantity and quality
Attributes (Cultural services)	Nature-based tourism	A river or wetland’s contribution to recreation/tourism appeal of a location	Overall health Water quality

ASSESSING CHANGE IN ECOSYSTEM SERVICES

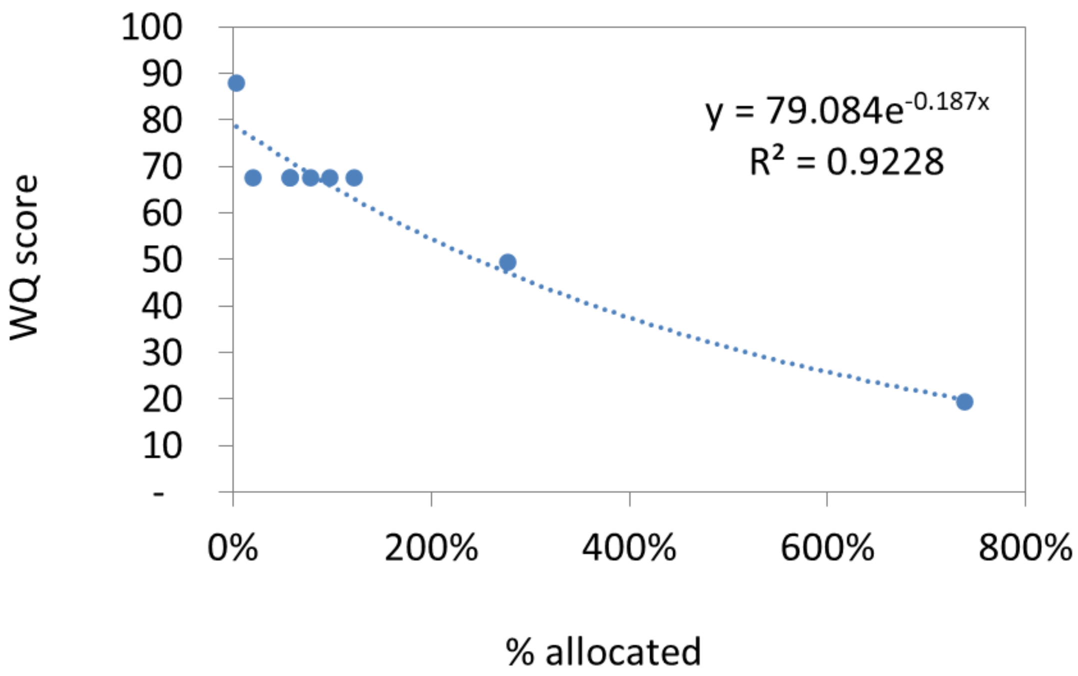
- Baseline valuation of ecosystem services – spatially explicit, focusing on main ecosystem services
- Estimation of the relationships between aquatic ecosystem health and supply of ecosystem services – produced simple models
- Models used to estimate changes under each scenario, at the level of IUAs.

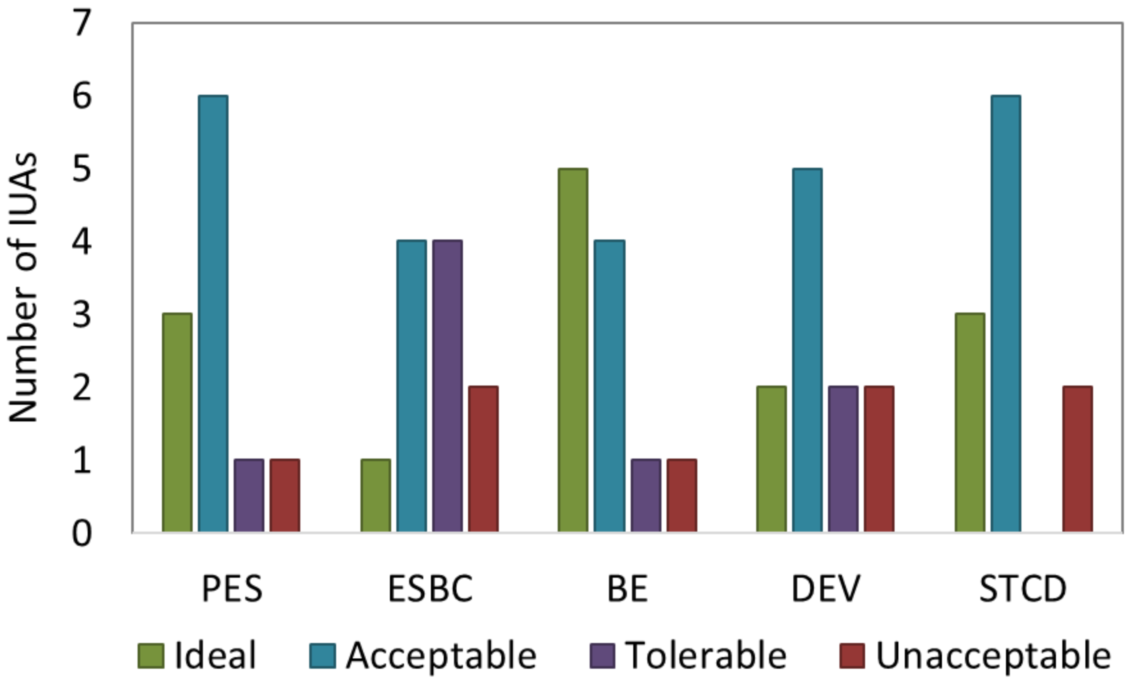


Tourism		Scenario Ecological Category					
		A	B	C	D	E	F
PES	A	1.0	1.0	0.9	0.8	0.5	0.1
	B	1.1	1.0	0.9	0.8	0.5	0.1
	C	1.1	1.1	1.0	0.9	0.6	0.1
	D	1.3	1.2	1.1	1.0	0.6	0.1
	E	2.0	1.9	1.8	1.6	1.0	0.2
	F	10.0	9.5	9.0	8.0	5.0	1.0

INCORPORATING WATER QUALITY INTO THE ANALYSIS

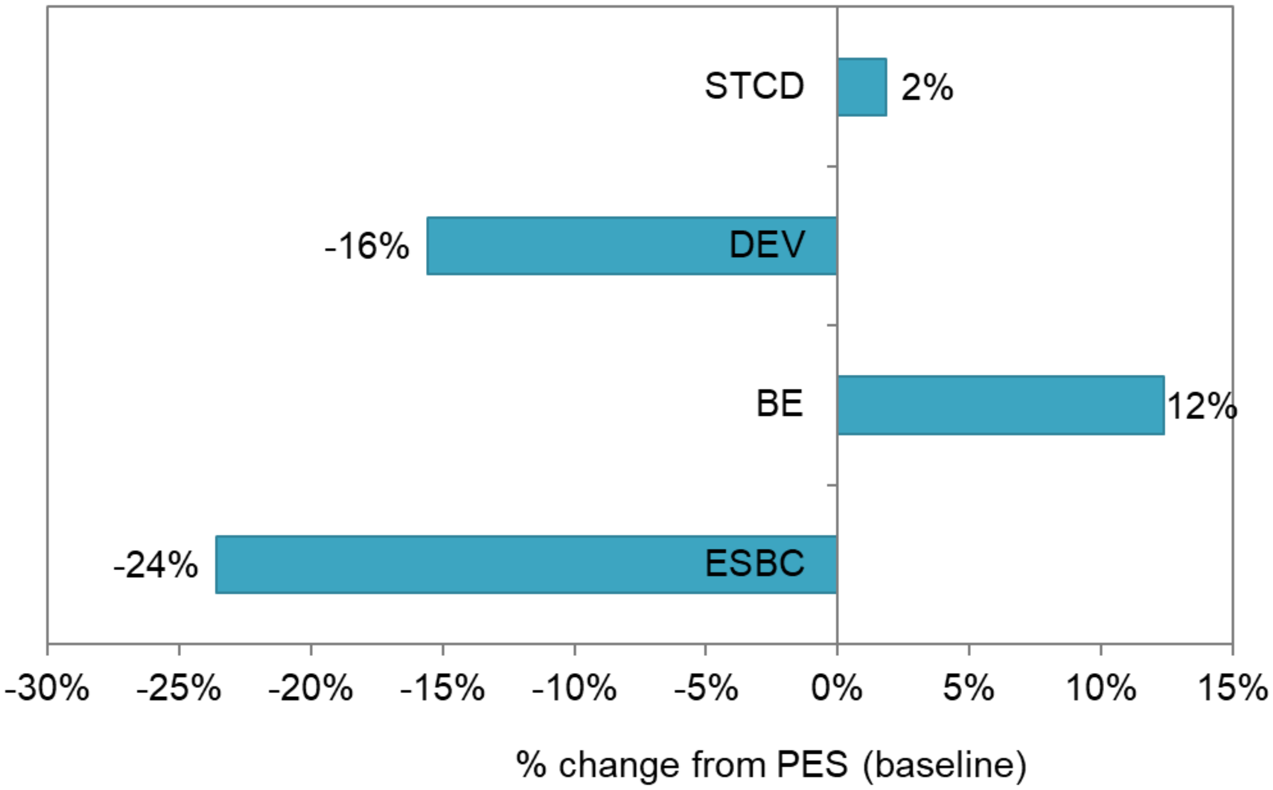
- WQ incorporated into the analysis using simple model





CHANGE IN ECOSYSTEM SERVICES

- Value of ecosystem services to increase under BE and STCD scenarios
- Significant losses under the DEV and ESBC scenarios
  - – Negative impact on livelihoods and wellbeing, poorest most affected.

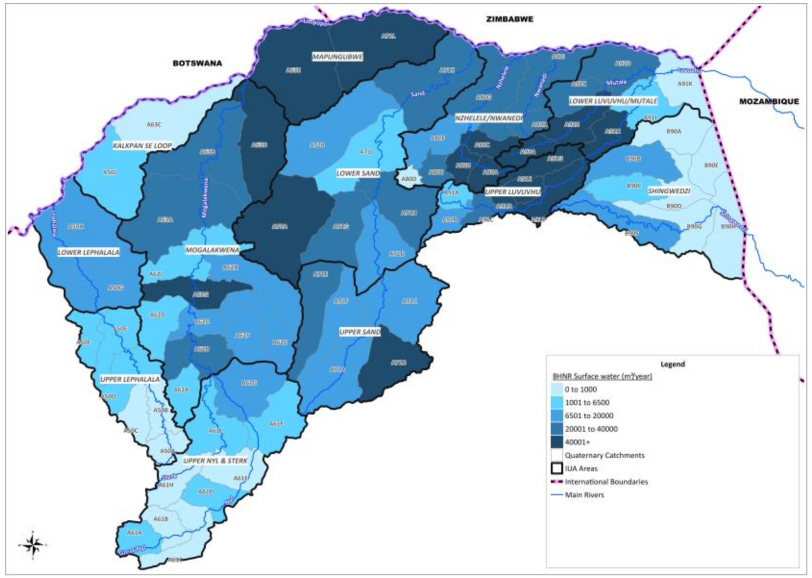


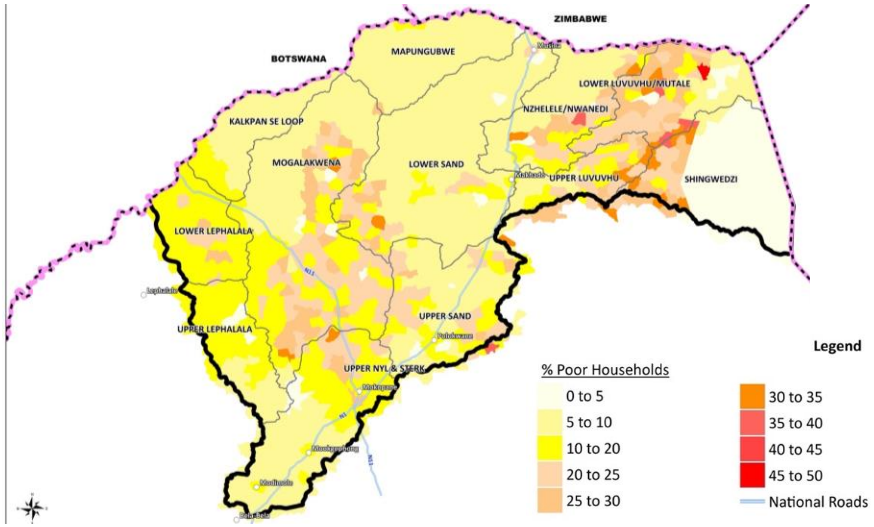
ASSESSING ECONOMIC CONSEQUENCES

- Main water using sectors considered:
  - Urban and domestic use
  - Industry and mining
  - Irrigation agriculture
- Nature-based tourism - affected by changes in ecosystem health
- Costs saved or incurred through having to supply water to meet growing demands or to meet EWR requirements.
- Losses or gains in value added to the economy (= contribution to GDP):
  - Output: productivity of water by sector (value per m^3 of water)
  - Limpopo Social accounting matrix multipliers to get change in value added

ASSESSING SOCIAL CONSEQUENCES

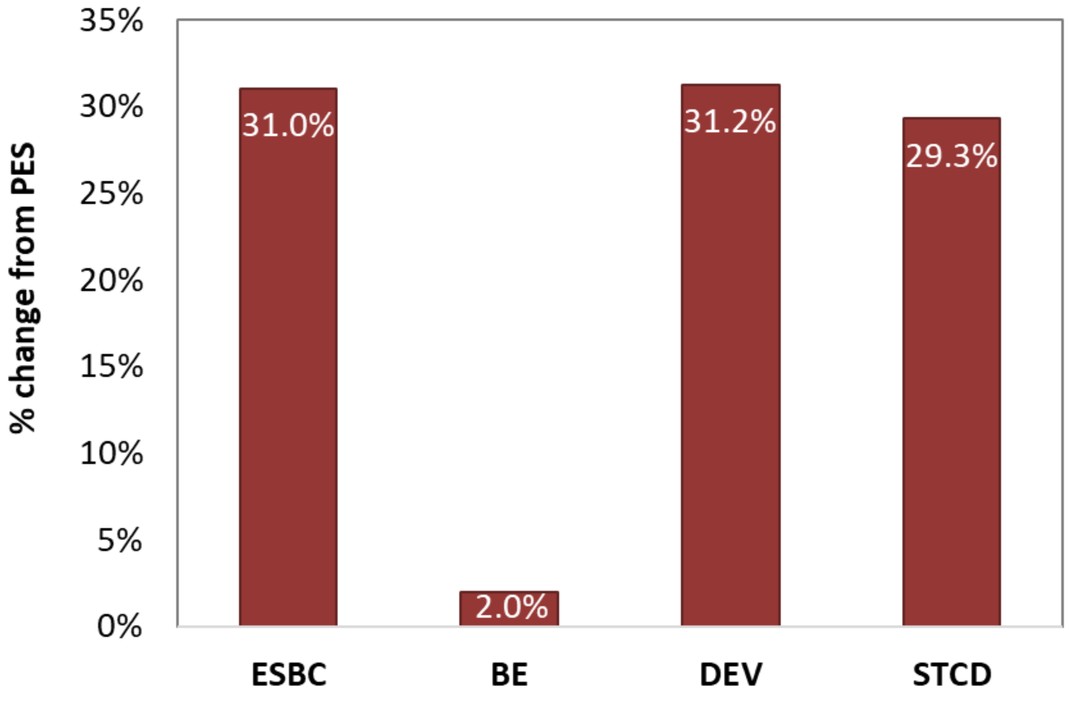
- Availability of water and other aquatic resources for use by vulnerable rural households.
  - Change in value of instream water use and harvested resources
- Household income
  - Multipliers from the Limpopo Social Accounting Matrix
- Climate impacts
  - Changes in carbon stocks, meeting national climate targets





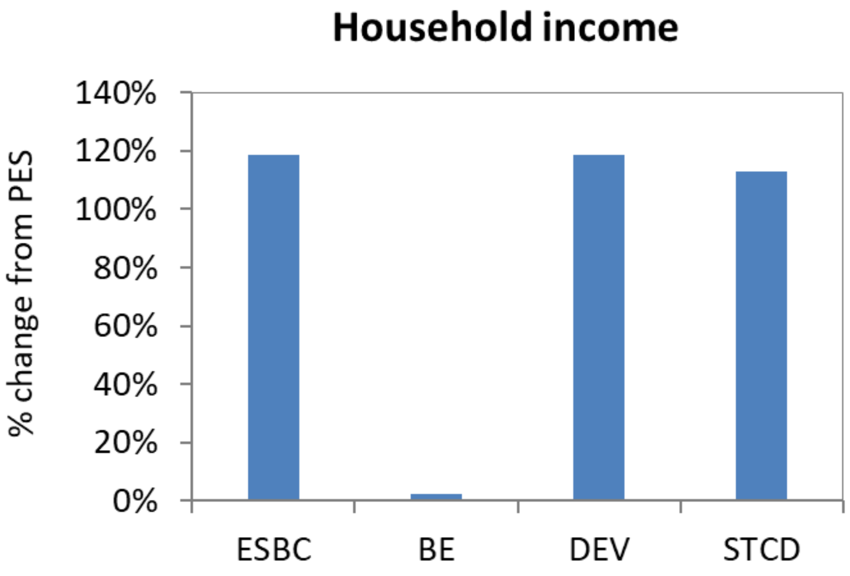
SOCIO-ECONOMIC CONSEQUENCES

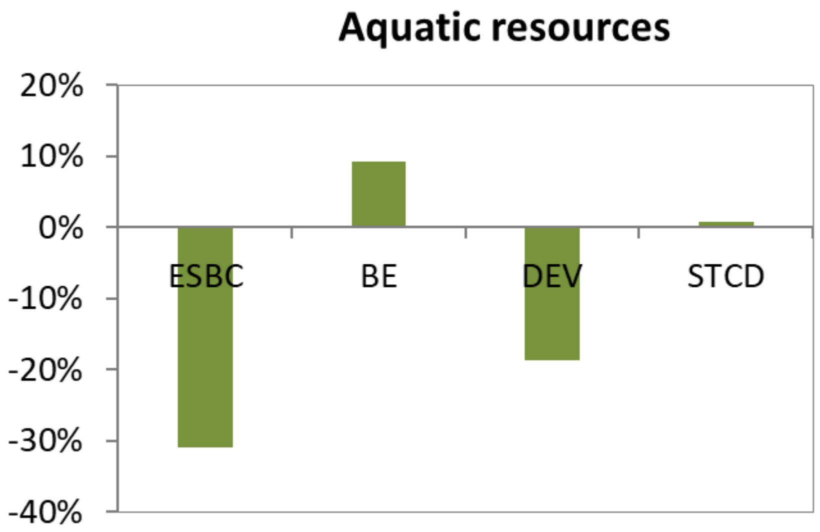
- Total costs to meet shortfalls in terms of increased demands & EWR requirements highest under STCD, ESBC
- Value added to economy highest under DEV, ESBC then STCD
- Overall economy gains highest under DEV

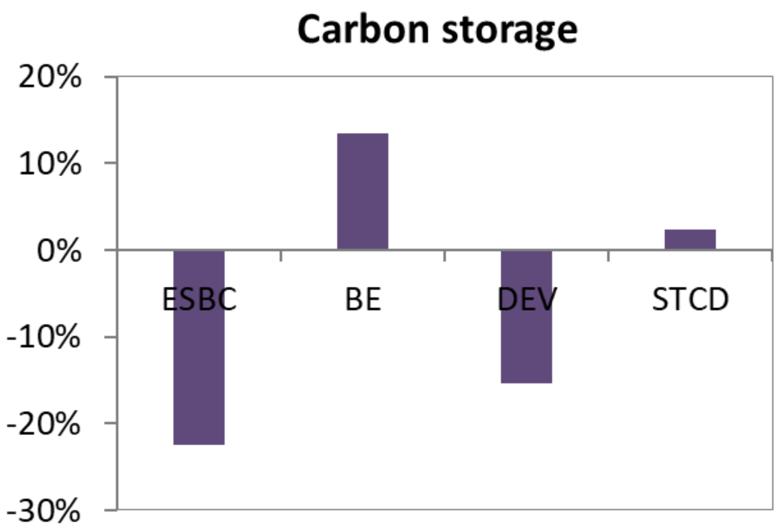


ECONOMIC GAINS

SOCIO-ECONOMIC CONSEQUENCES

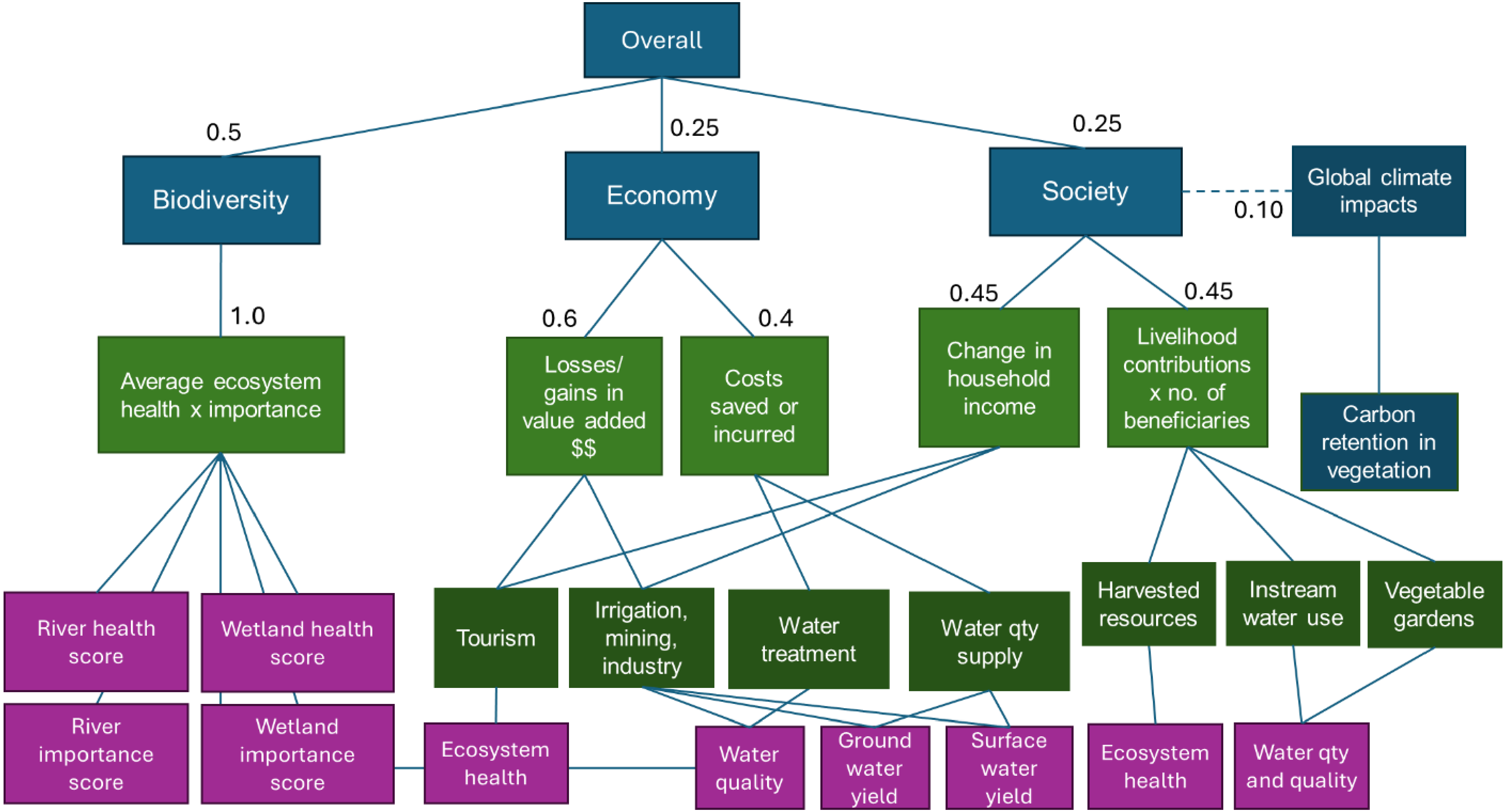






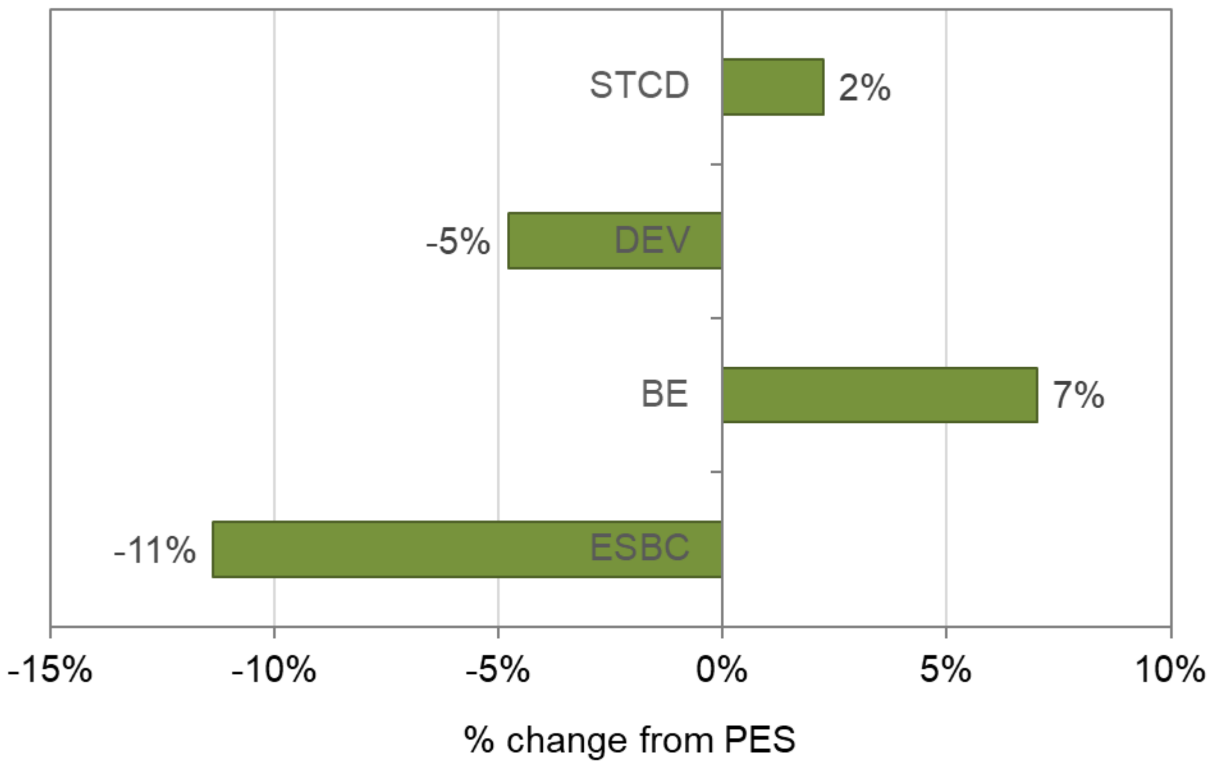
OVERALL COMPARISON OF SCENARIOS

MULTICRITERIA ANALYSIS

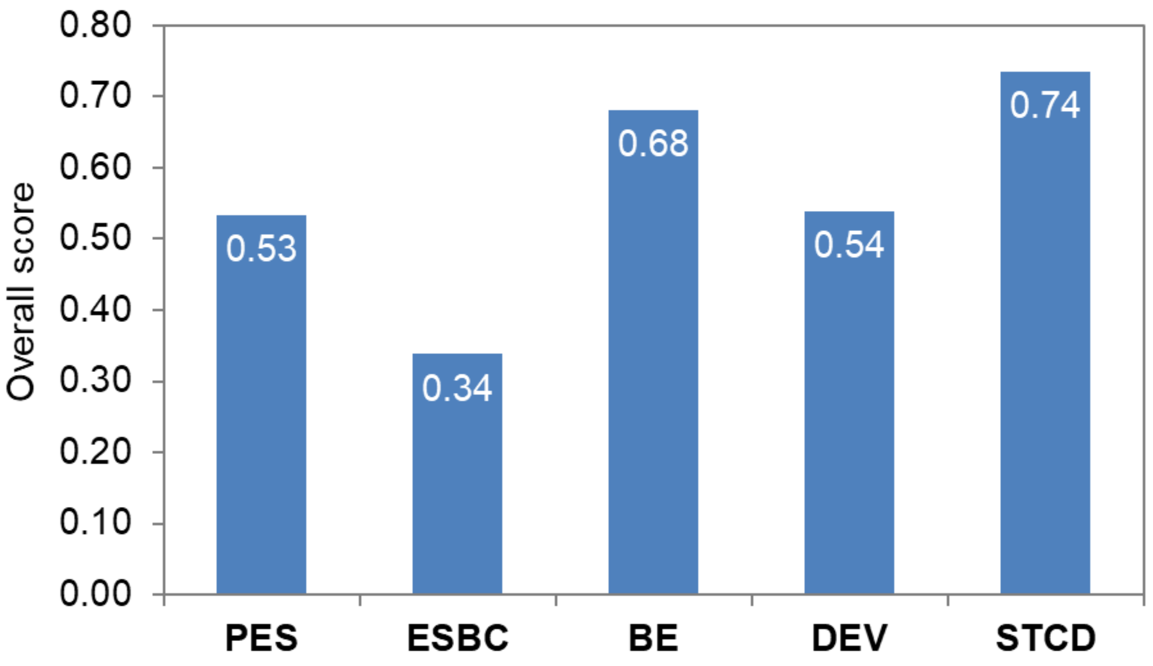


BIODIVERSITY

- Combined ecosystem health and importance
  - Rivers
  - Wetlands
- Similar changes as seen under the ES assessment, as expected.
- Weighted 0.5



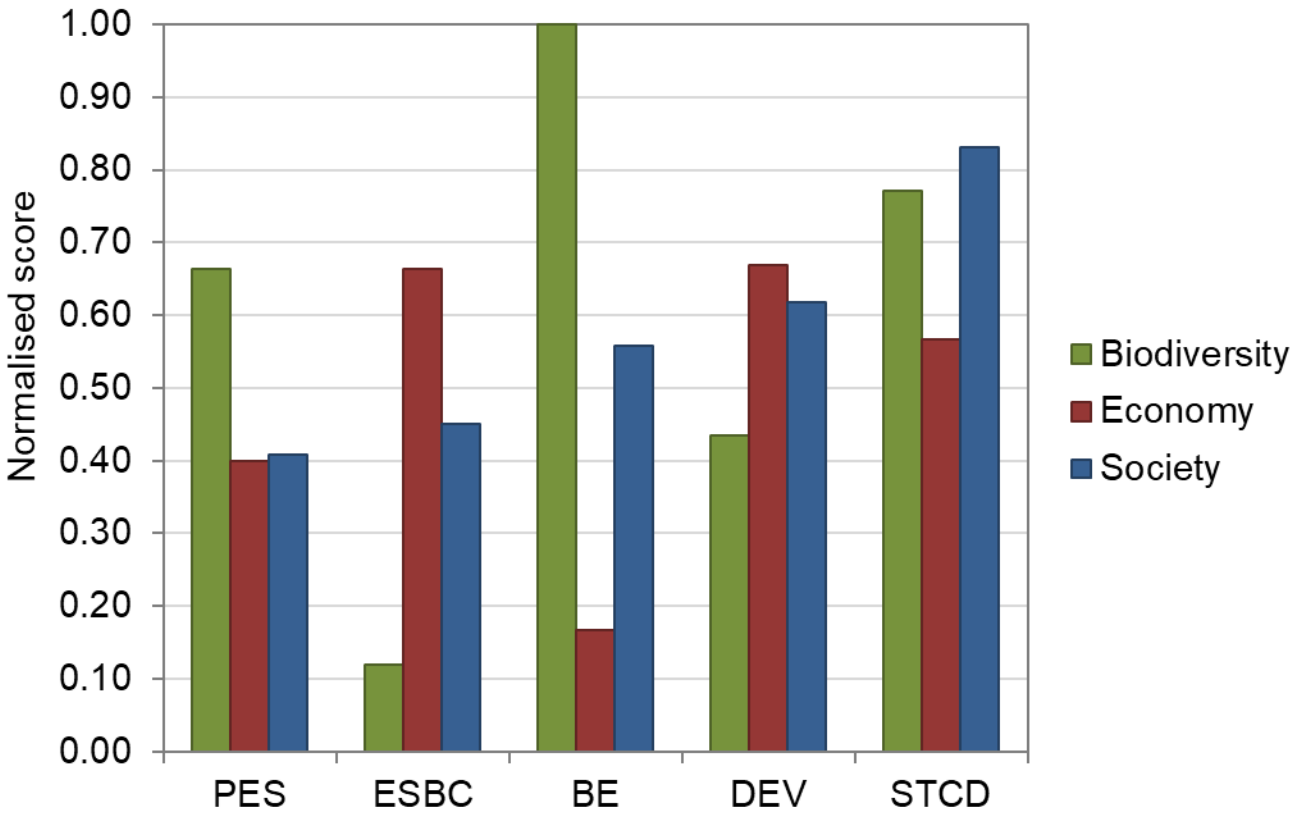
OVERALL RANKING OF SCENARIOS



Variable	PES	ESBC	BE	DEV	STCD
Biodiversity	0.66	0.12	1.00	0.44	0.77
Economy	0.40	0.66	0.17	0.67	0.57
Society	0.41	0.45	0.56	0.62	0.83
Overall score	0.53	0.34	0.68	0.54	0.74

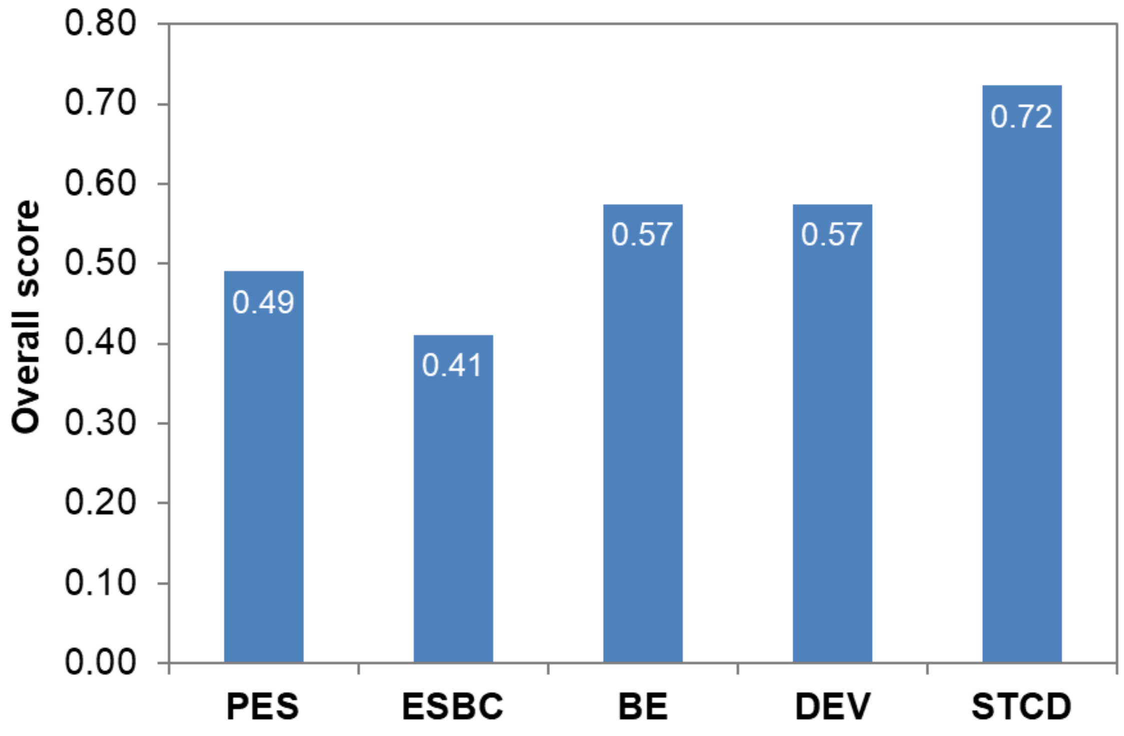
OVERALL RANKING OF SCENARIOS

- Trade-offs are clear
- Society gains are highest under the STCD scenario without much loss in biodiversity and economy



SENSITIVITY ANALYSIS

- Change weighting to be equal across Biodiversity, Economy, Society (0.33)
- Then STCD still ranked highest, followed by DEV and BE with equal scores
- Requires weighting Economy by more than 0.6 to drop STCD as top ranked scenario



CONCLUSIONS AND RECOMMENDATIONS

WATER RESOURCE CLASSES

- Classes set at IUA level based on proportion of EC's in the aquatic ecosystems.

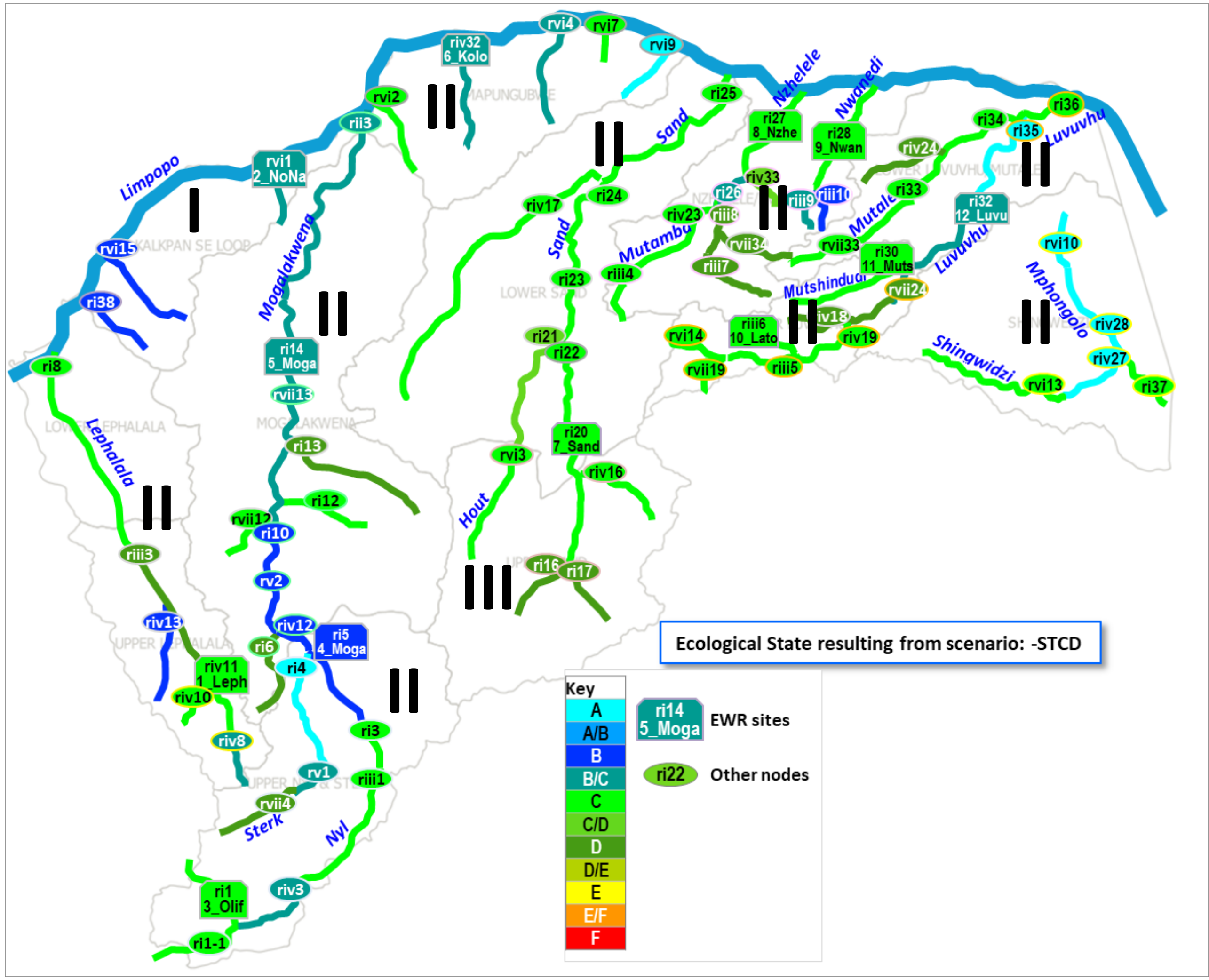
	A	B	C	D
Class I		70		
Class II			70	
Class III:				100
Alt Class II:		60		40

COMPARISON OF WATER RESOURCE CLASSES

IUA	PES	ESBC	BE	DEV	STCD
Lephalala	II	II	II	II	II
Kalkpan Se Loop	I	III	I	I	I
Upper Nyl & Sterk	III	III	II	III	II
Mogalakwena	II	III	II	II	II
Mapungupwe	II	III	I	II	II
Upper Sand	III	III	II	III	III
Lower Sand	II	II	II	II	II
Nzhelele/Nwanedi	II	III	II	II	II
Upper Luvuvhu	II	III	II	II	II
Lower Luvuvhu/Mutale	II	III	II	II	II
Shingwedzi	II	III	II	II	II

RECOMMENDATIONS

- Recommend the STCD scenario
- Overall societal gains highest
  - Net gains for both economy and biodiversity



THANK YOU!